“Collective intelligence may emerge from interactions between individuals.”

Emergent Sensing of Complex Environments by Mobile Animal Groups

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Presented by Ryan O'Loughlin

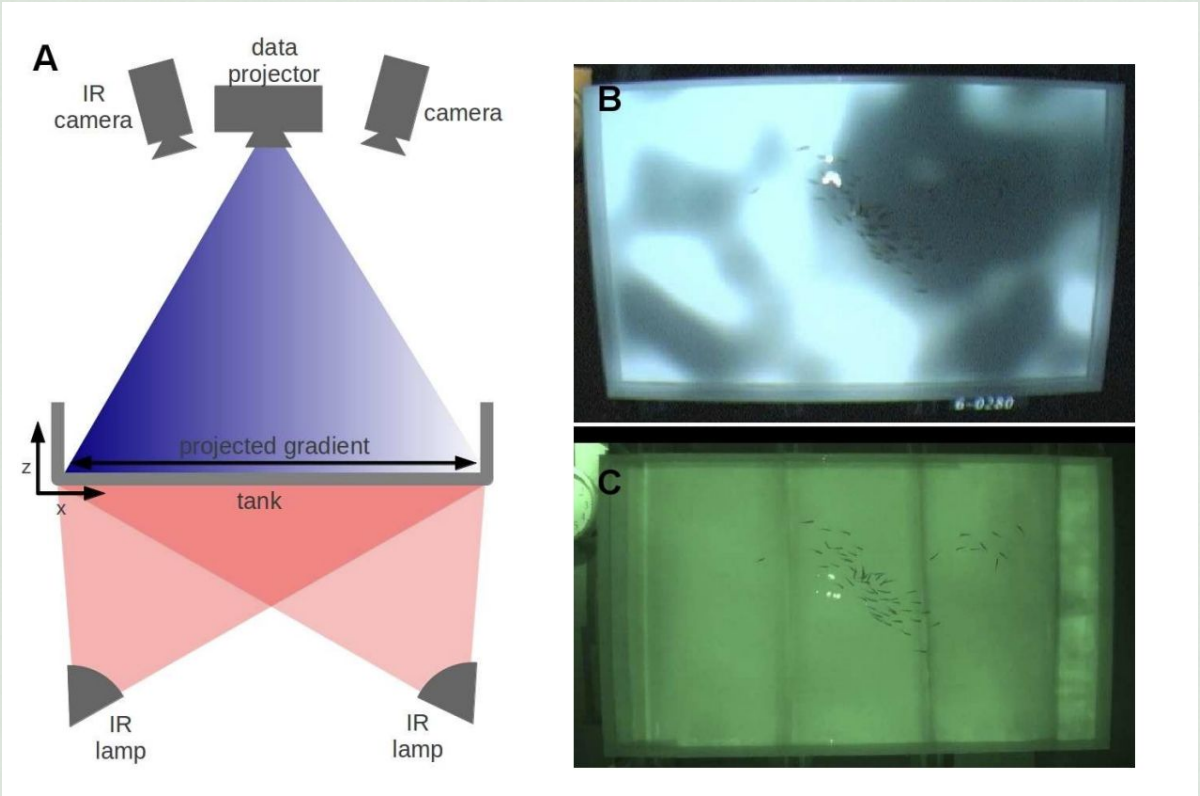
Notemigonus Crysoleucas

- Also known as a “Golden Shiner”
- A small fish (~5cm length)
- Prefers shaded waters


Hello darkness my old friend...

Light as an Environmental Cue

- Because Shiners prefer to avoid light, it thus becomes an environmental cue
- Lighting patches for a fish tank can easily be controlled from above
- Can stand in for any environmental cue
- *Critique: Light does not well represent non-continuous environmental cues*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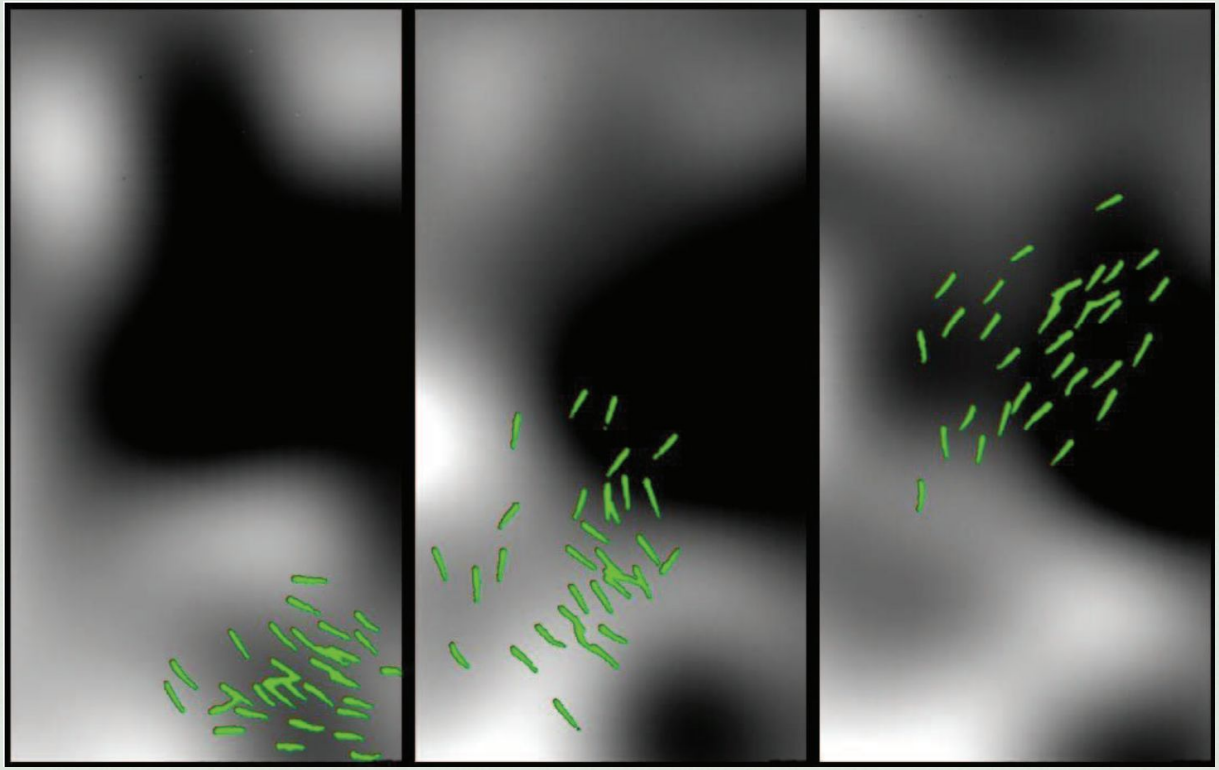


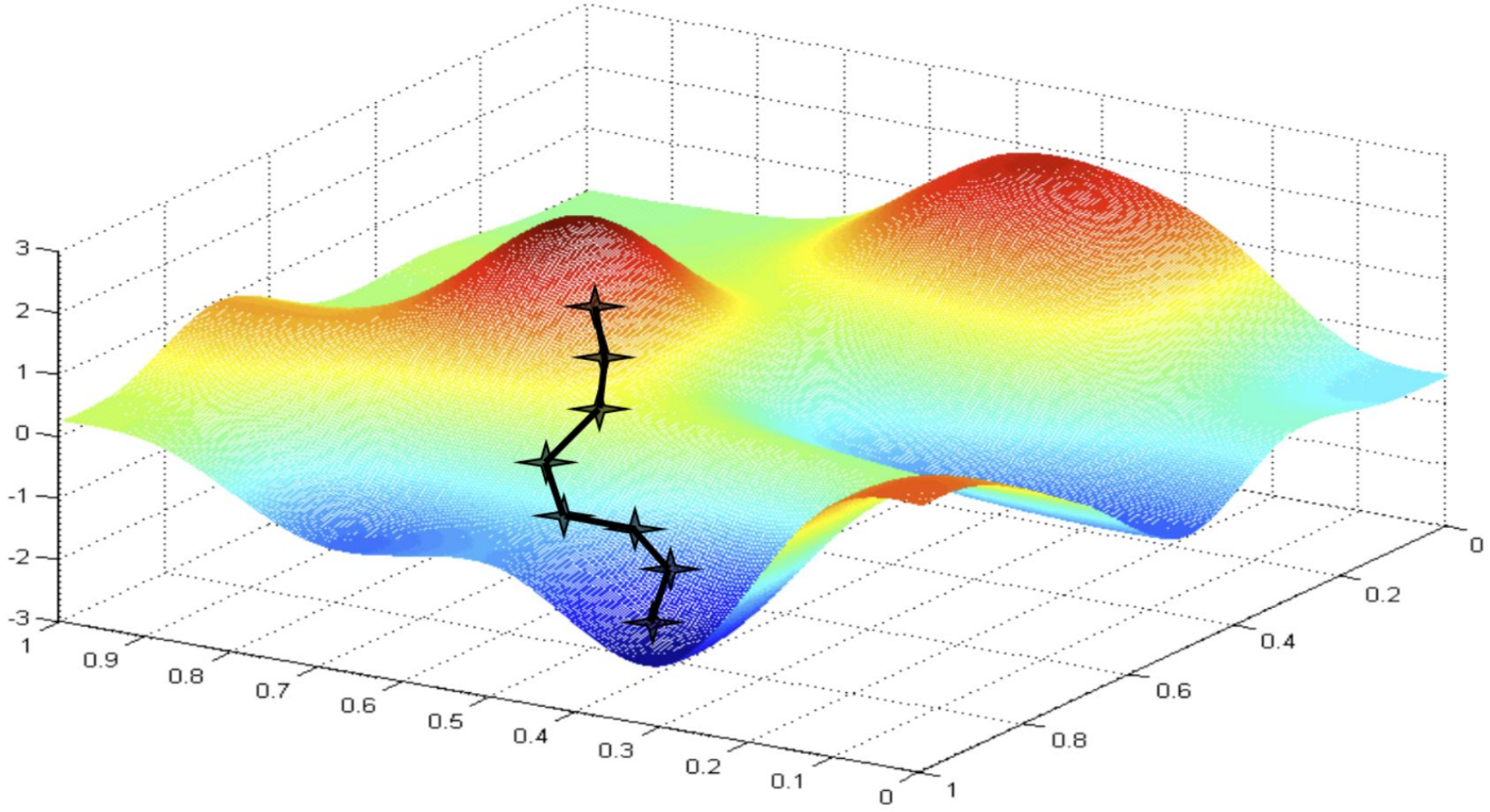
Sensing the Gradient

- To what degree is a collection of golden shiners sensitive to the environmental changes *beyond their own individual ability?*

- More fish, should be able to better assess the lighting-gradient of their environment

Experimental Features

- Ψ : *Performance metric* defined by the average darkness level per fish, averaged across all fish, averaged over time
- S_i : *Social vector* defined by direction of *conspecifics*
- G_i : Environmental vector defined by the direction of steepest ascent (or descent) into darkness, with a magnitude proportional to rate of increase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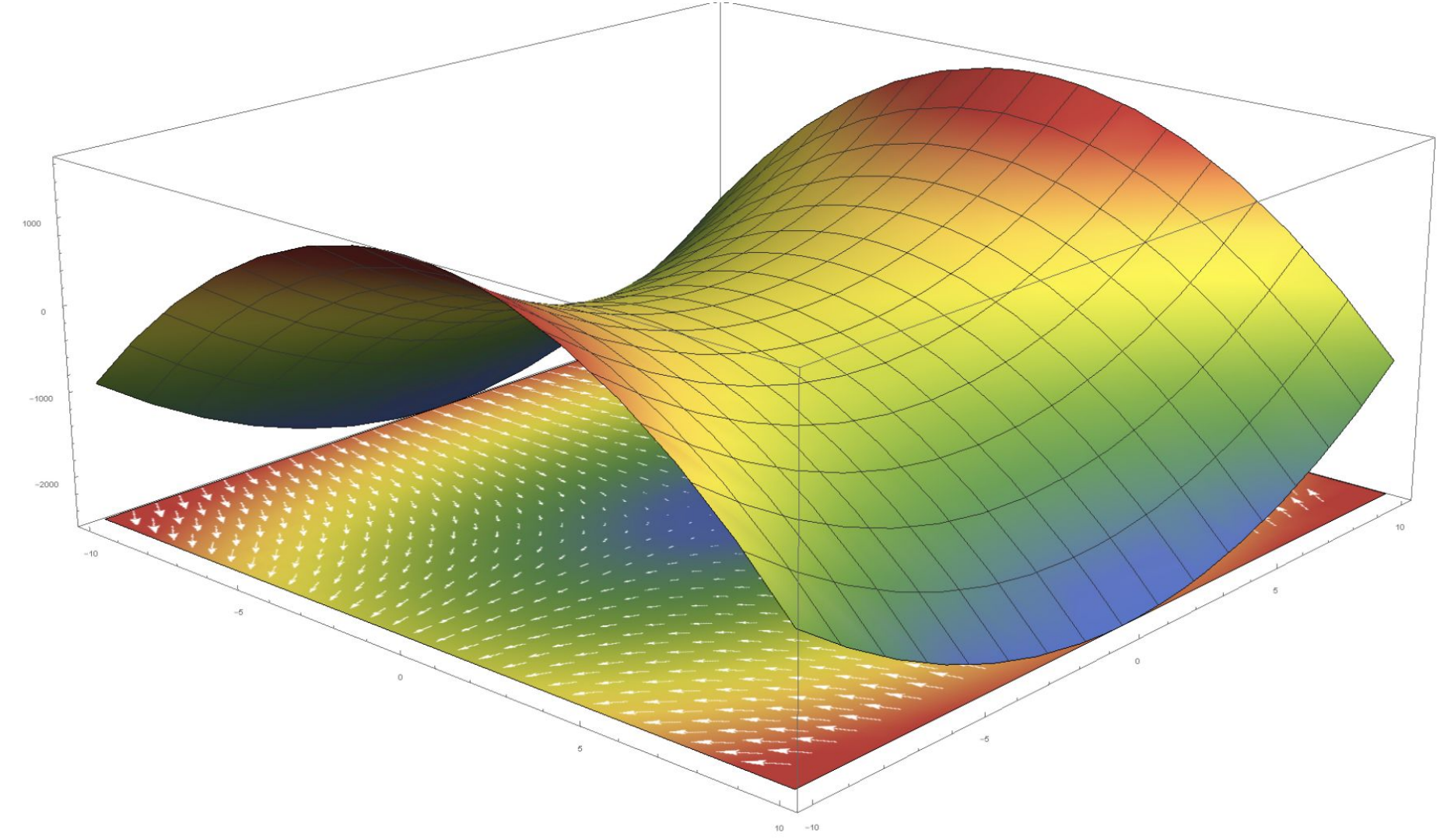
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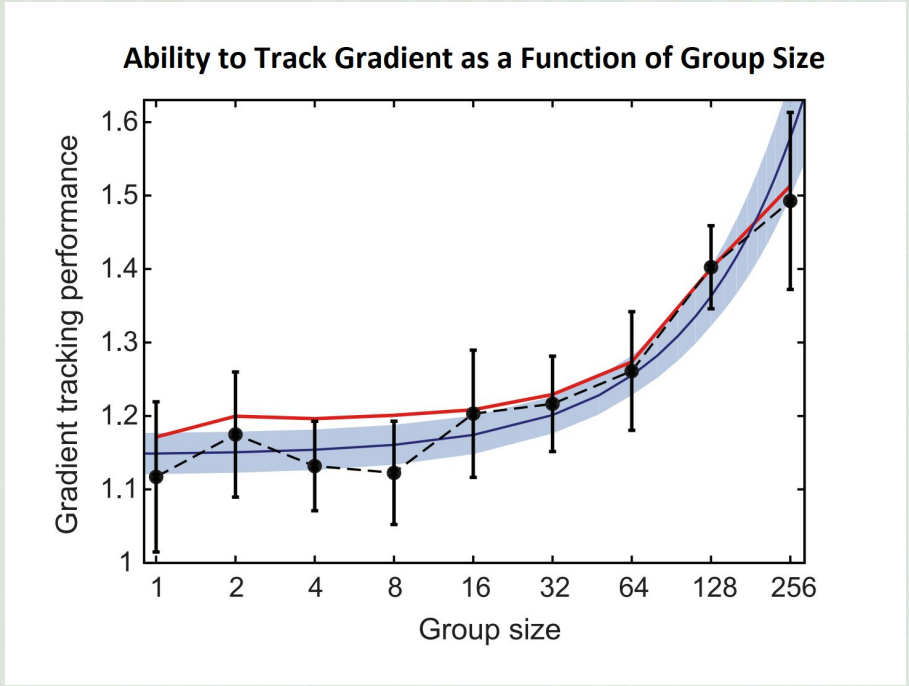
Group Performance

- *The performance metric is positively related to school size*

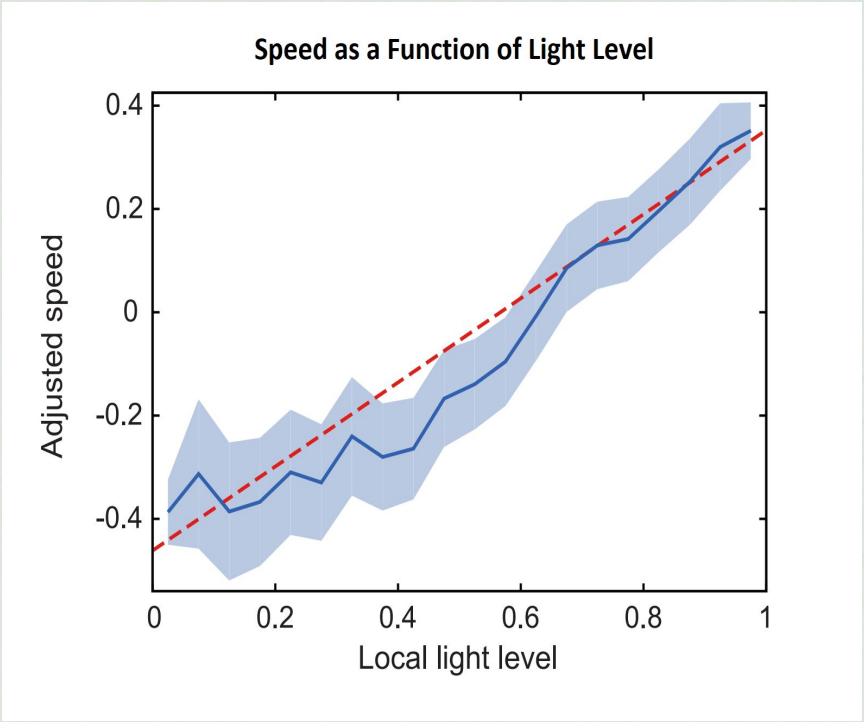
Performance, Ψ, as a function of group size. The data points show the mean Ψ over experimental trials, and the error bars show twice the standard error. The solid blue line is the statistical model's fit to the data, and the shaded region is its 95% confidence interval.



Speed and Light

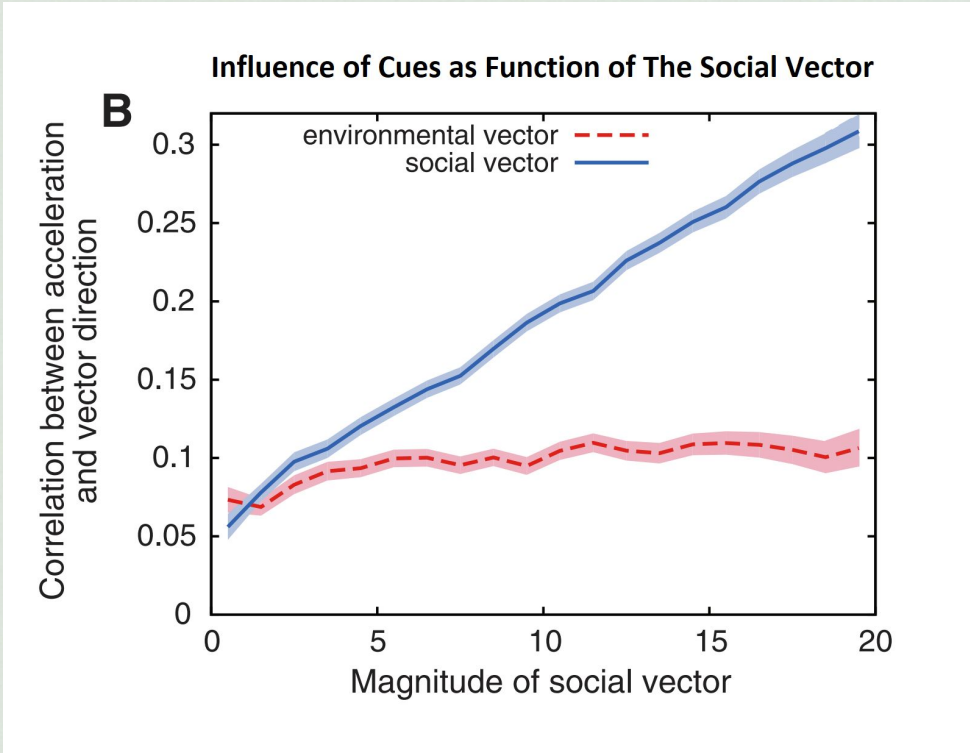
- Fish travel more slowly in dark regions (and quicker in bright)

Average speed as a function of local light level (solid blue curve; 0 is darker, 1 is brighter). Speeds are control-adjusted to account for spatial effects induced by tank walls. The dashed red line is the median slope of the speed-light relation when calculated at single points in time across the group, averaged over group sizes 16 to 128 (slopes at instantaneous time could not be calculated reliably for group sizes of eight and below).



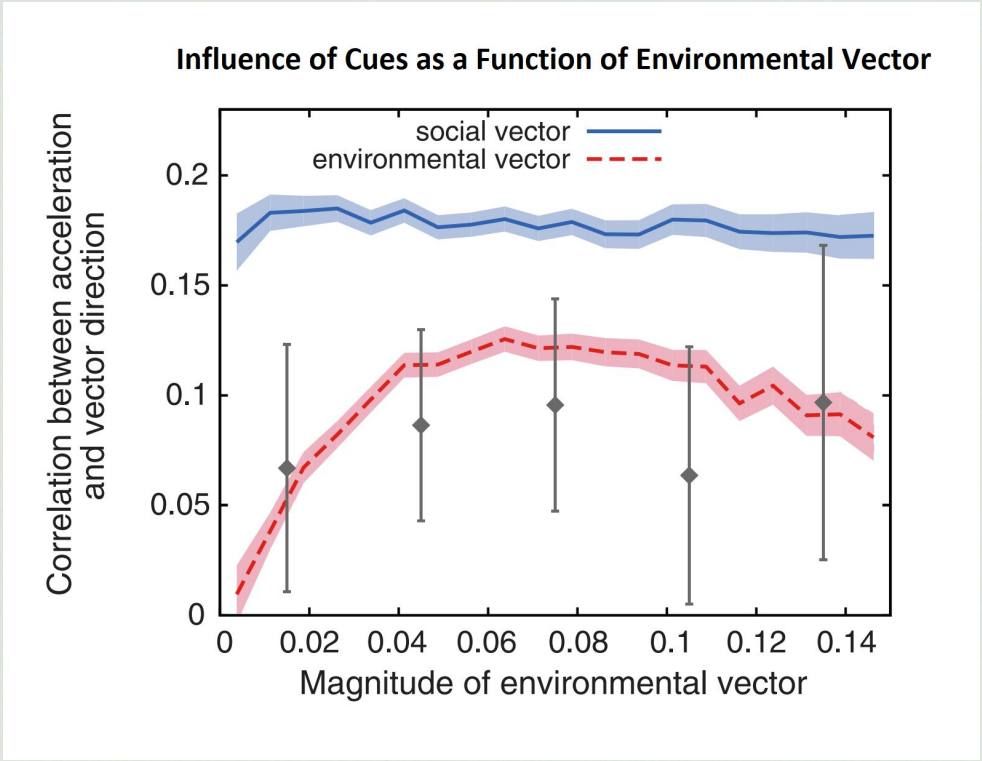
Influence of Social Vector on Group Acceleration

- The greater the magnitude of the social vector, the higher correlation that is found between acceleration and social vector direction



Influence of Gradient Vector on Group Acceleration

- The social vector is *more influential* on fish acceleration than the environmental cue
- The environmental vector still influences group motion up to a certain point



Concluding Remarks

- In terms of accomplishing their goals, golden shiners perform better in groups
- Moreover, this increase in efficacy comes from an *emergent sense*
- This sense is impossible for single fish, but increasingly accessible to groups
- Thus a group of Golden Shiners is ***more than the sum of its parts***


Thank you
for listening!
Bloop bloop

Questions

- Are there any questions directly concerning the presented paper?
- Can anyone think of examples of emergent senses for humans?
- Do you think you are yourself more sensitive to environmental or social cues?
- What emergent senses would you think possible for humans in the future?

Image Credits

- Fish: *https://en.wikipedia.org/wiki/Golden_shiner*
- Gradient Descent: *https://medium.com/swlh/machine-learning-fundamentals-2-gradient-descent-algorithm-6c8f5204bd9b*
- Gradient Vector Field: *https://malarney.github.io/vector-calc-visualization/*
- Plots: *Directly from paper*


What do you mean, *“How’s the water?”*

Equations for people who ask hard questions (Probably Leander)

$$\psi = \left\langle \langle 1 - L \rangle_{fish} \right\rangle_t \qquad \Psi = \psi / \psi_{null}$$

$$\mathbf{S}_i = \sum_{j \in r_s, j \neq i} \frac{\mathbf{c}_j - \mathbf{c}_i}{|\mathbf{c}_j - \mathbf{c}_i|} \qquad \mathbf{G}_i = -\nabla L\Big|_{\mathbf{c}_i} = -\hat{\mathbf{x}} \frac{\partial L}{\partial x}\Big|_{\mathbf{c}_i} - \hat{\mathbf{y}} \frac{\partial L}{\partial y}\Big|_{\mathbf{c}_i}$$

$$\text{individual response to social vector} = \left\langle \frac{\mathbf{S}_i}{|\mathbf{S}_i|} \cdot \frac{\mathbf{a}_i}{|\mathbf{a}_i|} \right\rangle_t$$

$$\text{individual response to environmental vector} = \left\langle \frac{\mathbf{G}_i}{|\mathbf{G}_i|} \cdot \frac{\mathbf{a}_i}{|\mathbf{a}_i|} \right\rangle_t$$