

Emotion

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Cross-Channel Adaptation Reveals Shared Emotion Representation From Face and Biological Motion

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Emotions in interpersonal interactions can be communicated simultaneously via various social signals such as face and biological motion (BM). Here, we demonstrate that even though BM and face are very different in visual properties, emotions conveyed by these two types of social signals involve dedicated and common processing mechanisms ($N = 168$, college students, 2020–2024). By utilizing the visual adaptation paradigm, we found that prolonged exposure to the happy BM biased the emotion perception of the subsequently presented morphed BM toward sad, and vice versa. The observed aftereffect disappeared when the BM adaptors were shown inverted, indicating that it arose from emotional information processing rather than being a result of adaptation to constitutive low-level features. Besides, such an aftereffect was also found for facial expressions and similarly vanished when the face adaptors were inverted. Critically, preexposure to emotional faces also exerted an adaptation aftereffect on the emotion perception of BMs. Furthermore, this cross-channel effect could not only happen from faces to BMs but also from BMs to faces, suggesting that emotion perception from face and BM are potentially driven by common underlying neural substrates. Overall, these findings highlighted a close coupling of BM and face emotion perception and suggested the existence of a dedicated emotional representation that can be shared across these two different types of social signals.


Keywords: adaptation, emotion perception, biological motion, face

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Perceiving and understanding the basic emotions (e.g., happiness or sadness) of other individuals is critical in human social life, as it enables us to infer the intentions of our conspecifics and further facilitates interpersonal interactions (Darwin & Phillip, 1998). Facial expressions present the most common and salient nonverbal social communicative signals regarding others' affective states and intentions (Ekman & Oster, 1979; Frith, 2009). The ability to read facial expressions emerges early in life, as evidenced in 7-month-old children (Kotsoni et al., 2001) and even newborn infants (Farroni et al., 2007). Besides, such ability is also present in nonhuman primates (e.g., chimpanzees; Hoffman et al., 2007; Parr et al., 2008), further indicating the evolutionary basis of facial expression

perception. Notably, the processing of facial expressions recruits a specialized mechanism that is dissociable from other aspects of face perception (Bruce & Young, 1986; Calder & Young, 2005; Haxby et al., 2000). Specifically, converging evidence from humans and macaques has shown that the superior temporal sulcus is selectively activated by facial expression rather than facial identity (Hadj-Bouziane et al., 2008; Hasselmo et al., 1989; Narumoto et al., 2001). Moreover, using an adaptation procedure, it has been observed that the anterior superior temporal sulcus is more sensitive to the repetition of facial expression as compared to the repetition of facial identity or head orientation (Fox et al., 2009; Taubert et al., 2020; Walther et al., 2013; Winston et al., 2004). These aforementioned

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The authors report how they determined their sample size, all data exclusions (if any), all manipulations, and all measures in the study, and they follow journal article reporting standards. This study's design and its analysis were not preregistered. All data, materials, and analysis code used in the present study could be accessed at the Knowledge Repository of Institute of Psychology, Chinese Academy of Sciences (<http://ir.psych.ac.cn/handle/311026/43476>; Yuan, Wang, & Jiang, 2023).

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findings together reveal that there might exist a specialized mechanism underlying facial emotion perception.

In addition to faces, the body movements of biological organisms also carry important emotional information. Compared with faces, these life motion signals convey direct action-oriented emotional information and remain salient even from a far distance (Aviezer et al., 2012; de Gelder, 2006). Human observers are highly adept at reading emotions from biological motion (BM), even when they are portrayed merely by the movements of several point lights placed on the major joints of living creatures (Alaerts et al., 2011; Johansson, 1973; Montepare et al., 1987; Troje, 2002, 2008). Moreover, the distinctively expressed emotions (e.g., sadness, happiness) in minimalistic point-light BM stimuli could be successfully recognized even by 8-month-old infants (Missana et al., 2015; Missana & Grossmann, 2015). Interestingly, the ability to read facial expressions also occurs during this period of development (Peltola et al., 2009). Such concurrent emergence of abilities to perceive emotions from BM and face implicates that emotion processing of BM may recruit a mechanism analogous to that of face. While the neural mechanism of facial expression processing has been well investigated (Engell & Haxby, 2007; Pessoa et al., 2002), it heretofore remains equivocal whether the BM emotion perception also involves specialized neural modules (Alaerts et al., 2014; Atkinson et al., 2012; Bachmann et al., 2018; Peelen et al., 2007). Furthermore, the fact that face and point-light BM are both critical social signals conveying obvious emotional information raises an important question as to whether there exists a shared neural module for emotion perception from face and BM.

Notably, albeit the point-light BM differed greatly from face in low-level features, they possessed analogous cognitive and neural processing mechanisms (Blake & Shiffrar, 2007; Engell & McCarthy, 2013; Grossman et al., 2000; Peelen et al., 2006; Servos et al., 2002; Simion et al., 2008; Thompson & Hardee, 2008; Troje & Westhoff, 2006). Such findings underscore the importance of using these two types of social signals as distinct visual features to probe a general social perception system (Minnebusch & Daum, 2009; Simion et al., 2008; Thompson & Hardee, 2008; Yuan, Ji, et al., 2023). Recently, emerging evidence has implied that the emotion perception of BM and face are also closely connected, as revealed by a strong correlation between the abilities to process emotions from BM and face (Actis-Grosso et al., 2015; Alaerts et al., 2011; Henry et al., 2012; Isernia et al., 2020; Miller & Saygin, 2013). Moreover, they both exhibit a happiness superiority during visual search (Becker et al., 2011; Lee & Kim, 2017) and in guiding social attention (Yuan, Ji, et al., 2023). Besides, the key brain areas (e.g., superior temporal sulcus) involved in facial expression perception (Engell & Haxby, 2007; Pitcher et al., 2014) are also essential for BM emotion perception (Alaerts et al., 2014; Basil et al., 2017). These findings together suggested a potentially shared neural mechanism for emotion processing in face and BM, but the direct empirical evidence is lacking. It is important to note that the aforementioned findings derived from separate studies that independently investigated BM and face emotion processing, while no study has yet integrated both face and BM into a single experiment to examine whether their emotion perception recruits common neural mechanisms.

The present research directly probed this issue by utilizing the visual adaptation technique, which is recognized for its ability to alter neuronal activities underlying specific feature encoding (Webster & MacLeod, 2011). In particular, visual adaptation

indicates the phenomenon that prolonged exposure to an extreme visual stimulus biases the perception of a subsequently presented stimulus away from the adapted feature. It serves as a central mechanism underlying the visual perception process which allows neurons to rapidly and flexibly change their tuning property and relocate the perceptually neutral point, thus expanding their perceptual boundary to cope with the enormous changes in the surrounding environment (Webster, 2011, 2015; Webster & MacLeod, 2011). This mechanism maintains the sensitivity of human visual system to detect mild changes and enables humans to readily adjust the current perception based on the previous experiences (Kohn, 2007). More importantly, the adaptation aftereffect directly revealed changes in response properties of neural channels that are activated by adapting stimuli (Benda, 2021). Therefore, the adaptation paradigm has been repeatedly described as “the psychologist’s microelectrode” (Frisby, 1980), serving as a powerful noninvasive tool for temporarily isolating and diminishing the neural populations encoding specific features (Calder et al., 2007; Ellamil et al., 2008; Webster & MacLeod, 2011; Winston et al., 2004). It is recognized for two distinct advantages: First, its effect occurred rapidly enough to capture the recent influence of visual experiences. Second, it linked the complex neuronal effects to simple changes in perception (Kohn, 2007). In fact, abundant studies have adopted this paradigm to explore the underlying neural mechanism subserving the perception of simple physical features (e.g., orientation, color, motion; Boynton & Finney, 2003; Clifford, 2002; McCollough, 1965) as well as high-level social attributes (e.g., facial expression, face identity; Calder et al., 2007; Hsu & Young, 2004; Winston et al., 2004). More importantly, it has been consistently reported that the behavioral aftereffects were strongly correlated with the neural effects (Fu et al., 2014; Thurman et al., 2016; Wang et al., 2017), further indicating the utility of the adaptation paradigm in probing the underlying neural activities.

We adopted this technique to first probe whether emotional information contained in the highly simplified BM could produce significant adaptation aftereffects. This would imply the existence of specific neural modules dedicated to the BM emotion encoding. The facial expression aftereffect was also examined as a complement and comparison to the BM study. Notably, we combined the BM and face in a cross-channel emotion adaptation paradigm to investigate whether altering neuronal activities underlying face emotion perception would cause subsequent changes in BM emotion perception and vice versa. Such an aftereffect, if observed, would indicate the existence of a common neural representation subserving emotion perception from these two types of social signals.

Transparency and Openness

The procedures of sample size determination, all data exclusions (if any), all manipulations, and all measures were reported in the study following JARS (Kazak, 2018). All data, materials, and analysis code used in the present study could be accessed at the Knowledge Repository of Institute of Psychology, Chinese Academy of Sciences (<http://ir.psych.ac.cn/handle/311026/43476>; Yuan, Wang, & Jiang, 2023). Data were analyzed using Jamovi, Version 2.2.5. This study’s design and its analysis were not preregistered.

Experiment 1: BM Emotion Adaptation

In Experiment 1, we adapted participants with the extreme happy or sad BM and asked them to make judgments upon the perceived emotion of the subsequently presented morph BM. To confirm such an effect appeared at the emotion processing level that is independent of simple constitutive feature adaptation, we further included an inverted adaptation condition by replacing the BM adaptors with their inverted counterparts. This is because inversion retains the parts-based retinotopic features (e.g., velocity, gesture, shape) that constitute the BM adaptor while significantly disrupting the holistic emotional information (Atkinson et al., 2007; Dittrich et al., 1996; Spencer et al., 2016).

Method

Participants

Forty-eight college students whose ages ranged from 18 to 30 with normal or corrected-to-normal vision were recruited in the study, with 24 (13 females, 11 males; $M = 21.4$ years, $SD = 2.1$ years) in the upright BM adaptation condition and 24 (13 females, 11 males; $M = 23.5$ years, $SD = 2.9$ years) in the inverted BM adaptation condition. We asked participants to provide their demographic information via self-report prior to the formal experiment. All reported that they were Asian undergraduate/graduate students without current employment and had no history of neurological or psychiatric disorders. They were unaware of the experimental purpose and gave written informed consent in conformity to the procedure and protocols approved by the institutional review board of the Institute of Psychology, Chinese Academy of Sciences. Data were collected in 2020–2022. Power analyses (F tests, repeated measures, within factors) with G*Power (Version 3.1.9.4; Faul et al., 2007) showed that a sample size of 24 participants under each condition (upright/inverted) would afford 80% power ($\alpha = .05$) to detect a medium-high adaptation aftereffect ($f = .27$). This sample size was equal to previous studies with similar designs (Watson & de Gelder, 2020). Besides, a sensitivity test was conducted to assess the smallest adaptation aftereffect the current sample size is able to detect. Specifically, the sample size of 24 participants would be sensitive to effects of $f = .31$ with 90% power ($\alpha = .05$). This means that our study could reliably detect effects larger than $f = .31$, which is a medium effect and is comparable to the effect reported in previous studies. For the interaction effect, the power analysis (F tests, repeated measures, within-between factors) showed that the current sample size would afford 80% power ($\alpha = .05$) to detect a small effect ($f = .19$). In addition, post hoc power analyses with analyses of variance (ANOVAs), Student's t tests, and Welch's t tests were performed in all experiments to assess the quality of our results. The results showed that all our significant tests afforded over 99% power ($\alpha = .05$).

Stimuli

Stimuli were displayed using MATLAB (Mathworks, Inc.) together with the Psychtoolbox extensions (Brainard, 1997; Pelli, 1997) on a 19-inc. cathode ray tube monitor ($1,280 \times 1,024$ at 60 Hz) with gray background, red–green–blue: 128, 128, 128. The parametric emotional BM stimuli were taken from Troje (2008; see at <https://www.biomotionlab.ca/html5-bml-walker/> for a vivid demonstration). Each BM walker consisted of 15 point-light dots

depicting the movements of the major joints (i.e., pelvis, thorax, shoulders, elbows, wrists, hips, knees, and ankles) and the head. Its emotional state was manipulated through a standardized score on a linear axis that adjusts the degree of differences between happy and sad walkers. The scores were based on the Fourier-based representation of observers' emotional ratings of 80 actual walkers and were then computed within a 10-dimensional subspace spanned by the first 10 principal components (Troje, 2008). This approach matches the biological motion stimuli in terms of frequency and phase, while exaggerates the diagnostic features that the classifier extracts to generate walking patterns with the respective properties and attributes. Happiness is usually linked with the occurrence of rewarding experiences, which motivates social engagement, while sadness signals the need for coping with loss, which motivates social withdrawal. These two types of emotions were maximally distant in emotional computation space (Susskind et al., 2007) and were rated as least similar in conceptions among six basic emotions (Brooks et al., 2019). Moreover, the happy and sad point-light walkers were easily recognizable and distinguishable (Spencer et al., 2016; Troje, 2008; Yuan, Ji, et al., 2023). Note that the identity and gender of these BM stimuli were set at the neutral point and were thus nonrecognizable as they were the averages of 80 actual walkers (half male, half female).

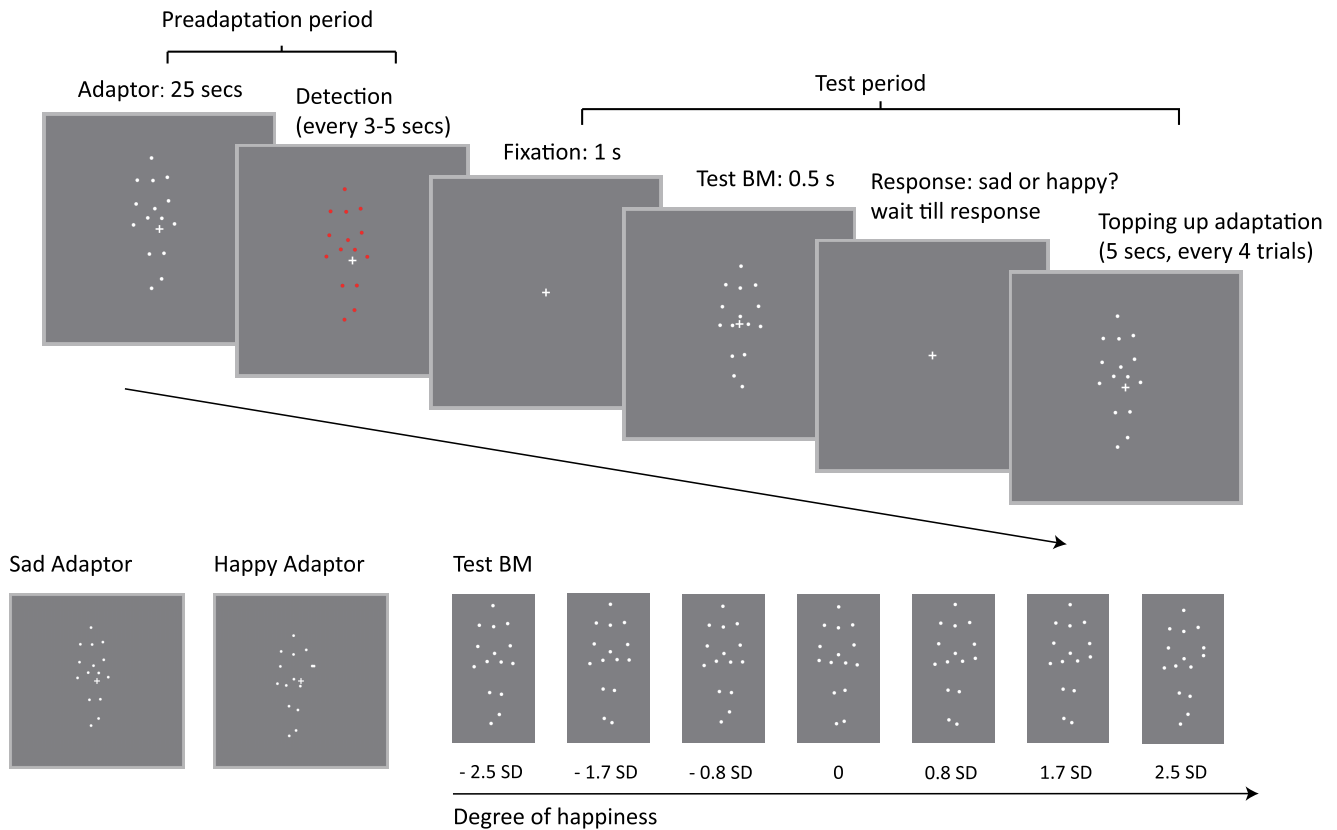
The extreme happy (6 SD into the happy part of the linear axis reflecting the differences between happy and sad walkers) and sad (6 SD into the sad part of the linear axis) BM walkers were employed as the upright BM adaptors (Yuan, Ji, et al., 2023). The inverted adaptors were created by mirror-flipping the upright BMs vertically. The test stimuli were seven morph BM stimuli that varied in the degree of happiness and were sampled from the corresponding points along the happy-sad linear axis ($-2.5 SD$, $-1.7 SD$, $-0.8 SD$, $0 SD$, $0.8 SD$, $1.7 SD$, $2.5 SD$; see Figure 1). This approach of using morphed stimuli was widely adopted by former adaptation studies on both BM (Jordan et al., 2006; Theusner et al., 2011; Troje et al., 2006) and face (Hadj-Bouziane et al., 2008; Xu et al., 2008; Yang et al., 2010; Ying & Xu, 2017). The reason for using the morphed stimuli is to enable us to directly measure the point of subjective equality (PSE), which is the point along the morphing continuum that is the most ambiguous perceptually (yielding 50% of happy/sad responses). According to the PSEs obtained in each condition (baseline, happy adaptation, and sad adaptation), we are able to compute the degree and the direction of subjective perceptual change under different adaptation conditions. This approach is recognized for its advantage in accurately and directly measuring the magnitude of adaptation aftereffects.

Procedure

Participants were seated in front of the computer screen at a viewing distance of 57 cm. They were asked to complete two experimental phases, namely a baseline phase followed by an adaptation phase. Each baseline trial started with 1,000-ms fixation at the central cross ($0.7^\circ \times 0.7^\circ$) of a white frame ($17.9^\circ \times 17.9^\circ$) followed by a test BM ($2.8^\circ \times 8.4^\circ$) presenting centrally for 500 ms. Then, participants had to judge whether the test stimulus was happy or sad as accurately as possible. The baseline phase contained 140 trials with 20 repeats for each test stimulus and a break after every 20 trials. For the adaptation phase, participants needed to complete two blocks (adaptation to sad or happy BM), and the

Figure 1

The Schematic Presentation of Stimuli and Design for the Adaptation Block in the Upright Condition of Experiment 1



Note. The adaptation block began with a preadaptation period lasting for 25 s, where a happy or sad biological motion (BM) stimulus was presented. Participants were asked to pay attention to the stimulus and detect the color change. The preadaptation period was followed by the test period. During the test period, a test stimulus was presented at the center of the screen for 500 ms, and participants were required to judge if it was happy or sad by pressing the response button. The test stimuli were a series of morphed BM stimuli. In addition, a 5-s topping-up adaptation was repeated after every four test trials to maintain the adaptation effect. The “+” symbol represents the fixation cross. See the online article for the color version of this figure.

sequence of the two blocks was counterbalanced between participants. Each adaptation block started with a 25-s preadaptation during which a happy or sad BM was presented as the adaptor, which maintains the aftereffect during the procedure (Fang et al., 2007; Ji et al., 2020; Thurman et al., 2016). The BM adaptor randomly moved within an area of $1.8^\circ \times 1.8^\circ$ to reduce the influence of low-level adaptation. In addition, its color changed to red every 3–5 s, and participants were instructed to follow the stimulus and report the color change immediately by pressing the space key. This color change detection task was administered to maintain the observer’s attention on the adaptor throughout the preadaptation period. After that, a test period of 140 trials identical to the baseline phase was conducted, and participants were asked to make judgments on the emotion of the test BM. Note that after every four trials, a 5-s topping-up adaptation without color change was administered to maintain the adaptation effect (see Figure 1). Before the formal experiment, participants received several practice trials and a minimum of 80% accuracy was required to pass the prior practice. For the inverted adaptation condition, the adaptors were changed to the inverted BM walkers.

Data Analysis

We computed the proportions that a test stimulus was judged as happy for each observer under each adaptation condition and fitted them with a Boltzmann sigmoid function $f(x) = 1/(1 + \exp(x - x_0)/\omega))$, where x denotes the physical difference between a happy stimulus and a sad one ($-2.5 SD$, $-1.7 SD$, $-0.8 SD$, $0 SD$, $0.8 SD$, $1.7 SD$, $2.5 SD$), x_0 denotes the PSE, at which the observer judged a test stimulus as neutral in emotion; and half the interquartile range of the fitted function denotes difference limen (DL), an index of discrimination sensitivity.

Results

We first examined whether prolonged exposure to emotional BM walkers (happy or sad) would bias the emotion perception of the subsequently presented morphed BMs. The mixed 2 (adaptor orientation: upright, inverted) \times 3 (adaptation condition: happy, sad, baseline) ANOVA was conducted on the PSEs. The results revealed a significant interaction between adaptor orientation and

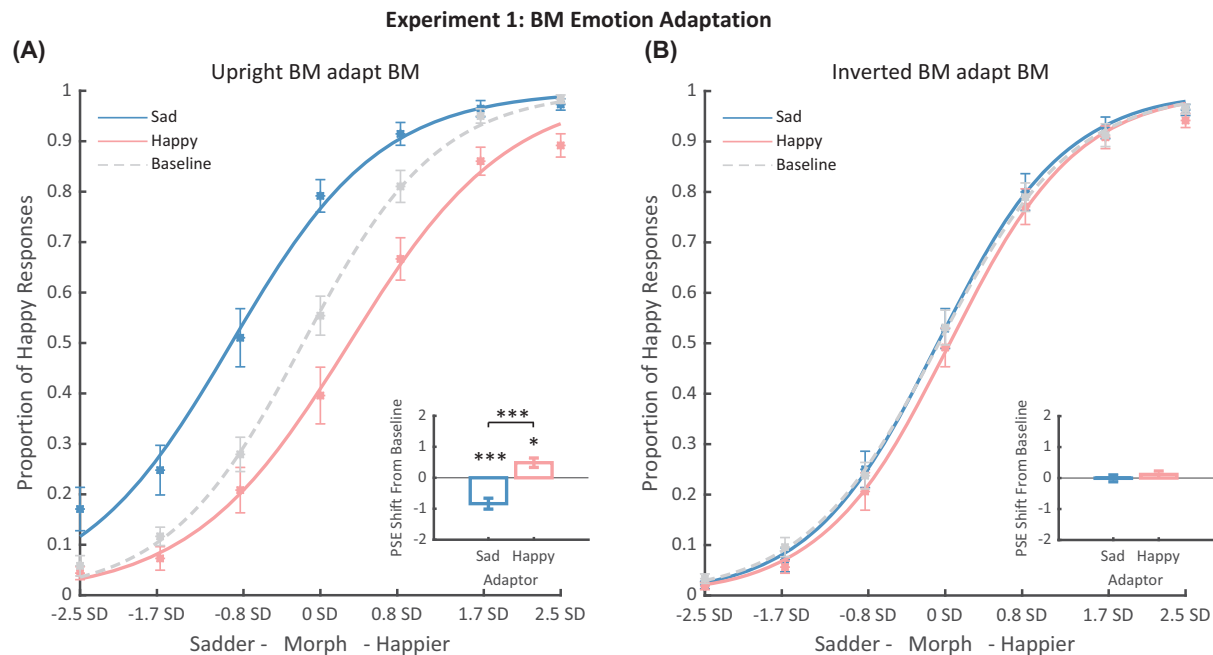
adaptation condition, $F(2, 92) = 19.6, p < .001, \eta_p^2 = 0.30$. To explore this interaction, the one-way repeated measures ANOVA across three adaptation conditions (happy, sad, baseline) was performed separately for the upright and inverted BM adaptors. Importantly, for the upright BM adaptors, we found a significant main effect of adaptation condition, $F(2, 46) = 31.2, p < .001, \eta_p^2 = 0.58$, see Figure 2A. We have then compared the PSE obtained in baseline condition with those obtained in the happy and sad adaptation condition, respectively, for upright and inverted BM adaptors. A positive shift of the PSE relative to baseline would indicate a rightward shift of the psychometric curve or more sad judgments of the test BMs. The paired t tests (Bonferroni-corrected) revealed a significantly larger PSE in the happy adaptation condition than the baseline, happy versus baseline: $t(23) = 3.20, p = .012, d = 0.65$, 95% confidence interval (CI) for the mean difference [0.17, 0.80], see Figure 2A. This showed that preexposure to happy BMs would significantly bias the emotion perception of the subsequent BMs toward sadness. In contrast, adaptation to sad BMs would produce a significantly negative shift in PSEs, sad versus baseline: $t(23) = -4.75, p < .001, d = -0.97$, 95% CI for the mean difference [-1.20, -0.47], see Figure 2A, suggesting an emotion perception bias toward happiness. Besides, a significant difference was also observed between the happy and sad conditions, happy versus sad: $t(23) = 7.41, p < .001, d = 1.51$, 95% CI for the mean difference [0.95, 1.69], Figure 2A. This further indicated that prolonged exposure to happy and sad walkers would systematically bias

participants' emotion perception of the subsequently presented test BMs toward opposite directions, revealing a significant BM emotion adaptation aftereffect. In addition, the observers' discrimination sensitivities (i.e., DL) in the adaptation conditions (baseline, sad, and happy) were not significantly different, $F(2, 46) = 0.38, p = .685, \eta_p^2 = 0.02$, showing that the observed emotion adaptation aftereffects were not caused by changes in sensitivities. Moreover, the obtained aftereffects could not be accounted for by changes in BM gender perception (see Supplemental Material).

In contrast, no significant main effect of adaptation condition was observed with the inverted BM adaptors, $F(1.6, 35.6) = 1.05, p = .345, \eta_p^2 = 0.04$; Greenhouse-Geisser corrected, see Figure 2B. Further post hoc paired-sample t tests on different adaptation conditions (Bonferroni-corrected) also found no significant differences, happy versus baseline: $t(23) = -1.08, p = .880, d = 0.219$, 95% CI for the mean difference [-0.11, 0.34]; sad versus baseline: $t(23) = -0.09, p = 1.000, d = 0.018$, 95% CI for the mean difference [-0.24, 0.22]; happy versus sad, $t(23) = 1.92, p = .204, d = 0.391$, 95% CI for the mean difference [-0.01, 0.27], see Figure 2B. Again, the DLs were not significantly different across the adaptation conditions, $F(2, 46) = 1.19, p = .315, \eta_p^2 = 0.05$. This further indicated that the observed emotion adaptation aftereffects in BM did not arise from the adaptation to parts-based retinotopic features that constitute the BM adaptors.

Overall, we found a salient emotion adaptation aftereffect in the minimalistic point-light BM that is independent of simple retinotopic

Figure 2
Adaptation Aftereffects on BM Emotion Perception From Experiment 1



Note. Proportion of happy responses plotted as a function of the degree of happiness in the morphed BM stimuli. Data are shown for the baseline (gray dashed line), happy adaptation (red line), and sad adaptation (blue line) conditions. Inset shows the mean PSEs for sad and happy adaptation conditions, relative to baseline. (A) Happy and sad upright BMs were taken as adaptors and the morphed BMs were taken as test stimuli. (B) The same test stimuli were used while the adaptors were inverted. Error bars showed standard errors of the mean. BM = biological motion; PSE = point of subjective equality. See the online article for the color version of this figure.

* $p < .05$. *** $p < .001$.

feature adaptation, which further suggested the existence of specific neural populations dedicated to coding higher-order emotional information in BMs.

Experiment 2: Face Emotion Adaptation

To complement the BM study, we further investigated the emotion adaptation aftereffects in face. Similarly, participants were adapted to the upright or inverted extreme happy/sad faces and tested with the morphed faces.

Method

A new group of 48 college students whose ages ranged from 19 to 28 with normal or corrected-to-normal vision were recruited in the study, with 24 (14 females, 10 males; $M = 23.0$ years, $SD = 2.2$ years) in upright face adaptation condition and 24 (15 females, nine males; $M = 23.4$ years, $SD = 2.1$ years) in inverted face adaptation condition. Data were collected in 2024. Three face images of one female actor with different expressions (happy, neutral, and sad) were adopted from the NimStim Set of Facial Expressions and were edited to cut out external features (Tottenham et al., 2009). The happy and sad face images were used as adapting stimuli ($3.7^\circ \times 4.8^\circ$). Besides,

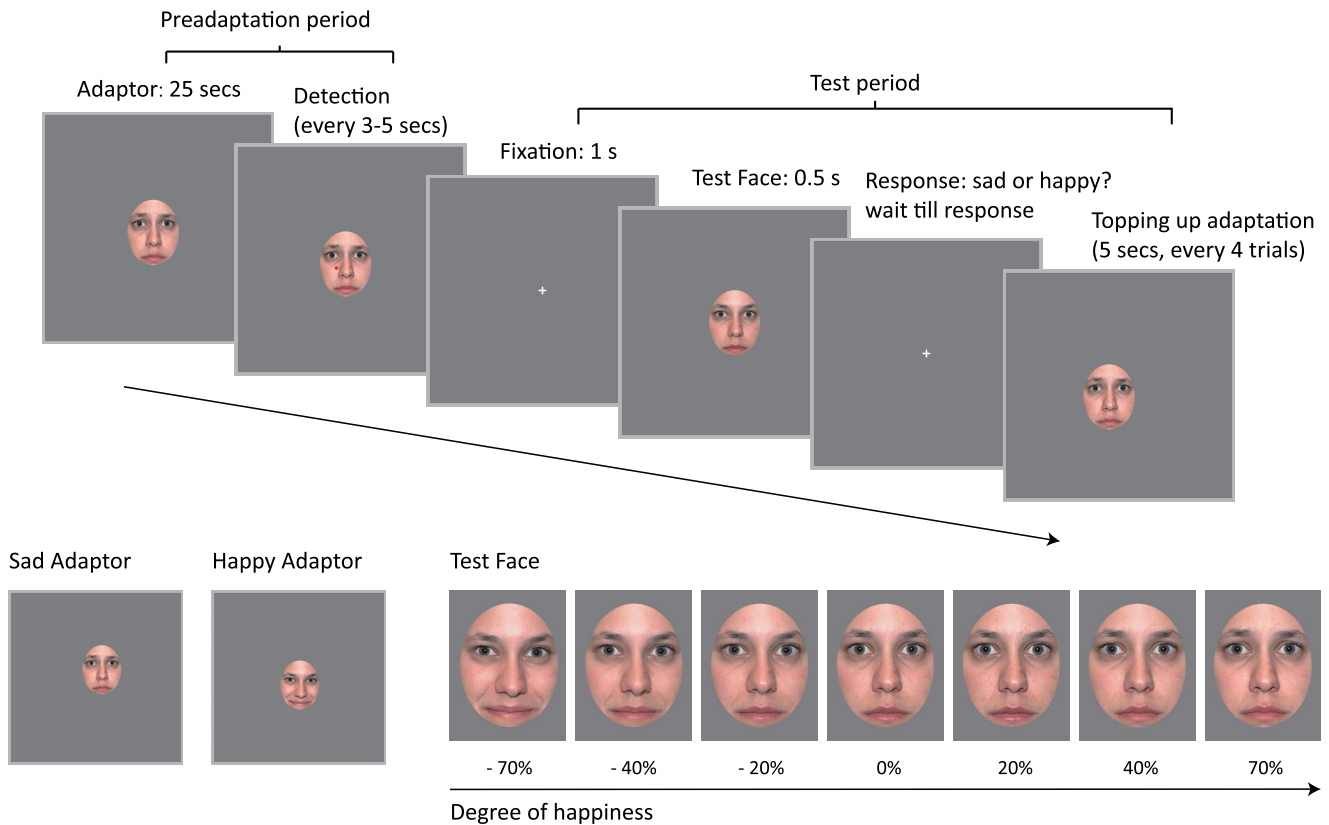
using the FantaMorph software, we generated a continuum of morphed faces for use as test stimuli (see Figure 3). Specifically, the sad face (-100%) was morphed with the neutral face (0%) to generate three images of test faces with -70% , -40% , -20% of happiness, and the happy face (100%) was morphed with the neutral face (0%) to generate another three faces with 20% , 40% , 70% of happiness. The original neutral face was used as the 0% test face. The structure and design of Experiment 2 were identical to that of Experiment 1, with variations being that the adaptors were changed to the upright faces and inverted faces respectively, and the test stimuli were changed to morphed faces. We similarly fitted the proportions of happy responses with a Boltzmann sigmoid function $f(x) = 1/(1 + \exp(x - x_0)/\omega)$, where x denotes the physical difference between a happy face and a sad one (-70% , -40% , -20% , 0 , 20% , 40% , 70%).

Results

We similarly examined whether adaptation to happy and sad faces would produce significant aftereffects on the subsequently presented morphed faces as reported in BM. Similar to Experiment 1, we conducted a mixed 2 (adaptor orientation: upright, inverted) \times 3 (adaptation condition: happy, sad, baseline) ANOVA on PSEs, and the results revealed a significant interaction, $F(2, 92) = 8.64$, $p < .001$,

Figure 3

The Schematic Presentation of Stimuli and Design for the Adaptation Block in the Upright Condition of Experiment 2



Note. The design is identical to that of Experiment 1, except that the adaptors and test stimuli were replaced by emotional faces. Participants were asked to maintain attentional focus and detect the color change during the preadaptation period. They were then asked to make happy or sad judgments on the subsequently presented morphed faces during the test phase. The "+" symbol represents the fixation cross. Images used in Figure are from the NimStim set of Facial Expressions (Tottenham et al., 2009). See the online article for the color version of this figure.

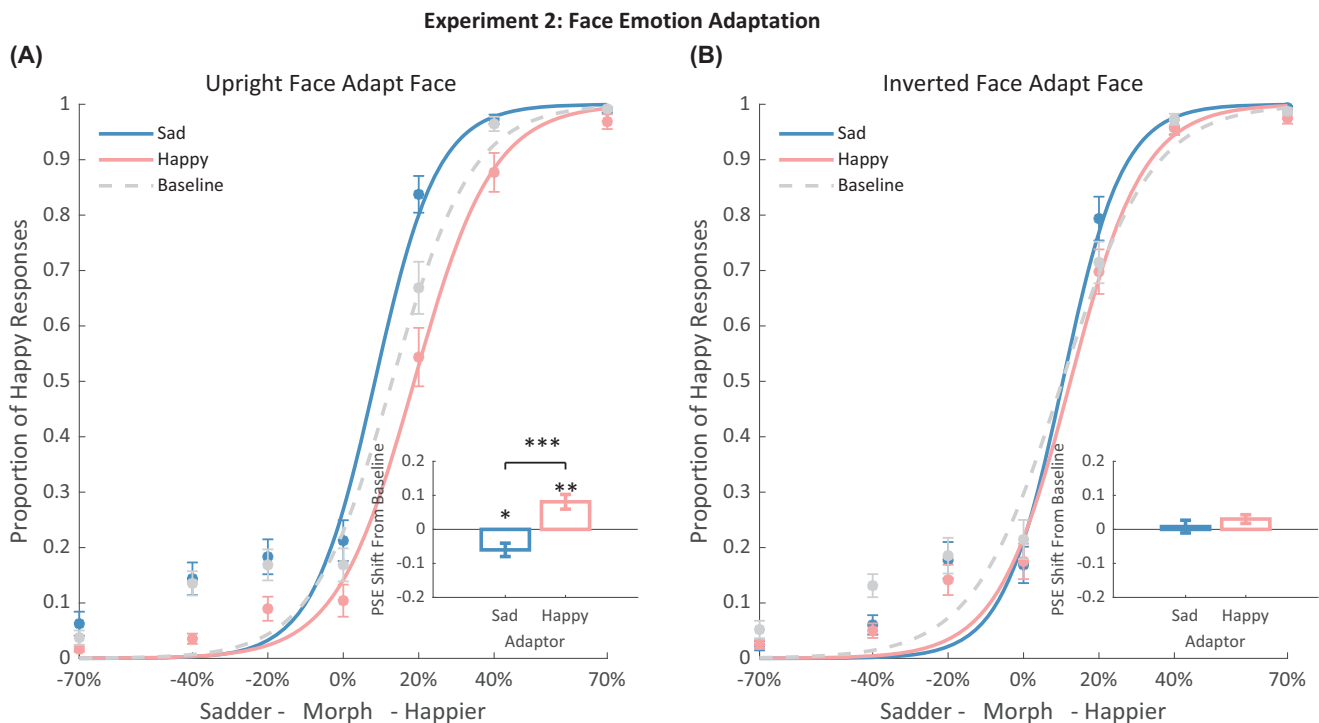
$\eta_p^2 = 0.16$. Further analysis into this interaction was conducted by performing the one-way repeated measures ANOVA on PSEs across three adaptation conditions (happy, sad, and baseline), individually for upright and inverted face adaptors. Results showed that prolonged exposure to upright happy and sad faces could similarly induce significant emotion adaptation aftereffects, $F(1.6, 36.6) = 17.8, p < .001, \eta_p^2 = 0.44$; Greenhouse–Geisser corrected, see Figure 4A, replicating the classic facial expression aftereffect (Benton et al., 2007; Fox & Barton, 2007; Hsu & Young, 2004). Specifically, the happy face induced a significant positive shift as compared to the baseline, $t(23) = 3.76, p = .003, d = 0.77, 95\% \text{ CI for the mean difference } [0.04, 0.13]$; Bonferroni-corrected, see Figure 4A, and the sad face, $t(23) = 4.85, p < .001, d = 0.99, 95\% \text{ CI for the mean difference } [0.08, 0.20]$; Bonferroni-corrected, see Figure 4A. The sad face instead induced a negative shift as compared to the baseline, $t(23) = -3.08, p = .016, d = 0.63, 95\% \text{ CI for the mean difference } [-0.10, -0.02]$; Bonferroni-corrected, see Figure 4A. Besides, the DLs were not significantly different across the adaptation conditions, $F(1.5, 35.5) = 1.23, p = .295, \eta_p^2 = 0.05$; Greenhouse–Geisser corrected, see Figure 4A.

As for the inverted face adaptors, we have observed no significant main effect of adaptation condition, $F(2, 46) = 1.9, p = .161, \eta_p^2 = 0.08$; see Figure 4B. Besides, the post hoc paired-sample t tests (Bonferroni-corrected) also revealed no significant differences, happy

versus baseline: $t(23) = 2.38, p = .078, d = 0.49, 95\% \text{ CI for the mean difference } [0.00, 0.06]$; sad versus baseline: $t(23) = -0.43, p = 1.000, d = 0.09, 95\% \text{ CI for the mean difference } [-0.03, 0.05]$; happy versus sad, $t(23) = 1.36, p = .560, d = 0.28, 95\% \text{ CI for the mean difference } [-0.01, 0.06]$, see Figure 4B. In addition, the DLs were not significantly different across adaptation conditions, $F(1.6, 36.5) = 1.99, p = .159, \eta_p^2 = 0.08$; Greenhouse–Geisser corrected, see Figure 4B. These findings together indicated that the facial expression aftereffect is indeed caused by adaptation to emotional information rather than the constitutive physical features (e.g., eye size).

Besides, to examine whether BM and face induced similar emotion adaptation aftereffects, we have further compared the PSEs obtained with the upright BM and face adaptors. Considering that the test faces and BMs varied in their morph steps and degrees, we converted the PSE obtained in the BM experiment into a percentage, achieved by dividing it by the intensity of the adaptor. This approach measured the distance of perceptual shift in reference to the adaptor, thereby normalizing the magnitude of the aftereffect. The mixed 2 (stimuli type: BM, face) \times 3 (adaptation condition: happy, sad, baseline) repeated measures ANOVA was then performed on the standardized BM and face PSEs, and we found no significant interaction, $F(2, 92) = 3.05, p = .052, \eta_p^2 = 0.06$, indicating that the adaptation to emotions from BM and face is comparable.

Figure 4
Adaptation Aftereffects on Face Emotion Perception



Note. Proportion of happy responses plotted as a function of the degree of happiness in the morphed face stimuli. Data are shown for the baseline (gray dashed line), happy adaptation (red line), and sad adaptation (blue line) conditions. Inset shows the mean PSEs for sad and happy adaptation conditions, relative to baseline. (A) Happy and sad upright face adaptors induced significant adaptation aftereffects on emotion perception of the subsequently presented morphed face. (B) Such aftereffects vanished when the adaptors were inverted. Error bars showed standard errors of the mean. PSE = point of subjective equality. See the online article for the color version of this figure.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Taken together, these results indicated that the high-level emotional attribute conveyed by BM and face could both induce significant adaptation aftereffects, and such aftereffects cannot be explained by the simple adaptation to retinotopic-based constitutive features. Given that the emergence of the adaptation aftereffect is related to alterations in neuronal activities subserving the encoding of particular attributes, these findings together suggest that emotion perception from social signals (i.e., face and BM) engaged specialized neural representations.

Experiment 3: Face-To-BM Emotion Adaptation

We went further to explore whether BM and face, as two distinctive types of social signals that both conveyed important emotional information, could produce a significant cross-channel emotion adaptation. In particular, we adapted participants with emotional faces and tested them with morphed BMs in Experiment 3. This cross-channel adaptation has been adopted in abundant former studies and was found to be effective in probing the common neural mechanisms underlying different types of stimuli (Wang et al., 2017; Watson et al., 2014).

Method

Another group of 36 participants whose ages ranged from 18 to 31 were recruited (21 females, 15 males; $M = 23.0$ years, $SD = 3.0$ years). Data were collected in 2020–2023. We expanded the sample size to 36 out of the consideration that the cross-channel adaptation aftereffect is potentially smaller. This sample size is comparable to or even larger than former similar studies (Cooney et al., 2015; Javadi & Wee, 2012; Wang et al., 2017). We have similarly conducted a sensitivity test to assess the smallest effect size the current sample size is able to detect, and we have found that the sample size of 36 would be sensitive to detect effects of $f = .25$ with 90% power ($\alpha = .05$).

In Experiment 3, we adopted two emotional faces (one with a happy expression and one with a sad expression) as adapting stimuli. Participants were required to detect a red dot appearing on the faces to ensure attention in the preadaptation phase and then judged the emotion of the morphed BMs. We tested the participants with the morphed BM stimuli, which were identical to those adopted in Experiment 1. In particular, we presented the adaptors and test stimuli at a distance of 3.5° to the left of the central cross, because the adaptation effect was stronger when the stimuli were presented in the peripheral vision than in the fovea (Bachy & Zaidi, 2014; Chen et al., 2015; Wang et al., 2017).

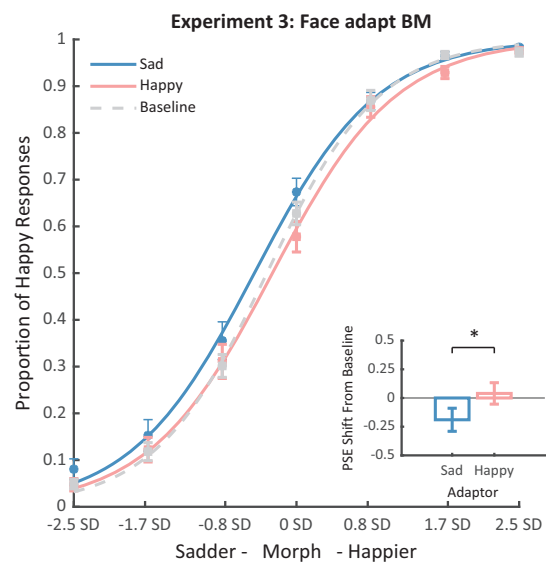
Results

In Experiment 3, we adapted participants with happy and sad faces and then tested them with the morphed emotional BM stimuli. The one-way repeated measures ANOVA was subsequently performed on PSEs obtained in the happy adaptation, sad adaptation, and baseline conditions. A significant main effect of adaptation condition was found, $F(2, 70) = 3.70$, $p = .030$, $\eta_p^2 = 0.10$, see Figure 5. The follow-up paired-sample t tests (Bonferroni-corrected) further showed that the adaptation to happy faces would significantly shift the PSEs rightwards as compared to sad faces, happy versus sad: $t(35) = 3.07$, $p = .012$, $d = 0.51$, 95% CI for the mean difference [0.08, 0.38], see Figure 5. No significant shifts were found for the sad and happy

adaptation conditions as compared to baseline, happy versus baseline: $t(35) = 0.43$, $p = 1.000$, $d = 0.07$, 95% CI for the mean difference [−0.15, 0.23]; sad versus baseline: $t(35) = -1.89$, $p = .202$, $d = 0.31$, 95% CI for the mean difference [−0.39, 0.01], see Figure 5, which may be due to the bias and inconsistency of the baseline condition and the adaptation condition. This is because another type of stimuli (i.e., face) was introduced as the adaptor in the adaptation condition, thus, participants may devote more attentional resources as they need to constantly shift their perceptions between static face and dynamic BM. It has been reported that the high cognitive load would inhibit the perception of sad emotion while the perception of happy emotion is unaffected (Gupta & Srinivasan, 2015; Tracy & Robins, 2008). Thus, participants may tend to make more happy judgments in the adaptation condition than baseline, resulting in a general leftward shift, which has been similarly discovered in former studies (Watson & de Gelder, 2020). Given that the cross-channel adaptation effect is relatively small, this may prevent the present study from discovering a significant difference between the adaptation condition and baseline condition. Notably, this should not influence the main contrast between the happy and sad adaptation conditions, as they are matched in this aspect. Still, future studies could adopt the neutral BM/face adaptors as the baseline to rule out this possible confound.

Overall, these results indicated that adaptation to faces with opposite emotions (i.e., happy and sad) would systematically bias the emotion perception in the subsequently presented morphed BM and induce a typical emotion adaptation aftereffect. In addition, the

Figure 5
Face-To-BM Emotion Adaptation Aftereffects From Experiment 3



Note. Proportion of happy responses plotted as a function of the degree of happiness in the morph stimuli. Data are shown for the baseline (gray dashed line), happy adaptation (red line), and sad adaptation (blue line) conditions. Inset shows the mean PSEs for each adaptation condition, as compared to the baseline. In Experiment 3, happy and sad faces were used as adaptors, and the morphed BMs were used as test stimuli. Error bars showed standard errors of the mean. BM = biological motion; PSE = point of subjective equality. See the online article for the color version of this figure.

* $p < .05$.

observers' DLs did not differ among the adaptation conditions, $F(2, 70) = 0.20, p = .817, \eta_p^2 = 0.01$, indicating that the observed cross-channel adaptation was not caused by differences in sensitivities. We have further conducted a mixed 2 (adaptation channel: BM-to-BM, Face-to-BM) \times 3 (adaptation condition: happy, sad, baseline) ANOVA on PSEs obtained in the upright condition of Experiment 1 and Experiment 3 to examine whether or not the cross-channel emotion adaptation varied from that obtained within the BM channel. The results showed a significant interaction between adaptation channel and adaptation conditions, $F(2, 116) = 19.3, p < .001, \eta_p^2 = 0.25$. To investigate this interaction, we computed the magnitude of the adaptation aftereffect by subtracting the sad PSEs from the happy PSEs. An independent-sample Welch's t test was then conducted on the magnitude of aftereffects obtained in the upright condition of Experiment 1 and Experiment 3. The results revealed a significant decrease in adaptation aftereffects when adaptors were from the different channel than from the same channel, 1.32 versus 0.23; $t(31.2) = 5.65, p < .001, d = 1.57, 95\%$ CI for the mean difference [0.70, 1.49], which parallels with former findings (Cooney et al., 2015; Wang et al., 2017). In addition, considering that the observed cross-channel adaptation effect is relatively small, we have further conducted a split-half reliability analysis to assess the internal consistency of the cross-channel adaptation task. Specifically, Cronbach's α coefficient was calculated for the

difference in PSEs obtained from the sad and happy adaptation conditions based on the odd and even split halves of trials, and the results indicated a moderate to high reliability of the task ($\alpha = .59$).

Experiment 4: BM-To-Face Emotion Adaptation

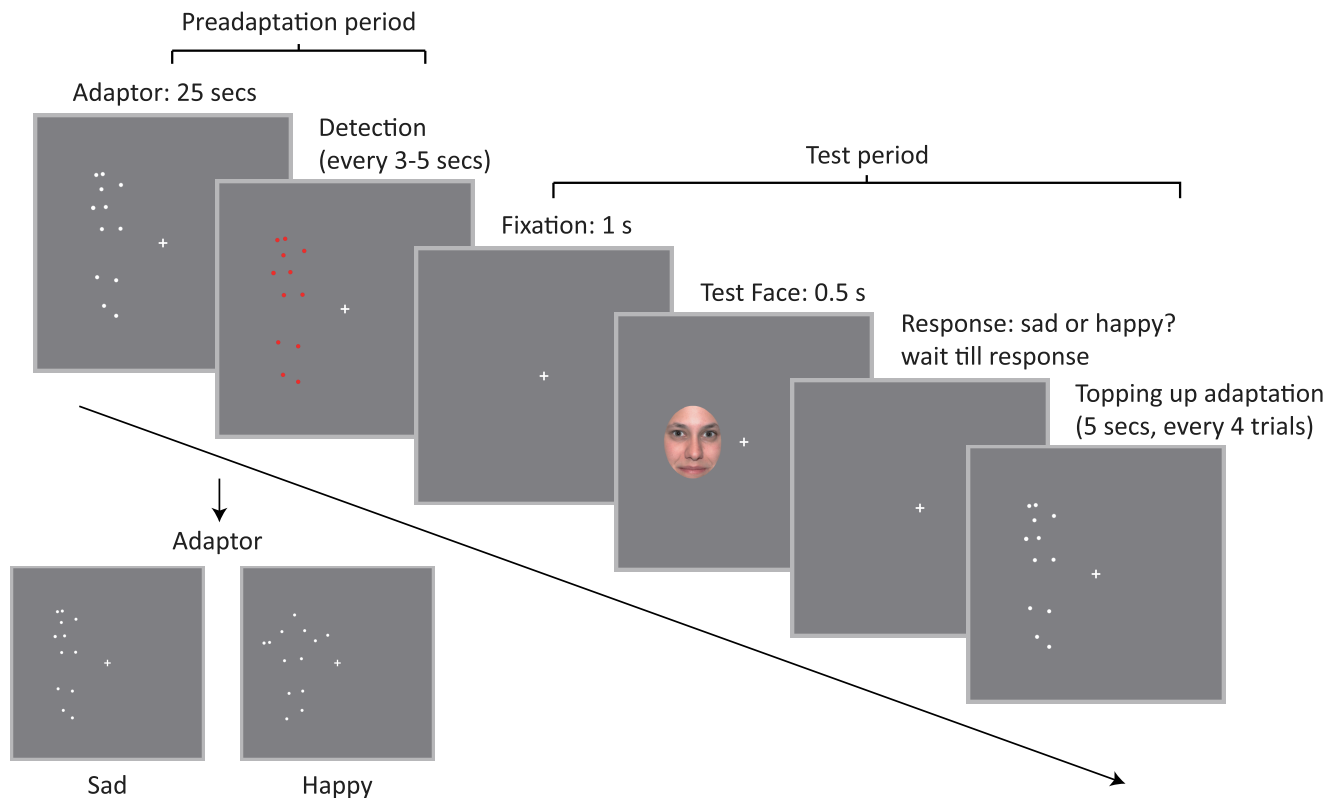
We subsequently examined whether the cross-channel adaptation is symmetric by adapting participants with emotional BMs and testing them with morphed faces in Experiment 4.

Method

Another 36 participants whose ages ranged from 18 to 31 were recruited (24 females, 12 males; $M = 23.3$ years, $SD = 3.0$ years). Data were collected in 2021–2023. In Experiment 4, faces and BMs switched their roles, namely, participants were exposed to happy and sad BM adaptors and were asked to make emotional judgments upon the morphed faces (Figure 6). Given that the cross-channel adaptation could be relatively small, we decided to use the happy and sad BM from Atkinson et al. (2012) as adaptors in the cross-channel adaptation experiment. Compared with Troje (2008), the stimuli from Atkinson et al. (2012) were more variant and naturalistic in emotion expression, as they were not restricted to the overall walking pattern. Moreover, we conducted a preliminary experiment

Figure 6

The Schematic Presentation of Stimuli and Design for the Adaptation Block in Experiment 4



Note. The design of Experiment 4 is similar to the upright condition of Experiment 1, except that we presented the adaptors and the test stimuli on the left side of the screen to enhance the adaptation aftereffect. Participants were adapted with happy or sad BMs and then required to make responses on whether the test face was happy or sad. BM = biological motion. The “+” symbol represents the fixation cross. Image used in Figure is from the NimStim set of Facial Expressions (Tottenham et al., 2009). See the online article for the color version of this figure.

to choose the strongest and clearest happy and sad BM as adaptors. Several participants were recruited to classify different emotional BM stimuli and rate their emotional intensity, and the two most recognizable happy (Actor 3) and sad (Actor 4) BM with matched emotional intensity in the preliminary experiment were selected as adaptors in our adaptation experiment. The test face stimuli used in Experiment 4 were taken from Experiment 2.

Results

An identical repeated measures ANOVA was conducted, and a significant main effect of adaptation condition was observed, $F(1.3, 46.5) = 4.31, p = .033, \eta_p^2 = 0.11$; Greenhouse–Geisser corrected, see Figure 7. Further analyses (Bonferroni-corrected) revealed a significantly smaller PSE after sad BM adaptation relative to happy BM adaptation, happy versus sad: $t(35) = 3.62, p = .003, d = 0.60, 95\% \text{ CI for the mean difference } [0.01, 0.05]$, see Figure 7. Again, no other significant differences were observed, happy versus baseline: $t(35) = -0.79, p = 1.000, d = 0.13, 95\% \text{ CI for the mean difference } [-0.06, 0.03]$; sad versus baseline: $t(35) = -2.50, p = .052, d = 0.42, 95\% \text{ CI for the mean difference } [-0.09, -0.01]$, see Figure 7. Besides, an identical split-half analysis was conducted to assess the reliability of the observed BM-to-face adaptation effect, and the effect was also moderate to high ($\alpha = .65$). These findings together demonstrate that viewing happy and sad BMs would similarly exert an emotion adaptation effect on the emotion perception of faces. Besides, no significant differences in DLs were found

across adaptation conditions, $F(1.62, 56.70) = 2.13, p = .138, \eta_p^2 = 0.06$; Greenhouse–Geisser corrected. We also conducted a mixed 2 (adaptation channel: Face-to-Face, BM-to-Face) \times 3 (adaptation condition: happy, sad, baseline) ANOVA on PSEs obtained in the upright condition of Experiment 2 and Experiment 4 to examine whether or not the same-channel and the cross-channel emotion adaptation differed. The results showed a significant interaction between adaptation channel and adaptation conditions, $F(2, 116) = 8.65, p < .001, \eta_p^2 = 0.13$. Similarly, the independent-sample Welch's t test was conducted on the magnitude of the adaptation aftereffect on morphed faces obtained with upright face and BM. The results revealed a significant drop when adaptors were from the different channel than from the same channel, 0.14 versus 0.03; $t(27.7) = 3.53, p = .001, d = 1.00, 95\% \text{ CI for the mean difference } [0.05, 0.17]$.

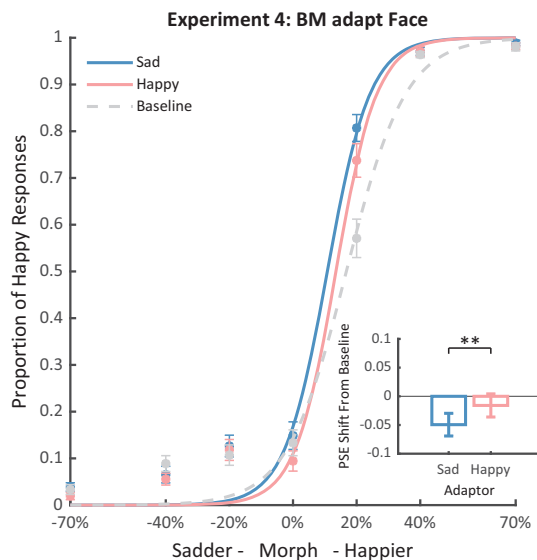
We went further to examine whether the observed cross-channel adaptation effect differed when the adaptors and test stimuli switched their roles in Experiments 3 and 4. Specifically, we converted the face-to-BM aftereffect into standardized percentage changes relative to the adaptor intensity, and a subsequent mixed 2 (adaptation type: Face-to-BM, BM-to-Face) \times 3 (adaptation condition: happy, sad, baseline) repeated measures ANOVA was conducted. Notably, no significant interaction between the adaptation type and adaptation condition was observed, $F(2, 140) = 0.54, p = .584, \eta_p^2 = 0.01$, indicating that the cross-channel emotion adaptation effects observed in both directions were comparable. Besides, we found a significant main effect of adaptation condition, $F(1.6, 108.5) = 7.55, p = .002, \eta_p^2 = 0.10$; Greenhouse–Geisser corrected. The follow-up post hoc analysis (Bonferroni-corrected) indicated that the sad adaptor (BM/face) induced significant negative shifts on emotion perception of another channel of test stimuli as compared to the baseline, $t(70) = -3.12, p = .008, d = 0.37, 95\% \text{ CI for the mean difference } [-0.07, -0.01]$, and the happy adaptation condition, $t(70) = -4.63, p < .001, d = 0.55, 95\% \text{ CI for the mean difference } [-0.05, -0.02]$. However, no significant difference was found between the happy and baseline conditions, $t(70) = -0.362, p = 1.000, d = 0.04, 95\% \text{ CI for the mean difference } [-0.03, 0.02]$. These results indicated that the sad emotion could produce significant aftereffects in the cross-channel adaptation condition. The reason why no significant difference was observed between the happy and baseline conditions is probably because of the general rightward shift brought by the introduction of another channel of stimuli.

Overall, the converging findings of Experiments 3–4 demonstrated that the emotions could be adapted across channels between face and BM, which together suggested the existence of a potentially shared neural representation for emotions contained in face and BM.

Discussion

Social cues, such as face and BM, convey salient emotional information that is crucial for human survival and social interactions (Schirmer & Adolphs, 2017). Here, we found that prolonged exposure to happy and sad BMs biased the emotion perception of the subsequently presented morphed BMs toward the opposite direction, showing a typical emotion adaptation aftereffect. This effect vanished when the inverted BM adaptors with identical visual features were presented, indicating that such an effect occurred at a level at which the emotional feature rather than the simple constitutive

Figure 7
BM-To-Face Emotion Adaptation Aftereffect From Experiment 4



Note. Proportion of happy responses plotted as a function of the degree of happiness in the morph stimuli. Data are shown for the baseline (gray dashed line), happy adaptation (red line), and sad adaptation (blue line) conditions. Inset shows the mean PSEs for each adaptation condition, as compared to the baseline. In Experiment 4, participants were adapted with happy and sad BMs and tested on the morphed faces. Error bars showed standard errors of the mean. BM = biological motion; PSE = point of subjective equality. See the online article for the color version of this figure.

** $p < .01$.

feature (e.g., speed) is encoded. Besides, a comparable emotion adaptation aftereffect was also observed in faces, which similarly disappeared when the adaptors were displayed inverted. More importantly, BM and face, though varied significantly in low-level properties and emotion expression, were found to produce a cross-channel emotion adaptation. Viewing happy and sad faces biased the emotion perception of the subsequently presented morphed BMs. Reversely, preexposure to emotional BMs also biased the facial emotion perception. Taken together, these findings demonstrate significant emotion adaptation aftereffects in both BM and face, and a bidirectional cross-channel emotion adaptation aftereffect between BM and face. Such aftereffects further suggested the existence of a specialized neural module for emotions that can be shared by these two different types of social signals.

The emotion adaptation aftereffects have been extensively investigated using faces in previous studies (for a review, see Webster & MacLeod, 2011). So far, only limited studies have explored the emotion plasticity in point-light BMs (Halovic et al., 2020; Mazzoni et al., 2017) and found a significantly slower identification time after exposure to BM with the same emotions. However, these studies did not use morph stimuli to directly measure the shifts in emotion perception (Halovic et al., 2020; Mazzoni et al., 2017), and the observed effect was also confounded with the adaptation to simple visual features that constitute the adaptors (Halovic et al., 2020). Here, we demonstrated an unambiguous BM emotion adaptation aftereffect that preexposure to happy BM would make the subsequently presented neutral stimuli appear sad and vice versa. Importantly, such an effect was not caused by the adaptation to constitutive perceptual features, as inverted BM adaptors with identical visual features failed to induce any aftereffects. Overall, these findings suggested the existence of specialized neural modules dedicated to the processing of higher-order emotion features in BM. Moreover, our finding also extends the line of inquiry showing that the human visual system, which is highly sensitive to life motion signals, could be adapted to the various higher-order attributes (e.g., gender, action, walking direction) of BM (Theusner et al., 2011; Thurman et al., 2016; Troje et al., 2006). Such experience-dependent plasticity allows us to readily detect minor changes in social signals and is especially vital for interpreting intentions and guiding social interactions.

Noticeably, this emotion adaptation can not only occur within the channel of BM but also happen across channels between face and BM. Such a cross-channel emotion adaptation aftereffect provided direct evidence for the tight coupling between the perception of point-light BM and face. It has been documented that despite significant differences in perceptual properties, BM and face still shared very similar and closely connected processing mechanisms. For instance, newborn infants already showed an early life preference for point-light BM and face (Simion et al., 2008; Thompson & Hardee, 2008; Valenza et al., 1996; Viola Macchi et al., 2004). Besides, a significant inversion effect was observed in the visual recognition and detection of face as well as BM (Chang et al., 2010; M. Pavlova & Sokolov, 2000; Sumi, 1984; Troje & Westhoff, 2006; Yin, 1969). Furthermore, patients with impairments in face recognition also showed deficiencies in BM processing (Lange et al., 2009). More importantly, neural studies have found that critical brain regions involved in face perception were also responsible for the processing of BM (Engell & McCarthy, 2013; Grossman et al., 2000; Peelen et al., 2006; Servos, 2002; Vaina et al., 2001). These findings together imply a possibly shared neural mechanism for these two

types of social signals. However, these studies only offered inferential evidence, as they were conducted independently with a focus on either face or BM. As of now, there still lacks direct investigation that manipulated neural activities underlying face perception to examine whether BM perception would be consequently changed, and vice versa. In the present study, we adopted the cross-channel visual adaptation paradigm, which is recognized for its ability to alter activities from the neuronal level. Importantly, we have obtained a significant cross-channel emotion adaptation aftereffect, and such an aftereffect persisted when the adaptor and the test stimuli switched their roles. Our finding thus offers reliable and unambiguous evidence for the close interconnections between face and BM from the emotion dimension, and further suggests a shared neural representation that processes emotional information from these two types of social signals. In contrast, former research has found no cross-channel adaptation between face and BM in the gender dimension (Hiris et al., 2016). Thus, the observed adaptation effect could be emotion-specific, which echoes previous research showing that the adaptation of emotion, unlike that of gender and identity, is special and can occur without conscious awareness (Adams et al., 2010; Amihai et al., 2011; Moradi et al., 2005). This is probably because emotion conveys critical evolutionary-related signals and its processing recruits more automatic subcortical neural circuits (e.g., amygdale; Jiang et al., 2009; Jiang & He, 2006; Killgore & Yurgelun-Todd, 2004; Williams et al., 2004). Notably, it has been reported that individuals with social cognitive disorders (e.g., autism) showed impairments in emotion perception of both face and BM (Harms et al., 2010; Hubert et al., 2007; Mazzoni et al., 2022; Nackaerts et al., 2012; M. A. Pavlova, 2012). Our finding hence provides a potential account for this shared deficiency by suggesting a common underlying neural basis for facial and BM emotion perception. More importantly, the observed cross-channel emotion adaptation effect, which involved the emotion processing of both face and BM, may potentially serve as a more sensitive and reliable behavioral marker for detecting early social disorders. Still, it should be noted that the present study is solely based on behavioral data and points to the necessity for future studies combining the cross-channel adaptation paradigm and functional magnetic resonance imaging technique, which could provide more convincing evidence for the common neural mechanism underlying face and BM (Calder et al., 2007; Watson et al., 2014).

Emotions are expressed by various social signals, including faces, human movements, and voices, thus, it seems critical for humans to possess a common neural representation of emotions across different channels to enable holistic interpretation of others' internal states (Schirmer & Adolphs, 2017). In fact, this idea has received support from multiple former studies showing a cross-modal emotion adaptation such that laughter could adapt facial expressions (Wang et al., 2017) and that facial expressions also biased the perception of emotional vocalizations (Pye & Bestelmeyer, 2015; Skuk & Schweinberger, 2013). An additional line of inquiry has shown that emotions expressed in face and body would interact to influence emotion perception across both conscious and unconscious routes (Albohn et al., 2022; Meeren et al., 2005). Different from face and body, the BM stimuli were dynamic and highly simplified, which relied on the movement of several point-light dots attached to the major joints to convey emotional information. Yet to today, no study has examined whether emotions could be integrated and even adapted across static and dynamic visual social signals. Here, we

reported a novel bidirectional cross-channel emotion adaptation between faces and the highly impoverished BM stimuli. This finding provides fresh insights into the multichannel integration of emotions and lends further support to the existence of a supramodal emotion neural representation. Notably, such cross-channel aftereffects could not be explained as the result of a pure conceptual adaptation. The underlying premise is that if the emotion adaptation did arise from the pure conceptual level, then adaptation to any form of emotional stimulus could create a cross-channel aftereffect (Webster & MacLeod, 2011). However, it has been found that nonfacial scene images or words that convey emotional information failed to exert aftereffects on facial expression perception (Fox & Barton, 2007). Particularly, no emotion adaptation aftereffect has been reported for emotional scenes (Palumbo et al., 2017). These findings collectively implied that the facial expression aftereffect observed in the present study is unlikely to be induced by the pure conceptual adaptation to BM emotions but would involve a shared perceptual module subserving BM and face emotion perception. They also suggested that the shared emotion module might exist specifically in the inherent biosocial signals but not in the emotional scenes, as the former represents the emotional state of our conspecifics and plays a central role in interpersonal interactions (Calder et al., 2011). Nevertheless, future research is needed to adopt the largely unaddressed BM stimuli together with other types of biosocial (e.g., voices) and nonbiosocial emotional stimuli (e.g., scenes) to further examine the specialized emotion processing mechanism underlying biosocial signals that is potentially distinct from the mechanism subserves nonbiosocial signals.

Constraints on Generality

It should be pointed out that we have only recruited Asian college students and we attempted to balance their genders. While this enrollment criterion enhanced the internal consistency, it may limit the external validity. Future research could include participants from diverse age groups (e.g., children, seniors) to examine the observed aftereffects within a more representative general population. In addition, given that emotion perception deficit is a central characteristic of social functioning disability (Harms et al., 2010; Hudepohl et al., 2015), it would also be valuable to investigate whether the observed same-channel and cross-channel emotion adaptation aftereffect still exist in individuals with social cognitive deficits. Besides, our study utilized only one female white face and BM stimuli with ambiguous gender and identity. Although it has been found that emotion adaptation is invariant to changes in identity, race, and gender (Bestelmeyer et al., 2010; Ellamil et al., 2008; Winston et al., 2004; Ying & Xu, 2017), future studies could incorporate emotional faces and BMs of different identities/genders to examine the generalizability of the observed aftereffects. Moreover, our experiments were conducted in standard laboratory conditions, and it would be beneficial for future studies to further investigate this issue in more naturalistic and ecological settings to provide valuable insights into the broader context of emotion perception from different types of social signals.

Conclusion

To conclude, the present study demonstrated a salient emotion adaptation aftereffect in BM and face, and a bidirectional

cross-channel adaptation between BM and face. These findings together suggested the existence of specific neural modules dedicated to coding emotions that can be shared across different types of social signals (face and BM). They also shed new light on the tight coupling of BM and face perception from the emotional perspective.

References

- Actis-Grosso, R., Bossi, F., & Ricciardelli, P. (2015). Emotion recognition through static faces and moving bodies: A comparison between typically developed adults and individuals with high level of autistic traits. *Frontiers in Psychology, 6*, Article 1570. <https://doi.org/10.3389/fpsyg.2015.01570>
- Adams, W. J., Gray, K. L. H., Garner, M., & Graf, E. W. (2010). High-level face adaptation without awareness. *Psychological Science, 21*(2), 205–210. <https://doi.org/10.1177/0956797609359508>
- Alaerts, K., Nackaerts, E., Meyns, P., Swinnen, S. P., & Wenderoth, N. (2011). Action and emotion recognition from point light displays: An investigation of gender differences. *PLOS ONE, 6*(6), Article e20989. <https://doi.org/10.1371/journal.pone.0020989>
- Alaerts, K., Woolley, D. G., Steyaert, J., Di Martino, A., Swinnen, S. P., & Wenderoth, N. (2014). Underconnectivity of the superior temporal sulcus predicts emotion recognition deficits in autism. *Social Cognitive and Affective Neuroscience, 9*(10), 1589–1600. <https://doi.org/10.1093/scan/nst156>
- Albohn, D. N., Brandenburg, J. C., Kveraga, K., & Adams, R. B., Jr. (2022). The shared signal hypothesis: Facial and bodily expressions of emotion mutually inform one another. *Attention, Perception, & Psychophysics, 84*(7), 2271–2280. <https://doi.org/10.3758/s13414-022-02548-6>
- Amihai, I., Deouell, L., & Bentin, S. (2011). Conscious awareness is necessary for processing race and gender information from faces. *Consciousness and Cognition, 20*(2), 269–279. <https://doi.org/10.1016/j.concog.2010.08.004>
- Atkinson, A. P., Tunstall, M. L., & Dittrich, W. H. (2007). Evidence for distinct contributions of form and motion information to the recognition of emotions from body gestures. *Cognition, 104*(1), 59–72. <https://doi.org/10.1016/j.cognition.2006.05.005>
- Atkinson, A. P., Vuong, Q. C., & Smithson, H. E. (2012). Modulation of the face- and body-selective visual regions by the motion and emotion of point-light face and body stimuli. *NeuroImage, 59*(2), 1700–1712. <https://doi.org/10.1016/j.neuroimage.2011.08.073>
- Aviezer, H., Trope, Y., & Todorov, A. (2012). Body cues, not facial expressions, discriminate between intense positive and negative emotions. *Science, 338*(6111), 1225–1229. <https://doi.org/10.1126/science.1224313>
- Bachmann, J., Munzert, J., & Krüger, B. (2018). Neural underpinnings of the perception of emotional states derived from biological human motion: A review of neuroimaging research. *Frontiers in Psychology, 9*, Article 1763. <https://doi.org/10.3389/fpsyg.2018.01763>
- Bachy, R., & Zaidi, Q. (2014). Factors governing the speed of color adaptation in foveal versus peripheral vision. *Journal of the Optical Society of America A, 31*(4), A220–A225. <https://doi.org/10.1364/JOSAA.31.00A220>
- Basil, R. A., Westwater, M. L., Wiener, M., & Thompson, J. C. (2017). A causal role of the right superior temporal sulcus in emotion recognition from biological motion. *Open Mind: Discoveries in Cognitive Science, 2*(1), 26–36. https://doi.org/10.1162/opmi_a_00015
- Becker, D. V., Anderson, U. S., Mortensen, C. R., Neufeld, S. L., & Neel, R. (2011). The face in the crowd effect unconfounded: Happy faces, not angry faces, are more efficiently detected in single- and multiple-target visual search tasks. *Journal of Experimental Psychology: General, 140*(4), 637–659. <https://doi.org/10.1037/a0024060>
- Benda, J. (2021). Neural adaptation. *Current Biology, 31*(3), R110–R116. <https://doi.org/10.1016/j.cub.2020.11.054>

- Benton, C. P., Eitchells, P. J., Porter, G., Clark, A. P., Penton-Voak, I. S., & Nikolov, S. G. (2007). Turning the other cheek: The viewpoint dependence of facial expression after-effects. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1622), 2131–2137. <https://doi.org/10.1098/rspb.2007.0473>
- Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., & Welling, L. L. M. (2010). Face aftereffects suggest interdependent processing of expression and sex and of expression and race. *Visual Cognition*, *18*(2), 255–274. <https://doi.org/10.1080/13506280802708024>
- Blake, R., & Shiffrar, M. (2007). Perception of human motion. *Annual Review of Psychology*, *58*(1), 47–73. <https://doi.org/10.1146/annurev.psych.57.102904.190152>
- Boynton, G. M., & Finney, E. M. (2003). Orientation-specific adaptation in human visual cortex. *The Journal of Neuroscience*, *23*(25), 8781–8787. <https://doi.org/10.1523/JNEUROSCI.23-25-08781.2003>
- Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision*, *10*(4), 433–436. <https://doi.org/10.1163/156856897X00357>
- Brooks, J. A., Chikazoe, J., Sadato, N., & Freeman, J. B. (2019). The neural representation of facial-emotion categories reflects conceptual structure. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(32), 15861–15870. <https://doi.org/10.1073/pnas.1816408116>
- Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology*, *77*(3), 305–327. <https://doi.org/10.1111/j.2044-8295.1986.tb02199.x>
- Calder, A. J., Beaver, J. D., Winston, J. S., Dolan, R. J., Jenkins, R., Eger, E., & Henson, R. N. A. (2007). Separate coding of different gaze directions in the superior temporal sulcus and inferior parietal lobule. *Current Biology*, *17*(1), 20–25. <https://doi.org/10.1016/j.cub.2006.10.052>
- Calder, A. J., Rhodes, G., Johnson, M., & Haxby, J. (2011). *Oxford handbook of face perception*. Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780199559053.001.0001>
- Calder, A. J., & Young, A. W. (2005). Understanding the recognition of facial identity and facial expression. *Nature Reviews Neuroscience*, *6*(8), 641–651. <https://doi.org/10.1038/nrn1724>
- Chang, D. H. F., Harris, L. R., & Troje, N. F. (2010). Frames of reference for biological motion and face perception. *Journal of Vision*, *10*(6), Article 22. <https://doi.org/10.1167/10.6.22>
- Chen, C., Chen, X., Gao, M., Yang, Q., & Yan, H. (2015). Contextual influence on the tilt after-effect in foveal and para-foveal vision. *Neuroscience Bulletin*, *31*(3), 307–316. <https://doi.org/10.1007/s12264-014-1521-5>
- Clifford, C. W. G. (2002). Perceptual adaptation: Motion parallels orientation. *Trends in Cognitive Sciences*, *6*(3), 136–143. [https://doi.org/10.1016/S1364-6613\(00\)01856-8](https://doi.org/10.1016/S1364-6613(00)01856-8)
- Cooney, S. M., O’Shea, A., & Brady, N. (2015). Point me in the right direction: Same and cross category visual aftereffects to directional cues. *PLOS ONE*, *10*(10), Article e0141411. <https://doi.org/10.1371/journal.pone.0141411>
- Darwin, C., & Phillip, P. (1998). *The expression of the emotions in man and animals*. Oxford University Press. <https://doi.org/10.1093/oso/9780195112719.001.0001>
- de Gelder, B. (2006). Towards the neurobiology of emotional body language. *Nature Reviews Neuroscience*, *7*(3), 242–249. <https://doi.org/10.1038/nrn1872>
- Dittrich, W. H., Troscianko, T., Lea, S. E., & Morgan, D. (1996). Perception of emotion from dynamic point-light displays represented in dance. *Perception*, *25*(6), 727–738. <https://doi.org/10.1068/p250727>
- Ekman, P., & Oster, H. (1979). Facial expressions of emotion. *Annual Review of Psychology*, *30*(1), 527–554. <https://doi.org/10.1146/annurev.ps.30.020179.002523>
- Ellamil, M., Susskind, J. M., & Anderson, A. K. (2008). Examinations of identity invariance in facial expression adaptation. *Cognitive, Affective & Behavioral Neuroscience*, *8*(3), 273–281. <https://doi.org/10.3758/CABN.8.3.273>
- Engell, A. D., & Haxby, J. V. (2007). Facial expression and gaze-direction in human superior temporal sulcus. *Neuropsychologia*, *45*(14), 3234–3241. <https://doi.org/10.1016/j.neuropsychologia.2007.06.022>
- Engell, A. D., & McCarthy, G. (2013). Probabilistic atlases for face and biological motion perception: An analysis of their reliability and overlap. *NeuroImage*, *74*, 140–151. <https://doi.org/10.1016/j.neuroimage.2013.02.025>
- Fang, F., Murray, S. O., & He, S. (2007). Duration-dependent fMRI adaptation and distributed viewer-centered face representation in human visual cortex. *Cerebral Cortex*, *17*(6), 1402–1411. <https://doi.org/10.1093/cercor/bhl053>
- Farroni, T., Menon, E., Rigato, S., & Johnson, M. H. (2007). The perception of facial expressions in newborns. *European Journal of Developmental Psychology*, *4*(1), 2–13. <https://doi.org/10.1080/17405620601046832>
- Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. <https://doi.org/10.3758/BF03193146>
- Fox, C. J., & Barton, J. J. S. (2007). What is adapted in face adaptation? The neural representations of expression in the human visual system. *Brain Research*, *1127*(1), 80–89. <https://doi.org/10.1016/j.brainres.2006.09.104>
- Fox, C. J., Moon, S. Y., Iaria, G., & Barton, J. J. S. (2009). The correlates of subjective perception of identity and expression in the face network: An fMRI adaptation study. *NeuroImage*, *44*(2), 569–580. <https://doi.org/10.1016/j.neuroimage.2008.09.011>
- Frisby, J. (1980). *Seeing: Illusion, mind and brain*. Oxford University Press.
- Frith, C. (2009). Role of facial expressions in social interactions. *Philosophical Transactions of the Royal Society of London: Series B, Biological Sciences*, *364*(1535), 3453–3458. <https://doi.org/10.1098/rstb.2009.0142>
- Fu, G., Mondloch, C. J., Ding, X. P., Short, L. A., Sun, L., & Lee, K. (2014). The neural correlates of the face attractiveness aftereffect: A functional near-infrared spectroscopy (fNIRS) study. *NeuroImage*, *85*(Pt. 1), 363–371. <https://doi.org/10.1016/j.neuroimage.2013.04.092>
- Grossman, E., Donnelly, M., Price, R., Pickens, D., Morgan, V., Neighbor, G., & Blake, R. (2000). Brain areas involved in perception of biological motion. *Journal of Cognitive Neuroscience*, *12*(5), 711–720. <https://doi.org/10.1162/089892900562417>
- Gupta, R., & Srinivasan, N. (2015). Only irrelevant sad but not happy faces are inhibited under high perceptual load. *Cognition and Emotion*, *29*(4), 747–754. <https://doi.org/10.1080/02699931.2014.933735>
- Hadj-Bouziane, F., Bell, A. H., Knusten, T. A., Ungerleider, L. G., & Tootell, R. H. (2008). Perception of emotional expressions is independent of face selectivity in monkey inferior temporal cortex. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(14), 5591–5596. <https://doi.org/10.1073/pnas.0800489105>
- Halovic, S., Kroos, C., & Stevens, C. (2020). Adaptation aftereffects influence the perception of specific emotions from walking gait. *Acta Psychologica*, *204*, Article 103026. <https://doi.org/10.1016/j.actpsy.2020.103026>
- Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism spectrum disorders: A review of behavioral and neuroimaging studies. *Neuropsychology Review*, *20*(3), 290–322. <https://doi.org/10.1007/s11065-010-9138-6>
- Hasselmo, M. E., Rolls, E. T., & Baylis, G. C. (1989). The role of expression and identity in the face-selective responses of neurons in the temporal visual cortex of the monkey. *Behavioural Brain Research*, *32*(3), 203–218. [https://doi.org/10.1016/S0166-4328\(89\)80054-3](https://doi.org/10.1016/S0166-4328(89)80054-3)
- Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences*, *4*(6), 223–233. [https://doi.org/10.1016/S1364-6613\(00\)01482-0](https://doi.org/10.1016/S1364-6613(00)01482-0)

- Henry, J. D., Thompson, C., Rendell, P. G., Phillips, L. H., Carbert, J., Sachdev, P., & Brodaty, H. (2012). Perception of biological motion and emotion in mild cognitive impairment and dementia. *Journal of the International Neuropsychological Society, 18*(5), 866–873. <https://doi.org/10.1017/S1355617712000665>
- Hiris, E., Mirenzi, A., & Janis, K. (2016). Biological form is sufficient to create a biological motion sex aftereffect. *Perception, 45*(10), 1115–1136. <https://doi.org/10.1177/0301006616652026>
- Hoffman, K. L., Gothard, K. M., Schmid, M. C., & Logothetis, N. K. (2007). Facial-expression and gaze-selective responses in the monkey amygdala. *Current Biology, 17*(9), 766–772. <https://doi.org/10.1016/j.cub.2007.03.040>
- Hsu, S., & Young, A. (2004). Adaptation effects in facial expression recognition. *Visual Cognition, 11*(7), 871–899. <https://doi.org/10.1080/13506280444000030>
- Hubert, B., Wicker, B., Moore, D. G., Monfardini, E., Duverger, H., Fonséca, D. D., & Deruelle, C. (2007). Brief report: Recognition of emotional and non-emotional biological motion in individuals with autistic spectrum disorders. *Journal of Autism and Developmental Disorders, 37*(7), 1386–1392. <https://doi.org/10.1007/s10803-006-0275-y>
- Hudepohl, M. B., Robins, D. L., King, T. Z., & Henrich, C. C. (2015). The role of emotion perception in adaptive functioning of people with autism spectrum disorders. *Autism: An International Journal of Research and Practise, 19*(1), 107–112. <https://doi.org/10.1177/1362361313512725>
- Isernia, S., Sokolov, A. N., Fallgatter, A. J., & Pavlova, M. A. (2020). Untangling the ties between social cognition and body motion: Gender impact. *Frontiers in Psychology, 11*, Article 128. <https://doi.org/10.3389/fpsyg.2020.00128>
- Javadi, A. H., & Wee, N. (2012). Cross-category adaptation: Objects produce gender adaptation in the perception of faces. *PLOS ONE, 7*(9), Article e46079. <https://doi.org/10.1371/journal.pone.0046079>
- Ji, H., Wang, L., & Jiang, Y. (2020). Cross-category adaptation of reflexive social attention. *Journal of Experimental Psychology: General, 149*(11), 2145–2153. <https://doi.org/10.1037/xge0000766>
- Jiang, Y., & He, S. (2006). Cortical responses to invisible faces: Dissociating subsystems for facial-information processing. *Current Biology, 16*(20), 2023–2029. <https://doi.org/10.1016/j.cub.2006.08.084>
- Jiang, Y., Shannon, R. W., Vizueta, N., Bernat, E. M., Patrick, C. J., & He, S. (2009). Dynamics of processing invisible faces in the brain: Automatic neural encoding of facial expression information. *NeuroImage, 44*(3), 1171–1177. <https://doi.org/10.1016/j.neuroimage.2008.09.038>
- Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception & Psychophysics, 14*(2), 201–211. <https://doi.org/10.3758/BF03212378>
- Jordan, H., Fallah, M., & Stoner, G. R. (2006). Adaptation of gender derived from biological motion. *Nature Neuroscience, 9*(6), 738–739. <https://doi.org/10.1038/nn1710>
- Kazak, A. E. (2018). Editorial: Journal article reporting standards. *American Psychologist, 73*(1), 1–2. <https://doi.org/10.1037/amp0000263>
- Killgore, W. D. S., & Yurgelun-Todd, D. A. (2004). Activation of the amygdala and anterior cingulate during nonconscious processing of sad versus happy faces. *NeuroImage, 21*(4), 1215–1223. <https://doi.org/10.1016/j.neuroimage.2003.12.033>
- Kohn, A. (2007). Visual adaptation: Physiology, mechanisms, and functional benefits. *Journal of Neurophysiology, 97*(5), 3155–3164. <https://doi.org/10.1152/jn.00086.2007>
- Kotsoni, E., de Haan, M., & Johnson, M. H. (2001). Categorical perception of facial expressions by 7-month-old infants. *Perception, 30*(9), 1115–1125. <https://doi.org/10.1068/p3155>
- Lange, J., de Lussanet, M., Kuhlmann, S., Zimmermann, A., Lappe, M., Zwitserlood, P., & Dobel, C. (2009). Impairments of biological motion perception in congenital prosopagnosia. *PLOS ONE, 4*(10), Article e7414. <https://doi.org/10.1371/journal.pone.0007414>
- Lee, H., & Kim, J. (2017). Facilitating effects of emotion on the perception of biological motion: Evidence for a happiness superiority effect. *Perception, 46*(6), 679–697. <https://doi.org/10.1177/0301006616681809>
- Mazzoni, N., Jacobs, C., Venuti, P., Silvanto, J., & Cattaneo, L. (2017). State-dependent TMS reveals representation of affective body movements in the anterior intraparietal cortex. *The Journal of Neuroscience, 37*(30), 7231–7239. <https://doi.org/10.1523/JNEUROSCI.0913-17.2017>
- Mazzoni, N., Ricciardelli, P., Actis-Grosso, R., & Venuti, P. (2022). Difficulties in recognising dynamic but not static emotional body movements in autism spectrum disorder. *Journal of Autism and Developmental Disorders, 52*(3), 1092–1105. <https://doi.org/10.1007/s10803-021-05015-7>
- McCollough, C. (1965). Color adaptation of edge-detectors in the human visual system. *Science, 149*(3688), 1115–1116. <https://doi.org/10.1126/science.149.3688.1115>
- Meeren, H. K. M., van Heijnsbergen, C. C. R. J., & de Gelder, B. (2005). Rapid perceptual integration of facial expression and emotional body language. *Proceedings of the National Academy of Sciences of the United States of America, 102*(45), 16518–16523. <https://doi.org/10.1073/pnas.0507650102>
- Miller, L. E., & Saygin, A. P. (2013). Individual differences in the perception of biological motion: Links to social cognition and motor imagery. *Cognition, 128*(2), 140–148. <https://doi.org/10.1016/j.cognition.2013.03.013>
- Minnebusch, D. A., & Daum, I. (2009). Neuropsychological mechanisms of visual face and body perception. *Neuroscience and Biobehavioral Reviews, 33*(7), 1133–1144. <https://doi.org/10.1016/j.neubiorev.2009.05.008>
- Missana, M., Atkinson, A. P., & Grossmann, T. (2015). Tuning the developing brain to emotional body expressions. *Developmental Science, 18*(2), 243–253. <https://doi.org/10.1111/desc.12209>
- Missana, M., & Grossmann, T. (2015). Infants' emerging sensitivity to emotional body expressions: Insights from asymmetrical frontal brain activity. *Developmental Psychology, 51*(2), 151–160. <https://doi.org/10.1037/a0038469>
- Montepare, J. M., Goldstein, S. B., & Clausen, A. (1987). The identification of emotions from gait information. *Journal of Nonverbal Behavior, 11*(1), 33–42. <https://doi.org/10.1007/BF00999605>
- Moradi, F., Koch, C., & Shimojo, S. (2005). Face adaptation depends on seeing the face. *Neuron, 45*(1), 169–175. <https://doi.org/10.1016/j.neuron.2004.12.018>
- Nackaerts, E., Wagemans, J., Helsen, W., Swinnen, S. P., Wenderoth, N., & Alaerts, K. (2012). Recognizing biological motion and emotions from point-light displays in autism spectrum disorders. *PLOS ONE, 7*(9), Article e44473. <https://doi.org/10.1371/journal.pone.0044473>
- Narumoto, J., Okada, T., Sadato, N., Fukui, K., & Yonekura, Y. (2001). Attention to emotion modulates fMRI activity in human right superior temporal sulcus. *Cognitive Brain Research, 12*(2), 225–231. [https://doi.org/10.1016/S0926-6410\(01\)00053-2](https://doi.org/10.1016/S0926-6410(01)00053-2)
- Palumbo, R., D'Ascenzo, S., Quercia, A., & Tommasi, L. (2017). Adaptation to complex pictures: Exposure to emotional valence induces assimilative aftereffects. *Frontiers in Psychology, 8*, Article 54. <https://doi.org/10.3389/fpsyg.2017.00054>
- Parr, L. A., Waller, B. M., & Heintz, M. (2008). Facial expression categorization by chimpanzees using standardized stimuli. *Emotion, 8*(2), 216–231. <https://doi.org/10.1037/1528-3542.8.2.216>
- Pavlova, M., & Sokolov, A. (2000). Orientation specificity in biological motion perception. *Perception & Psychophysics, 62*(5), 889–899. <https://doi.org/10.3758/BF03212075>
- Pavlova, M. A. (2012). Biological motion processing as a hallmark of social cognition. *Cerebral Cortex, 22*(5), 981–995. <https://doi.org/10.1093/cercor/bhr156>
- Peelen, M. V., Atkinson, A. P., Andersson, F., & Vuilleumier, P. (2007). Emotional modulation of body-selective visual areas. *Social Cognitive*

- and *Affective Neuroscience*, 2(4), 274–283. <https://doi.org/10.1093/scan/nsm023>
- Peelen, M. V., Wiggett, A. J., & Downing, P. E. (2006). Patterns of fMRI activity dissociate overlapping functional brain areas that respond to biological motion. *Neuron*, 49(6), 815–822. <https://doi.org/10.1016/j.neuron.2006.02.004>
- Pelli, D. G. (1997). The VideoToolbox software for visual psychophysics: Transforming numbers into movies. *Spatial Vision*, 10(4), 437–442. <https://doi.org/10.1163/156856897X00366>
- Peltola, M. J., Leppänen, J. M., Mäki, S., & Hietanen, J. K. (2009). Emergence of enhanced attention to fearful faces between 5 and 7 months of age. *Social Cognitive and Affective Neuroscience*, 4(2), 134–142. <https://doi.org/10.1093/scan/nsn046>
- Pessoa, L., McKenna, M., Gutierrez, E., & Ungerleider, L. G. (2002). Neural processing of emotional faces requires attention. *Proceedings of the National Academy of Sciences of the United States of America*, 99(17), 11458–11463. <https://doi.org/10.1073/pnas.172403899>
- Pitcher, D., Duchaine, B., & Walsh, V. (2014). Combined TMS and fMRI reveal dissociable cortical pathways for dynamic and static face perception. *Current Biology*, 24(17), 2066–2070. <https://doi.org/10.1016/j.cub.2014.07.060>
- Pye, A., & Bestelmeyer, P. E. G. (2015). Evidence for a supra-modal representation of emotion from cross-modal adaptation. *Cognition*, 134, 245–251. <https://doi.org/10.1016/j.cognition.2014.11.001>
- Schirmer, A., & Adolphs, R. (2017). Emotion perception from face, voice, and touch: Comparisons and convergence. *Trends in Cognitive Sciences*, 21(3), 216–228. <https://doi.org/10.1016/j.tics.2017.01.001>
- Servos, P., Osu, R., Santi, A., & Kawato, M. (2002). The neural substrates of biological motion perception: An fMRI study. *Cerebral Cortex*, 12(7), 772–782. <https://doi.org/10.1093/cercor/12.7.772>
- Simion, F., Regolin, L., & Bulf, H. (2008). A predisposition for biological motion in the newborn baby. *Proceedings of the National Academy of Sciences of the United States of America*, 105(2), 809–813. <https://doi.org/10.1073/pnas.0707021105>
- Skuk, V. G., & Schweinberger, S. R. (2013). Adaptation aftereffects in vocal emotion perception elicited by expressive faces and voices. *PLOS ONE*, 8(11), Article e81691. <https://doi.org/10.1371/journal.pone.0081691>
- Spencer, J. M. Y., Sekuler, A. B., Bennett, P. J., Giese, M. A., & Pilz, K. S. (2016). Effects of aging on identifying emotions conveyed by point-light walkers. *Psychology and Aging*, 31(1), 126–138. <https://doi.org/10.1037/a0040009>
- Sumi, S. (1984). Upside-down presentation of the Johansson moving light-spot pattern. *Perception*, 13(3), 283–286. <https://doi.org/10.1068/p130283>
- Susskind, J. M., Littlewort, G., Bartlett, M. S., Movellan, J., & Anderson, A. K. (2007). Human and computer recognition of facial expressions of emotion. *Neuropsychologia*, 45(1), 152–162. <https://doi.org/10.1016/j.neuropsychologia.2006.05.001>
- Taubert, J., Japee, S., Murphy, A. P., Tardiff, C. T., Koele, E. A., Kumar, S., Leopold, D. A., & Ungerleider, L. G. (2020). Parallel processing of facial expression and head orientation in the macaque brain. *The Journal of Neuroscience*, 40(42), 8119–8131. <https://doi.org/10.1523/JNEUROSCI.0524-20.2020>
- Theusner, S., de Lussanet, M. H. E., & Lappe, M. (2011). Adaptation to biological motion leads to a motion and a form aftereffect. *Attention, Perception, & Psychophysics*, 73(6), 1843–1855. <https://doi.org/10.3758/s13414-011-0133-7>
- Thompson, J. C., & Hardee, J. E. (2008). The first time ever I saw your face. *Trends in Cognitive Sciences*, 12(8), 283–284. <https://doi.org/10.1016/j.tics.2008.05.002>
- Thurman, S. M., van Boxtel, J. J. A., Monti, M. M., Chiang, J. N., & Lu, H. (2016). Neural adaptation in pSTS correlates with perceptual aftereffects to biological motion and with autistic traits. *NeuroImage*, 136, 149–161. <https://doi.org/10.1016/j.neuroimage.2016.05.015>
- Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., Marcus, D. J., Westerlund, A., Casey, B. J., & Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, 168(3), 242–249. <https://doi.org/10.1016/j.psychres.2008.05.006>
- Tracy, J. L., & Robins, R. W. (2008). The automaticity of emotion recognition. *Emotion*, 8(1), 81–95. <https://doi.org/10.1037/1528-3542.8.1.81>
- Troje, N. F. (2002). Decomposing biological motion: A framework for analysis and synthesis of human gait patterns. *Journal of Vision*, 2(5), Article 2. <https://doi.org/10.1167/2.5.2>
- Troje, N. F. (2008). Retrieving information from human movement patterns. In T. F. Shipley & J. M. Zacks (Eds.), *Understanding events: How humans see, represent, and act on events* (pp. 308–334). Oxford University Press.
- Troje, N. F., Sadr, J., Geyer, H., & Nakayama, K. (2006). Adaptation aftereffects in the perception of gender from biological motion. *Journal of Vision*, 6(8), Article 7. <https://doi.org/10.1167/6.8.7>
- Troje, N. F., & Westhoff, C. (2006). The inversion effect in biological motion perception: Evidence for a “life detector”? *Current Biology*, 16(8), 821–824. <https://doi.org/10.1016/j.cub.2006.03.022>
- Vaina, L. M., Solomon, J., Chowdhury, S., Sinha, P., & Belliveau, J. W. (2001). Functional neuroanatomy of biological motion perception in humans. *Proceedings of the National Academy of Sciences of the United States of America*, 98(20), 11656–11661. <https://doi.org/10.1073/pnas.191374198>
- Valenza, E., Simion, F., Cassia, V. M., & Umiltà, C. (1996). Face preference at birth. *Journal of Experimental Psychology: Human Perception and Performance*, 22(4), 892–903. <https://doi.org/10.1037/0096-1523.22.4.892>
- Viola Macchi, C., Turati, C., & Simion, F. (2004). Can a nonspecific bias toward top-heavy patterns explain newborns’ face preference? *Psychological Science*, 15(6), 379–383. <https://doi.org/10.1111/j.0956-7976.2004.00688.x>
- Walther, C., Schweinberger, S. R., Kaiser, D., & Kovács, G. (2013). Neural correlates of priming and adaptation in familiar face perception. *Cortex*, 49(7), 1963–1977. <https://doi.org/10.1016/j.cortex.2012.08.012>
- Wang, X., Guo, X., Chen, L., Liu, Y., Goldberg, M. E., & Xu, H. (2017). Auditory to visual cross-modal adaptation for emotion: Psychophysical and neural correlates. *Cerebral Cortex*, 27(2), 1337–1346. <https://doi.org/10.1093/cercor/bhv321>
- Watson, R., & de Gelder, B. (2020). The representation and plasticity of body emotion expression. *Psychological Research*, 84(5), 1400–1406. <https://doi.org/10.1007/s00426-018-1133-1>
- Watson, R., Latinus, M., Noguchi, T., Garrod, O., Crabbe, F., & Belin, P. (2014). Crossmodal adaptation in right posterior superior temporal sulcus during face-voice emotional integration. *The Journal of Neuroscience*, 34(20), 6813–6821. <https://doi.org/10.1523/JNEUROSCI.4478-13.2014>
- Webster, M. A. (2011). Adaptation and visual coding. *Journal of Vision*, 11(5), Article 3. <https://doi.org/10.1167/11.5.3>
- Webster, M. A. (2015). Visual adaptation. *Annual Review of Vision Science*, 1(1), 547–567. <https://doi.org/10.1146/annurev-vision-082114-035509>
- Webster, M. A., & MacLeod, D. I. (2011). Visual adaptation and face perception. *Philosophical Transactions of the Royal Society of London: Series B, Biological Sciences*, 366(1571), 1702–1725. <https://doi.org/10.1098/rstb.2010.0360>
- Williams, M. A., Morris, A. P., McGlone, F., Abbott, D. F., & Mattingley, J. B. (2004). Amygdala responses to fearful and happy facial expressions under conditions of binocular suppression. *The Journal of Neuroscience*, 24(12), 2898–2904. <https://doi.org/10.1523/JNEUROSCI.4977-03.2004>
- Winston, J. S., Henson, R. N. A., Fine-Goulden, M. R., & Dolan, R. J. (2004). fMRI-adaptation reveals dissociable neural representations of

- identity and expression in face perception. *Journal of Neurophysiology*, 92(3), 1830–1839. <https://doi.org/10.1152/jn.00155.2004>
- Xu, H., Dayan, P., Lipkin, R. M., & Qian, N. (2008). Adaptation across the cortical hierarchy: Low-level curve adaptation affects high-level facial-expression judgments. *The Journal of Neuroscience*, 28(13), 3374–3383. <https://doi.org/10.1523/JNEUROSCI.0182-08.2008>
- Yang, E., Hong, S.-W., & Blake, R. (2010). Adaptation aftereffects to facial expressions suppressed from visual awareness. *Journal of Vision*, 10(12), Article 24. <https://doi.org/10.1167/10.12.24>
- Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology*, 81(1), 141–145. <https://doi.org/10.1037/h0027474>
- Ying, H., & Xu, H. (2017). Adaptation reveals that facial expression averaging occurs during rapid serial presentation. *Journal of Vision*, 17(1), Article 15. <https://doi.org/10.1167/17.1.15>
- Yuan, T., Ji, H., Wang, L., & Jiang, Y. (2023). Happy is stronger than sad: Emotional information modulates social attention. *Emotion*, 23(4), 1061–1074. <https://doi.org/10.1037/emo0001145>
- Yuan, T., Wang, L., & Jiang, Y. (2023). *Data from: Cross-category adaptation reveals shared emotion representation for face and biological motion*. PSYCH OpenIR. <http://ir.psych.ac.cn/handle/3111026/43476>

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