

Eccentric perception of biological motion is unscalably poor

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Abstract

Accurately perceiving the activities of other people is a crucially important social skill of obvious survival value. Human vision is equipped with highly sensitive mechanisms for recognizing activities performed by others [Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception and Psychophysics*, 14, 201; Johansson, G. (1976). Spatio-temporal differentiation and integration in visual motion perception: An experimental and theoretical analysis of calculus-like functions in visual data processing. *Psychological Research*, 38, 379]. One putative functional role of biological motion perception is to register the presence of biological events anywhere within the visual field, not just within central vision. To assess the salience of biological motion throughout the visual field, we compared the detectability performances of biological motion animations imaged in central vision and in peripheral vision. To compensate for the poorer spatial resolution within the periphery, we spatially magnified the motion tokens defining biological motion. Normal and scrambled biological motion sequences were embedded in motion noise and presented in two successively viewed intervals on each trial (2AFC). Subjects indicated which of the two intervals contained normal biological motion. A staircase procedure varied the number of noise dots to produce a criterion level of discrimination performance. For both foveal and peripheral viewing, performance increased but saturated with stimulus size. Foveal and peripheral performance could not be equated by any magnitude of size scaling. Moreover, the inversion effect—superiority of upright over inverted biological motion [Sumi, S. (1984). Upside-down presentation of the Johansson moving light-spot pattern. *Perception*, 13, 283]—was found only when animations were viewed within the central visual field. Evidently the neural resource responsible for biological motion perception are embodied within neural mechanisms focused on central vision.

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1. Introduction

Being able to recognize people and to perceive what they are doing are crucially important visual abilities. Indeed, these perceptual skills can be key to survival in some situations, and they are certainly skills we rou-

tinely utilize in our everyday social interactions. It is not surprising to learn, therefore, that our visual system is equipped with perceptual mechanisms exquisitely sensitive to the kinematics defining human activity and individual identity. These mechanisms are most dramatically revealed when those kinematics are portrayed by point-light animations which remove static form cues from the visual information available for perception. First popularized by Johansson (1973), point-light animation involves placing small light “tokens” to points of articulation of an individual who is then filmed while engaging in various activities. Despite the absence of recognizable form within individual frames of the film,

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viewers can readily perceive what the actor is doing. Called “biological motion perception” this unique form of structure from motion has been widely studied in recent years, and several good reviews of this work are available (Giese & Poggio, 2003; Thornton, Pinto, & Shiffrar, 1998; Verfaillie, 2000). Moreover, there are converging lines of evidence suggesting that the human visual system contains specialized neural mechanisms for the registration of biological motion, including evidence from human brain imaging experiments and from neuropsychological studies of brain damaged people (for a recent review of this work, see Blake, Sekuler, & Grossman, 2004).

One can envisage several possible reasons why perception of biological motion may have acquired special status during the course of evolution. For one, this visual skill could allow us quickly to detect the presence of other creatures anywhere within our field of view. Befitting this role, it is known that viewers can accurately perceive biological motion from animations as brief as 200 ms (Johansson, 1976), although longer exposures afford considerably better sensitivity (Neri, Morrone, & Burr, 1998). Moreover, people can perceive biological motion from point light animations embedded in dense arrays of dynamic noise (Bertenthal & Pinto, 1994; Cutting, Moore, & Morrison, 1988), suggesting that in the natural environment biological motion might be readily detectable because of relative immunity to camouflage. It is also possible, however, that biological motion perception comes into play primarily after visual motion has been detected, with its primary role involving recognition of a given activity or a given individual. Befitting this more refined role, it is known that observers viewing point light animations can reliably discriminate the gender of an actor (Kozlowski & Cutting, 1977; Mather & Murdoch, 1994; Murray, Yong, & Rhodes, 2000; Pollick, Lestou, Ryu, & Cho, 2002), the identity of a familiar individual (Cutting, 1978; Cutting & Kozlowski, 1977; Hill & Pollick, 2000), and the affective connotation of an action (Dittrich, Troscianko, Lea, & Morgan, 1996; Pollick, Paterson, Bruderlin, & Sanford, 2001).

Although these two functional roles—rapid detection and reliable recognition—certainly are not mutually exclusive, the former leads to a prediction that the latter necessarily does not. If biological motion perception plays an important role in detecting biologically relevant events anywhere within the field of view, then perception of biological motion should be salient throughout the visual field. After all, the sudden, unexpected appearance of another person rarely originates at the point of fixation; instead, we detect most objects and events within more peripheral regions of the visual field and then shift our attention to them for further scrutiny. This, then, represents the question that motivated the present experiment: How good are we at perceiving biological motion appearing within the peripheral visual field?

To answer this question, we cannot simply compare foveal viewing with peripheral viewing, for nearly all aspects of visual performance deteriorate with increasing eccentricity from the fovea (e.g., Beard, Levi, & Klein, 1997; Levi, Klein, & Aitsebaomo, 1985; Levi, McGraw, & Klein, 2000; Westheimer, 1982). The fundamental reasons for this deterioration are the lower spatial sampling of the retina and the reduced cortical representation of the peripheral visual field (Daniel & Whitteridge, 1961). Hence, performance deteriorates in the periphery for most tasks when the size of a stimulus remains constant. However, by “magnifying” a stimulus imaged within the peripheral visual field, it is possible to learn whether that stimulus can be placed on more even footing with its foveally viewed counterpart. In fact, when this spatial-scaling is done, performance in the fovea and performance in the periphery are indeed equated for a number of visual tasks including motion detection of slowly drifting gratings (Johnston & Wright, 1986; Wright, 1987) and contrast detection of Gabor micro-patterns (Watson, 1987). Importantly, however, there are other visual tasks, including letter recognition (Melmoth & Rovamo, 2003) and face perception (Melmoth, Kukkonen, Mäkelä, & Rovamo, 2000), for which spatial scaling does not equate performance. For those tasks, foveal performance remains superior despite all magnitudes of size increase in the periphery. This failure of magnification implies that the resources required for these tasks are concentrated within neural mechanisms primarily subserving the central region of the visual field.¹

In the present study, we applied the spatial scaling paradigm to the perception of biological motion. Biological motion animations were shown at various eccentricities and at various sizes. They were presented within noise masks made up of dots with the same spatio-temporal properties as the dots portraying the biological motion event (Bertenthal & Pinto, 1994; Cutting et al., 1988). Detectability of biological motion was indexed in terms of the number of noise dots required to produce a criterion level of performance on a two-alternative, forced choice task (2AFC). Our aim was to learn whether performance in the periphery could be matched to foveal performance by magnifying the animations. A positive outcome (i.e., matching performance) would imply that human vision can rapidly and efficiently detect the presence of biological relevant events throughout the visual field. A negative outcome (i.e., inability to match foveal and peripheral viewing), however, would suggest that the neural resources for perception

¹ Note that “spatial scaling” is a purely functional approach. This is a major advantage of spatial scaling, compared to cortical scaling, because it does not require any assumption about underlying physiological processes. However, a failure of spatial scaling inevitably indicates a failure of cortical magnification for the function examined.

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