Biological motion perception from sequential position information.

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Introduction

Both in generating human activity and in the visual perception of it, the brain is confronted with the many degrees of freedom involved in the movement of body and limbs. Not unlikely, the perception of motor actions is supported by mechanisms that are very similar to those in control of these actions. Hints towards an interaction between perceptual and action processes can be found in psychophysical studies, such as mental imagery, but also from recordings of single neurons in monkey premotor cortex.

For the recognition of human action, such as walking or dancing, only a few lightpoints attached to the joints of an otherwise invisible body already suffice [1]. How and where the brain processes this so called biological motion is still relatively unknown. Likely, a representation might be formed along the motion pathway. But, the fact that patients with lesions in their motion-sensitive areas still perceive biological motion [2, 3], indicates that the form pathway may also be involved. We here aim to investigate the contributing sources of information to the perception of biological motion more thoroughly.

To decouple the role of form and motion, we introduce a stimulus that displays biological motion devoid of local motion signals [4]. In classic experiments, the lightpoints are located on the joints and are continuously visible (Fig. 1a). To remove local motion cues, we distribute the points randomly between the joints, and let each point jump to a new random location on the limb in each subsequent frame (Fig. 1b). This single frame lifetime (SFL) stimulus conveys only sequential position information about the limb movements, but no local motion signals.

Using the SFL stimulus, we investigated whether recognition of biological motion is possible without local motion cues. The performance in a number of tasks was compared to that measured for the classic walker. In a second experiment, we quantified the contribution of motion signals by extending dot lifetime to several frames. Pilot studies revealed a qualitative difference in the perception of a walking figure when more than one dot was presented per limb per frame. As this suggested that orientation signals from pairs of dots on the same limb might play a role, we also varied the number of dots.

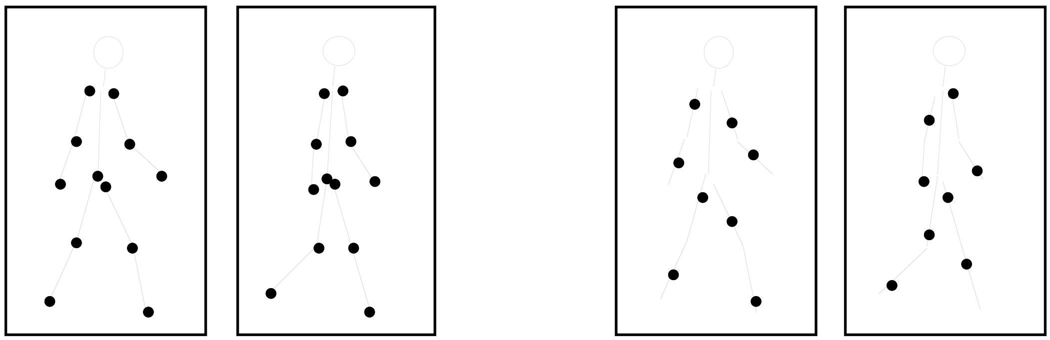

Fig. 1. Frames taken from biological motion stimulus with (left) and without (right) local motion signals. Left pair: Classic walker. Each dot remains on the joint in the next frame. Thus, besides position information, also a motion vector is available. Right pair: Single frame lifetime (SFL) walker. Each dot is reallocated in the next frame, thus not conveying a motion vector consistent with the limb's movement.

Methods

A sequence of frames displaying a man walking on a treadmill was generated using Cutting’s algorithm [5]. Subjects viewed the stimuli (about 5 x 9 deg) on a monitor from about 60 cm distance under daylight conditions. In the first experiment, we compared recognition of the SFL walker (8 points) with that of the classic walker (12 points). Subjects had no prior experience with biological motion stimuli. Each subject participated only once. They were asked to look at the pattern of moving dots and, by the time they had a clear percept, report verbally what they recognized. Furthermore, we tested performance for experienced observers in discrimination tasks. In the direction task, subjects indicated whether the walker was walking towards the left or right. In the coherence task, subjects had to distinguish a regular walker from a walker whose upper and lower body part were directed oppositely. In the second experiment, we measured the recognition time (RT) needed to perform a direction task while varying dot lifetime (1-8 frames) and number of dots (1-32).

Results I: Classic vs. SFL walker

About as many subjects (70%) recognised a walking human figure in the SFL stimulus as in the classic walker (80%), although the time required for recognition was about three times as long for the SFL walker. A control experiment showed that 50% of the subjects could recognize a human figure when the SFL walker was shown in only one pose, indicating that static form already conveys important information, although less than the sequence of forms. Furthermore, we found performance in the direction task was far above chance level (>80%) for both the classic and SFL walker. When a background of dynamic noise is added to the display, the detection of the SFL walker was more impaired than detection of the classic walker.

Results II: Role of motion and orientation signals

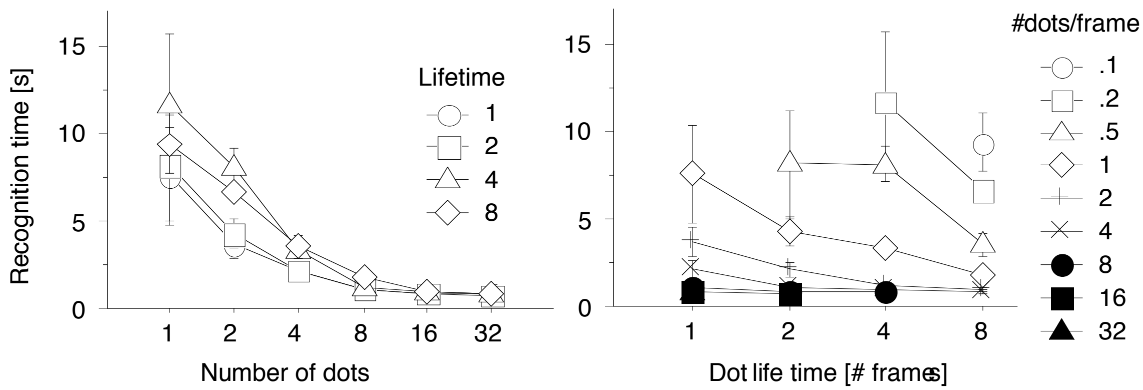

Fig. 2. Recognition time (RT) in a direction discrimination task, averaged over 3 subjects. Left: RT as function of number of dots for different dot lifetimes. Right: RT as function of dot lifetime, split by average number of displayed dots per frame (=#dots/lifetime).

If information on the orientation of limbs were to play an important role, we would expect a sharp drop in recognition time when the number of dots increases from one to two dots per limb. We found, however, that the recognition time only gradually decreased with increasing number of dots (Fig. 2a), arguing against a contribution of orientation signals. Fig. 2a also shows that recognition time rises with increasing dot lifetime. This suggests that the addition of local motion signals complicates rather than facilitates the task. Possibly, this opposite effect is due to reduced form information, since a longer lifetime reduces the number of jumps and therefore reduces the different positions drawn out by the dots over time. For data grouped by equal number of jumps per time we find that an increase in lifetime does reduce recognition time (Fig. 2b).

Discussion

We presented evidence that local motion signals are not essential for the perception of biological motion. The sequence of frames containing positional information already suffices. Addition of local motion signals reduced the time required for spontaneous recognition, but not the recognition time in a discrimination task. The higher performance for a walker with local motion cues in the presence of a noisy background suggests local motion signals rather play a role in segmenting out figure from background.

References

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