"Life Detection" in Central and Peripheral Vision

By

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FACULTY OF GRADUATE STUDIES
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Abstract

Gunnar Johansson (1973) was the first to demonstrate that human observers can perceive

animate activity from dynamic "point light" displays that are devoid of form cues. The saliency

of these displays makes sense from an evolutionary perspective, and suggests that there may be a

simple "life detector" that allows us to orient quickly to potential prey or predators. Recently,

Troje and Westhoff (2006) suggested that local (as opposed to configural) information about the

movements of a terrestrial animal may be sufficient to trigger this simple detector. The main goal

of the current project was to further characterize this life detection mechanism. In two

experiments, I assessed participants' ability to make accurate direction-facing judgments about

point light walkers presented very briefly in central vision. The walkers varied in terms of the

amount of configural information available in the displays, and in terms of their orientation

(upright or inverted) and facing direction. In three additional experiments, I examined

participants' sensitivity to coherent and to spatially shuffled or scrambled walkers presented

briefly in the visual periphery. The results of these studies provide strong support for the idea

that the automatic processing of natural, local motion cues from human and non-human species

support detection of facing direction in central and peripheral vision, and that global (shape)

processing mechanisms operate best on upright human stimuli. As such, they support Troje and

Chang's (2007) view that separate mechanisms support local and global processing of biological

motion.

Acknowledgements

I would like to thank first and foremost my supervisor, Dr. Lorna Jakobson. She has taught me so much about research and life in general. Along with this I would like to thank Dr. Niko Troje for his valuable assistance and use of his biological motion stimuli. I extend my thanks and appreciation to my committee members: Dr. Andrea Kilgour, Dr. Jonathon Marotta, and Dr. Pauline Pearson. I would also like to thank Andrea Piotrowski for helping me collect the data for Experiment 5, Dr. Jason Leboe for the use of his laptop, and the entire Jakobson laboratory for their guidance and support. Finally, I would like to thank my parents (Dr. Peter, and Elizabeth Williamson) for their encouragement and reassurance throughout the whole process.

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"Life Detection" in Central and Peripheral Vision

The ability to perceive actions is a valuable perceptual skill that is important for survival. This skill is also utilized in daily social interactions. Therefore, it makes sense that our visual system has evolved specialized mechanisms to process animate activity. A type of stimulus that portrays this type of movement in isolation (i.e. without additional form or colour cues) is a point-light animation. Johansson (1973) was the first to use point-light displays. He demonstrated that people are readily able to recognize human actions based purely on information available from the movements of lights attached to the head and joints of an otherwise invisible figure. Biological motion perception, as it has come to be known, is a robust phenomenon. It has been shown, for example, that participants are able to correctly recognize actions in biological motion displays with exposure durations under 200 ms (Johansson, 1976).

The ability to recognize animate activity is an adaptive function due to the importance of being able to detect living creatures within the environment, and to identify and appropriately respond to their actions and intentions. Specific biological motion patterns within the displays also allow for the identification of socially relevant attributes such as gender, age, and mental states (Barclay, Cutting & Kozlowski, 1978; Blakemore & Decety, 2001; Dittrich, Troscianko, Lea & Morgan, 1996; Pollick, Peterson, Bruderline & Sandford, 2001; Troje, 2002a, 2002b). Likewise, even with limited information, a participant can identify familiar individuals, such as friends or family members (Cutting and Kozlowski, 1977; Mather and West, 1993). Furthermore, specific actions can be recognized from the movements, such as hammering, ball bouncing, and stirring (Dittrich, 1993). In addition, inferences can be drawn from these displays about the intentions of unfamiliar individuals (Blakemore & Decety, 2001), and about their emotional states, as conveyed through dynamic facial expressions or dance (Bassili, 1978; Dittrich, 1993).

Multiple areas in the brain have been shown to be involved in processing of biological motion displays (Allison, Puce, McCarthy, 2000; Puce & Perrett, 2003). A number of brain imaging studies have shown that the posterior part of the superior temporal sulcus (STSp) is active when viewing upright point light walkers (Bonda, Petrides, Ostry & Evans, 1996; Grossman *et al.* 2000; Grossman & Blake, 2002). Other areas besides the STSp that have been shown to be involved in biological motion processing are the ventral surface of the temporal lobe (Vaina, et al. 2001), the fusiform gyrus (Beauchamp, Lee, Haxby & Martin, 2002) and the fusiform face area (Grossman & Blake, 2002). However, for the previously listed areas it is unclear if they specifically respond to biological motion or to human motion in general. There are limited studies that have examined human versus nonhuman representations and none have used standard biological motion displays (Downing, Jiang, Shuman & Kanwisher, 2001; Buccino *et al.* 2004). More research is still needed to further characterize the circuits that are involved in biological motion detection.

A new suggestion to come out of recent research is that biological motion perception might involve multiple, dedicated perceptual systems (Troje & Westhoff, 2006). Troje (in press) has suggested, in fact, that there might be four separate processes involved: life detection, structure from motion, action recognition and style recognition. The *life detection* mechanism has been proposed to use local movement cues present in the ballistic movements of the limbs of terrestrial animals. Troje and Westhoff argue that these cues allow our visual system to orient toward and distinguish a moving animal from its environment, without undertaking a detailed analysis of its shape. Troje proposes that the *structure-from-motion* mechanism comes into operation once a creature is detected. At this stage the movements of individual body parts are organized to allow perception of an animal's structure, or shape. At the next level, *action*

recognition, classification and categorization of actions are achieved through the integration of structural and kinematic information. Troje proposes that the mechanism supporting these operations is designed to pick up invariants and that, as such, it should operate well regardless of the particular agent, viewing conditions, or style of action. Lastly, a *style recognition* mechanism has been proposed to operate after the agent and action have been perceived. It has been suggested that this mechanism is involved in pattern recognition at a subordinate level (cf. Rosch, 1988). This mechanism, then, is used to retrieve specific information about the agent and action, such as individual identity, gender, age, emotional state, or personality traits (Troje, 2002a, 2002b; Troje, Sadr, Geyer & Nakayama, 2006; Troje, Westhoff, & Lavrov, 2005; Westhoff & Troje, 2007).

The main goal of the current project was to further characterize the life detection mechanism. Troje and Westhoff (2006) recently presented evidence in support of the idea that this mechanism can be triggered by local (as opposed to configural) information about the movements of a terrestrial animal. They created scrambled point-light displays of humans, cats, and pigeons, in which the local motion was preserved but the global configuration was disrupted. Although participants could not identify the type of animal they were viewing, they could discern the direction of motion in these displays, at above-chance levels. Their ability to do this, however, was dramatically impaired when the local motion from the feet (but not the rest of the body) was inverted. This latter result suggests that the detector is hard-wired to expect that large-amplitude movements of the feet will be constrained by the forces of gravity.

In their study, Troje and Westhoff (2006) allowed unlimited viewing of their point light displays. The first question that the current research addressed was whether this simple detector could be triggered at brief exposure durations. I predicted that this would be possible;

specifically, in Experiment 1, I expected to find that participants would be able to discern the direction that upright, shuffled stimuli were facing at above chance levels, despite the fact that the global configuration of a human figure is disrupted in these displays. Performance was expected to drop to chance levels with inverted, shuffled displays. For comparison purposes, performance with upright and inverted, coherent (configural) displays was also assessed. Performance was assessed at two exposure durations: 170 ms and 200 ms. In a follow-up study (Experiment 2), global and local cues were isolated and participants' ability to use each type of cue to determine facing direction with different types of displays was assessed. We were also interested in exploring whether participants showed a directional (facing) bias, given that previous research has shown directional biases in a variety of contexts (e.g., Halpern & Kelly, 1993; Maass & Russo, 2003).

Another set of questions addressed in the present study (Experiments 3-5) was whether the life detection mechanism could be triggered by stimuli presented in the visual periphery and, if so, whether performance would be uniform throughout the visual periphery or not. Research has suggested that many kinds of visual information are not processed with equal efficiency throughout the visual field (VF). Evidence suggests that there is often a systematic link between upper/right and lower/left visual fields (for a recent review see Christman, & Niebauer, 1997). Specifically, the prevailing trend suggests an upper and a right VF advantage for local processing and categorical spatial relations, and for performing visual search. On the other hand, research suggests a lower and a left VF advantage for processing of global structure, coordinate spatial relations, and global motion. Lower and left VF deficits are also associated with clinical phenomena such as neglect. There is also tentative support for a lower/left VF advantage for simple reaction time and processing of low spatial frequencies.

Although there is considerable evidence supporting a systematic link between upper/right and lower/left visual fields, as outlined above, several exceptions to this link have been described. First, lower and right VF advantages have been reported for temporal resolution (see Christman, & Niebauer, 1997). Likewise, robust differences favouring upper and lower fields in processing far (uncrossed disparities) and near (crossed disparities) targets, respectively, have been described, but there do not appear to be robust left/right VF differences in stereopsis. Similarly, while long-range motion (e.g., motion-in-depth, structure-from-motion) is processed better in the lower VF, short-range motion does not show an upper/lower asymmetry (Previc, 1990).

In reviewing the findings described above, several predictions might be generated. One might predict that processes supporting life detection would show an upper VF advantage, since predators and prey typically appear in the distance. On the other hand, one might predict that processes supporting life detection would show a lower and, perhaps, a left VF advantage because simple reaction time and several aspects of motion perception are better in those fields. Indeed, Previc (1990, pp. 274-5) states that a lower VF advantage for aspects of motion perception may be common across many species, and that praying mantis, for example, exhibit "...greater behavioral responsiveness in predatory behavior to stimuli moving in their lower, relative to upper, visual field." The second goal of the present research was to test these opposing predictions.

LIFE DETECTION IN CENTRAL VISION

Experiment 1

Method

Participants

Thirty-two right-handed, undergraduate students were recruited to participate. An equal

number of males and females took part. All participants were required to have normal or

corrected-to-normal vision, and to have a normal birth history and no known history of

neurological or developmental problems. The mean age of participants was 21.8 years (SD = 1.9

years). Participants were recruited through the Introductory Psychology subject pool at the

University of Manitoba. Participants received credit toward a course requirement for their

participation. None of the participants was familiar with point light walker displays. All provided

informed, written consent. The testing protocol was approved by the Human Research Ethics

Board at the University of Manitoba.

Stimuli

Biological motion stimuli were presented on a PC computer running MatLab, using

custom-made software supplied by Dr. N. Troje (Queen's University, Kingston ON). Coherent

(configural) stimuli were composed of 11 marker dots representing the head, one shoulder, one

hip, and each of the elbows, wrists, knees and ankles of a human figure. The positions and

movements of the dots were based on average motion-capture data from 50 male and 50 female

walkers (for further information about the data acquisition and the creation of the stimuli see

Troje, 2002a). Each stimulus figure was presented in a sagittal view at the centre of the computer

screen, and appeared to be walking on a treadmill. The gait frequency of the walker was 0.93Hz

and the size of the walker was 2 x 5 degrees of visual angle. In all conditions, the portion of the step cycle that was displayed varied randomly across trials.

All other stimuli were created through manipulation of the coherent point light walker displays. "Shuffled" displays were created by randomly shuffling the locations of the markers on each trial. For example, on one trial the right elbow marker might be reassigned to the position that would have represented the left knee in a coherent display. While these shuffled displays do contain some form information, the normal configuration of a human walker is disrupted. All of the normal local movement cues, however, are preserved. [Note that these shuffled displays differ from the "scrambled" displays used by Troje and Westhoff (2006), which were created by randomly displacing the markers across the display area. These scrambled displays do not contain any residual form information.] Inverted stimuli were created by flipping coherent or shuffled displays along the planar axis.

Procedure

Participants were tested individually. At the beginning of each session, each participant completed a demographic questionnaire (see Appendix), and was then shown a short series of familiarization trials (administered via computer) to familiarize them with the stimuli and the task (2 left- and 2 right-facing stimuli of each type, presented for 1 sec on each trial). Participants were asked to indicate the direction the walker was facing on each familiarization trial, and feedback was given on their performance. Following the demonstration trials, the experimental test began. The experiment was run in two, counterbalanced blocks differing in exposure duration (170 ms and 200 ms). During testing, the participant's head remained in a chin rest located approximately 57 cm from the computer screen. At the beginning of each trial in a given block, the participant was required to stare at a central fixation point which disappeared when the

stimulus was presented (eye movements were not monitored). After viewing the stimulus, the participant was asked to decide if the walker was facing left or right, and to indicate their response using a key press. Each block consisted of 10 left- and 10 right-facing walkers of each type (coherent upright, coherent inverted, shuffled upright, and shuffled inverted) presented in random order (80 trials in total). A short break was provided between blocks to prevent fatigue.

Results

Accuracy data (% correct) for each exposure duration were entered into separate 2 (Type: Coherent vs. Shuffled) x 2 (Orientation: Upright vs. Inverted) x 2 (Direction: Left vs. Right) analysis of variance (ANOVA) tests, with repeated measures on all three factors.

In the case of stimuli displayed for 200 ms, a significant main effect of Type was found, $F(1,31) = 164.4$, $p < .001$, $\eta_p^2 = .841$. Overall, it was easier for participants to judge the facing direction of coherent stimuli than shuffled stimuli; indeed, mean accuracy scores were 85.0 % correct ($SD = 11.2$) and 57.7 % correct ($SD = 9.6$) for coherent and shuffled displays, respectively. A significant main effect of Orientation was also observed, $F(1,31) = 81.0$, $p < .001$, $\eta_p^2 = .723$. Examination of this main effect revealed that participants were more accurate in judging the facing direction of upright than inverted displays ($M = 83.8\%$ correct, $SD = 6.1$ vs. $M = 58.9\%$ correct, $SD = 15.1$, respectively). Importantly, this effect did not interact with stimulus type; in other words, it was evident with both coherent and shuffled displays. A series of planned comparisons showed a significant inversion effect (i.e., higher accuracy for upright than inverted displays, $p < .05$) for both coherent and shuffled stimuli, and no difference in accuracy ($p > .05$) between coherent inverted and shuffled upright displays (see Figure 1). Additional planned comparisons (utilizing one sample t-tests) showed above-chance performance with all stimulus types except for shuffled inverted.

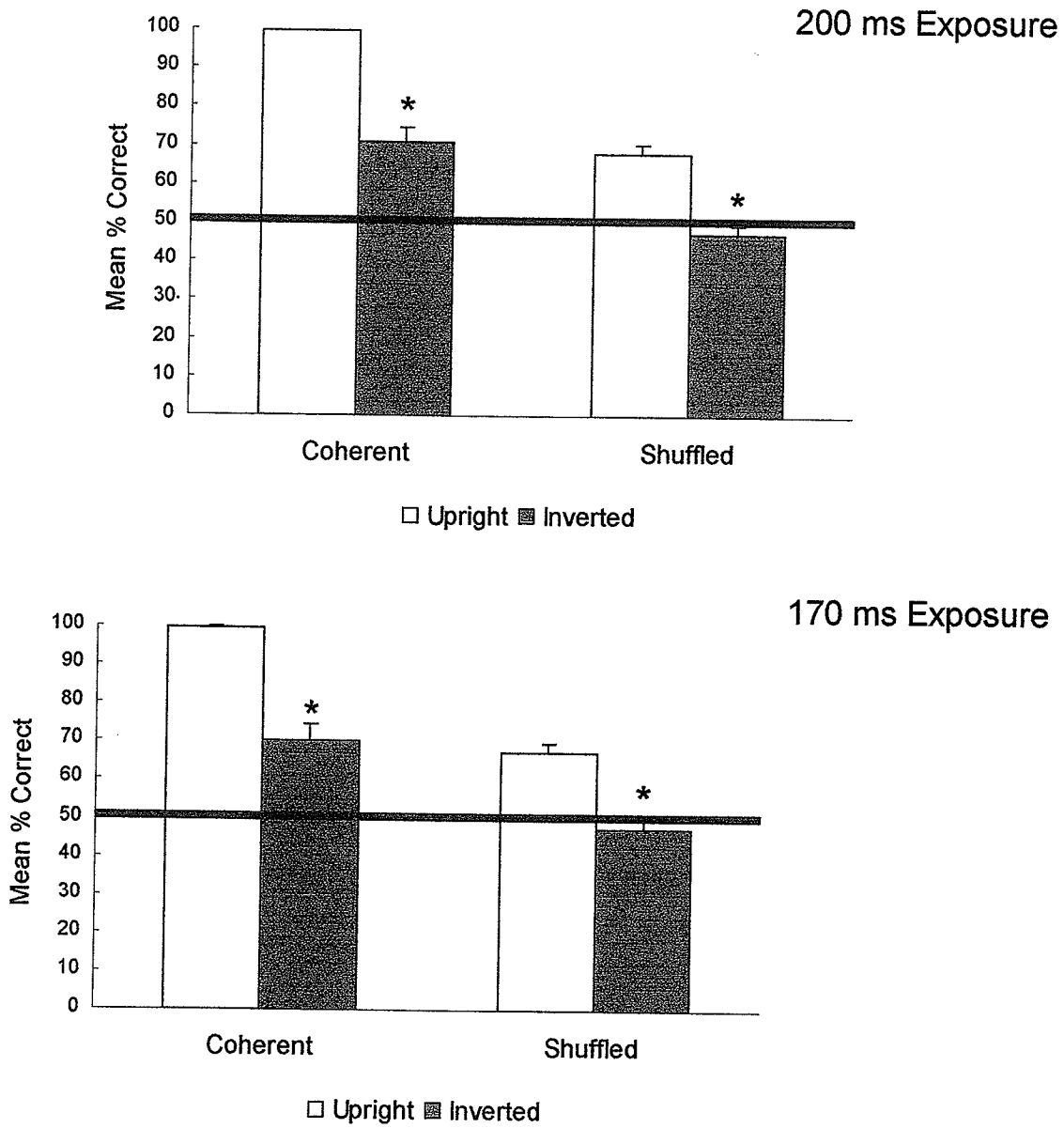Figure 1. Mean accuracy of facing judgments in Experiment 1 for coherent and shuffled walkers presented in upright and inverted orientations at for 200 ms exposure duration and 170 ms exposure duration. All stimuli were presented in central vision. Solid line indicates chance level performance. * Upright stimuli > inverted stimuli ($p < .001$). Performance for inverted, shuffled walkers was below chance.

When the data from the 170 ms exposure duration block were analyzed, the results were the same as those reported above for the 200 ms exposure duration block (see Figure 1). Thus, once again significant main effects of Type, $F(1,31) = 144.0, p < .001, \eta_p^2 = .823$, and Orientation, $F(1,30) = 45.4, p < .001 \ \eta_p^2 = .594$, were found, with above-chance performance being seen with all stimuli except the shuffled inverted.

Discussion

The results from Experiment 1 demonstrate that, even at brief exposure durations, one finds a clear inversion effect for shuffled walkers (cf. Troje & Westhoff, 2006). The fact that the direction that upright, shuffled walkers are facing can be judged at above-chance levels – even with only 170 ms exposure – lends support to the notion that there may be a simple "life detector" (or sensory filter) that can be triggered by natural (i.e., upright) local movement cues.

If the "life detector" evolved to alert us to the presence of predators and prey, in addition to conspecifics, then one would expect that it should be sensitive to the movements of many different terrestrial species – not just humans. To test this prediction, in the next experiment we assessed sensitivity to direction facing in shuffled displays derived from human, cat, and pigeon walkers. We expected to find that participants would show accurate responses for upright shuffled stimuli, regardless of species. Thus, performance with human displays was not expected to be disproportionately better than performance with other species.

In Experiment 1, performance was far superior with coherent than with shuffled displays. Since the local motion cues were identical in these two types of displays, this finding suggests that presenting stimuli in the normal configuration confers an advantage. This seems to make sense since, from an evolutionary standpoint, humans have considerable experience viewing natural movements, and no experience viewing "shuffled" movements.

However, it is difficult to isolate the contributions that local and global cues made to direction judgments in Experiment 1, for two reasons. First, the coherent displays used in Experiment 1 contained both useful local and global information, so it was not possible to isolate the contributions of the two types of cues in these displays. Second, while the normal, global configuration of a human walker was disrupted in the shuffled displays used in Experiment 1, these displays still contained some residual structure. To isolate the contributions of local and global processing to performance, in Experiment 2 we created displays from which facing direction (heading) could only be discerned by attending to either local or global cues.

Experiment 2

Method

Participants

Thirty-two right-handed, undergraduate students were recruited to participate. An equal number of males and females took part. The mean age of participants was 21.8 years (SD = 3.1 years). Participants in Experiment 2 met the same inclusion criteria, and were recruited in the same fashion, as in Experiment 1.

Stimuli

The human point light stimuli used in Experiment 2 were derived from the same database used to create the stimuli for Experiment 1. In addition, cat and pigeon stimuli were generated using software supplied by Dr. N. Troje (Queen's University, Kingston ON). The cat displays were created from high speed (200 fps) video sequences made while a cat was walking on a treadmill. The positions of 18 marker points were sampled manually from single frames. The pigeon displays were created from recordings made of a pigeon that had been trained to walk back and forth between two feeders. An optical motion capture system was used to capture 11

retroreflective markers on the pigeon. The gait frequencies were 1.7 Hz for the cat and 1.6 Hz for the pigeon.

Two different types of stimuli ("local" and "global") were created for this experiment. Both types of stimuli were presented in both upright and inverted orientations so that inversion effects could be measured. Inverted stimuli were created by flipping upright displays along the planar axis.

Local task. To force reliance on local processing, participants were shown "scrambled" stimuli, in which the dots comprising the walker were randomly placed within a restricted plot area in the center of the monitor. For human stimuli, this area was 3.1 x 5.7 degree of visual angle; for cats it was 5.7 x 3.1 degrees of visual angle; and for pigeons it was 4.4 x 4.4 degrees of visual angle. Unlike the shuffled displays used in Experiment 1, these scrambled displays do not retain any structural information and thus heading must be extracted solely from local motion cues. The point light display was embedded in a 100 dot flicker mask with a limited lifetime of 120 ms. This flicker mask contained no motion. There were 10 left-facing and 10 right-facing stimuli of each type and orientation, for a total of 120 trials. Stimuli were presented for 500 ms each.

Global task. To force reliance on global processing, participants were shown coherent stimuli embedded in a same-species, scrambled walker mask that rendered local motion information useless for determining direction-facing. On a given trial, the mask was comprised of dots derived from scrambled human, cat, or pigeon walkers. The dots comprising the mask were spatially scrambled within a 10 cm x 10 cm plot area. For the human and pigeon stimuli, the mask always contained 11 dots from an animal moving in the same direction as the coherent target, and 22 dots derived from an animal moving in the opposite direction. As such, there was

no net directional information available at the local level for the human or pigeon targets. This was not the case for the cat target (which had 7 markers more than either of the other targets). Because of this error, analyses were restricted to the data from the trials involving human and pigeon displays. To make an accurate facing judgment about these two species, a participant would have to have been able to extract the global figure from the dynamic noise in the mask. There were 10 left- and 10 right-facing target walkers of each species, shown in each orientation (upright or inverted), for a total of 120 trials. Stimuli were presented for 500 ms.

Procedure

For Experiment 2, the procedure was basically the same as Experiment 1 with the addition that participants were given extra familiarization trials. They were first familiarized with unmasked human, cat and pigeon stimuli and then, preceding administration of both the local and the global task, participants were familiarized with the specific stimuli to be used in the task to follow by being shown 1 upright left-facing and 1 inverted right-facing stimulus of each species, presented for 1 sec each. Each task was run in a separate block of 120 randomly-ordered trials, including 10 left- and 10 right-facing walkers of each species, shown in each orientation. The two tasks were presented in counterbalanced order, with a short break being provided between blocks to prevent fatigue.

<div style="text-align:center">Results</div>

Local task

Accuracy data (% correct) for the local task were entered into a 3 (Species: Human, Cat, Pigeon) x 2 (Direction: Left vs. Right) X 2 (Orientation: Upright vs. Inverted) ANOVA test, with repeated measures on all three factors.

There was a trend [$F(1,31) = 3.3$, $p = .08$, $\eta_p^2 = .096$] for right-facing walkers to be processed more accurately than left-facing walkers, overall ($M = 63.2\%$ correct, $SD = 13.5$ vs. $M = 57.0\%$ correct, $SD = 12.6$, respectively). In addition, the analysis revealed significant main effects of Species, $F(2,62) = 5.3$, $p = .007$, $\eta_p^2 = .146$, and Orientation, $F(1,31) = 100.5$, $p < .001$, $\eta_p^2 = .764$ and a significant Species X Orientation interaction, $F(2,62) = 39.4$, $p < .001$, $\eta_p^2 = .560$ (see Figure 2). Examination of the interaction means (% correct) revealed that performance with scrambled upright human walkers ($M = 64.2$, $SD = 11.3$) was comparable to that seen with shuffled upright human walkers viewed for 170 ms in Experiment 1 ($M = 67.5$, $SD = 12.2$). Interestingly, tests of simple main effects (using a Bonferroni correction) showed that performance with scrambled upright cats and pigeons was actually superior to that seen with scrambled upright humans. As predicted, however, there was a significant inversion effect for each species. In addition, planned comparisons (utilizing one sample t-tests) showed that, for all three species, performance was significantly above chance for upright stimuli, but was at (or below) chance for inverted stimuli.

Global task

Recall that the data from the cat trials could not be used because the cat displays contained proportionately more signal dots than the human or pigeon displays. Accuracy data (% correct) for the global task were entered into a 2 (Species: Human, Pigeon) x 2 (Direction: Left vs. Right) X 2 (Orientation: Upright vs. Inverted) ANOVA test, with repeated measures on all three factors.

A significant main effect of Direction was found, $F(1,31) = 8.3$, $p < .01$, $\eta_p^2 = .21$, with right-facing walkers being processed more accurately than left-facing walkers, overall ($M = 56.6\%$ correct, $SD = 11.1$ vs. $M = 48.7\%$ correct, $SD = 14.5$, respectively). Humans were
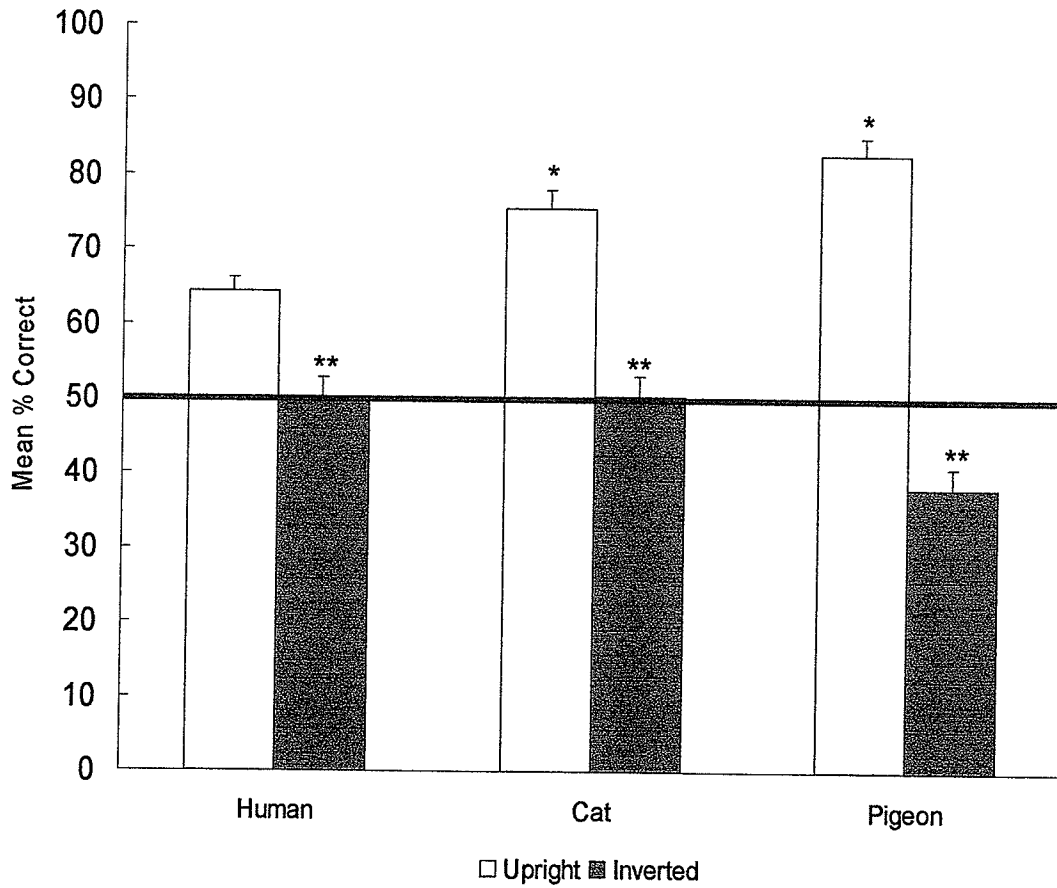
Figure 2. Mean accuracy rates of direction facing for human, cat and pigeon for both upright and

inverted stimuli in the Experiment 2: Local task. Solid line indicates chance level performance. *

Upright cat and pigeon > upright human; ** Upright stimuli > inverted stimuli ($p < .001$).

processed more accurately than pigeons, overall ($M = 57.5\%$ correct, $SD = 11.5$ vs. $M = 47.7\%$ correct, $SD = 11.9$, respectively), $F(1,31) = 24.5$, $p < .001$, $\eta_p^2 = .442$. A significant main effect of Orientation was also observed, with upright displays being processed more accurately than inverted displays, overall ($M = 58.0\%$ correct, $SD = 16.0$ vs. $M = 47.2\%$ correct, $SD = 9.9$), $F(1,31) = 13.2$, $p = .001$, $\eta_p^2 = .299$. A trend for a Species X Orientation interaction was found, $F(1,31) = 3.4$, $p = .07$, $\eta_p^2 = .099$. Planned comparisons (utilizing one sample t-tests) showed that correct response rates were only above chance for upright human stimuli, $p = .001$. Performance with inverted pigeons was actually significantly below chance, $p = .001$, suggesting (perhaps) that something in these displays produced a miscue that led participants to make errors in their direction judgments (see Figure 3). Indeed, even performance with upright human displays, while above chance (one sample t-test), was quite poor ($M = 64.7\%$ correct, $SD = 18.2$), unlike in Experiment 1 where performance with unmasked, coherent upright human displays was essentially at ceiling.

Discussion

In the local task of the present experiment participants showed an inversion effect for scrambled walkers, comparable to that seen with shuffled walkers in Experiment 1. Scrambled walkers were employed in this experiment because they provide no structural cues. Despite this, participants were still able to determine the direction that the upright scrambled walkers were facing, regardless of the species. In all three species, an inversion effect was observed with upright stimuli being processed more accurately than inverted stimuli. It was not disproportionately easier to extract heading from the local motion of humans compared to cats or pigeons (indeed, performance with upright cat and pigeon displays was better than performance with upright human displays). This is what we would expect if the life detector is a general
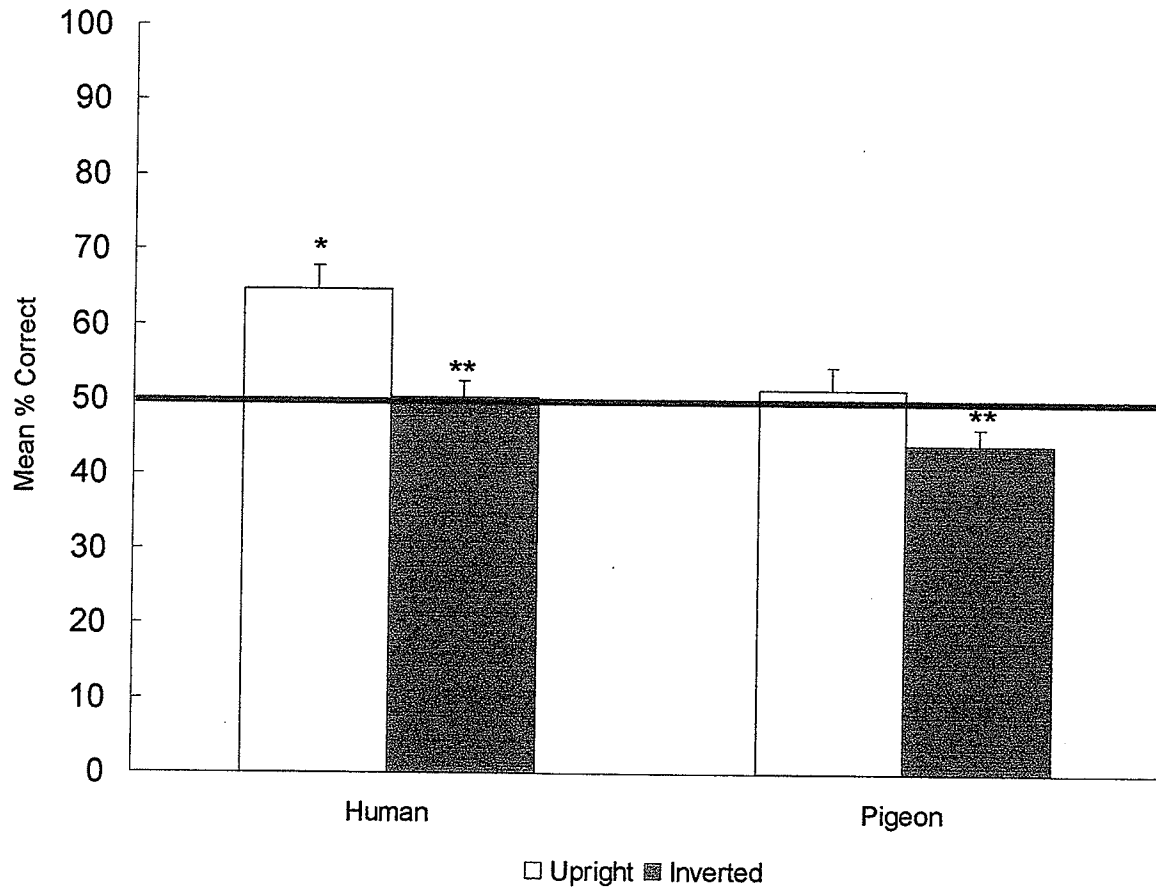
Figure 3. Mean accuracy rates of direction facing for human and pigeon for both upright and

inverted stimuli in the Experiment 2: Global task. Solid line indicates chance level performance.

* Upright human above chance; ** Upright stimuli > inverted stimuli ($p < .001$).

purpose mechanism. These results, then, lend additional support to Troje and Westhoff's (2006) proposal that the natural (i.e., upright) local motion of terrestrial animals is quickly and accurately processed in the human visual system. The fact that an inversion effect was seen with scrambled displays containing only local motion cues calls into question the conclusion that inversion effects result solely from disruption of global processing. Troje and Westhoff (2006) suggest, instead, that there may be two types of inversion effects – one arising from disruption of the life detection mechanism (through violation of natural, local motion patterns), and another that arises from disruption of the structure-from-motion mechanism (through inversion of the familiar configuration or shape of the figure).

Compared to the local task, performance on the global task was very poor. This might reflect poor effort, but it may also be that removing all useful local motion information has a very deleterious effect on performance. The fact that only upright humans were processed at above-chance levels lend tentative support to Troje and Chang's (2007) proposal that global mechanisms supporting shape processing (structure-from-motion) operate best on human stimuli. This makes sense since humans have more experience with their own species and this learning would affect our ability to use global cues to extract shape information. The different patterns of performance seen in the local and global tasks add support to Troje and Chang's hypothesis that global structure-from-motion processing is distinct from life detection.

In both the local and global tasks, participants tended to show a right-facing advantage which was not observed in Experiment 1. This difference in the two experiments could be related to the fact that longer exposure durations were used in the present experiment. Another way in which the two experiments differed was that Experiment 1 involved unmasked displays, while Experiment 2 involved masked displays. Thornton, Vuong and Bulthoff (2003) have found that

observers show a bias to report seeing a right-facing walker in chimeric displays containing

balanced right- and left-facing local motion information, but only when the walkers are

embedded in a random mask of transparently translating, jittering dots. This task is more similar

to the present experiment. It may be that the right-facing advantage is most obvious in situations

where greater attentional resources are required, as is the case when a target must be

disembedded from a mask.

Despite the fact that the walkers used in the present experiments appear to be walking on

a treadmill, and are not actually translating across the screen, the displays likely still "imply"

movement in a particular direction. Past research suggests that biological motion displays are not

immune to the memory or perceptual biases that occur within representational momentum

displays (Jarraya, Amorim & Bardy, 2005). Representational momentum occurs when a viewer's

memory for a target's location is biased in the direction of its continuing, or implied, motion

(Freyd & Finke, 1984). Interestingly, research examining representational momentum has shown

a directional advantage similar to that seen in Experiment 2. Thus, Halpern and Kelly (1993)

have shown that there is a larger memory bias for objects implied to be moving right compared

to left.

Saccadic eye movements could play a role in the rightward bias seen in the

representational momentum effect, and in Experiment 2. For instance, saccadic movements to

the right have been shown to be to present when there is a large memory bias in the rightward

direction (Halpern & Kelly, 1993). This may be associated with reading habits, since readers of

many written languages are trained to read from left to right, and not in the oppose direction.

Evidence that humans develop specialized scanning habits as they learn to read comes from a

recent study by Maass and Russo (2003). These investigators found that individuals from Italy

show a scanning bias from left-to-right, while Arabs show a scanning bias from right-to-left. Results from a sentence-picture matching task showed facilitated performance when the direction of stimulus presentation was in the direction that the written language was read. The right-facing advantage observed in the present study might reflect a directional scanning bias. It should be noted that we did not collect information about the language that the participants learned to read during development, though it is assumed that the majority of our participants first learned to read, and continue to read predominantly in a left-to-right direction. The potential influence of reading biases could, however, be examined in future research.

LIFE DETECTION IN PERIPHERAL VISION

Only a handful of studies, to date, have examined the processing of biological motion stimuli in the visual periphery, and the research that does exist does not provide a clear picture about the operation of the life detection mechanism. Gibson, Sadr, Troje, and Nakayama (2005) showed that, in contrast to what is seen with simple or complex *stationary* forms, complex *moving* patterns are coded very efficiently in the visual periphery. Likewise, Zyborowicz and Pinto (2005) showed that, while spatial acuity and form perception declined rapidly outside the fovea, observers were able to discriminate coherent from spatially scrambled point-light walkers at the most extreme eccentricities used [75 deg in the temporal VF (monocular viewing)]. The above two studies show that accurate direction-facing (Gibson et al. 2005) and detection (Zyborowicz & Pinto, 2005) judgments can be made regarding coherent stimuli presented in the visual periphery, but in both cases target eccentricity was only varied along the left/right dimension. In addition, the accuracy with which direction-facing could be discerned in scrambled displays (in which configural cues are disrupted) was not investigated in either study.

In a recent report by Ikeda, Blake and Watanabe (2005), biological motion stimuli were presented at three different eccentricities (0, 4 or 12 deg to the right of fixation). On each trial, participants had to decide whether or not a coherent walker was present within a scrambled walker mask. As such, this task required processing of structure-from-motion (i.e., local motion cues were rendered uninformative due to the presence of the mask). Both upright and inverted displays were used. The sizes of the displays were systematically varied across trials, and the number of masking dots used was varied using a staircase method to establish a criterion level of performance. Results showed that, for central vision, better performance was found for larger stimulus sizes, especially for upright compared to inverted stimuli. Performance in peripheral vision was always worse than that seen in central vision. Furthermore, the researchers were not able to equate performance in the central and peripheral conditions by using any magnitude of size scaling. In contrast to Gibson et al. (2005), these authors concluded that perception of biological motion in the visual periphery was "unscalably poor." However, while they concluded that their task, which required active (top-down) processing, could be carried out best in central vision, they conceded that it may be possible to process other types of biological motion stimuli well in the periphery, in a more bottom-up (passive) manner.

Thornton and Vuong (2004) used a flanker-interference paradigm to examine incidental (bottom-up) processing of biological motion in the visual periphery. The prediction would be that if peripheral flankers (point-light walkers) are being processed automatically, then subjects should be quicker to respond when the direction the central (target) walker is facing matches the direction the flanking walkers are facing (congruent trials), than when it does not (incongruent trials). In the first and second experiments, they found a walker congruency effect that held across a range of eccentricities; importantly, it was not seen when a static display capturing a

point-light walker at the most extreme part of the step cycle was presented in the visual periphery. This suggests that coherent, biological motion displays can be processed incidentally in a passive, bottom up fashion in the visual periphery. In the third experiment, they compared the effect of coherent vs. scrambled flankers. Flankers were presented in all four visual quadrants simultaneously. Coherent walkers produced a walker congruency effect, but scrambled walkers did not, suggesting that it is the global motion in the periphery that influences responses to the central target. This provides evidence that global direction can be extracted in a passive, bottom-up fashion in the visual periphery, but it does not provide evidence that the local motion cues contained in a scrambled walker are processed automatically. As such, the results appear to be at odds with the prediction that the direction-facing of scrambled walker stimuli should be processed automatically throughout the visual field. It is important to note, however, that Thornton and Vuong's stimuli were derived from walkers similar to the Cutting display (Cutting, 1978), in which the movements of the feet do not mimic a natural movement pattern (Saunders, Suchan & Troje, 2007). This may be relevant, given the presumed importance of the feet for life detection (cf. Troje & Westhoff, 2006). In addition, Thornton and Vuong did not systematically compare the influence of upper vs. lower, or left vs. right, flankers. It may be that simultaneous presentation of the flanking stimuli masked some potentially interesting effects. It might have been the case, for example, that scrambled flankers presented in the upper, or the lower, VF (in isolation) would have produced a congruency effect. Based on this, one of the objectives of the next experiment was to examine the accuracy with which observers could discriminate the direction a peripheral, point-light walker was facing to see if it differed across the four visual quadrants. In the crucial test displays, shuffled figures (in which the local motion is preserved

but the global configuration is disrupted) were presented. Only upright displays were used in this experiment.

Another interesting question addressed in Experiment 3 was whether there are visual field differences in participants' ability to discern the direction that an animal is moving (i.e., whether it appears to be moving toward or away from fixation). To date, no one has examined people's ability to discriminate direction-facing in shuffled or scrambled displays in the visual periphery. Researchers have, however, described various biases in processing other kinds of motion in the visual periphery (e.g., Edward & Badcock, 1993). Specific types of motion create various patterns of optic flow. These optic flow patterns are important because they help guide and regulate normal locomotion (Gibson, 1958; Lee 1980; Regan & Beverly, 1982). The sensitivity to three types of optic flow patterns has been examined: (a) centrifugal, (b) centripetal and (c) uniform translation. A centrifugal pattern is described as a radially expanding optic flow pattern. Centripetal optic flow refers to a radially contracting optic flow pattern. A uniform translating flow pattern refers to motion in the frontoparallel plane. Centrifugal motion (created on the retina by forward motion) is more common than centripetal motion (created by backward motion) (Ball & Sekuler, 1980). This may explain why, in psychophysical and electrophysiological studies, more cells are found to be tuned to movement away from the fovea, shorter response latencies are seen to centrifugal motion onset, and there is a stronger motion aftereffect for centrifugal motion compared to centripetal motion (Albright, 1989; Ball & Sekuler, 1980; Scott, Lavender, McWhirt & Powell, 1966).

Evidence of a centrifugal bias is not consistently reported. In fact, other researchers have found a centripetal bias (Mateeff & Hohnsbein, 1988; Mateef, Yakimoff, Hohnsbein, Ehrenstein, Bohdanecky & Radil, 1991). Specifically, a centripetal bias was found in a task similar to that of

Ball and Sekuler (1980) when the stimuli consisted of a single dot rather than an optic flow field (Mateeff & Hohnsbein, 1988; Mateef, Yakimoff, Hohnsbein, Ehrenstein, Bohdanecky & Radil, 1991), although a result qualitatively similar to Ball and Sekuler's was found when a random-dot field was used. Another study done by Edward and Badcock (1994) found a centripetal bias in centrally presented targets, however a complete loss of this bias was found at greater eccentricities.

If the perceptual biases that have been described for optic flow fields also affect the processing of peripheral point-light walkers, then one might expect that accuracy rates for direction discrimination might be different for walkers appearing to move in particular directions. If there is a centrifugal bias, one would predict that there would be an advantage for walkers appearing to move away from the central fixation point (i.e., left-facing walkers in the left VF and right-facing walkers in the right VF). If there is a centripetal bias, one might predict that there would be an advantage for walkers appearing to move toward the centre of the display (a result that would be interesting as it might suggest that we are more sensitive to movement signifying approach of another animal, than to movement signaling movement away from us). If, on the other hand, attentional biases associated with reading habits affect the processing of peripheral point-light displays (cf. discussion of Experiment 2), then participants might be expected to show a advantage for right-facing walkers, particularly when they are presented on the right side of space. The second objective of Experiment 3 was to see if there was a visual field asymmetries in the ability to determine the direction a walker is facing.

Experiment 3

Method

Participants

With one exception, the participants who took part in Experiment 3 were the same as those who took part in Experiment 1. (One of the original participants in Experiment 1 had to be dropped from Experiment 3 due to equipment failure, but was replaced.) Again, an equal number of males and females took part. The mean age of the 32 participants was 21.8 years ($SD = 1.9$).

Stimuli

The stimuli were generated in the same manner as in Experiment 1 with the exception that all walkers were presented in the upright orientation only. No masking dots were used, and all stimuli were presented for 170 ms on each trial. Eye movements were not monitored.

Procedure

Upon completion of Experiment 1, participants took a short break before beginning Experiment 3. Since they were already familiar with the general requirements of the task, no additional familiarization trials were completed before proceeding on to the test trials. During each test trial, participants fixated a point located 8 degrees of visual angle to the left or right, and 5.7 degrees of visual angle above or below, the center of the display. The location of the fixation point varied across blocks (upper left, upper right, lower left and lower right). During each block, the chin rest was positioned 57 cm in front of the fixation point, at eye level. After each trial, the participant was asked to decide if the walker was facing left or right. There were 10 left- and 10 right-facing walkers of each type (coherent and shuffled) presented in each quadrant, for a total of 160 trials. The order in which the quadrants were tested was counterbalanced.

Results

Data (% correct) were entered into a 2 (Type: Coherent vs. Shuffled) x 2 (Direction:

Right vs. Left) x 2 (Height: Upper VF vs. Lower VF) x 2 (Side: Left VF vs. Right VF) ANOVA,

with repeated measures on all factors.

A main effect of Type, $F(1,30) = 433.7$, $p < .001$ $\eta_p^2 = .933$, was found, indicating that

coherent displays were more accurately processed overall. There were no other significant main

effects or interactions involving Type. Planned comparisons (one sample t-tests) showed above-

chance performance in all conditions. Specifically, the direction that both coherent and shuffled

walkers were facing could be discerned at above-chance levels in all four quadrants ($p < .001$ in

all cases) (see Figure 4).

There were no significant main effects involving Height (upper vs. lower VF) or Side

(left vs. right VF). However, a significant interaction was observed between the side of

presentation and the direction the walker was facing, $F(1, 30) = 7.9$, $p = .009$, $\eta_p^2 = .202$. Follow-

up tests of simple main effects showed that participants were equally accurate at registering both

directions of movement in the left VF. This was not the case in the right VF, where participants

more accurately registered movements directed to the right than those directed to the left, $F(1,$

$31) = 7.5$, $p = .01$, $\eta_p^2 = .195$. This effect was observed both in the upper and lower visual fields

(see Figure 5), and for both coherent and shuffled displays (see Figure 6).

Discussion

In Experiment 3, results showed that coherent walkers were processed more accurately

than shuffled walkers, suggesting that consistent form cues do improve performance in the

periphery. Nonetheless, above chance performance was observed for shuffled walkers in all four

quadrants. There was no indication that performance was better overall (i.e., regardless of
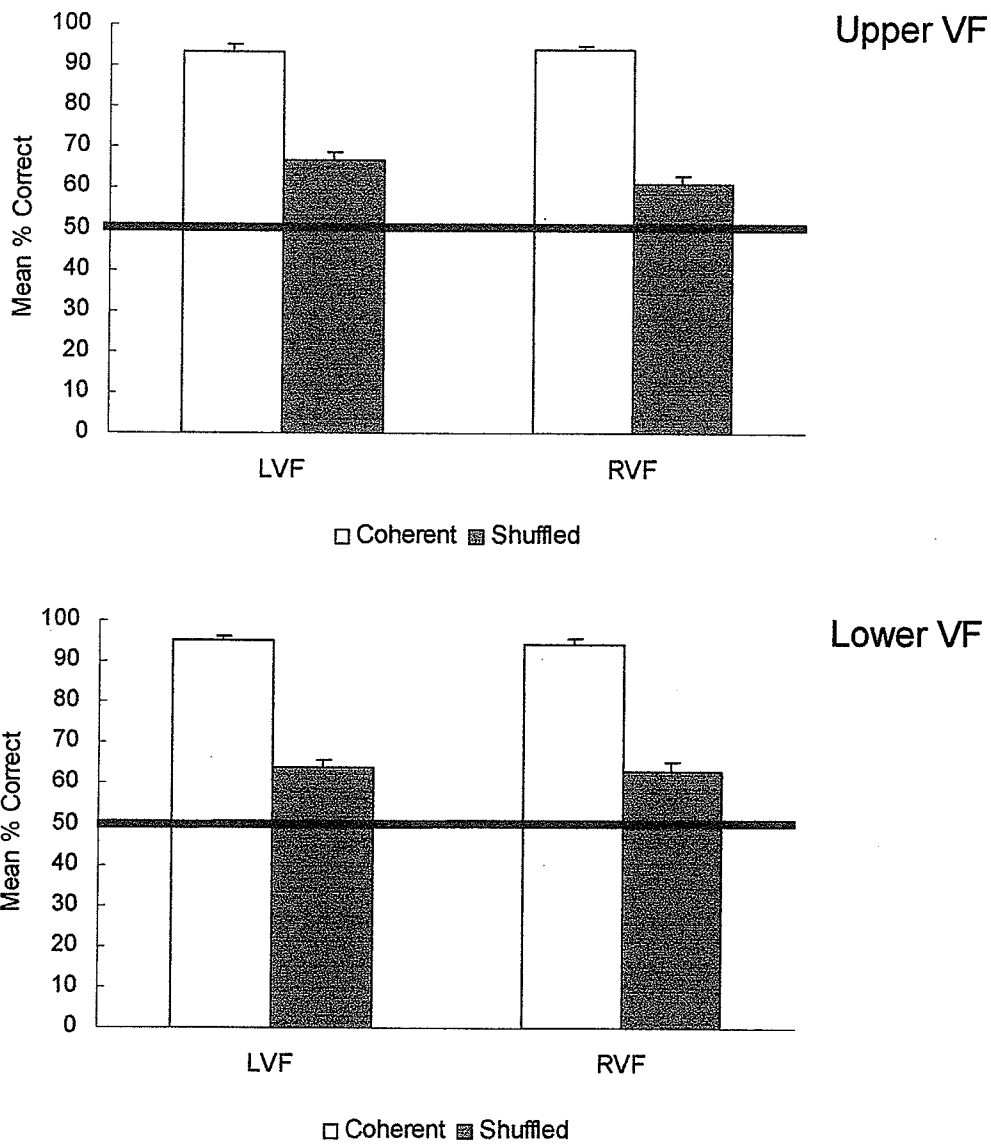
Figure 4. Mean accuracy of facing judgments for coherent and shuffled displays as a function of height and side in Experiment 3. Solid line indicates chance level performance. All means were significantly above chance ($p < .001$).
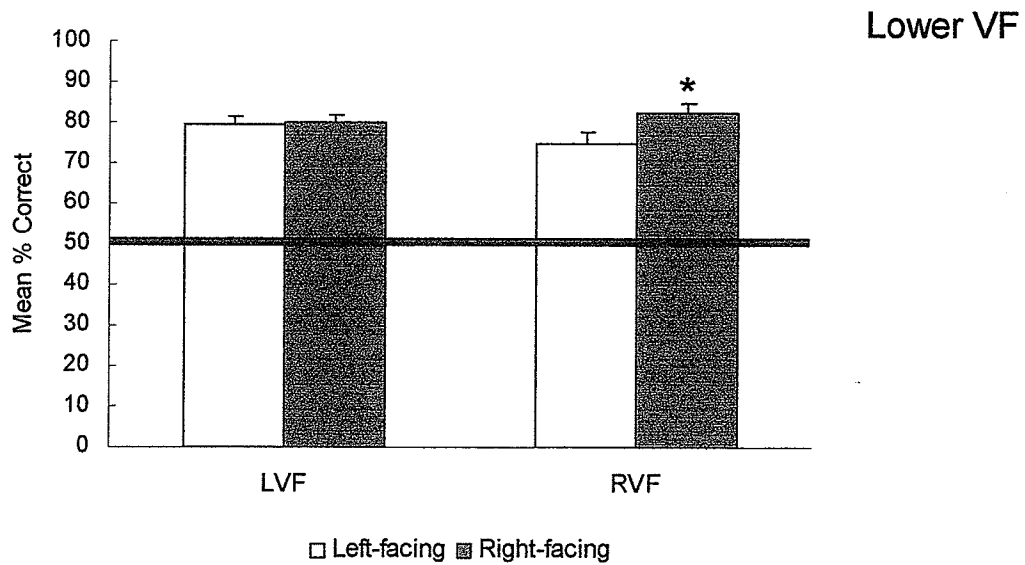
Figure 5. Mean accuracy of facing judgments in upper and lower visual fields as a function of

side of presentation and direction facing in Experiment 3. [LVF: left visual field; RVF: right

visual field] Solid line indicates chance level performance. * Right-facing advantage ($p = .009$).
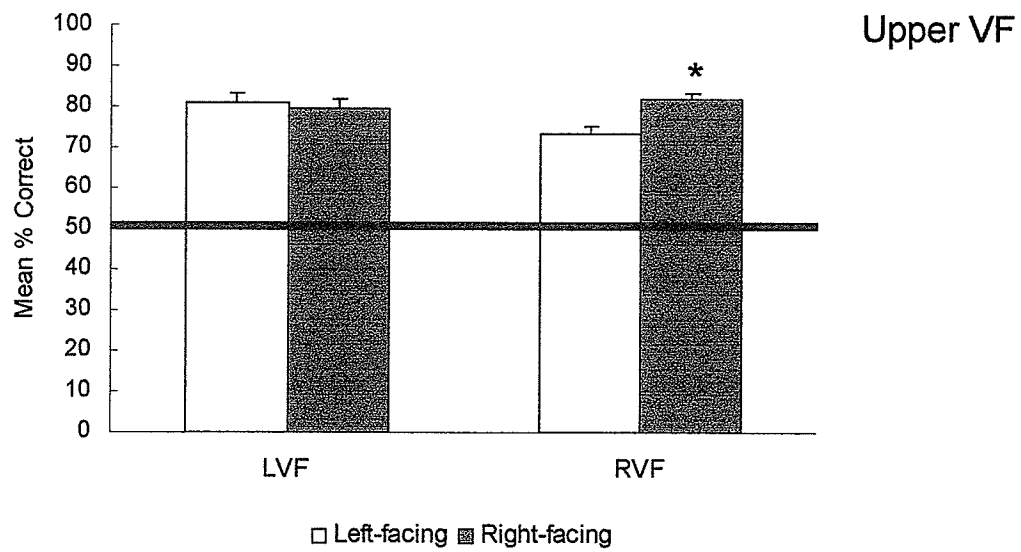
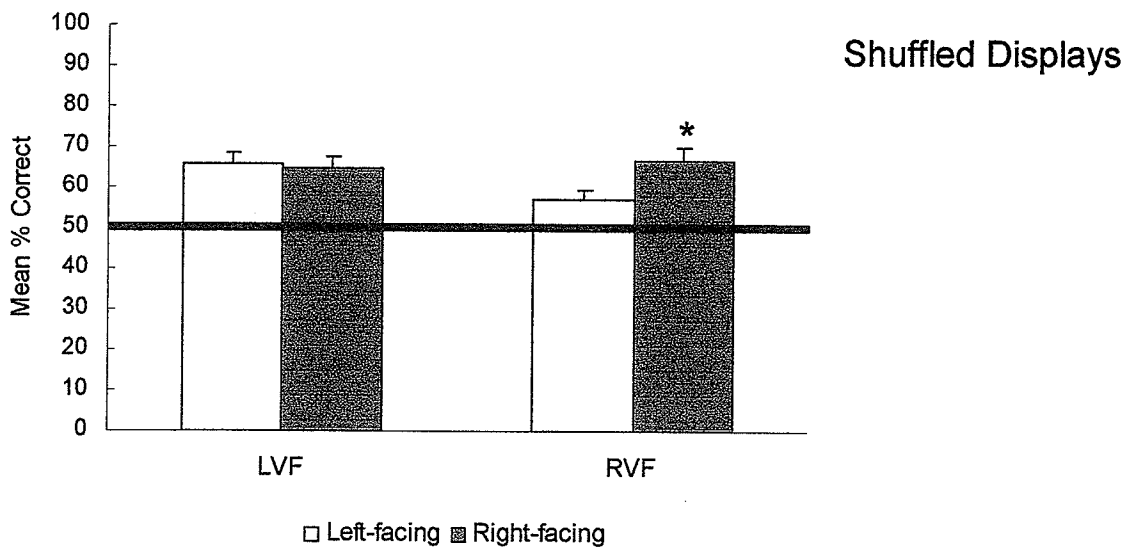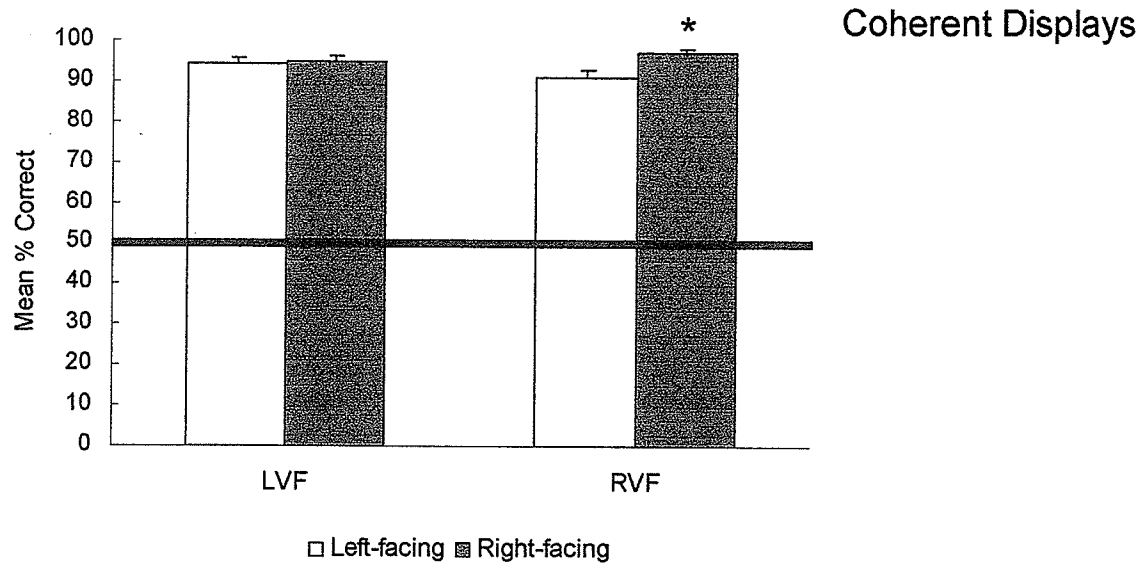**Coherent Displays**

Shuffled Displays

Figure 6. Mean accuracy of facing judgments as a function of side of presentation and direction facing in Experiment 3 for coherent stimuli and shuffled stimuli. [LVF: left visual field; RVF: right visual field] Solid line indicates chance level performance. * Right-facing advantage ($p = .009$).

direction facing) in any given quadrant/field. This result suggests that the life detector can be successfully triggered by local motion cues throughout the periphery even at very brief exposure durations. This result seems to contradict the results of Thornton and Vuong (2004), who suggested that scrambled flankers do not produce a coherency effect in the visual periphery. A possible explanation for the differences observed in these studies lies with the stimuli used. In the Thornton and Vuong (2004) paper they employed the Cutting walker which has been shown to not contain natural local motion of the feet (Saunders, Suchan & Troje, 2007). Given the presumed importance of the feet for life detection (cf. Troje & Westhoff, 2006), this may explain why they did not find that local motion of scrambled walkers was processed automatically in the visual periphery.

Results from the present study also showed that there was no difference in overall accuracy based on the height or side of stimulus presentation. This is interesting as there is a lot of research to suggest that certain visual processes are carried out better in particular regions of the visual periphery (e.g., Previc, 1990; Christman, & Niebauer, 1997). One should keep in mind, however, that participants always knew which quadrant the stimulus would be presented in, so they may have been able to pre-cue their attention to the general location in which the target would appear. As such, an important goal of the next experiment was to try and replicate the present result when the stimulus location was varied randomly across the four quadrants (instead of running each quadrant separately in a block). This would prevent participants from being able to consciously direct their attention to one quadrant, and allow for a more pure test of the hypothesis that the life detection mechanism operates most efficiently in particular areas of the visual periphery.

Lastly, results showed that, while participants were equally able to detect left and right

facing walkers in the left VF, right facing walkers were processed better than left facing walkers

in the right VF. This right-facing advantage occurred even with shuffled stimuli. This result

raises several questions, which were also addressed in Experiment 4. The first question was, does

the right-facing advantage reflect a tendency to see a walker going right, or is it actually easier to

determine the general shape of right-facing walkers in the right visual field? To examine this

issue, we had participants make both left/right facing judgments, and judgments about whether

or not the stimuli were coherent. The second question was, does mirror neuron/simulation theory

(DiPellegrino, Fadiga, Fogassi, Gallese & Rizzolatti, 1992) provide a possible explanation for

the right-facing advantage? According to this theory, particular neurons (mirror neurons) fire not

only when an individual produces a particular action, but also when he/she observes that same

action. It may be that the bias I observed in the right visual field reflects an underlying

hemispheric asymmetry in the mirror neuron system. Note that, if the mirror neuron system is

implicated here, then the present results suggest that the representations we have of our own

bodies must be quite unusual, as the right-facing advantage was seen even with shuffled displays,

in which the normal configuration is disrupted.

<div align="center">Experiment 4</div>

<div align="center">Method</div>

Participants

Thirty-two right-handed, undergraduate students were recruited to participate. An equal

number of males and females took part. The mean age of participants was 21.6 years (SD = 5.1

years). Participants in Experiment 4 met the same inclusion criteria, and were recruited in the

same fashion, as in Experiment 1.

Stimuli

The stimuli were generated in the same way as those used in Experiment 3, with the exception that a central fixation point was used, and the stimuli were presented randomly in one of four locations (upper right, lower right, upper left, lower left) rather than being run in four separate blocks. The stimuli were centered 8 degrees of visual angle to the left or right, and 5.7 degrees of visual angle above or below, the center of the display. Both coherent and shuffled walkers were presented. All stimuli were presented in the upright orientation only. The stimuli were presented for 170 ms and there were 10 left- and 10 right-facing walkers of each type presented in each quadrant, for a total of 160 trials. The walkers were made 30% smaller than those used in Experiment 3 in order to increase the vertical separation between the bottom of the stimuli presented in the upper VF, and the top of the stimuli presented in the lower VF on the same side.

Procedure

Before beginning the experimental trials, participants completed a series of familiarization trials in which they were shown each type of stimulus that would be presented in the actual experiment. Specifically, coherent and shuffled walkers were presented in each quadrant, facing either left or right. Each participant completed the familiarization and experimental trials with his/her head in a chin-rest located 57 cm from the screen. During each test trial, participants fixated centrally while a point light walker was presented randomly in one of four locations (upper left, upper right, lower left and lower right). This task was run twice; in one run, participants made direction-facing judgments; in the second run, they had to state whether the display they had just seen was coherent or shuffled. The order of the runs was counterbalanced across participants.

Results

Accuracy data (% correct) for the direction-facing and coherency judgments were entered into separate 2 (Type: Coherent vs. Shuffled) x 2 (Direction: Left vs. Right) x 2 (Side: Left vs. Right VF) x 2 (Height: Upper VF vs. Lower VF) ANOVAs, with repeated measures on all factors. The results of the two analyses are described separately, below.

Direction Discrimination

A significant main effect of Type was found, $F(1,31) = 78.6, p < .001, \eta_p^2 = .72$, with coherent walkers being processed more accurately than shuffled walkers, overall ($M = 76.5\%$ correct, $SD = 12.6$ vs. $M = 58.6\%$ correct, $SD = 7.4$, respectively). The analysis also revealed a main effect of Height, $F(1, 31) = 4.7, p = .038, \eta_p^2 = .13$, with accuracy in the lower visual field ($M = 69.1\%$ correct, $SD = 9.0$) being slightly higher than in the upper visual field ($M = 66.0\%$ correct, $SD = 9.8$), overall.

We observed a significant main effect of Direction, $F(1,31) = 14.0, p < .001, \eta_p^2 = .31$, with right-facing walkers being processed more accurately, overall. The mean accuracy scores were 72.2% correct ($SD = 11.8$) vs. 62.9% correct ($SD = 10.3$) for right- and left-facing stimuli, respectively. There was also, however, a significant three way Direction x Side x Height interaction, $F(1,31) = 12.2, p = .001 , \eta_p^2 = .28$ (see Figure 7). In following up on this interaction, we performed a test of the simple main effect of direction in each of the four quadrants. These tests showed that right-facing walkers were processed more accurately than left-facing walkers in both the lower left and upper right quadrants ($p < .05$ in both cases). A similar trend ($p < .10$) was observed in the lower right quadrant. No effect of direction was observed in the upper left quadrant, however ($p = 1.0$). It is important to note that, as in Experiment 3, the results described
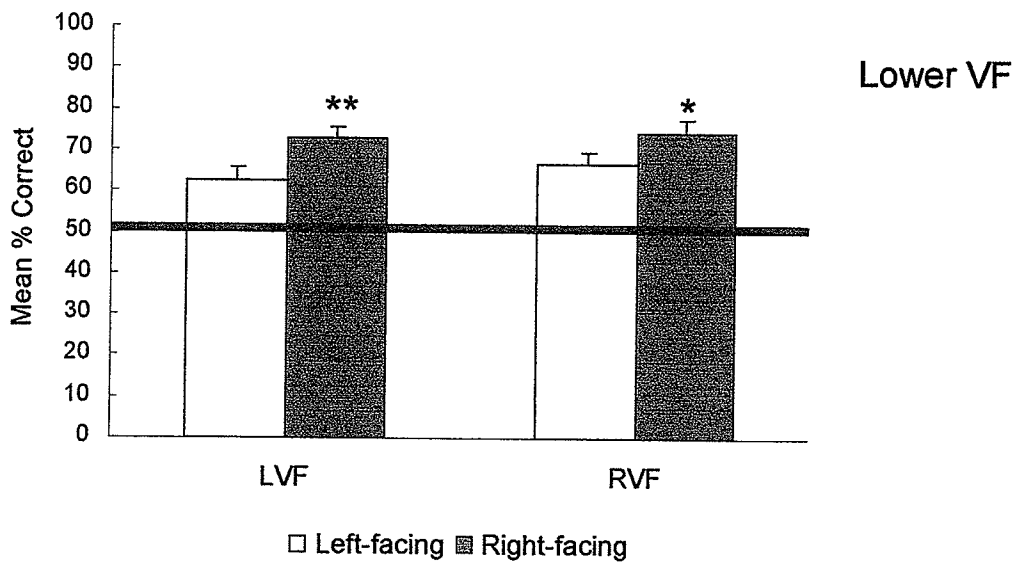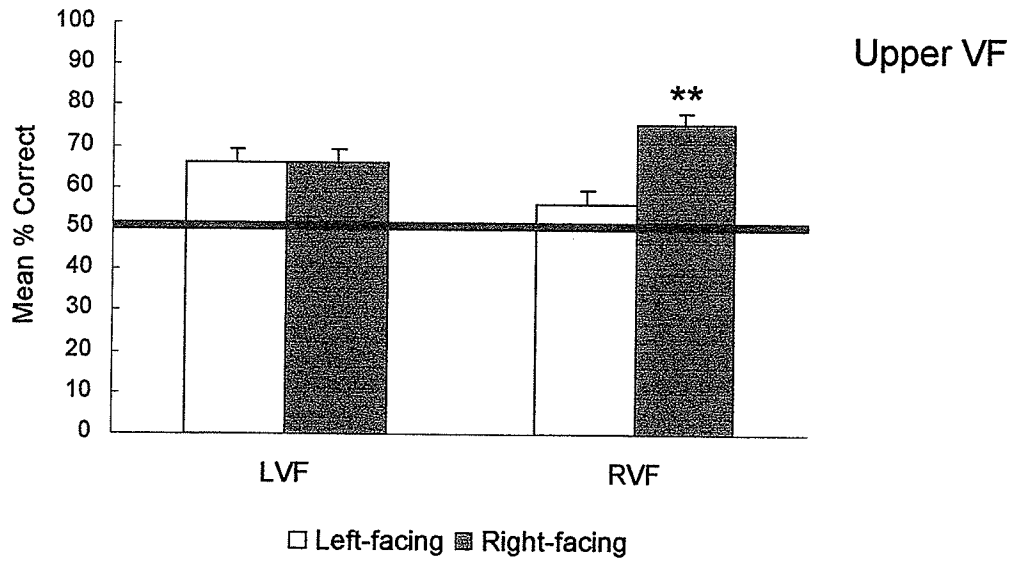
Figure 7. Mean accuracy of facing judgments in upper and lower visual fields as a function of side of presentation and direction facing in Experiment 4. [LVF: left visual field; RVF: right visual field] Solid line indicates chance level performance. * Right-facing advantage ($p < .1$). ** Right-facing advantage ($p < .05$).

above applied both to coherent and shuffled walkers; thus, no significant interactions involving type of display were observed.

Planned, one-sample *t*-tests showed that performance with coherent stimuli was well above chance in all four quadrants (*p* < .001 in all cases). Overall, however, mean scores with coherent displays (*M* = 76.5% correct, *SD* = 12.6) were not as high as those seen in Experiment 3 (*M* = 94.2% correct, *SD* = 5.4). This result is probably due to the use of slightly smaller stimuli in the present experiment. More importantly, planned comparisons showed that overall accuracy with shuffled stimuli was also significantly above chance in all four quadrants (*p* < .005 in all cases).

Coherency Judgments

The analysis of the data from the coherency judgments task revealed significant main effects of Direction, $F(1,31) = 5.3, p = .028, \eta_p^2 = .15$, and Type, $F(1,31) = 91.6, p < .001, \eta_p^2 = .75$, and a significant Type x Direction interaction, $F(1,31) = 5.5, p = .026, \eta_p^2 = .15$. Follow-up tests of simple main effects showed that, overall, participants were more accurate at judging coherency of left- than right-facing walkers with coherent displays, but their overall accuracy with shuffled displays did not show a facing advantage (see Figure 8). There was also a significant Type x Side interaction, $F(1,31) = 7.6, p = .01, \eta_p^2 = .20$. Follow-up tests of simple main effects showed that: (a) participants were equally accurate at judging the coherency of coherent stimuli in both the left and the right VFs, but their judgments of shuffled stimuli were more accurate when the stimuli were presented in the right VF; and (b) participants were better able to judge the coherency of coherent than of shuffled displays, regardless of the side of presentation (see Figure 9).
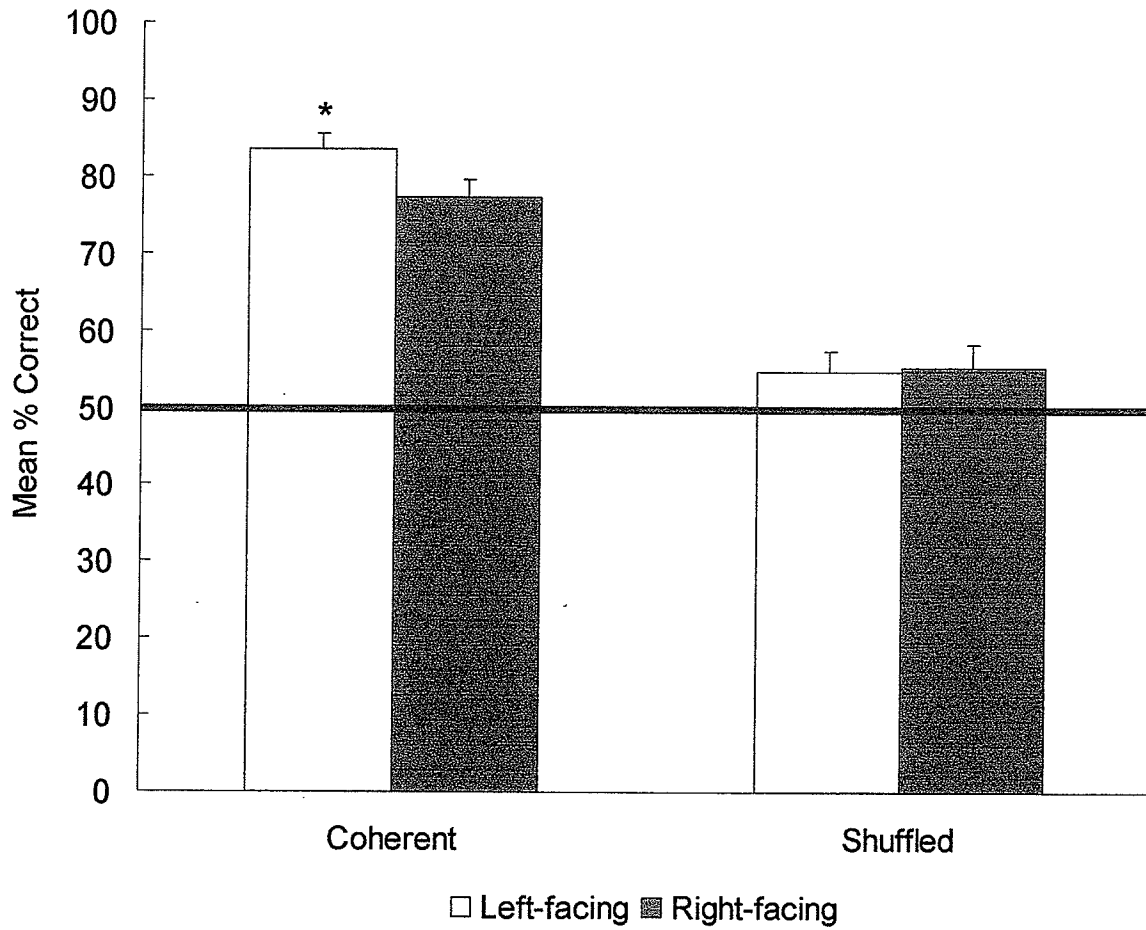
Figure 8. Mean accuracy of coherency judgments as a function of display type and side in

Experiment 4. Solid line indicates chance level performance. * Left-facing advantage ($p = .028$).
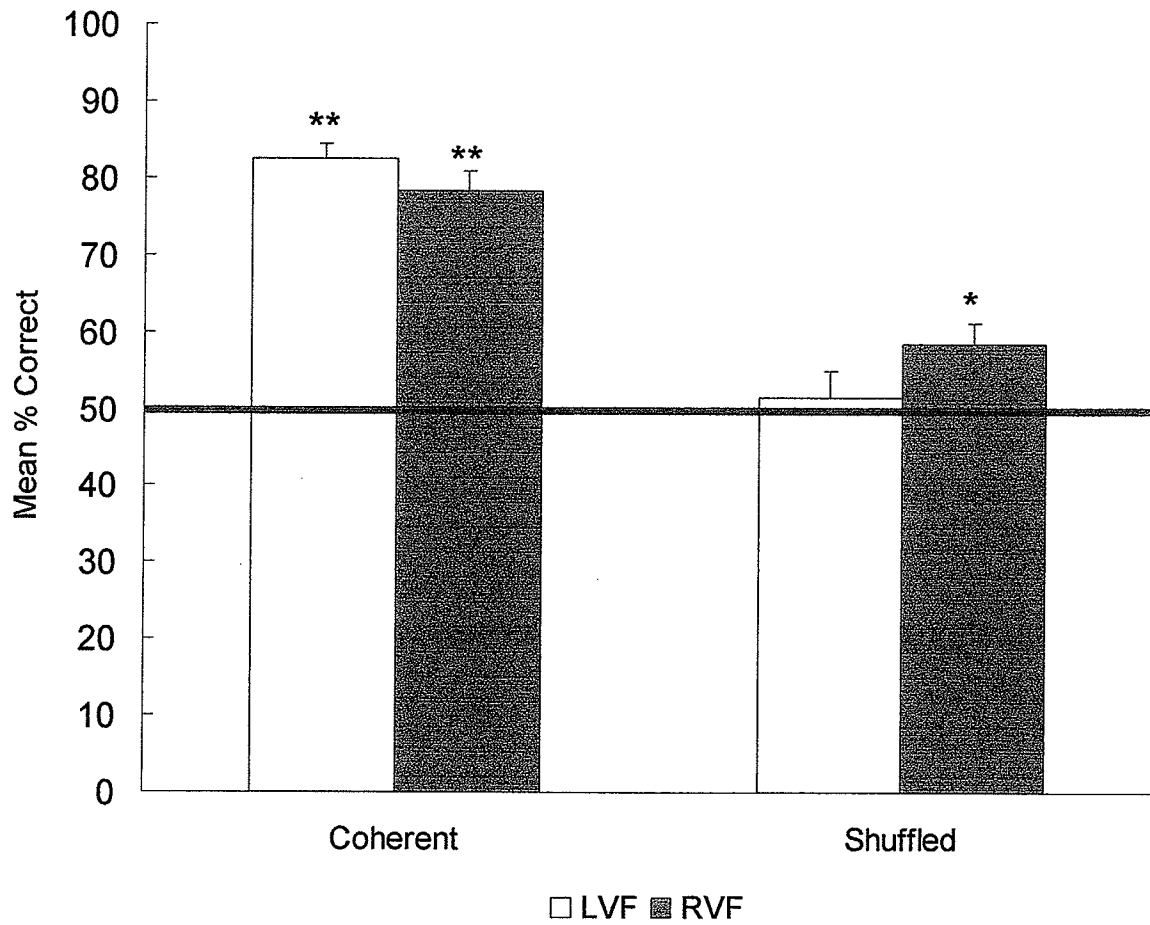
Figure 9. Mean accuracy of coherency judgments for both coherent and shuffled stimuli in the right and left visual field in Experiment 4. Solid line indicates chance level performance. * Right visual field advantage ($p = .01$). ** Coherent > shuffled ($p < .001$).

Discussion

Results from the direction discrimination task suggest that information about a walker's heading can be accurately judged for shuffled walkers at above chance levels throughout the visual field, even at brief exposure durations and when attention cannot be pre-cued to a particular quadrant. These results give additional evidence for the existence of simple "life detector" that can be triggered automatically by local motion cues signaling animate activity.

An intriguing difference between the results of Experiments 3 and 4 was that, with randomized presentation of the stimuli, participants were slightly more accurate in the lower visual field, overall. This would make sense since research has suggested that a lower VF advantage for aspects of motion perception may be common across many species (Previc, 1990). Therefore, these results seem to lend tentative support for my hypothesis that local cues signaling animate activity would not be processed with equal efficiency throughout the visual field. One should exercise some caution in drawing this conclusion, however, since the effect of height (while significant) was quite small.

Another interesting aspect of the present results is that viewers also showed a slightly different pattern of accuracy depending on the direction the walker was facing. Specifically, viewers processed right-facing walkers more accurately than left-facing walkers in both the lower left and upper right quadrants, and showed a similar trend in the lower right quadrant. Only when stimuli were presented in the upper left quadrant was the heading of right- and left-facing walkers judged with equal accuracy. It is important to note that, as in Experiment 3, the results described above applied both to coherent and shuffled walkers; thus, no significant interactions involving type of display were observed.

What is the basis of the right-facing advantage we found? Certainly, it does not arise simply because it is easier to determine the general shape of right-facing walkers. Indeed, when participants were asked to judge the *coherency* of the display they had just seen, they showed either no facing advantage (shuffled displays) or a left-facing advantage (coherent displays) (see Figure 8). The accuracy of coherency judgments was higher for stimuli presented in the right than the left VF for shuffled (but not coherent) displays. Of greater interest, however, was the fact that when presented with shuffled displays participants often appeared unaware that the dots were not arranged in a coherent configuration. Thus, the overall accuracy of coherency judgments for shuffled displays was only 55% correct (compared to 80% correct for coherent displays); in other words, participants showed a bias to report that shuffled displays were coherent. Together, these results suggest that participants were not using a shape cue to make their heading judgments for either coherent or shuffled targets.

The present results are also not consistent with what one would expect if there were a bias favouring either centripetal or centrifugal motion. Instead, the present results suggest that viewers are biased to see right-facing walkers. As noted earlier in this document, this might reflect an attentional or scanning bias associated, perhaps, with participants' reading history. In an interesting study relating to this, Nachson, Argaman and Luria (1999) showed that Russian readers had an aesthetic preference for facial and body profiles turned to the right, while Arabic and Hebrew readers preferred those turned to the left (a pattern of preferences that mimicked their reading biases). An attentional or scanning bias associated with reading history might also explain the right-facing bias seen in representational momentum (Halpern & Kelly, 1993), and viewers' tendency to see right-facing walkers when presented with masked, chimeric displays that contain no net directional information (Thornton, Vuong & Bulthoff, 2003).

While it is possible that asymmetry in the mirror neuron system could provide an explanation for the right-facing advantage we observed, we think this is unlikely. If this hypothesis was correct, the representations must be quite unusual as the advantage was once again seen even with shuffled displays, in which the normal configuration was disrupted (cf. Experiment 3). It is also not obvious why, based on what we know about the mirror-neuron system, one should see a right-facing advantage everywhere except in the upper left quadrant.

Another problem with an explanation based on mirror neuron theory relates to how the mirror neuron system is usually conceptualized. Investigators who have described this system in monkeys (e.g., DiPellegrino et al., 1992) and humans (e.g., Iacoboni et al., 1999) have emphasized the fact that this system becomes activated by viewing the movements of a conspecific (or, at least, an animal with a similar body type). If this is correct, one might predict that the mirror neuron system would be specialized to process human activity. To examine this hypothesis I conducted one last experiment. In this experiment, I presented point-light displays of cats and pigeons, as well as humans, to see if the right-facing advantage in peripheral vision would apply selectively to human displays. In this last experiment, I used both coherent stimuli and completely scrambled stimuli that eliminate all global cues to shape. If the right-facing advantage does reflect a characteristic of the mirror-neuron system, then one would expect to find that the right-facing advantage would not be seen with cat and pigeon stimuli. However, if the right-facing advantage is seen in all three species, the mirror neuron theory should probably be rejected as a possible explanation.

Experiment 5

Method

Participants

Eighteen right-handed, undergraduate students were recruited to participate through the Introductory Psychology subject pool at the University of Manitoba. An equal number of males and females took part. The mean age of participants was 19.2 years ($SD = 1.4$ years). Participants in Experiment 5 met the same inclusion criteria, and were recruited in the same fashion, as those who took part in Experiment 1.

Stimuli

The stimuli were generated in the same way as those used in Experiment 3, with the exception that scrambled walkers were used instead of shuffled walkers to eliminate any residual structural cues to form, and three different species (human, cat, pigeon) were used. The stimuli were presented randomly in one of two locations located 8 degrees of visual angle to the left or right of the screen. The stimuli were presented for 170 ms and there were 6 left- and 6 right-facing walkers of each type presented on each side, for a total of 144 trials. The size of the displays was 30% smaller than the size of the targets used in the local task of Experiment 2.

Procedure

Before beginning the experimental trials, participants completed a series of familiarization trials similar to those used in Experiment 4. The procedure was the same as in Experiment 4, with the exception that the stimuli only appeared to the left or right side of the central fixation point (i.e., height in the field was not varied). The experiment was run twice; in one run, participants made direction-facing judgments; in the second run, they had to state

whether or not the display was coherent. The order of the runs was counterbalanced across participants.

Results

Accuracy data (% correct) for the direction-facing and coherency judgments were entered into separate 3 (Species: Human, Cat, Pigeon) x 2 (Type: Coherent vs. Scrambled) x 2 (Visual Field: Left vs. Right) x 2 (Direction-facing: Left vs. Right) ANOVAs, with repeated measures on all factors. The results for the two tasks are described separately, below.

Direction Discrimination

A significant main effect of Type was found, $F(1,17) = 119.5, p < .001, \eta_p^2 = .875$, with coherent walkers being processed more accurately than scrambled walkers, overall ($M = 87.5\%$ correct, $SD = 9.6$ vs. $M = 61.3\%$ correct, $SD = 9.6$, respectively). There was also a significant main effect of Species, $F(2,34) = 9.60, p = .001, \eta_p^2 = .36$. Follow-up tests (using a Bonferroni correction) showed that the facing-direction of pigeons was discerned more accurately than that of humans (Pigeons: $M = 79.2\%$ correct, $SD = 11.8$; Humans: $M = 70.1\%$ correct, $SD = 7.5$). The facing-direction of cats was discriminated at an intermediate level of accuracy ($M = 73.9\%$ correct, $SD = 8.9$). A significant Species x Type interaction was also observed, $F(2,34) = 5.14, p = .011, \eta_p^2 = .232$, but follow-up tests confirmed that (as predicted) there was a significant simple main effect of Type for each species, $F > 49.7, p < .001, \eta_p^2 > .617$ in all cases, and that above-chance level responding was seen with scrambled stimuli, regardless of species ($p < .001$ in all cases). There were no other significant interactions involving species.

The predicted Direction x Side interaction was also observed, $F(1,17) = 5.5, p = .032, \eta_p^2 = .244$ (see Figure 10). Tests of simple main effects showed no significant facing effect in the left VF, but a right-facing advantage in the right VF, $F(1,17) = 14.5, p = .001, \eta_p^2 = .460$. While
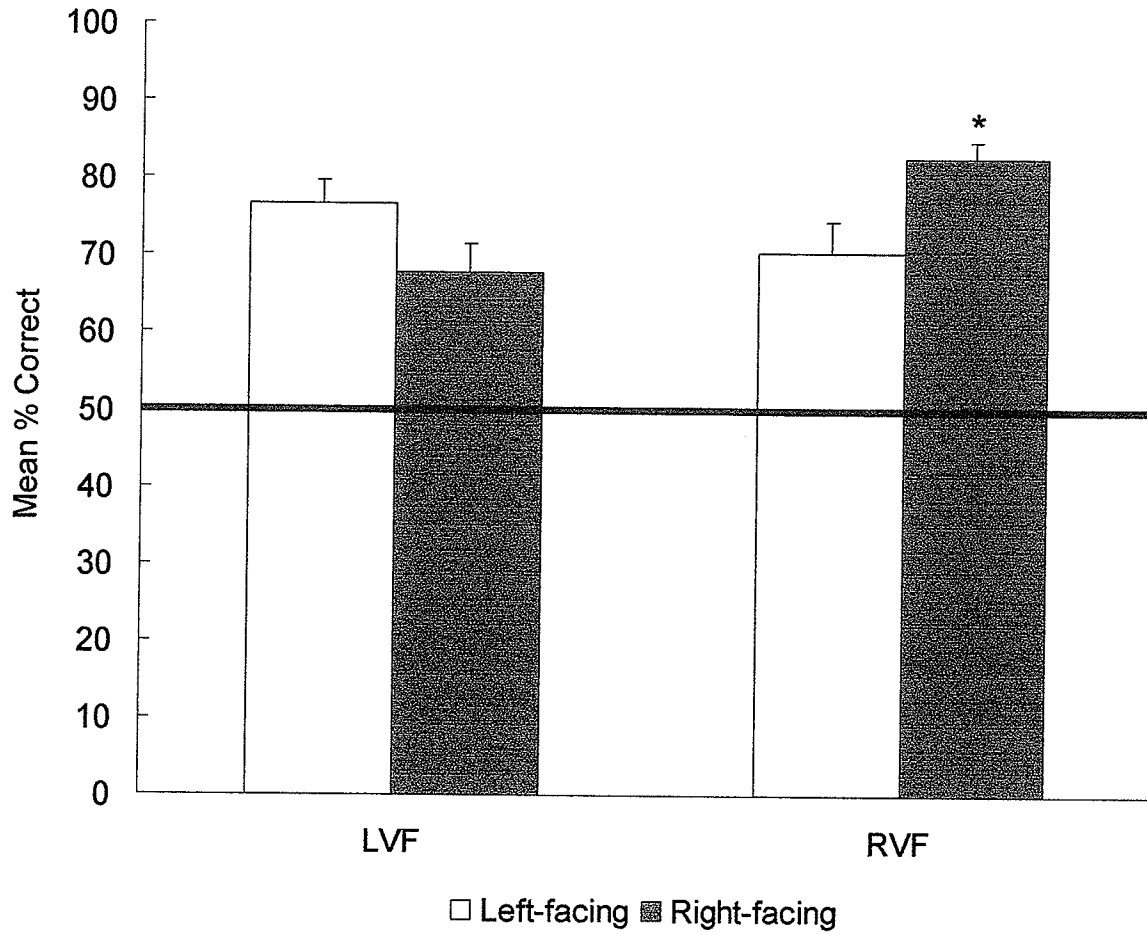
Figure 10. Mean accuracy of direction facing for left and right visual field in Experiment 5. Solid

line indicates chance level performance. * Right-facing advantage (p = .001).

there was also a significant Type x Direction x Side interaction, $F(1,17) = 5.8$, p = .028, $\eta_p^2 =$ .254, follow-up tests revealed that the pattern described above (i.e., right-facing advantage in the right VF) was seen with both coherent and scrambled stimuli (see Figure 11). Overall accuracy (collapsing across the direction the target was facing) was above chance ($p < .001$) in both visual fields for both coherent and scrambled stimuli.

Coherency Judgments

For the second task, in which participants made coherency judgments, the main effect of Direction was significant, $F(1,17) = 8.5$, p = .009, $\eta_p^2 = .334$. Participants were slightly better at judging the coherency of left-facing stimuli than right-facing stimuli overall ($M = 85.8\%$ correct, $SD = 9.5$ vs. $M = 83.2\%$ correct, $SD = 9.8$). The Direction x Visual Field interaction was not significant. Thus, unlike when they were making direction discriminations, participants were equally accurate at judging the coherency of left- and right-facing walkers in both visual fields (see Figure 12).

A significant Species x Type interaction was observed, $F(2,34) = 4.36, p < .021, \eta_p^2 = .204$ (see Figure 13). Tests of simple main effects showed that: (a) it was easier to judge the coherency of coherent than scrambled displays for human stimuli, but this was not the case for other species, $F(1,17) = 19.6, p < .001, \eta_p^2 = .536$; and (b) it was easier to judge the coherency of coherent human stimuli than coherent pigeon stimuli, $F(2,34) = 3.6, p = .038, \eta_p^2 = .175$.

Discussion

Once again, these results support my prediction that the life detector operates in the visual periphery, as direction discrimination judgments of both coherent and scrambled displays were made at above chance levels in both the left and right VFs. It is important to note that the facing-direction of scrambled displays could be discerned at above-chance levels regardless

Coherent Displays
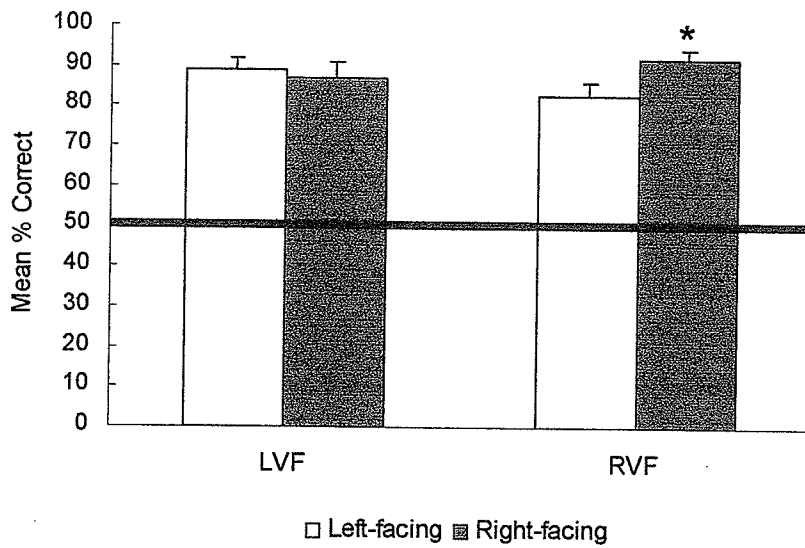
Scrambled Displays
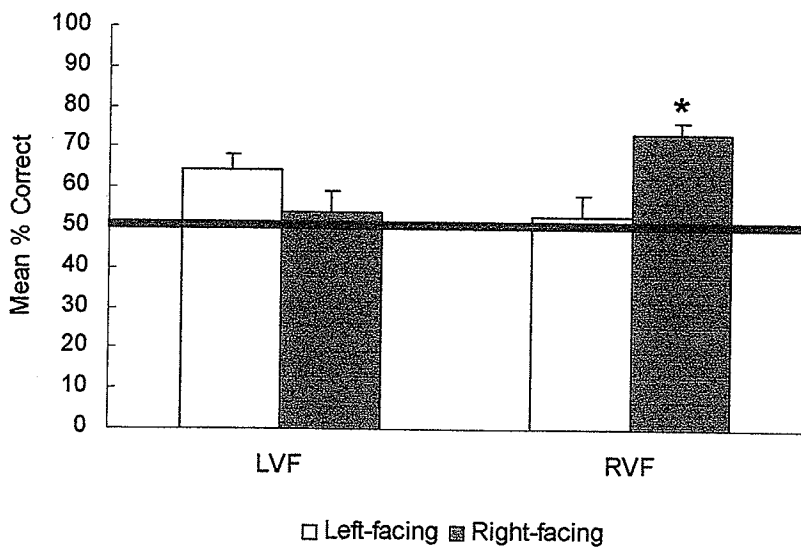
Figure 11. Mean accuracy of direction facing in Experiment 5 for left and right visual field for coherent stimuli and scrambled stimuli. Solid line indicates chance level performance. * Right-facing advantage ($p = .005$).
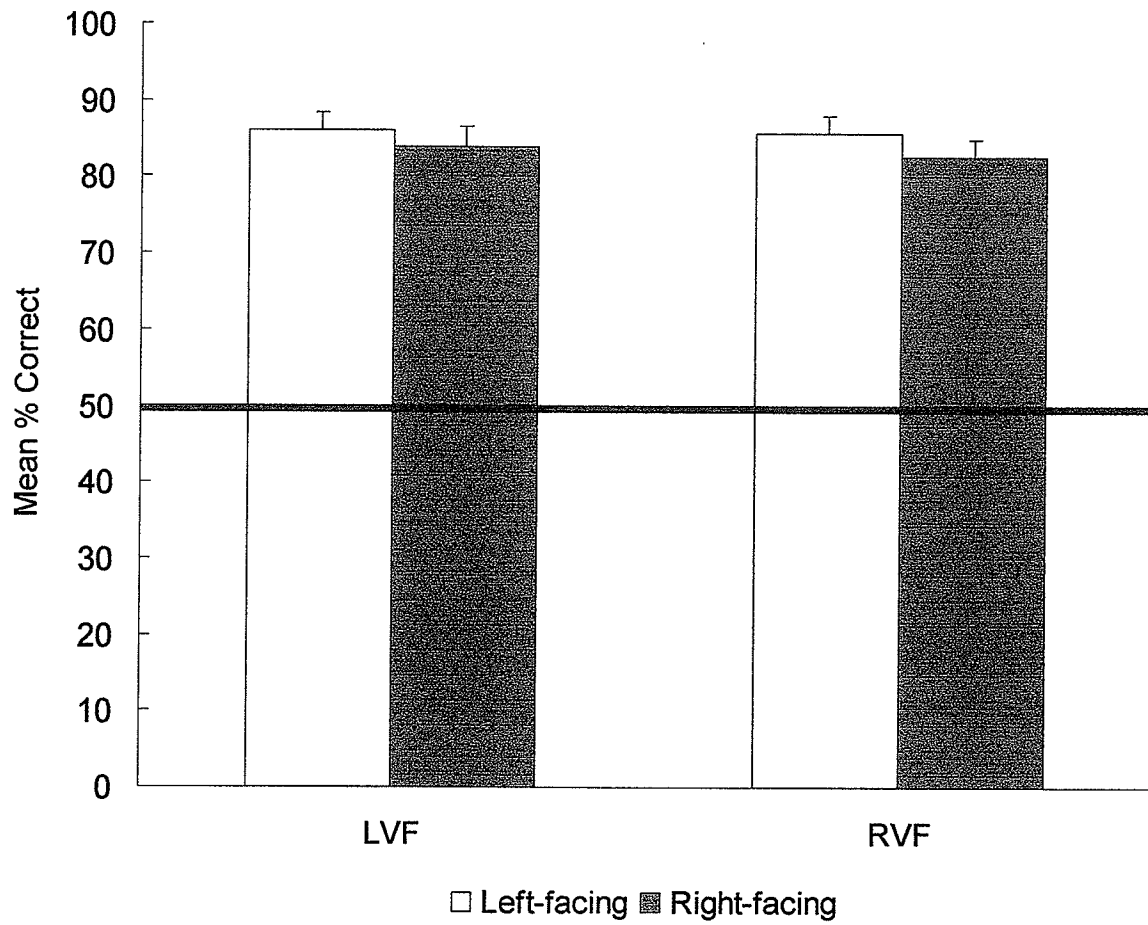
Figure 12. Mean accuracy of coherency judgments for left and right facing for both right and left

visual field in Experiment 5. Solid line indicates chance level performance.

Figure 13. Mean accuracy of coherency judgments for coherent and scrambled stimuli in human,

cat and pigeon in Experiment 5. Solid line indicates chance level performance. * Human

coherent > human scrambled ($p < .001$); ** Human coherent > pigeon coherent ($p < .05$).

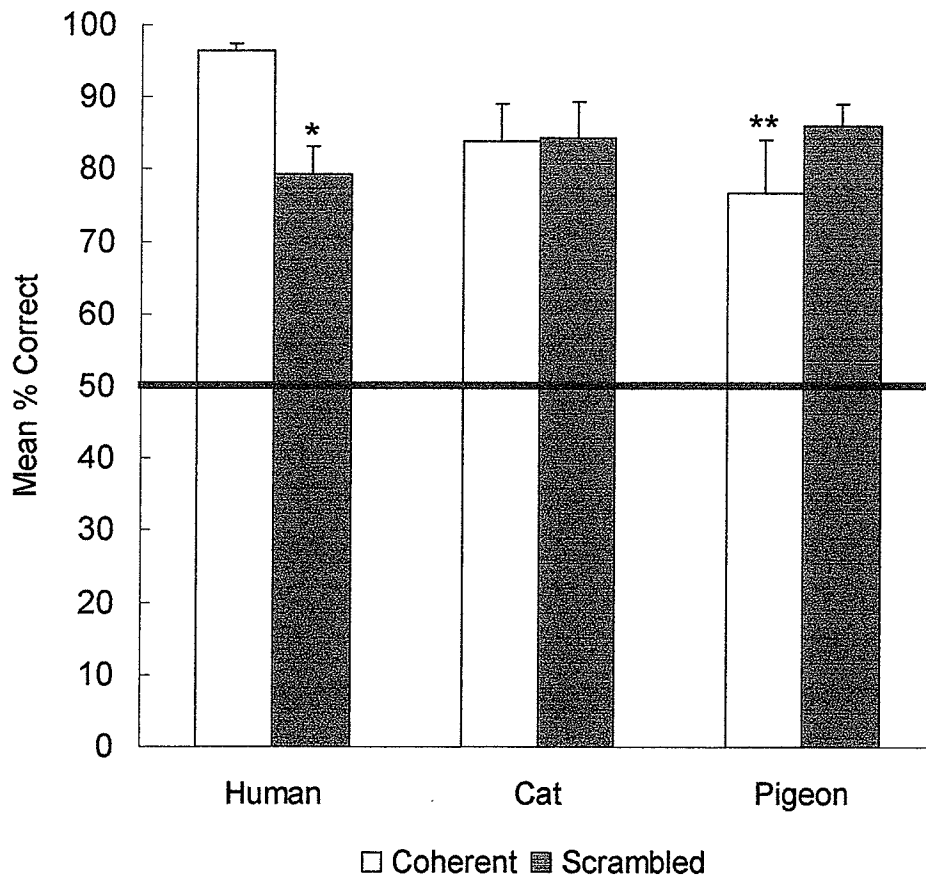of the species depicted (i.e., above-chance performance was not limited to human displays). This supports Troje and Chang's (2007) argument that the life detector picks up movement of not only conspecifics, but predators and prey as well.

Along with this, a right-facing advantage in the right VF was found – with both coherent and scrambled displays, and regardless of species. This finding replicates and extends the findings in Experiments 3 and 4. Again, this advantage does not appear to arise because it is easier to judge the shape of a right-facing walker. Instead, it seems that viewers have a tendency to see right-facing walkers, a result that is consistent with the bias seen by Thornton, Vuong and Bulthoff (2003) with masked, chimeric displays containing no net directional information. It is unclear exactly what the cause of the right-facing advantage is, but as discussed in Experiment 4 it could reflect a larger memory bias for objects implied to be moving right compared to left (Halpern, & Kelly, 1993), which may arise due to an attentional or scanning bias associated with reading habits. More research needs to be done to fully understand what causes the right-facing advantage. However, it is clear that the classically defined mirror neuron/simulation theory does not provide an adequate account, as the right-facing advantage is seen even with displays of scrambled non-human species.

One last interesting result is that participants are actually better at making coherency (shape) judgments with coherent human displays than with coherent pigeon displays. These results are similar to those seen in the global task in Experiment 2. The main effect of Type seen with human displays in Experiment 4 was also replicated here (i.e., it was easier for participants to judge the coherency of coherent human displays than of scrambled human displays), but in the present experiment we were able to show that this effect is not seen with non-human displays.

Together, these results suggest that shape processing is most accurate when viewers are presented with coherent human displays.

General Discussion

The series of five experiments described above have provided support for the existence of a 'life detection' mechanism. Specifically, results have shown that, even with brief exposure durations, local motion cues in biological motion displays are sufficient to allow an individual to determine the direction a walker is facing in both central and peripheral vision. Thus, above-chance direction discrimination was achieved even with displays in which local motion cues were arranged in an unnatural configuration (shuffled), or were reassigned to completely random positions across trials (scrambled displays). In the latter case, only local motion cues could have triggered the detector.

Further it is important to note that participants were able to determine the direction that upright shuffled walkers were facing in all four quadrants. This effect was seen not only when participants could pre-cue their attention to a particular quadrant (Experiment 3), but also when stimuli were presented randomly in the visual periphery (Experiment 4). This is important because it would make sense that people should be able to detect animate activity throughout the visual periphery. In particular, if a conspecific, prey or predator appears it would be advantageous to be able to detect and orient your attention to that area in space. Therefore, this would suggest that the human visual system has some basic sensory filter that is tuned to local motion signaling animate motion.

Another interesting discovery was a directional advantage for right-facing walkers in both central and peripheral vision. Specifically, a right-facing advantage was seen in Experiment 2 (in both local and global tasks) and in all peripheral tasks. Although no such advantage was

found in Experiment 1, an important difference between the two central tasks was that in Experiment 2 longer exposure durations and masking dots were introduced. The addition of the masking dots could have created a harder task and as such required the participant to utilize more attentional and visual search resources. Peripheral presentation would also increase these demands for covert shifts of attention. This explanation gains support from the fact that research examining visual search patterns has shown that participants tend to begin to search in the upper left VF and proceed from left to right (Chedru, Leblanc & Lhermitte, 1973) (reflecting, perhaps, a bias associated with their reading history). With randomized, peripheral presentation (Experiment 4), participants showed no facing advantage for direction discrimination in the upper left quadrant but a right-facing advantage in the rest of the quadrants

The right-facing advantage is particularly interesting since it has not been properly explored in the biological motion literature. Based on a series of experiments, it appears that this advantage is not due to perceptual biases for particular optic flow patterns, or to better analysis of the shape of right-facing walkers (as results from both coherency tasks do not show a similar right-facing advantage). It also seems unlikely that the mirror neuron hypothesis can explain the pattern observed since the directional advantage was observed in all three species and for scrambled stimuli. Therefore, a likely candidate to explain this finding is that there is an attentional or scanning bias for right-facing stimuli. As noted above, this bias may be related to participants' reading history. It would also be interesting to examine this phenomenon for English and Hebrew readers. Since Hebrew readers process textual material right-to-left, it would be particularly interesting to see if these readers show a left-facing advantage rather than a right-facing advantage. This directional advantage could further be examined in infants or young children who have no reading history. Troje (in press) suggests that the life detection mechanism

should develop early in an infant's life. As such, examining infants' ability to detect animate motion would allow us to investigate the influence of experience and reading habits on the development of a directional advantage in processing scrambled biological motion displays. Both the studies proposed above would be help to tease out what mechanism(s) are involved in producing the facing advantage observed and whether this advantage has to do with the influence of reading habits on attentional strategies.

Overall, these studies have provided insight into the operation of the life detection mechanism and structure-from-motion system in both central and peripheral vision. In the local task in Experiment 2 and in the direction discrimination tasks in Experiments 3-5, results have shown that the local motion cues present in various terrestrial animals' locomotion are sufficient to trigger the life detection mechanism. These results lend support to Troje and Chang's (2007) hypothesis that structure-from-motion and life detection mechanisms operate through independent mechanisms.

Another important point that should be addressed is that similar results were found in the global task in Experiment 2 and the coherency tasks in Experiments 4-5. The results showed that global (shape) processing of upright biological motion stimuli is carried out more efficiently for displays depicting humans than for those depicting other species. This once again supports Troje and Chang's (2007) hypothesis that structure-from-motion should be processed more easily for human species due to our extensive knowledge of human locomotion. Overall, the results are consistent with the view that life detection and structure-from-motion involve distinct systems.

Another future direction would be to investigate the inversion effect in the visual periphery. This is of interest since it has not yet been shown whether an inversion effect is seen in peripheral vision for scrambled stimuli. Based on the above review, it would be hypothesized

that participants would not be able to determine the walker's direction for inverted orientation but would be able to do for upright orientation, regardless of stimulus configuration (coherent vs. scrambled). This would confirm the importance of having the local motion appear in its natural orientation when one attempts to discern heading.

The exciting findings described in this thesis provide the groundwork for future studies that will explore the how these important visual skills develop in healthy infants and children, and in populations of children at risk for problems with cortical visual function. Troje (in press) suggests that 'life detection' is expected to be shown to develop very early compared to structure-from-motion because viewers need to learn through experience how to determine the particular shape of the display. Given their different developmental profiles, we might expect to find that mechanisms supporting life detection and structure-from-motion processing would be differentially sensitive to the effects of early brain injury. Research in this area could potentially lead to developing better diagnostic and screening tools that could be used in different clinical populations. Problems with biological motion perception have been described in numerous pediatric populations. Pavlova, Sokolov, Birbaumer and Krageloh-Mann (2006), for example, have shown that children born very prematurely are impaired at processing biological motion displays that require global analyses (i.e., that would activate a structure-from-motion system). Similarly, individuals with autism have been shown to have difficulty perceiving human motion portrayed by point-light walkers that were coherent or temporally scrambled (Blake, Turner, Smoski, Pozdol & Stone, 2003). If we could develop tests that measure an individual's sensitivity to isolated local and global cues in biological motion displays they may be useful as diagnostic and screening tools. This could lead to early detection of problems within these individuals, which could lead to earlier and more successful interventions or treatments.

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Appendix

Demographic Questionnaire

Participant Code: _____

1. What is your gender?

   ☐ Male   ☐ Female

2. What is your age? _____

3. What hand do you use to write with? _____

4. Were you born at term (within 2 weeks of your expected due date)? _____

5. Have you ever lost consciousness, experienced seizures, or had other known neurological problems? _____

6. Have you been identified as having a learning disability? _____