



Individual differences in the perception of biological motion: Links to social cognition and motor imagery



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ABSTRACT

Biological motion perception is often claimed to support social cognition, and to rely upon embodied representations and motor imagery. Are people with higher levels of social traits or more vivid motor imagery better at biological motion perception? We administered four experiments measuring sensitivity in using (global) form and (local) motion cues in biological motion, plus well-established measures of social cognition (e.g., empathy) and motor imagery (e.g., kinesthetic motor imagery). This first systematic investigation of individual variability in biological motion processing demonstrated significant relationships between these domains, along with a dissociation. Sensitivity for using form cues in biological motion processing was correlated with social (and not the imagery) measures; sensitivity for using motion cues was correlated with motor imagery (and not the social) measures. These results could not be explained by performance on non-biological control stimuli. We thus show that although both social cognition and motor imagery predict sensitivity to biological motion, these skills likely tap into different aspects of perception.

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1. Introduction

Detecting and interpreting the movements of others is an important problem that the brain must solve to ensure the survival and wellbeing of an organism. The visual system can extract biological motion information even in situations where other visual cues are impoverished. Point-light biological motion stimuli are animations composed solely of points of light attached to the joints of a moving agent (Johansson, 1973). When in motion, such stimuli evoke a vivid percept of a human body in action. Point-light stimuli have allowed researchers to thoroughly investigate the perceptual mechanisms underlying biological motion perception for several decades (Blake & Shiffrar, 2007).

There is significant intersubject variability in the sensitivity to biological motion, the sources of which have been explored in only a few studies. In stroke patients, deficits in biological motion processing correlate with deficits in face processing, but not with motion coherence thresholds (Saygin, 2007). Individual differences in biological motion detection in noise do not correlate with performance on other visual tasks involving grouping and segmentation (Jung, Zabood, Lee, & Blake, 2012). However, this ability is correlated with gray matter volume in the posterior superior temporal sulcus and ventral premotor cortex (Gilaie-Dotan, Kanai, Bahrami, Rees, & Saygin, 2013), brain regions critical for the perception of biological motion (Grossman & Blake, 2002; Pelphrey & Carter, 2008; Saygin, 2007; Saygin, Wilson, Hagler, Bates, & Sereno, 2004; van Kemenade, Muggleton, Walsh, & Saygin, 2012). The correlates of individual variability in biological motion tasks can also extend into more general perceptual and cognitive domains. For example, performance in biological motion tasks correlated with some (e.g., Stroop interference) but not all (e.g., orienting, visual search efficiency) tests of

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attention and executive function (Chandrasekaran, Turner, Bulthoff, & Thornton, 2010).

Here, we used direction discrimination tasks with point-light walkers and with non-biological control stimuli to explore individual differences in sensitivity to biological motion in relation to two different domains: social perceptual and cognitive abilities, and motor imagery.

The first potential source of variability we considered was individual differences in social cognition. Although papers on biological motion perception commonly motivate the research by mentioning how important this ability is for social functions, the link between these domains has not been sufficiently explored. There is also active discussion regarding the relationship between social abilities and biological motion processing in clinical populations such as Autism Spectrum Conditions (ASC, see Section 4); here we aimed to explore this relationship in the non-clinical population.

Another potential correlate of variability in biological motion perception is motor imagery, the ability to imagine the performance of an action from first or third person, either visually or kinesthetically (Lotze & Halsband, 2006). According to simulation theory (often linked with the mirror neuron system; Iacoboni & Dapretto, 2006), both biological motion perception and motor imagery involve a (partial) internal simulation of the seen or imagined action in the viewer's own motor representations (Jeannerod, 2001). Here we explored motor imagery with the rationale that shared resources with biological motion perception may be evidenced by a correlation between the two abilities.

In the visual system, form and motion are processed in partially segregated streams, which are dynamically integrated at multiple levels (Kourtzi, Krekelberg, & van Wezel, 2008). There is active discussion about the relative role of (local) motion information vs. (global) form information in biological motion processing, and the underlying neural systems (Beintema & Lappe, 2002; Garcia & Grossman, 2008; Jastorff & Orban, 2009; Lu, 2010; Thompson, Clarke, Stewart, & Puce, 2005; Thurman, Giese, & Grossman, 2010). Results on the direction discrimination task are especially mixed regarding the involvement of form and motion mechanisms. Some researchers have argued that the individual local motions of the point-light walker's limbs play an important role in direction discrimination (e.g. Troje & Westhoff, 2006). Other data highlight the role of form, since the direction discrimination task can also be solved in the absence of local motion cues (Lange & Lappe, 2007). Thus, the direction discrimination task can be solved by using either form or motion cues. Furthermore, biological motion processing has been found normal in both patients who cannot perceive motion (McLeod, Ditrach, Driver, Perrett, & Zihl, 1996), as well as in patients with visual agnosia who have trouble utilizing form information (Gilaie-Dotan, Bentin, Harel, Rees, & Saygin, 2011).

To distinguish the relative use of form and motion cues, we used "moonwalkers", i.e. walkers whose direction of walking is opposite to the direction they are facing (Lange & Lappe, 2007). In separate experiments, we asked participants to determine either the facing direction of a point-light walker, or the walking (motion) direction of

a point-light walker. In the presence of moonwalkers, the facing direction task requires participants to rely heavily on form information since motion is not informative as to the direction of facing. Although it is possible to complete the direction discrimination task with local motion, when half the trials are moonwalkers, motion cues are no longer informative regarding facing direction. Likewise, the walking direction task requires participants to rely heavily upon local motion cues (the movements of the individual dots, or possibly subgroups of dots) since the facing direction is not informative as to the direction of walking when half the trials contain moonwalkers. Although it is conceivable that this task involves some form processing, or integration of form and motion (e.g., if we consider a version of the template-matching model that is sensitive to motion through the temporal sequence of form-based snapshots), the brain would still need to override the straightforward use of form cues, and it is unlikely for this task to be performed without strong reliance on motion cues.

To explore the specificity of effects to biological motion, analogous tasks were also administered with a non-biological control stimuli (a point-light shape, see Section 2).

2. Methods

We administered four experiments of motion processing as well as a number of experimental and questionnaire-based measures of social cognition and imagery [Empathy Quotient, Autism-Spectrum Quotient, Reading the Mind in the Eyes Test, Cambridge Face Memory Test, Vividness of Movement Imagery Questionnaire, which consists of internal, external and kinesthetic imagery]. All participants reported normal or corrected-to-normal vision and no history of mental illness, neurological or cognitive impairments. Although we tried to have all participants complete all tests, some attrition inevitably occurred due to the multiple sessions required to administer all experiments. The experiments were approved by the UCSD IRB and all participants gave informed consent.

2.1. Experiment 1: Biological motion facing direction (Bio-Facing)

2.1.1. Participants

Sixty-seven adults (15 males) between 18 and 31 years of age (mean: 20.8, SD: 1.73) participated in a biological motion task. Subsets of these participants also completed the social cognition and mental imagery measures: Empathy Quotient ($N = 65$), Autism Quotient ($N = 65$), Reading the Mind in the Eyes Test ($N = 59$), Cambridge Face Memory Test ($N = 63$), Vividness of Motor Imagery Questionnaire ($N = 64$).

2.1.2. Stimuli

Stimuli were point-light walkers (Fig. 1) composed of 12 white point-lights, some of which could be briefly occluded during the motion, presented on a black background. The point-light walker was created by videotaping a walker and encoding the joint positions in the digitized video (Ahlstrom, Blake, & Ahlstrom, 1997). The point-light

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