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RESEARCH ARTICLE

Emotional cues and social anxiety resolve ambiguous perception of biological motion

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Abstract
Perceptions of ambiguous biological motion are modulated b di˜ erent individual cognitive abilities (such as inhibition and empath) and emotional states (such as an iet). This stud e plored facing-the-viewer bias (FTV) in perceiving ambiguous directions of biological motion, and investigated whether task-irrelevant simultaneous face emotional cues in the background and the individual social an iet traits could a˜ ect FTV. We found that facial motion cues as background a˜ ect sociobiologicall relevant scenarios, including biological motion, but not non-biological situations (conve ed through random dot motion). Individuals with high an iet traits demonstrated a more dominant FTV bias than individuals with low an iet traits. Ensemble coding-like processing of task-irrelevant multiple emotional cues could magnif the facing-the-viewer bias than did in the single emotional cue. Overall, those ndings suggest a correlation between high-level emotional processing and high-level motion perception (subjective to attentional control) contributes to facing-the-viewer bias.

Keywords Biological motion · Emotion · Social an iet · Ambiguit · Visual perception · Ensemble coding · Facing-the-viewer bias

Introduction

Humans are sensitive to the movements of others, especiall when the movements hold sociobiologicall relevance to the observer. For e ample, we are able to learn others actions b imitation, understanding the intentions of others while watching their actions (Iacoboni et al. 2005; Ri olatti and Craighero 2004; Ri olatti and Fabbri-Destro 2010).The particular sensitivit to biological motion was rst documented in the classical studies of Johansson (1973), who developed an e perimental paradigm that enabled data about the movements of a few joints, i.e., critical points (forming a point light walker, PLW) to generate compelling percepts of human motion (Johansson 1973). The information in PLW include not onl simple d namic information, such as motion direction and velocit (Bertenthal and Pinto 1994; de Lussanet and Lappe 2012; Mather et al. 1999; Pavlova et al. 2014), but also interesting social information such as gender (Pahe i 1999), but also inte7.70000075(ir).5(actioo)]Tc0t1999

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b mistaking an approaching biological motion as receding; this bias is higher than perceiving the reverse (perceiving receding motion as approaching) (Weech et al. 2014; Yilti and Chen 2015).

Social and emotional information e tracted from (biological) motion ma signi cantl in uence the visual processing of d namic information associated with the motion stimuli (Brooks et al. 2008; Heenan and Troje 2014, 2015; Pavlova 2011; Schouten et al. 2010; Van de Cru s et al. 2013). On the one hand, PLW contained social information such as age (Insch et al. 2012), gender (Cutting and Ko lowski 1977; Pollick et al. 2005), and emotional state (Clarke et al. 2005). On the other hand, the internal emotional states of the observers could bias the perception of point-light walkers. Emotional factors that can induce bias include empath level (Yilti and Chen 2015), an iet level (Van de Cru s et al. 2013), and inhibition capacit (Heenan and Troje 2015).

Investigations into facing-the-viewer bias are important. First, it is ecologicall important to protect humans and animals in dangerous environments, b activel and e ectivel avoiding approaching threatening predators or objects. The perception of PLW (with bi-stabilit in direction) imposes an e ample of perceptual decision under uncertaint . Judgment made under uncertaint can result in over-or underestimations. To cope with the perceptual decision with uncertaint , humans favor an error management bias toward making the less costl error. For instance, the costs of false alarm of wasting time b estimating too earl the arrival time of the approaching object are relativel low compared to the costs of misses (i.e., not being prepared for an approaching object.) (Haselton et al. 2009; Holbrook et al. 2014). Second, e amining the si e of the facing-the-viewer bias e ect will quantitativel reveal how the underl ing cognitive and individual traits modulate and relate to this perceptual bias, and how the bias is modulated in the framework of error management , hence to help humans make decisions and secure the chance for survival and reproduction (Haselton et al. 2009; Holbrook et al. 2014).

Humans and some animals are endowed with the abilit to rapidl take in comple sensor arra s or events b means of perceptual averaging, i.e., ensemble coding (Ariel 2001; Hunt et al. 2008). Being able to e tract statistical properties such as the mean of numbers, si es, spatial la out, or even emotions from a set of simultaneousl viewed objects (Alvare 2011; Ariel 2001; Chong and Treisman 2003; de Gardelle and Summer eld 2011; Haberman et al. 2009; Haberman and Whitne 2007; Walker and Vul 2014), or a series of auditor beeps (Miller et al. 2013; Pia a et al. 2013), can greatl e pedite perceptual decisions, as well as social cognition, in ever da life PLW perception is a high-level cognitive construct, which might di er from the percept upon other forms of visual (apparent) motion. Therefore, the FTV e ect could be modulated b the correspondence of perceived high-level cognitive and emotional factors but outside emotional information conve ed b PLW stimuli themselves. We h pothesi ed that the acquired mean emotion stimuli facial gures (given b either a single face or multiple faces), though task-irrelevant, could be used b an ensemble coding like processing, to modulate the FTV e ect on PLWs but not on the percept of low/middle level random dot motion (containing non-sociobiological meanings). Moreover, this modulation (if e ists) is dependent on the abilit of association the background emotional information onto the PLWs. Previous evidence demonstrated the modulating e ect of an iet on the perceptions about PLW. Individuals with high an iet level are more sensitive to emotional cues with higher valence (Bar-Haim et al. 2007; Fo et al. 2002; Gra et al. 2009; MacLeod et al. 1986; Mathews and MacLeod 1985; Singer et al. 2012). We further h pothesi ed that b presenting the task-irrelevant emotional facial gures, observers with high an iet would use the ensemble coding to e tract the mean emotion, and the would be subject to a stronger facing-the-viewer bias than individuals with low an iet would be.

Based on this background, we implemented two e periments to e amine the perception of PLW under a single facial emotional cue (E periment 1) and multiple facial emotional cues (E periment 2). We investigated individual di erences in FTV bias, due to di erent levels of social an iet traits (low vs. high an iet). To our best knowledge, this stud showed the rst empirical evidence that task-irrelevant but subjectivel (face) emotional cues, mediated b individual cognitive abilities, could modulate FTV bias.

Experiment 1

We investigated how a single task-irrelevant facial emotion cue as background a ected the perception of dominant direction (facing-the-viewer bias) of an ambiguous point-light walker, and how social an iet level interacts with emotional perception to modulate the facing-the-viewer bias.

Method

Participants

Thirt -two undergraduate students (18 female; 14 male) from Peking Universit participated in this e periment. Participants were aged from 18 to 25 (mean: 21.9, SE = 2.0), with either normal or corrected to normal vision, none of whom reported an neurological s mptoms. Observers were not informed about the purposes of the stud , and were paid for their participation. The e periment was performed in compliance with all institutional guidelines established b the Academic A airs Committee, Department of

Ps cholog at Peking Universit . All observers provided written informed consent, according to institutional guidelines and the Declaration of Helsinki.

Visual stimuli and equipment

Visual stimuli included target stimuli (foreground) and a task-irrelevant facial emotion cue (background). The target stimuli included either a point light walker or circular random dots (Fig. 1). For each trial, we randoml chose an a imuth rotation angle for the point-light walker as either 90 or 90 , and counterbalanced both t pes of PLW. We then displa ed an animation of PLW, with a full walking c cle of 1300 ms. We pla ed the video with 130 frames on Cathode Ra Tube (CRT) monitor at a vertical refresh rate of 100 H (10 ms per frame),with a resolution of 1024 768 (pi els^{2}). The random dots stimuli consisted of 1000 random dots in a circular area within an imaginar contour diameter equal to the height of the PLW. Appro imatel half of the rst 10 s were dropped to prevent potential initial response bias and to allow the observer to establish bi-stabilit of the ambiguous motion. Data from the last 60 s were used for anal sis.

During the e periment, PLW and random dots motion (RDM) were presented in blocks, while the background visual conditions were presented using randomi ed trial-b -trial. Each block consisted of 16 trials, with each of the four emotional valences repeated four times (Fig. 2). Observers rested for at least 30 s ever ve trials. To e amine the validit of the subjective appraisal of emotional valences of facial cues (including the no-facial-image baseline condition), we asked observers to rate emotional valences for the faces on a Likert scale from 1 to 7 (i.e., 1-most angr , 7-most happ) after the e periment.

Results for Experiment 1

The dependent variable is the duration of perceived motion direction, which characteri es the stabilit of a dominant perceived direction over a non-dominant direction. Because the perceived direction is the result of a resolution of ambiguit (approaching vs. receding), the perception is bi-stable. The dominant perceived direction changes over time, switching between two perceptions. We e cluded two observers data for anal sis. One of these e perienced a ceiling eˆ ect, perceiving all the PLW as moving outward. That person did not perceive the bi-stabilit of the ambiguous stimuli. The second e cluded observer did not complete the e periment due to an accidental failure of the response devices. Due to large individual variances, we normali ed the duration within observers (the duration in each trial was divided b the mean duration from all trials). Further, the stud s LSAS scores did not e actl follow normal distribution (con rmed b SPSS normalit plots with tests). Because of this, due to the large individual variances, we divided subjects into two groups using split-half (median) method. We grouped participants with mean LSAS score greater than the median as the high an iet group; the remaining participants were grouped as the low an iet group.

We used a repeated measure anal sis of variance (ANOVA) to anal e the data. Stimuli t pes (point-light walker vs. random dot motion), background visual information (negative, neutral, positive, and baseline black visual background), and perceived direction (approaching vs. receding) were used as within subject factors. Social an i-et group (high vs. low) was a between-subject factor and the dominant duration was a dependent variable. The main eˆ ect of the background information was statisticall signi -cant, $F(3,84)=2.771$, $p<0.05$. The mean normali ed duration of dominant perceptions for negative, neutral, happ , and baseline conditions were 1.038 0.027, 1.013 0.019, 0.954 0.012, and 1.042 0.024, respectivel . The duration under the happ condition (0.954) was signi cantl shorter than in the baseline condition (1.042), $p<0.05$ (see Fig. 3). The main effects of stimuli t pes and dominant directions were non-signi cant, $F(1,28)=0.089$, $p=0.768$ and $F(1,28)=3.944$, $p=0.057$. The interaction between stimuli t pe (PLW vs. random dots) and perceived direction was statisticall signi cant, $F(1,28)=106.572$, $p<0.001$. We also found a signi cant three-wa interaction between stimuli t pe, perceived direction, and background visual information, $F(3,84)=6.414$, $p<0.01$. Ne t, we investigated these

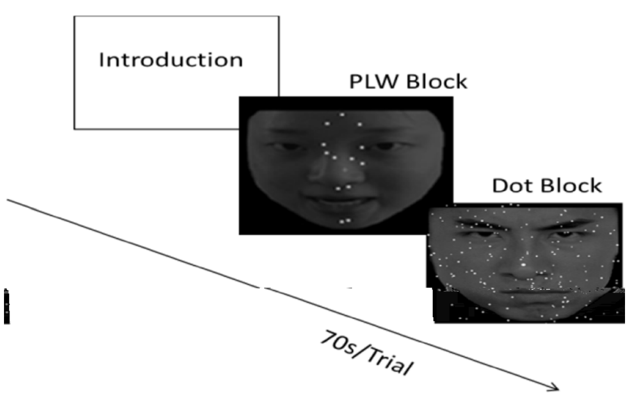

Fig. 2 Procedure for E periment 1. We measured social an iet level using the LSAS. Observers watched a video and practiced the task. The t pe of the target stimuli (point-light walker vs. random dots) were randomi ed in blocks. Each block consisted of 16 trials, with each emotional valence (negative, neutral, positive, or baseline) repeated four times. Each trial continued for 70 s

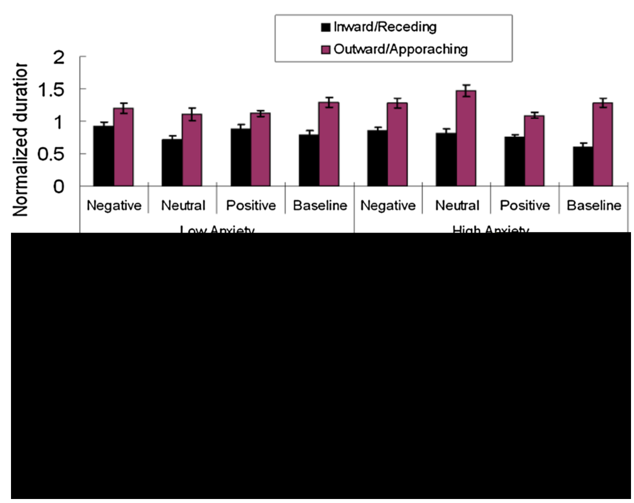

Fig. 3 Results for E periment 1 (a single emotion cue). The black bars indicate normali ed durations for perceptions of the dominant direction of a point-light walker as walking awa from the viewer (receding), or perceiving the dominant direction of the coherence motion (of random dots) as centripetal (moving inwards) random dots during the presentation of those ambiguous visual stimuli. The gra bars indicate normali ed durations of dominant perceptions when the are approaching/outward

interactions by exploring the statistical results within each stimulus category (PLW vs. random dots).

To further investigate the stimulus/task effects, we applied two separate repeated measures ANOVA for PLW and random dot presentations, with normalized dominant duration as the dependent variable and the same set of predictor variables (emotion valences, perceived direction, and social anxiety group) as the independent variables.

For the PLW task (with the point-light walkers as the visual stimuli), the main effect of perceived direction was statistically significant, $F(1,28) = 107.243$, $p < 0.001$, where a Bonferroni corrected pairwise test showed the normalized duration for receding (facing away from the viewer) (0.787, SE = 0.0.023) was significantly lower than for approaching (1.235, SE = 0.023). This shows a typical FTV bias. The main effect of the background visual information was non-significant, $F(3,84) = 1.321$, $p = 0.273$. The interaction between visual information and anxiety groups was statistically significant, $F(3,84) = 4.332$, $p < 0.01$. Simple main effect ANOVA tests showed that, for neutral emotion cues, the normalized duration for high social anxiety group was significantly longer (1.125) than the duration in the low social anxiety group (0.914), $F(1,28) = 9.86$, $p < 0.01$. For appraisal of the neutral cues (Likert points 1–7), the mean scores for the high anxiety group was 3.53 (0.15); the mean for the low anxiety group was 4.06 (0.18), $F(1,29) = 4.923$, $p < 0.05$. In contrast, when the emotional cue has a positive valence, the normalized duration for the high social anxiety group was significantly shorter (0.919) than the duration in the low social anxiety group (1.010), $F(1,28) = 6.26$, $p < 0.05$.

The mean dominant durations for receding and approaching perceptions were 0.834 (0.038) and 1.183 (0.032), respectively, for the low social anxiety group; the durations for receding and approaching perceptions were 0.761(0.035) and 1.283 (0.030) for the high social anxiety group. The interaction between perceived direction and social anxiety group was statistically significant, $F(1,28) = 3.881$, $p < 0.05$. This result indicates a strong facing-the-viewer bias. The dominant duration of receding (facing away from the viewer) motion was 0.798 (0.026); the duration of approaching was 1.233 (0.022), $F(1,28) = 93.480$, $p < 0.001$. The difference in the normalized duration between perceiving receding and approaching motion was higher for high social anxiety group (0.52, SE = 0.03) than the difference in duration for low social anxiety group (0.35, SE = 0.03), $F(1,28) = 3.706$, $p < 0.05$.

For the non-sociobiologically relevant task (random dots as the visual stimuli), there was no two-way or three-way interaction between emotional cues and/or response type when the anxiety factor was considered. The main effect of emotional valence and perceived direction was significant, with $F(3,84) = 4.802$, $p < 0.01$ and $F(1,28) = 40.11$, $p < 0.001$. For emotional valences, a Bonferroni corrected pairwise test showed the normalized duration under a positive emotional cue (0.95, SE = 0.01) was significantly shorter than baseline (1.09, SE = 0.03), $p < 0.001$. For perceived direction, a Bonferroni corrected pairwise test showed the normalized duration for perceiving receding random dots (1.17, SE = 0.02) was significantly longer than for perceiving approaching random dots (0.86, SE = 0.03), $p < 0.001$. However, no significant interactions between the valence of emotional cues and perceived direction was found, $F(3,93) = 0.543$, $p = 0.654$. There were no group differences between the low and high anxiety groups, $F(1,28) = 2.896$, $p = 0.099$.

Experiment 2

Experiment 1 examined the influence of task-irrelevant single emotional cues (a single figure of human face at various emotional valences) on perception of ambiguous visual motion, using a point-light walker PLW for biological motion stimulus and random dots for non-biological motion. However, visual environments in the real world are much more complex. For example, when we see a friend walking far away from us among a crowd of people, we may be inclined to welcome the others approaching us if we feel safe. Here, we assessed whether the perceived averaged (mean) valence of facial cues, with an ensemble coding-like processing, could modulate the FTV bias for a group of PLWs.

Method

Experiment 2 included 30 undergraduate students (16 female; 14 males) from Peking University, aged from 19 to 24 (21.4, SD = 2.7). The experimental design was like Experiment 1, except we increased the number of task-irrelevant facial emotion cues from one to eight, presented simultaneously on an imaginary circle with a radius of 650 mm (approximately 36 degrees of visual angle). We also increased the number of point light walker from one to three, presented side by side at the observer's eye level (see Fig. 4). The average valences of visual cues were the same as previous experiment, and included a background with positive, neutral, negative faces, or a blank screen (no facial cues). The face configurations were as follows: six out of the eight (75%) faces were congruent with the "mean" valence level (such as "positive"); the remaining two were of the opposite valence ("negative"). Figure 4 showed a typical example of the mean valence as "angry"; two happy faces and six angry faces were located within a circle but in random order. For neutral valence, we used neutral emotional faces for all eight facial stimuli.

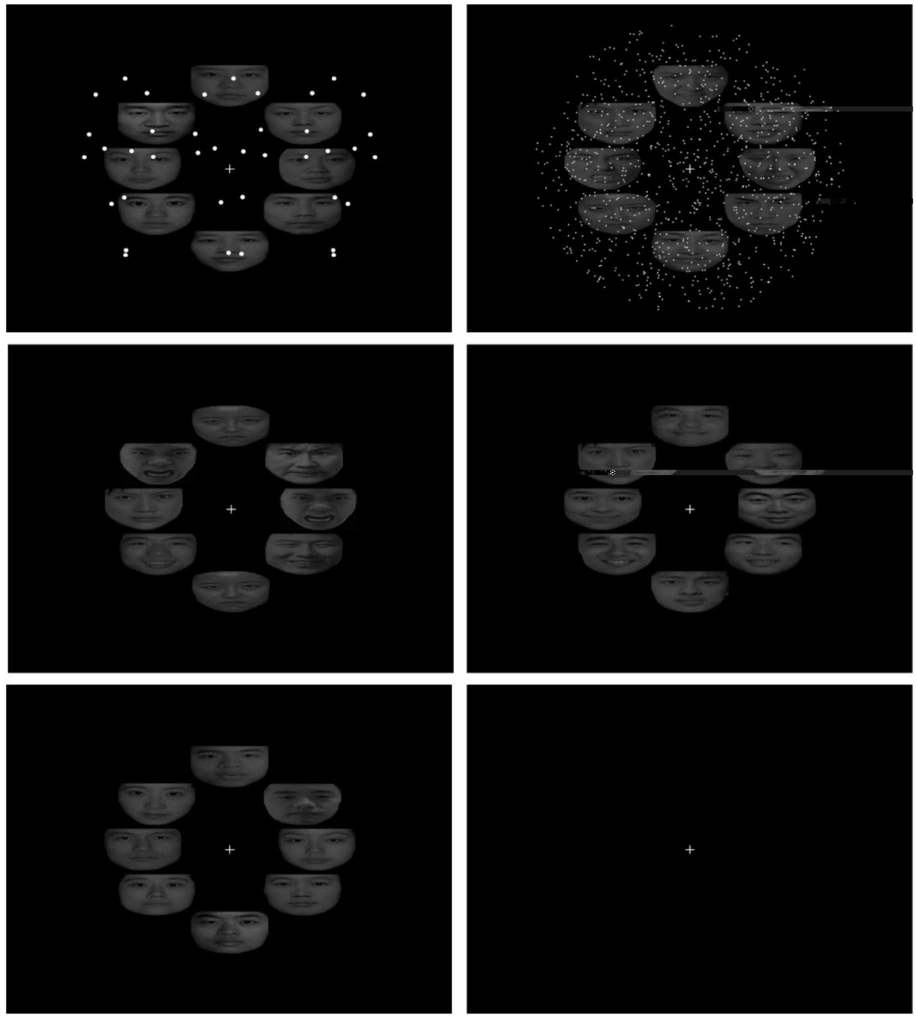

Fig. 4 Eight task-irrelevant facial emotion cues (located on an imaginar circle). First row shows three PLWs (left) with a crowd of faces; and random dots (right) with a crowd of faces. The second and third rows show an e ample of an average valences of facial emotion cues as: negative, with si angr faces and two happ faces (second row left); positive, with si happ faces and two angr faces (second row right); neutral, with eight neutral faces (third row left); and the baseline, without an facial emotion cues but a black background

Three PLWs were presented side-b -side on the screen; the middle point-light walker was at the center of the screen, and the other two was set at 650 mm (roughl 36 degrees of visual angle) from the center. To prevent duplication of all the point-light walkers, at the ver beginning of presentation (300 ms), the facing directions of the two surrounding PLWs (i.e., left and right PLW) were tilted randoml , with a 20 angle either to the right or left along the a imuth a is. All three point-light walkers had the same walking c cle, starting at a random time-point in their c cle (phases randomi ed). We used three PLWs to balance the visual displa areas between background multiple faces and the target of biological motion stimuli, so that the ratio of focusing PLWs relative to the background faces in E periment 2 was tantamount to the one in E periment 1, and the relative salienc between the background faces and foreground PLWs was largel controlled. However, the perceptual identit and qualit of each PLW was the same, which did not a ect the bias of the perceived direction of PLWs. Participants reported the dominant walking/facing direction (either inward or outward) of the three PLWs or random dots.

To e amine the validit of the subjective appraisal of emotional valences of facial cues (including the no-facial-image baseline condition), we asked observers to rate emotional valences for the faces on a Likert scale from 1 to 7 (i.e., 1-most angr , 7-most happ) after the e periment.

The remaining con gurations were the same as in E periment 1.

Results for Experiment 2

A similar set of anal sis was conducted for E periment 2 as for E periment 1. We applied a repeated measure ANOVA with stimulus t pe (PLWs vs. random dots), average emotion valences of the task-irrelevant background visual cues (negative, neutral, positive, and baseline), and perceived direction (approaching vs. receding) as the within-subject factors. The social an iet group (high social an iet vs. low social an iet) was the between-subject factor.

There were no significant main effects detected for stimuli t pe, $F(1,29)=0.127$, $p=0.725$; for visual cues, $F(3,87)=0.682$, $p=0.565$; and for perceived direction,

$F(1,29) = 3.128$, $p = 0.087$. The interaction between visual cues and social an iet group was statisticall signi cant, $F(3,87) = 2.91$, $p < 0.05$. The interaction between stimuli t pe and social an iet group was borderline signi cant, $F(1,29) = 3.652$, $p = 0.06$. The interaction between perceived direction and social an iet group was also statisticall signi cant, $F(1,29) = 4.949$, $p < 0.05$. The interactions between target stimuli t pe and perceived direction was statisticall signi cant, $F(1,29) = 57.16$, $p < 0.001$. The interaction between visual cues and perceived direction was borderline signi cant, $F(3,87) = 2.500$, $p = 0.065$. A threewa interaction between stimulus t pe, background visual cues, and social an iet group was statisticall signi cant, $F(3,87) = 3.217$, $p < 0.05$ (Fig. 5). Ne t, we e plore these critical interactions, b investigating the statistical results within each t pe of stimuli (PLW vs. random dots).

We performed separate repeated measure ANOVA tests for the PLW and random dots stimuli, and e amined the e ects of the mean valences of facial emotion cues (negative, neutral, positive valences, and baseline)*, the perceived motion, and social an iet group (low vs. high), on the normali ed duration of dominant perception.

For the PLWs task, the three-wa interaction between emotion valences, social an iet groups, and perceived direction was signi cant, $F(3,87) = 2.88$, $p < 0.05$. A subsequent simple main e ect anal sis showed that the normali ed duration of the dominant perception of approaching is higher than the perception of receding for all valences of emotional cues (negative, neutral, positive, and baseline), $p < 0.001$. The main e ect of perceived direction is signi cant, $F(1,29) = 66.42$, $p < 0.001$. A Bonferroni corrected pairwise test showed that the normali ed duration for the perception of approaching (1.25, SE = 0.029) is signi cantl longer than the duration of the perception of receding (0.741, SE = 0.026), $p < 0.001$, showing a t pical facing-the-viewer bias as found in E periment 1. The interaction between the task-irrelevant facial emotion cues and social an iet was signi cant, $F(3,87) = 3.558$, $p < 0.05$.

A further simple main e ects anal sis found no signi cant group e ect when emotion valence was neutral, positive, or when no facial emotion cues were presented (baseline), $p > 0.05$. However, when emotion valence was negative, the normali ed duration for the high social an iet group (0.912) was signi cantl shorter than the duration (1.144) for the low social an iet group, $F(1,29) = 5.41$, $p < 0.05$. The interaction between perceived direction and social an iet group was statisticall signi cant, $F(1,29) = 6.20$, $p < 0.05$. A further anal sis of simple main e ect showed that, the low an iet group reported a longer normali ed duration of a dominant receding perception (0.842) than the high an iet group did (0.639). $F(1,29) = 3.72$, $p = 0.064$. However, for the dominant approaching perception, this contrast between the two groups was non-significant, $F(1,29) = 2.73$, $p = 0.109$, with dominant durations of 1.197 for low an iet and 1.307 for high an iet . Also, a Bonferroni corrected pairwise test showed that the di erence between normali ed durations of perceived receding and approaching is higher for high social an iet group (0.67, SE = 0.05) than the di erence in low social an iet group (0.36, SE = 0.04), $p < 0.05$.

The interaction between perceived direction and social an iet group was signi cant in conditions where the average valence of emotion cues was either negative or neutral, $F(1,29) = 5.11$, $p < 0.005$ and $F(1,29) = 16.57$, $p < 0.001$, respectivel . That is, facing-the-viewer bias was more readil observed when the average valence of facial emotion cues was negative and neutral. However, the interaction between perceived direction and an iet group was not signi cant the duration of perceived approaching random dots motion (0.816, SE = 0.042).

Likert scale rating showed that in E periment 2, the main eˆ ect of the perceived emotion valence was signi - cant, $F(3,81) = 6.934$, $p < 0.001$. The mean scores for negative, neutral, positive, and baseline were 3.395(0.252), 3.832(0.124), 4.797(0.279), and 3.720(0.166), respectivel . A Bonferroni corrected comparison revealed signi cant diˆ erences in the appraisal of negative vs. positive cues, $p < 0.05$; neutral vs. positive cues, $p < 0.05$; and positive vs. baseline cues, $p < 0.05$.

We summari ed and compared the ke ndings of the two e periments in Table 1.

Discussion

This stud investigated how task-irrelevant emotional cues, presented as background visual information, aˆ ected the processing of ambiguous visual motion conve ed through point light walkers (biological motion) or random dots (non-biological motion). Emotional valences (happ , anger, or neutral) were presented as a single facial image (E periment 1) or as an average of a group of faces (E periment 2). The results indicated that both a single emotional cue and an average of a group of emotional cues aˆ ected how a dominant perception of PLW, but not random dots motion, was resolved. Speci call , negative and neutral valences of task-irrelevant facial emotion cues contributed to FTV bias. Moreover, this modulation eˆ ect was higher for the group with higher social an iet than for the group with low social an iet . This nding echoes a previous h pothesis that perceiving an approaching biological motion as receding is

Table 1 Ke results with statistical signi cances (main eˆ ects or interaction eˆ ects) in single face and multiple face conditions

Factors	Single face	Multiple faces
Combined anal sis		
T pe (PLW vs.RDM) Visual an iet	N	*
T pe (PLW vs.RDM) Resp an iet	0.063	**
Visual an iet	**	*
T pe an iet	N	0.066
Resp an iet	N	*
Visual Resp	0.060	0.065
T pe Resp	***	**
Visual T pe	*	*
PLW		
Resp	(Facing viewer bias)***	(Facing viewer bias)***
Visual	N	N
Visual an iet	(Neutral emotion)**	(Neutral, negative emotion)**
Resp an iet	*	*
RDM		
Resp	***	***
Visual	**	N
Visual an iet	N	N
Resp an iet	N	N

T pe shows the stimuli categories (point light walker PLW and random dots motion RDM); visual shows the conditions of background visual information (happ , angr , neutral, and baseline). An iet indicates lower or higher social an iet . Resp represents the two dominant response directions: approaching and receding. The numbers indicate borderline signi cance. For RDM, there was no interaction eˆ ect among the given factors. In both single face and multiple face conditions, the facing-the-viewer bias was larger in individuals with higher an iet compared to the group with lower an iet . This bias was robust with neutral and negative background facial valences in the multiple faces tests (E periment 2), but was onl seen with the neutral face condition for in the single face tests (E periment 1)

N there was no statistical signi cance detected

*Shows that the *p* value is less than 0.05

**Indicate a *p* value less than 0.01

***Indicate a *p* value less than 0.001

riskier than the opposite (perceiving a receding gure as approaching), especiall when this motion is accompanied b potentiall menacing emotional information (angr faces) (Heenan and Troje 2015; Van de Cru s et al. 2013). An ious individuals displa an attentional bias towards more threatening stimuli (Bar-Haim et al. 2007; MacLeod et al. 1986; Mathews and MacLeod 1985).

bi-stability rather than the other direction. The perception of motion direction using point-light walkers was in the direction coming out from the center (facing-the-viewer). Human observers tend to process visual stimuli in the central visual field more efficiently than in the peripheral field. This resulted in a perception of dominant receding (centripetal) motion (Aaen-Stockdale et al. 2008). Unexpectedly, we found that the presence of the single facial image affected the perceived dominant direction in random dots motion; however, the group of facial images did not have this effect. This further confirms that the central visual cues (a single face) played a major role in modulating the lower-level perception of random dots motion. Nevertheless, we could not find a specific modulation effect based on social anxiety level in the random dots motion experiment. This results implies that individual cognitive abilities, including anxiety level, is specifically aligned with life-relevant sociobiological motion stimuli such PLWs (Heenan and Troje 2014, 2015), but is not aligned with non-biological motion stimuli.

Unlike other approaches in ensemble coding, which directly reveal that many objects were pooled into a sum-

Chong SC, Treisman A (2003) Representation of statistical properties. Vision Res 43(4):393 404

Clarke TJ, Bradshaw MF, Field DT, Hampson SE, Rose D (2005) The perception of emotion from bod movement in point-light displa s of interpersonal dialogue. Perception 34(10):1171 1180. https://doi.org/10.1068/p5203

Cutting JE, Ko lowski LT (1977) Recognition of friends b their walk: gait perception without familiarit cues. Bull Ps chon Soc 9:353 356

Daniel PM, Whitteridge D (1961) The representation of the visual eld on the cerebral corte in monke s. J Ph siol 159(2):203 221

de Lussanet MH, Lappe M (2012). Depth perception from point-light biological motion displa s. J Vis 12(11). doi: 2.11.14[pii]10.1167/12.11.14

de Gardelle V, Summer eld C (2011) Robust averaging during perceptual judgment. Proc Natl Acad Sci USA 108(32):13341 13346. https://doi.org/10.1073/pnas.1104517108

Felleman DJ, Van Essen DC (1991) Distributed hierarchical processing in the primate cerebral corte . Cereb Corte 1(1):1 47

Fo E, Russo R, Dutton K (2002) Attentional bias for threat: evidence for dela ed disengagement from emotional faces. Cogn Emot 16(3):355 379. https://doi.org/10.1080/02699930143000527

Giese MA, Poggio T (2003) Neural mechanisms for the recognition of biological movements. Nat Rev Neurosci 4(3):179 192

Gilboa-Schechtman E, Foa EB, Amir N (1999) Attentional biases for facial e pressions in social phobia: the face-in-the-crowd paradigm. Cogn Emot 13(3):305 318

Gong X, Huang YX, Wang Y, Luo YJ (2011) The revision of chinese facial a ̂ ective s stem. Chin Mental Health J 25(1):40 46

Gra KL, Adams WJ, Garner M (2009) The in uence of an iet on the initial selection of emotional faces presented in binocular rivalr . Cognition 113(1):105 110. https://doi.org/10.1016/j.cognition.2009.06.009

Haberman J, Whitne D (2007) Rapid e traction of mean emotion and gender from sets of faces. Curr Biol 17(17):R751 753

Haberman J, Harp T, Whitne D (2009) Averaging facial e pression over time. J Vis 9(11):1 1 13

Haselton MG, Br ant GA, Wilke A, Frederick DA, Galperin A, Frankenhuis WE, Moore T (2009) Adaptive rationalit : an evolutionar perspective on cognitive bias. Soc Cogn 27(5):733 763

He Y, Zhang M (2004) Ps chometric investigation of liebowit social an iet scale. J Diagn Concepts Pract 3:89 93

Heenan A, Troje NF (2014) Both ph sical e ercise and progressive muscle rela ation reduce the facing-the-viewer bias in biological motion perception. PLoS One 9(7):e99902. https://doi.org/10.1371/journal.pone.0099902

Heenan A, Troje NF (2015) The relationship between social an iet and the perception of depth-ambiguous biological motion stimuli is mediated b inhibitor abilit . Acta Ps chol (Amst) 157:93 100. https://doi.org/10.1016/j.actps .2015.02.012

Hindi Attar C, Muller MM, Andersen SK, Buchel C, Rose M (2010) Emotional processing in a salient motion conte t: integration of motion and emotion in both V5/hMT + and the am gdala. J Neurosci 30(15):5204 5210. doi:30/15/5204 [pii]10.1523/JNEUROSCI.5029 09.2010

Holbrook C, Galperin A, Fessler DM, Johnson KL, Br ant GA, Haselton MG (2014) If looks could kill: anger attributions are intensi ed b a ̂ ordances for doing harm. Emotion 14(3):455 461. https://doi.org/10.1037/a0035826

Hunt S, Low J, Burns KC (2008) Adaptive numerical competenc in a food-hoarding songbird. Proc Biol Sci 275(1649):2373 2379. https://doi.org/10.1098/rspb.2008.0702

Iacoboni M, Molnar-S akacs I, Gallese V, Buccino G, Ma iotta JC, Ri olatti G (2005) Grasping the intentions of others with one s own mirror neuron s stem. PLoS Biol 3(3):e79. https://doi.org/10.1371/journal.pbio.0030079

Ikeda H, Blake R, Watanabe K (2005) Eccentric perception of biological motion is unscalabl poor. Vision Res 45(15):1935 1943

Insch PM, Bull R, Phillips LH, Allen R, Slessor G (2012) Adult aging, processing st le, and the perception of biological motion. E p Aging Res 38(2):169 185. https://doi.org/10.1080/0361073X.2012.660030

Johansson G (1973) Visual perception of biological motion and a model for its anal sis. Percept Ps choph s 14:195 204

Levi DM, Klein SA, Aitsebaomo AP (1985) Vernier acuit , crowding and cortical magni cation. Vision Res 25(7):963 977

Levi DM, McGraw PV, Klein SA (2000) Vernier and contrast discrimination in central and peripheral vision. Vision Res 40(8):973 988

MacLeod C, Mathews A, Tata P (1986) Attentional bias in emotional disorders. J Abnorm Ps chol 95(1):15 20

Manera V, Schouten B, Becchio C, Bara BG, Verfaillie K (2010) Inferring intentions from biological motion: a stimulus set of point-light communicative interactions. Behav Res Methods 42(1):168 178. https://doi.org/10.3758/BRM.42.1.168

Mather G, Radford K, West S (1999). Low-level processing of biological motion. Proc Ro al Soc London Ser B 249:149 155

Mathews A, MacLeod C (1985) Selective processing of threat cues in an iet states. Behav Res Ther 23(5):563 569

McNair NA, Goodbourn PT, Shone LT, Harris IM (2017) Summar statistics in the attentional blink. Atten Percept Ps choph s 79(1):100 116. https://doi.org/10.3758/s13414-016-1216-2

Miller JE, Carlson LA, McAule JD (2013) When what ou hear in uences when ou see: listening to an auditor rh thm in uences the temporal allocation of visual attention. Ps chol Sci 24(1):11 18

Neri P, Morrone MC, Burr DC (1998) Seeing biological motion. Nature 395(6705):894 896

Pan J, Zhang J, Ma P, Liang H, Wang H, Tao J, Wen S, Zhang J (2006) The utilit of Liebowit Social An iet Scale in the patients with social an iet disorder in Chinese. Chin J Nerv Ment Dis 32(3):206 210

Pavlova MA (2011) Biological motion processing as a hallmark of social cognition. Cereb Corte 22(5):981 995 doi:bhr156[pii]10.1093/cercor/bhr156

Pavlova MA, Sokolov AN, Bidet-Ildei C (2014). Se di ̂ erences in the neuromagnetic cortical response to biological motion. Cereb Corte . doi:bhu175[pii]10.1093/cercor/bhu175

Pell DG, Cavanagh P, Desimone R, Tjan B, Treisman A (2007) Crowding: including illusor conjunctions, surround suppression, and attention. J Vis 7(2):1

Pelli DG (1997) The VideoToolbo software for visual ps choph sics: transforming numbers into movies. Spat Vis 10(4):437 442

Pia a EA, Sween TD, Wessel D, Silver MA, Whitne D (2013) Human use summar statistics to perceive auditor sequences. Ps chol Sci 24(8):1389 1397

Pollick FE, Ka JW, Heim K, Stringer R (2005) Gender recognition from point-light walkers. J E p Ps chol Hum Percept Perform 31(6):1247 1265. doi:2005-15838-006[pii]10.1037/0096-1523.31.6.1247

Ri olatti G, Craighero L (2004) The mirror-neuron s stem. Annu Rev Neurosci 27:169 192. https://doi.org/10.1146/annurev.neuro.27.070203.144230

Ri olatti G, Fabbri-Destro M (2010) Mirror neurons: from discover to autism. E p Brain Res 200(3 4):223 237. https://doi.org/10.1007/s00221-009-2002-3

R twinski NK, Fresco DM, Heimberg RG, Coles ME, Liebowit MR, Cissell S, Hofmann SG (2009) Screening for social an iet disorder with the self-report version of the Liebowit Social An iet Scale. Depress An iet 26(1):34 38. https://doi.org/10.1002/da.20503

Safren SA, Heimberg RG, Horner KJ, Juster HR, Schneier FR, Liebowit MR (1999) Factor structure of social fears: the Liebowit Social An iet Scale. J An iet Disord 13(3):253 270

Schouten B, Troje NF, Brooks A, van der Zwan R, Verfaillie K (2010) The facing bias in biological motion perception: eˆ ects of stimulus gender and observer se . Atten Percept Ps choph s 72(5):1256 1260. https://doi.org/10.3758/APP.72.5.1256

Schouten B, Troje NF, Verfaillie K (2011) The facing bias in biological motion perception: structure, kinematics, and bod parts. Atten Percept Ps choph s 73(1):130 143. https://doi.org/10.3758/s13414-010-0018-1

Shim W, Alvare G, Jiang Y (2008) Spatial separation between targets constraints maintenance of attention on multiple objects. Ps chon Bull Rev 15(2):390 397

Singer N, Eapen M, Grillon C, Ungerleider LG, Hendler T (2012) Through the e es of an iet : Dissecting threat bias via emotional-binocular rivalr . Emotion 12(5):960 969. https://doi.org/10.1037/a0027070

Thornton IM, Rensink RA, Shiˆ rar M (2002) Active versus passive processing of biological motion. Perception 31(7):837 853

Troje NF, Westhoˆ C (2006) The inversion eˆ ect in biological motion perception: evidence for a life detector ? Curr Biol 16(8):821 824. doi:S0960-9822(06)01281-4[pii]10.1016/j.cub.2006.03.022

Van de Cru s S, Schouten B, Wagemans J (2013) An an iet -induced bias in the perception of a bistable point-light walker. Acta Ps chol (Amst) 144(3):548 553. doi:S0001-6918(13)00215-1[pii]10.1016/j.actps .2013.09.010

Vanrie J, Verfaillie K (2004) Perception of biological motion: a stimulus set of human point-light actions. Behav Res Methods Instrum Comput 36(4):625 629

Walker D, Vul E (2014) Hierarchical encoding makes individuals in a group seem more attractive. Ps chol Sci 25(1):230 235

Weech S, McAdam M, Troje NF (2014) What causes the facing-the-viewer bias in biological motion? JVis 14:1 15

Westheimer G (1982) The spatial grain of the perifoveal visual eld. Vision Res 22(1):157 162

Whitne D, Levi DM (2011) Visual crowding: a fundamental limit on conscious perception and object recognition. Trends Cogn Sci 15(4):160 168. https://doi.org/10.1016/j.tics.2011.02.005

Yilti H, Chen L (2015) Tactile input and empath modulate the perception of ambiguous biological motion. Front Ps chol 6:161. https://doi.org/10.3389/fps g.2015.00161

Ying HJ, Xu H (2017). Rapid sequential visual presentation and ensemble coding in facial e pression adaptation. J Vi 17(15). https://doi.org/10.1167/1117.1161.1115