Searching for a "super foot" with evolutionary-guided adaptive psychophysics

Dorita H. F. Chang[1] & Nikolaus F. Troje[1,2]

[1]Centre for Neuroscience Studies and [2]Department of Psychology, Queen's University, Canada

BIO MOTION LAB
www.biomotionlab.ca

Queen's UNIVERSITY

INTRODUCTION

- The facing direction of a walker can be retrieved from displays that are devoid of structural cues and contain solely local motion signals. This ability:
  - relies on the local motion of the feet[1]
  - is orientation-dependent[1], a characteristic carried by vertical acceleration in the foot's motion[2]

What is the adequate local biological motion for the human visual system?

- we searched for a "super foot", defined as one that carries salient directional information and a pronounced inversion effect

METHODS

Participants

- Two groups of participants were recruited online and participated in one of two rounds of searches via a web-based interface.
- Run 1 = 185 observers (81 males); 25 000 trials
  Run 2 = 167 observers (81 males); 27 000 trials

The search space

- Eight-dimensional space derived from a second-order Fourier series defining the motion of a single dot in a 2D plane[3].

$$F_x(t) = a_{x,1}\sin(\omega t + \phi_{x,1}) + a_{x,2}\sin(2\omega t + \phi_{x,2})$$
$$F_y(t) = a_{y,1}\sin(\omega t + \phi_{y,1}) + a_{y,2}\sin(2\omega t + \phi_{y,2})$$

Stimuli

- Each "foot" was shown in saggital view (facing left or right).
- A stimulus consisted of 5 copies of a "foot" displaced randomly in space with random onset times, and shown upright/inverted.

Genetic algorithm

- A multi-objective GA based on NSGA-II[4] was used to drive the psychophysical searches:

Initialization
Initial generation of 50 feet.

Evaluation
Generation evaluated for "fitness" based on:
- performances for upright stimuli
- inversion effect

Generation sorted based on Pareto ranking and crowd-ing distance (distance to others) in parameter space.

Selection and Evolution
Parents selected and used to generate subsequent generation via:
- crossover
- mutation

repeat until termination

Termination
"Super foot" revealed!

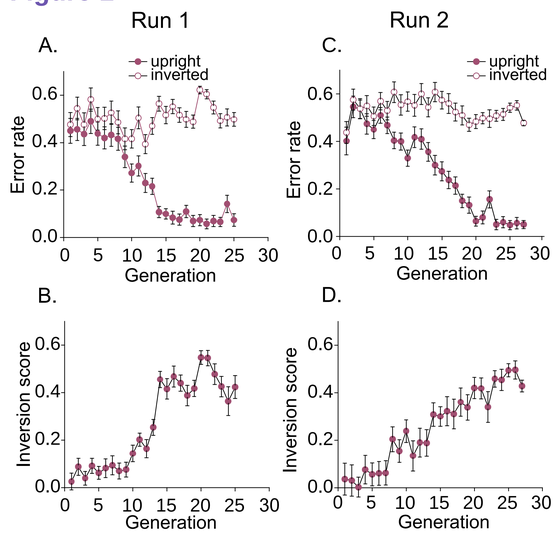
Task

LEFT << ? >> RIGHT

- Data saved in 50 trial blocks.
- One generation = 1 000 trials (50 "feet" x 2 directions x 2 orientations x 5 repetitions).

RESULTS

Figure 1



- For both Runs, error rates for the upright stimuli decreased, and the inversion effect increased across generations (Fig. 1).
- PCA applied to data of both Runs revealed that the first two pcs account for 93% of the variance.
- The Runs began at neighbouring points in space and evolved in the same general direction (Fig. 2).
- Loadings revealed that pc1 was largely contributed to by vertical amplitudes. Frequency was the main source of variation along pc2.

Figure 2

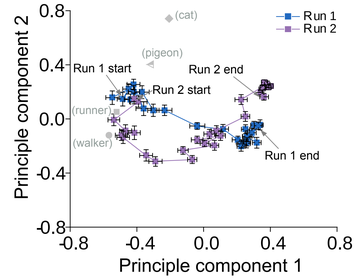
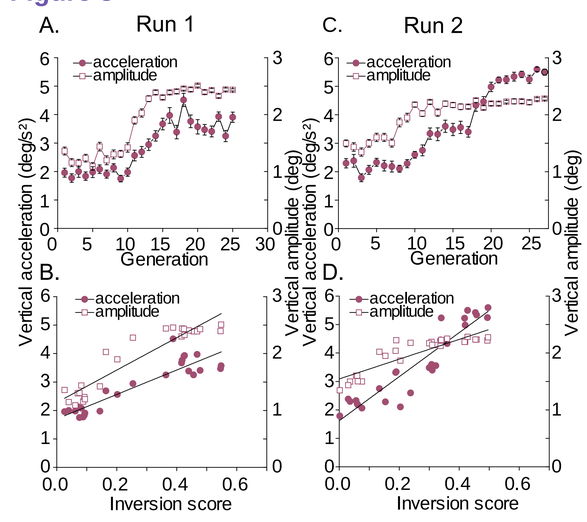


Figure 3



Acceleration?

- For each foot, we computed the difference between max and min vertical acceleration.
- For both runs, vertical acceleration generally increased across generations (Fig. 3A, C) and was correlated with the inversion effect (r = 0.91 and 0.93 for Runs 1 and 2, respectively) (Fig. 3B, D).

DISCUSSION

- The GA was effective at optimizing behavioural discrimination rates. These changes were accompanied by the evolution of stimuli towards containing greater vertical amplitude and acceleration.
- The data emphasize the importance of acceleration for the perception of local biological motion and support the notion of a mechanism that is tuned to a gravity-defined invariant[2].

The "super foot"?

Run 2, generation 27, top foot

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References

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Contact: 5dc16@queensu.ca