



## Behavioural evidence for distinct mechanisms related to global and biological motion perception

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### ABSTRACT

The perception of human motion is a vital ability in our daily lives. Human movement recognition is often studied using point-light stimuli in which dots represent the joints of a moving person. Depending on task and stimulus, the local motion of the single dots, and the global form of the stimulus can be used to discriminate point-light stimuli. Previous studies often measured motion coherence for global motion perception and contrasted it with performance in biological motion perception to assess whether difficulties in biological motion processing are related to more general difficulties with motion processing. However, it is so far unknown as to how performance in global motion tasks relates to the ability to use local motion or global form to discriminate point-light stimuli. Here, we investigated this relationship in more detail. In Experiment 1, we measured participants' ability to discriminate the facing direction of point-light stimuli that contained primarily local motion, global form, or both. In Experiment 2, we embedded point-light stimuli in noise to assess whether previously found relationships in task performance are related to the ability to detect signal in noise. In both experiments, we also assessed motion coherence thresholds from random-dot kinematograms. We found relationships between performances for the different biological motion stimuli, but performance for global and biological motion perception was unrelated. These results are in accordance with previous neuroimaging studies that highlighted distinct areas for global and biological motion perception in the dorsal pathway, and indicate that results regarding the relationship between global motion perception and biological motion perception need to be interpreted with caution.

### 1. Introduction

We constantly perceive movement from the world around us, from leaves being blown by a gust of wind, to people walking in the street. The former is related to bottom up processing and is predominantly stimulus driven: we integrate the motion of all leaves into the percept of their global movement. The latter is an example of biological motion, which requires top-down processing and a reliance on stored movement patterns.

In an experimental setting, random dot kinematograms (RDK) are often used to study the properties of global motion perception. These RDK stimuli resemble a dense swarm of bees, and by integrating the local motion of all 'bees', it is possible to determine the general direction in which the swarm is flying. Stimulus parameters are often chosen such that it is impossible to track individual dots and it is necessary to integrate the motion of the individual dots to achieve a global impression of coherent motion. There are a number of factors that affect our ability to determine the general direction of movement, such as the

proportion of dots moving in a single direction (coherence, or signal-to-noise ratio), and the duration of the stimulus. The discrimination of global motion is thought to rely on processing in area hMT/V5, as part of the dorsal visual stream. Neurons in this area have been shown to be sensitive to global motion, with a similar sensitivity to behaviourally measured motion coherence thresholds (Britten, Shadlen, Newsome, & Movshon, 1992). In addition, Braddick, O'Brian, Wattam-Bell, Atkinson, and Hartley (2001) found that neurons in hMT/V5 show greater activation to coherent than incoherent global motion, whereas in V1, for example, activation is higher for incoherent motion.

In contrast to global motion perception as described above, biological motion describes the complex visual pattern we perceive as the movement of a person or other animate being. This kind of motion is often investigated experimentally using point-light stimuli (often walkers): simplified dynamic visual representations of the human (or animal) form, in which small dots represent the location of the head and major joints of the body. With just this sparse information, adults can quickly identify human movement (Johansson, 1973). The

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perception of biological motion is reportedly present from as early as 5 months of age (Bertenthal, Proffitt, & Kramer, 1982), and by adulthood we are able to determine the gender (Kozlowski & Cutting, 1977; Pollick, Kay, Heim, & Stringer, 2005), emotions (Dittrich, Troscianko, Lea, & Morgan, 1996; Roether, Omlor, & Giese, 2008; Spencer, Sekuler, Bennett, Giese, & Pilz, 2016), and even individual identity of point-light stimuli (Kozlowski & Cutting, 1977; Loula, Prasad, Harber, & Shiffrar, 2005; Troje, Westhoff, & Lavrov, 2005).

It was originally thought that the local motion cues of the single dots were key to biological motion perception. Due to the robustness of biological motion perception from just a few point-lights, Johansson (1973) believed that the process must be driven by low-level processes. Mather, Radford, and West (1992) investigated this idea in a series of experiments. They asked participants to discriminate normal point-light walkers from walkers in which the top and bottom half were moving in opposite directions. In a first experiment, they varied the temporal characteristics of the stimuli and found that participants were only able to discriminate the walkers with short inter-frame intervals. A second experiment showed that participants' performance was also affected by the amount of spatial displacement of each dot from frame-to-frame. The authors suggested that these results highlight a reliance on low-level motion processes for processing point-light walkers, as such processes are typically implemented over short temporal and spatial increments. Interestingly, when dots were removed from the animations, performance was only significantly affected by the removal of dots representing the wrists and ankles, the dots with the most informative motion trajectories, which led the authors to the overall conclusion that low-level processes appear to be essential for biological motion processing.

Despite evidence of the importance of low-level motion processes for the perception of biological motion, other studies showed that point-light walkers can be discriminated by form information alone. Beintema and Lappe (2002), for example, disrupted the local motion information in point-light walkers by placing dots at random points along a limb in each frame of the motion sequence, rather than on the joint, thereby destroying the local motion trajectories but preserving the global form of the walkers. Similar stimuli have been used many times to show that participants are able to discriminate motion direction and actions from point-light animations even when the local motion information is disrupted (Beintema & Lappe, 2002; Pilz, Bennett, & Sekuler, 2010; Lange & Lappe, 2006; Agnew, Phillips, & Pilz, 2016). Disrupting the local information by embedding the walker in noise has also been shown to not significantly affect the perception of point-light walkers (Bertenthal & Pinto, 1994), which indicates that the global form is important for biological motion processing.

More recent research converges on the idea that biological motion can be processed using both the local signals and the global form, and that it depends on the task and specific stimulus used as to which one is more beneficial (Thirkettle, Benton, & Scott-Samuel, 2009). Performance seems to be best when both kinds of information can be accessed. A model by Giese and Poggio (2003) nicely summarises this idea and suggests that biological motion can be processed via motion analysis in the dorsal stream and via form analysis in the ventral stream in a bottom-up manner, with information from both pathways being integrated in higher-level areas. In the dorsal stream, local motion signals are processed in early visual areas such as V1 or V2, and integrated into more complex global motion signals in MT/V5. In the ventral pathway, early visual areas process orientation information that is integrated into more complex form features in areas such as V2 or V4 and snapshots of more meaningful shapes in IT, for example. The information from both pathways is then integrated over time into meaningful biological motion in the superior temporal sulcus, for example. Compelling evidence for the dual stream hypothesis was provided by Mather, Battaglini, and Campana (2016) who used TMS over hMT/V5 while participants performed a coherent motion and a biological motion direction discrimination task. Whereas TMS disrupted the processing of coherent

motion, biological motion perception remained unaffected. These results clearly highlight that hMT/V5 is not necessary for processing biological motion.

As indicated above, many studies have investigated the contribution of local motion and global form to biological motion processing. Performance in tasks involving more basic global motion processing such as the discrimination of motion direction from RDKs is often compared to performance in biological motion perception in special populations such as schizophrenia, autism or ageing, to assess whether deficits in biological motion perception are related to a more general motion processing deficit (e.g., Spencer et al., 2000; Billino, Bremner, & Gegenfurtner, 2008; Koldewyn, Whitney, & Rivera, 2010; Spencer, Sekuler, Bennett, & Christensen, 2013). However, it is unclear up to now as to whether these two abilities are related and whether it is reasonable to make such a comparison. Therefore, this study directly investigates the relationship between global motion perception and local motion and global form processing in biological motion perception. In Experiment 1, we measured motion coherence thresholds for translational motion using RDKs, and participants were asked to discriminate the facing direction of point-light actions that contained primarily local motion information, global form information or both. If there was a relationship between processing global motion and the local motion information in point-light stimuli, we would expect a strong correlation between motion coherence thresholds and the ability to discriminate actions that primarily contained the local motion information. Experiment 2 assessed the relationship between biological motion direction discrimination with or without noise, and coherent motion perception from RDKs. A correlation between motion coherence thresholds and the ability to discriminate point-light stimuli in noise would indicate that both tasks rely on the ability to discriminate signal from noise.

## 2. Experiment 1

### 2.1. Methods

#### 2.1.1. Subjects

Participants were recruited from the staff and student population at the University of Aberdeen. Twenty-one individuals (5 males), aged 18–29 ( $M = 22.71$ ,  $SD = 2.97$ ) participated. All had normal or corrected to normal vision (visual acuity  $> 0.8$  on the ETDRS chart). Participants received £5/hour for their participation and all gave written informed consent. The experiment was carried out in accordance with the Declaration of Helsinki.

#### 2.1.2. Apparatus

Stimuli were presented on a 19 inch CRT Dell monitor (model M993S) with a resolution of  $1024 \times 768$  pixels and a refresh rate of 100 Hz. Stimuli were presented using the MATLAB (The MathWorks, Inc., Natick, MA, USA) based Psychtoolbox extension (Brainard, 1997; Kleiner, Brainard, & Pelli, 2007).

#### 2.1.3. Stimuli

**2.1.3.1. Motion coherence task.** Stimuli were RDKs in a circular aperture of  $9.4$  deg with 150 dots. These white dots were 2 pixels in area, had a limited lifetime of 200 ms, and were shown on a black background. Dots were randomly positioned within the aperture at the beginning of each trial with a random lifetime. At the end of a dot's lifetime, or if the dot moved out of the aperture, it was replaced at a random location in the aperture on the next refresh, moving in its previously assigned direction. Motion coherence (the percentage of dots moving in the same direction) was set to 10, 20, 30, 40, 50, 60, and 80. There were 20 trials for each motion direction (left or right) for each level of motion coherence, resulting in 280 trials total. The motion direction of each noise dot was randomly chosen between 0 and 360 degrees. Stimulus duration was set to 400 ms. For each observer, a logistic psychometric

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