

Serial bias in the perception of biological motion emotional states

Authors: Tan, Haoyuan, Xiangrui Zhu, Shen, Zaixu, Shi, Shenghao, Kuai, Yijie, Kuai, Yijie

Date: 2023-05-15T00:00:00+00:00

Abstract

People can judge the emotions of other individuals by their movements, which are influenced by previously occurring movements, possibly because previously occurring movements provide a priori information about the current. In the current study, we presented sequences of biological motion of different emotional states and examined the influence of previously occurring actions on the evaluation of emotion for the current action in the biological motion sequence. We found that: first, emotion evaluation for the current biological motion systematically deviated from, rather than bias toward, past evaluation, showing a repulsive bias, with the amplitude of the bias negatively correlated with overall emotion recognition error. Second, the amplitude of the bias was not found to correlate with autistic traits or empathy, but with third-person movement imagery. Results tentatively suggest that there is no attractive bias in biological motion emotion perception, and the repulsive bias produced by previously observed biological motion states on current evaluation is an adaptation-like aftereffect, which enhances the accuracy of emotion recognition, but it is part of general visual cognitive rather than social cognitive functioning.

Full Text

Preamble

Serial Bias in the Perception of Emotional States from Biological Motion

Haoyuan Tan, Xiangrui Zhu, Zaixu Shen, Shenghao Shi, and Yijie Kuai
Department of Psychology, Yanbian University, Yanji, China

Correspondence to: Department of Psychology, Yanbian University, 977 Gongyuan Road, Yanji 133000, China.

E-mail address: yjkuai@ybu.edu.cn (Yijie Kuai)

Abstract

People can infer the emotional states of others from their movements, and these judgments are influenced by previously observed movements, likely because prior movements provide a priori information for interpreting current actions. In the present study, we presented sequences of biological motion displays depicting different emotional states and examined how preceding actions influence the evaluation of emotion for the current action within the sequence. We found that, first, emotion evaluations for the current biological motion systematically deviated from past evaluations, exhibiting a repulsive bias rather than an attractive one, with the magnitude of this bias negatively correlated with overall emotion recognition error. Second, the bias magnitude did not correlate with autistic traits or empathy, but did correlate with third-person movement imagery ability. These results tentatively suggest that biological motion emotion perception does not show attractive serial bias; instead, the repulsive bias produced by previously observed biological motion states on current evaluations functions as an adaptation-like aftereffect that enhances emotion recognition accuracy, yet appears to be part of general visual-cognitive rather than social-cognitive functioning.

Keywords: biological motion; adaptation; autistic traits; movement imagery

Introduction

Perceiving and evaluating the body movements of others to extract socially relevant information represents a crucial social-cognitive ability that facilitates understanding of others' emotional states. Research demonstrates that both facial and bodily cues serve as important sources of emotional information. A noteworthy consideration is that humans typically perceive others' actions within group contexts, where the perception of an individual's action is influenced by surrounding actions. For instance, Cheng et al. (2022) showed that perceiving an individual's action in a group is biased by the simultaneous presence of other individuals' actions nearby. Understanding how such environmental contexts shape our social perceptions is therefore important. Similarly, actions that appear sequentially may also influence the perception of current actions, exhibiting a form of serial bias. What remains unclear is whether such serial bias exists in biological motion emotion perception and, if so, what factors influence it. The current study aimed to clarify (1) whether serial bias exists in emotional perception of biological motion and (2) whether it is influenced by social-cognitive ability or movement imagery.

Human beings demonstrate remarkable sensitivity to animate movements, known as biological motion. Researchers commonly use point-light displays to simulate biological motion in social cognition experiments. Substantial individual differences exist in biological motion perception sensitivity, with Miller and Saygin (2013) demonstrating that sensitivity for biological motion processing correlates with social cognition (autistic traits, empathy) and

movement imagery. The majority of research suggests that biological motion perception sensitivity correlates with autistic traits, with most studies comparing biological motion perception between individuals with and without ASD using walking direction recognition or motion naming tasks. Some studies have also employed emotion-related tasks, which may offer better differentiation between varying levels of autism traits due to the social skill and empathy deficits characteristic of individuals with strong autistic traits.

Movement imagery represents another important factor influencing biological motion perception. Humans actively perceive actions by selecting and running offline restored sensory-motor memories through mental simulation of actions. Additionally, according to classical mirror neuron theory, motor imagery may be related to mirror neurons that help us understand others' actions. Miller and Saygin (2013) found a correlation between the vividness of motor imagery and the ability to process biological motion.

Past studies show that to optimize visual processing for stable and efficient encoding of the external environment, the visual system must utilize past perceptual information to process current stimuli, making visual information processing regularly influenced by history. Ample evidence indicates that this influence involves both early-stage reliance on and later rejection of past perceptions. Attractive bias makes the perception of current stimuli closer to past perception to form stable representations, a phenomenon termed "serial dependence" in previous research. This effect has been observed in judgments of both simple physical stimuli and social features of faces. Additionally, repulsive bias, considered an adaptation-like aftereffect, manifests as systematic deviation of current stimulus perception from past perceptions. Such mechanisms have been demonstrated in processing social features and emotions of facial expressions. These findings suggest that serial biases may represent common principles for the visual system to process both physical and social information. To date, several studies have explored adaptive aftereffects of walking direction and speed in biological motion, but these studies did not examine adaptive aftereffects across entire sequences, and no studies have investigated attractive serial bias in biological motion perception.

In the current study, we presented sequences of biological motions and asked participants to rate them sequentially, then fitted the results using the derivative of the Gaussian function. Our research hypotheses were as follows. First, based on past results and theories on serial bias, we hypothesized that both attractive and repulsive biases exist in biological motion emotion perception, and that bias amplitude correlates with recognition error, as serial bias increases the efficiency and stability of visual perception. Second, to explore factors influencing serial bias in biological motion emotion recognition, we hypothesized correlations between autism traits, empathy, movement imagery vividness, and serial bias based on previous biological motion perception research.

Methods

Participants

Forty college students (19 males and 21 females, mean age = 20.37 years, SD = 1.54) with normal or corrected-to-normal vision participated in this study. We selected 40 as the sample size based on previous studies of serial bias and biological motion perception. All participants were naïve to the experimental purpose and provided informed consent, with ethics approval granted by the Medical Ethics Committee at Yanbian University.

Self-Report Questionnaires

We administered the pencil-and-paper Autism-spectrum Quotient (AQ; Baron-Cohen et al., 2001) translated into Chinese by Liu (2008), and the Empathy Quotient (EQ; Baron-Cohen & Wheelwright, 2004) translated into Chinese by Zhao et al. (2018). These questionnaires measure participants' autistic traits and empathy, respectively, with higher scores indicating greater autistic traits and empathy, and they have generally shown negative correlations in past research. The AQ comprises five dimensions: social skills, attention switching, attention to detail, communication, and imagination.

We also administered the Vividness of Movement Imagery Questionnaire (VMIQ; Roberts et al., 2008), which assesses movement imagery across three components: visual imagery from third-person (external) and first-person (internal) perspectives, as well as kinesthetic imagery. Lower scores indicate higher movement imagery ability.

Stimuli

We used 50 different front-view dynamic point-light walker animations created using a web application (<https://www.biomotionlab.ca/Experiments/BMLstimuli/index.html>) developed by the BioMotion Lab. This tool enables reliable adjustment of the emotional state and body posture of point-light walkers. Each animation displayed 15 light dots arranged in a human configuration, representing joint movements to simulate human walking posture. This stimulus type has been widely used in previous research. The light dots depicting biological motion were white and presented on a black background.

We manipulated the levels of happiness and nervousness in the biological motion displays so that each animation conveyed different emotions. To better simulate real-world conditions, we also varied the gender and weight of the walkers in the animations.

Procedure

Prior to the experiment, participants completed the AQ, EQ, and movement imagery self-report questionnaires. The experimental procedure was adapted

from previous studies to facilitate comparison with past findings [Figure 1: see original paper]. Each trial presented a 2-second point-light walker animation, after which participants rated the walkers' happiness on a 7-point Likert scale (1 = most sad, 7 = most happy) using the keyboard. The 50 animations were each repeated 4 times in random order, totaling 200 trials. Before each video, a 1-second fixation cross appeared at the center of the screen to direct participants' attention. Text appeared on screen reminding participants to rate the animation after viewing. Participants were encouraged to respond within 3 seconds; after 3 seconds, the on-screen font color changed to prompt quicker responses. Following the rating, there was a 1-second interval before the next trial began. We did not restrict participants' eye movements throughout the experiment. Before starting, all participants completed brief practice to familiarize themselves with the procedure and develop preliminary judgments of the motion states.

Figure 1. (A) Temporal structure of one trial. (B) An example of a biological motion animation (dynamic in actual experiments).

Analytic Strategy

General Analytic Strategy First, we calculated the average rating of each animation across all participants as estimated scores, representing the general emotion evaluation. Recognition error was operationalized as each participant's actual rating in a given trial minus the estimated score. Ratings deviating from estimated scores by more than 3 SDs were replaced with the corresponding estimated score. Each participant's holistic recognition error across all 200 trials was operationalized as the Euclidean distance between their actual scores and the 200 estimated scores, reflecting cumulative error per trial. Serial bias amplitude was operationalized as the parameter a value from DoG fitting results (see below).

We tested correlations between serial bias amplitude and AQ, EQ, and movement imagery, as well as between recognition error and serial bias amplitude. In addition to p values, we reported Bayesian factors to compensate for the limitations of null hypothesis significance testing regarding sample size and its inability to support the null hypothesis.

DoG Fitting We used the derivative of a Gaussian function (DoG) fitting method to compute serial bias amplitude. We obtained current trial rating error by subtracting estimated scores from individual participants' ratings. We then fitted the experimental results to DoG using Python's "least_squares" function. DoG is defined as:

$$y = \Delta awce^{-(w\Delta)^2}$$

where y denotes the current trial error, Δ indicates the rating difference between the current trial and the n -back trial, a indicates the curve's peak amplitude,

w adjusts curve width, and c is a constant equal to $\sqrt{2/e} - 0.5$. To ensure reasonable parameters, we restricted w to a range of 0.15 to 5. The amplitude parameter a served as the strength of serial bias, indicating how much the current stimulus rating could be biased toward or away from a previous stimulus with maximally effective difference. If current trial error shares the same direction as the n-back difference, then $a > 0$, representing attractive bias; conversely, $a < 0$ represents repulsive bias. We obtained parameter a from 1-back to 40-back trials (meaning results from the first 40 trials were excluded).

To assess the significance of a , we pooled all participants' results, replaced n-back trial differences with random numbers ranging from -6 to 6 to eliminate systematic serial bias, then refitted DoG to obtain a . This process was repeated 1000 times to generate an artificial null distribution of a . Since we considered both attractive and repulsive biases, we performed a two-sided test, with the p -value representing the proportion of 1000 outcomes where the actual a was greater (attractive bias) or less (repulsive bias) than the threshold. We set the significance level at 0.05.

Results

We first examined serial bias in biological motion emotion recognition by analyzing the effect of 1-back to 40-back trials on the current trial. Results showed that all trials from 1-back to 40-back (each trial averaged 5.37s) produced significant repulsive bias for the current trial (a range: -1.13 to -0.98, all $ps < 0.05$), but no attractive bias [Figure 2: see original paper]. Since only repulsive bias was present and all a values were negative, we used the absolute value of a as the repulsive bias amplitude in subsequent analyses, with larger absolute values indicating greater repulsive bias magnitude.

Figure 2. DoG fitting results. (A) To illustrate our statistical approach, DoG fit results for the 1-back trial for one participant are shown ($a = -1.11$). The orange curve represents the DoG function, and gray points represent raw data. The peak-to-valley distance indicates bias amplitude. (B) DoG fit results for the 40-back trial for the same participant ($a = -1.77$). (C) Bias amplitude from 1-back to 40-back across all participants; gray shading represents 0.95 confidence intervals.

Next, we examined correlations between repulsive bias amplitude and AQ, EQ, and movement imagery. Results showed that 1-back trial repulsive bias amplitude significantly correlated with third-person perspective scores on the VMIQ ($r = 0.35$, $p = 0.02$, $BF_{10} = 2.92$), but not with other interval durations. This suggests that weaker third-person movement imagery is accompanied by greater repulsive bias. No correlations were found between repulsive bias amplitude and EQ, AQ, any AQ dimension scores, or other VMIQ dimension scores (all $ps > 0.05$, $BF_{10} < 1$).

Finally, we examined the correlation between 1-back trial repulsive bias amplitude and holistic recognition error. A significant negative correlation emerged (r

= -0.34, $p = 0.03$, $BF_{10} = 2.69$), indicating that larger repulsive bias amplitude was associated with lower recognition error.

Discussion

This study investigated serial biases in biological motion emotion recognition. We found that (1) judgments of biological motion emotion systematically deviated from past judgments, showing repulsive bias without attractive bias, and that repulsive bias amplitude correlated with emotion recognition error, with larger repulsive bias accompanied by lower recognition error; and (2) external third-person movement imagery correlated with repulsive bias amplitude, such that poorer third-person motor representation ability was associated with larger repulsive bias.

The first notable finding is the absence of attractive bias. While attractive bias has emerged in most previous studies, it was not observed here. One possible explanation is that attractive bias primarily functions to establish object continuity for stimuli presented continuously. Most prior studies used static stimulus materials processed as “frames” in the visual system, whereas our dynamic stimuli were processed as “units.” This unexpected finding warrants consideration in future research.

We observed a prolonged repulsive bias that may represent an adaptation process, involving continuous recalibration of emotion recognition. Consequently, we found a significant correlation with lower emotion recognition error, indicating that modulation of current perception through past biological motion perception enhances emotion recognition accuracy. Previous studies have reported similar effects in face recognition. However, because we used the mean rating across all participants as the “correct” rating, this result actually represents a large repulsive aftereffect that brings individual participants’ ratings closer to the population average. Since people constantly interact with many others throughout the day, understanding how each judgment is affected in such sequences is important. Previous research, such as Troje et al. (2006), demonstrated similar adaptive aftereffects when identifying gender from biological motion.

Another key finding was that repulsive bias amplitude was not associated with empathy, overall autistic traits, or individual autism dimension traits, with Bayesian factors supporting the null hypothesis. This suggests that repulsive bias amplitude is not influenced by social-cognitive functioning but rather by third-person movement imagery—that is, adaptation to biological motion emotion is linked not to social cognition but to general visual-cognitive function or movement perception. Biological motion emotion judgment may be achieved based on physical characteristics such as body sway and walking speed. Our results showed that poorer third-person movement imagery ability was accompanied by larger bias amplitude, possibly reflecting a compensatory effect of visual adaptation. Individuals with weak third-person movement imagery may expe-

rience greater ambiguity in action recognition and therefore require stronger recalibration to achieve accurate recognition.

A limitation of this study is that we found only repulsive bias, yet the DoG fitting method is primarily a tool for investigating attractive bias in most research. This is because we initially considered both attractive and repulsive biases at the study's outset. Although DoG fitting can provide evidence for adaptation, it makes comparison difficult with past experiments using visual adaptation paradigms. However, one advantage of this approach is that it allows analysis of adaptation magnitude in continuously presented biological motion sequences. Our preliminary finding of no attractive bias in biological motion emotion recognition requires further investigation to determine whether this is universal or specific to our experimental design. Therefore, our future research plans include further examination of attractive bias in biological motion emotion recognition and revalidation of our current findings using visual adaptation paradigms.

Declaration of Interest Statement

The authors report no competing interests to declare.

Data Availability Statement

The resulting data have been uploaded to the Open Science Framework, DOI:10.17605/OSF.IO/4XCP7.

Funding

This research was supported by grants from the National 2023 College Student Innovation Training Program (No. 2023YDCXCXY045) in China.

References

- App, B., Reed, C. L., & McIntosh, D. N. (2012). Relative contributions of face and body configurations: perceiving emotional state and motion intention. *Cognition & Emotion*, 26(4), 690–698. <https://doi.org/10.1080/02699931.2011.588688>
- Bachmann, J., Zabicki, A., Munzert, J., & Krüger, B. (2020). Emotional expressivity of the observer mediates recognition of affective states from human body movements. *Cognition & Emotion*, 34(7), 1370–1381. <https://doi.org/10.1080/02699931.2020.1747990>
- Baron-Cohen, S., & Wheelwright, S. (2004). The empathy quotient: an investigation of adults with Asperger syndrome or high functioning autism, and normal sex differences. *Journal of Autism and Developmental Disorders*, 34(2), 163–175. <https://doi.org/10.1023/b:jadd.0000022607.19833.00>
- Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): evidence from Asperger

- syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, 31(1), 5–17. <https://doi.org/10.1023/a:1005653411471>
- Bliss, D. P., Sun, J. J., & D'Esposito, M. (2017). Serial dependence is absent at the time of perception but increases in visual working memory. *Scientific Reports*, 7(1), 14739. <https://doi.org/10.1038/s41598-017-15199-7>
- Cheng, Y., Liu, W., Yuan, X., & Jiang, Y. (2022). Following Other People's Footsteps: A Contextual-Attraction Effect Induced by Biological Motion. *Psychological Science*, 33(9), 1522–1531. <https://doi.org/10.1177/09567976221091211>
- Clifford, C. W., Wyatt, A. M., Arnold, D. H., Smith, S. T., & Wenderoth, P. (2001). Orthogonal adaptation improves orientation discrimination. *Vision Research*, 41(2), 151–159. [https://doi.org/10.1016/s0042-6989\(00\)00248-0](https://doi.org/10.1016/s0042-6989(00)00248-0)
- Federici, A., Parma, V., Vicovaro, M., Radassao, L., Casartelli, L., & Ronconi, L. (2020). Anomalous Perception of Biological Motion in Autism: A Conceptual Review and Meta-Analysis. *Scientific Reports*, 10(1), 4576. <https://doi.org/10.1038/s41598-020-61252-3>
- Fischer, J., & Whitney, D. (2014). Serial dependence in visual perception. *Nature Neuroscience*, 17(5), 738–743. <https://doi.org/10.1038/nn.3689>
- Foglia, V., Siddiqui, H., Khan, Z., Liang, S., & Rutherford, M. D. (2022). Distinct Biological Motion Perception in Autism Spectrum Disorder: A Meta-Analysis. *Journal of Autism and Developmental Disorders*, 52(11), 4843–4860. <https://doi.org/10.1007/s10803-021-05352-7>
- Fritsche, M., Spaak, E., & de Lange, F. P. (2020). A Bayesian and efficient observer model explains concurrent attractive and repulsive history biases in visual perception. *eLife*, 9, e55389. <https://doi.org/10.7554/eLife.55389>
- Hsiung, E. Y., Chien, S. H., Chu, Y. H., & Ho, M. W. (2019). Adults with autism are less proficient in identifying biological motion actions portrayed with point-light displays. *Journal of Intellectual Disability Research*, 63(9), 1111–1124. <https://doi.org/10.1111/jir.12623>
- Hubert, B., Wicker, B., Moore, D. G., Monfardini, E., Duverger, H., Da Fonséca, 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>
- Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception & Psychophysics*, 14, 201–211. <https://doi.org/10.3758/BF03212378>
- Johnson, M. H. (2006). Biological motion: a perceptual life detector? *Current Biology*, 16(10), R376–R377. <https://doi.org/10.1016/j.cub.2006.04.008>
- Karaminis, T., Arrighi, R., Forth, G., Burr, D., & Pellicano, E. (2020). Adaptation to the Speed of Biological Motion in Autism. *Journal of Autism and*

Developmental Disorders, 50(2), 373–385. <https://doi.org/10.1007/s10803-019-04241-4>

Liu, M. (2008). Screening adults for Asperger's syndrome and high-functioning autism by using the Autism-Spectrum Quotient (AQ) (Mandarin version). *Bulletin of Special Education*, 33, 73–92. <http://ir.lib.ntnu.edu.tw/ir/handle/309250000Q/>

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>

Minemoto, K., & Ueda, Y. (2022). Face identity and facial expression representations with adaptation paradigms: New directions for potential applications. *Frontiers in Psychology*, 13, 988497. <https://doi.org/10.3389/fpsyg.2022.988497>

Murphy, P., Brady, N., Fitzgerald, M., & Troje, N. F. (2009). No evidence for impaired perception of biological motion in adults with autistic spectrum disorders. *Neuropsychologia*, 47(14), 3225–3235. <https://doi.org/10.1016/j.neuropsychologia.2009.07.026>

Pascucci, D., Tanrikulu, Ö. D., Ozkırli, A., Houborg, C., Ceylan, G., Zerr, P., Rafei, M., & Kristjánsson, Á. (2023). Serial dependence in visual perception: A review. *Journal of Vision*, 23(1), 9. <https://doi.org/10.1167/jov.23.1.9>

Puglia, M. H., & Morris, J. P. (2017). Neural Response to Biological Motion in Healthy Adults Varies as a Function of Autistic-Like Traits. *Frontiers in Neuroscience*, 11, 404. <https://doi.org/10.3389/fnins.2017.00404>

Rhodes, G., Watson, T. L., Jeffery, L., & Clifford, C. W. (2010). Perceptual adaptation helps us identify faces. *Vision Research*, 50(10), 963–968. <https://doi.org/10.1016/j.visres.2010.03.003>

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*, 27, 169–192. <https://doi.org/10.1146/annurev.neuro.27.070203.144230>

Roberts, R., Callow, N., Hardy, L., Markland, D., & Bringer, J. (2008). Movement imagery ability: development and assessment of a revised version of the vividness of movement imagery questionnaire. *Journal of Sport & Exercise Psychology*, 30(2), 200–221. <https://doi.org/10.1123/jsep.30.2.200>

Savaki, H. E., & Raos, V. (2019). Action perception and motor imagery: Mental practice of action. *Progress in Neurobiology*, 175, 107–125. <https://doi.org/10.1016/j.pneurobio.2019.01.007>

Theusner, S., de Lussanet, M. H., & 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>

Troje, N. F., Sadr, J., Geyer, H., & Nakayama, K. (2006). Adaptation after-effects in the perception of gender from biological motion. *Journal of Vision*, 6(8), 850–857. <https://doi.org/10.1167/6.8.7>

Troje, N. F. (2008). Retrieving information from human movement patterns.

van Boxtel, J. J. A., Peng, Y., Su, J., & Lu, H. (2017). Individual differences in high-level biological motion tasks correlate with autistic traits. *Vision Research*, 141, 136–144. <https://doi.org/10.1016/j.visres.2016.11.005>

Webster, M. A. (2015). Visual adaptation. *Annual Review of Vision Science*, 1, 547–567. <https://doi.org/10.1146/annurev-vision-082114-035509>

Wincenciak, J., Palumbo, L., Epihova, G., Barraclough, N. E., & Jellema, T. (2022). Are adaptation aftereffects for facial emotional expressions affected by prior knowledge about the emotion? *Cognition & Emotion*, 36(4), 602–615. <https://doi.org/10.1080/02699931.2022.2031907>

Yu, J. M., & Ying, H. (2021). A general serial dependence among various facial traits: Evidence from Markov Chain and derivative of Gaussian. *Journal of Vision*, 21(13), 4. <https://doi.org/10.1167/jov.21.13.4>

Zhao, Q., Neumann, D. L., Cao, X., Baron-Cohen, S., Sun, X., Cao, Y., Yan, C., Wang, Y., Shao, L., & Shum, D. H. K. (2018). Validation of the Empathy Quotient in Mainland China. *Journal of Personality Assessment*, 100(3), 333–342. <https://doi.org/10.1080/00223891.2017.1324458>

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv — Machine translation. Verify with original.