Motions of Parts and Wholes: An Exogenous Reference-Frame Model of Non-Retinotopic Processing

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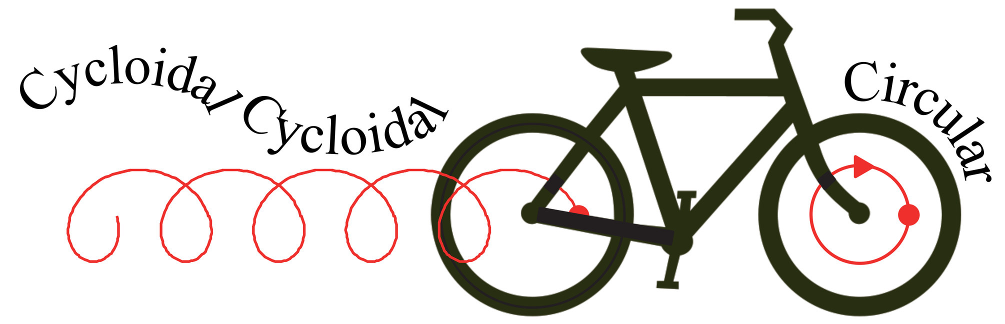
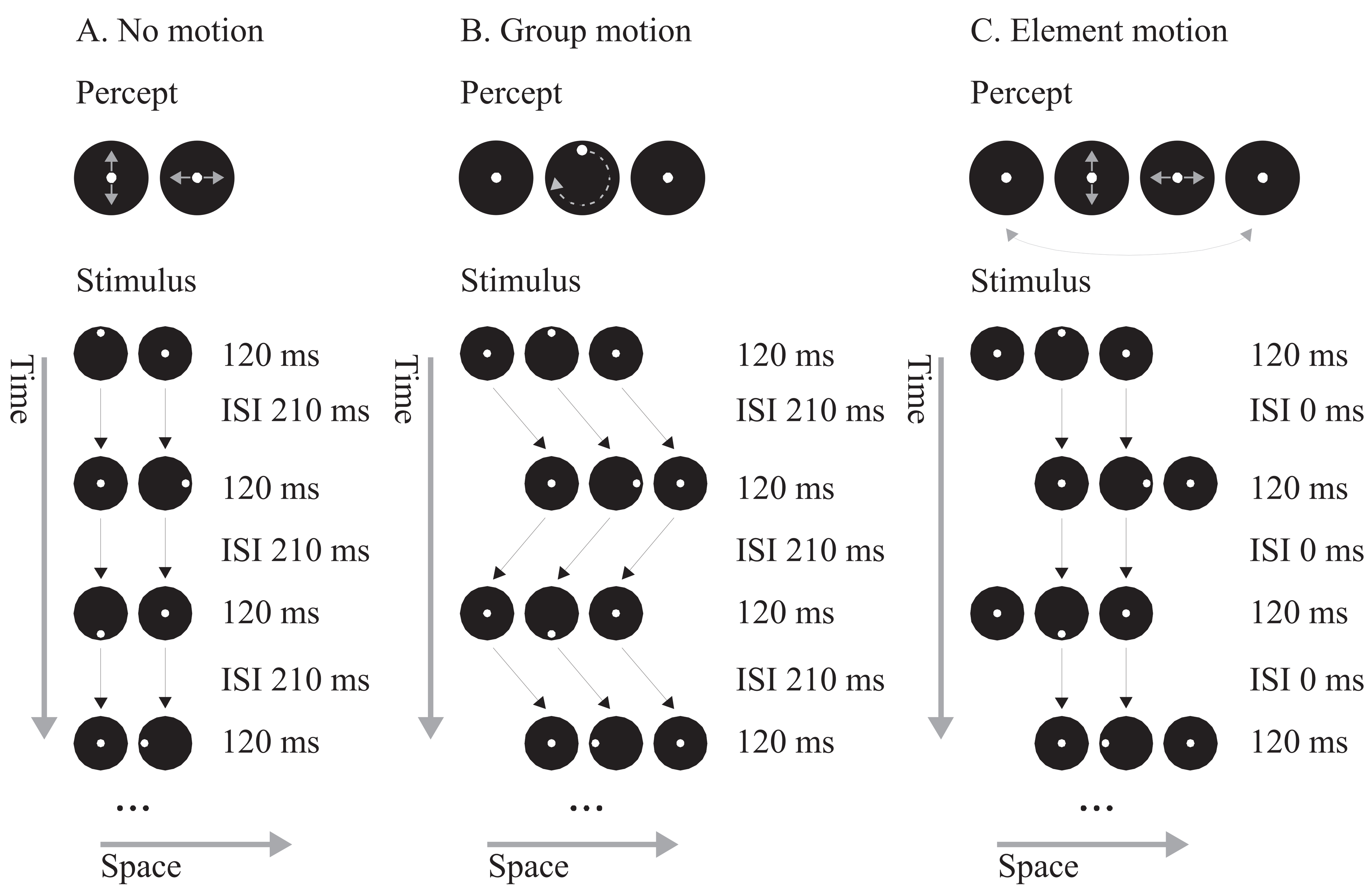
Introduction:

A reflector on a moving bicycle wheel appears to follow a circular path even though its physical trajectory is actually cycloidal. Hence, the brain interprets motion not in a purely retinotopic manner, but relative to the non-retinotopic reference frame established by the bicycle.



Ternus-Pikler Display:

To study non-retinotopic motion perception we used the Ternus-Pikler display, which directly pits retinotopic against non-retinotopic processing.



A. With an ISI of 210 ms, the two black disks flicker. The white dots move up-down and left-right, respectively. **B.** The three black disks appear to move back and forth as a group. A white dot on the central disk appears to rotate because of the surrounding non-retinotopic reference frame. Importantly, the two central disks are the same as in panel A. **C.** With an ISI of 0 ms, the outer-most disk appears to jump from one side of the display to the other, while the central two disks appear stationary. The dot motions are again perceived to move up-down and left-right.

Model:

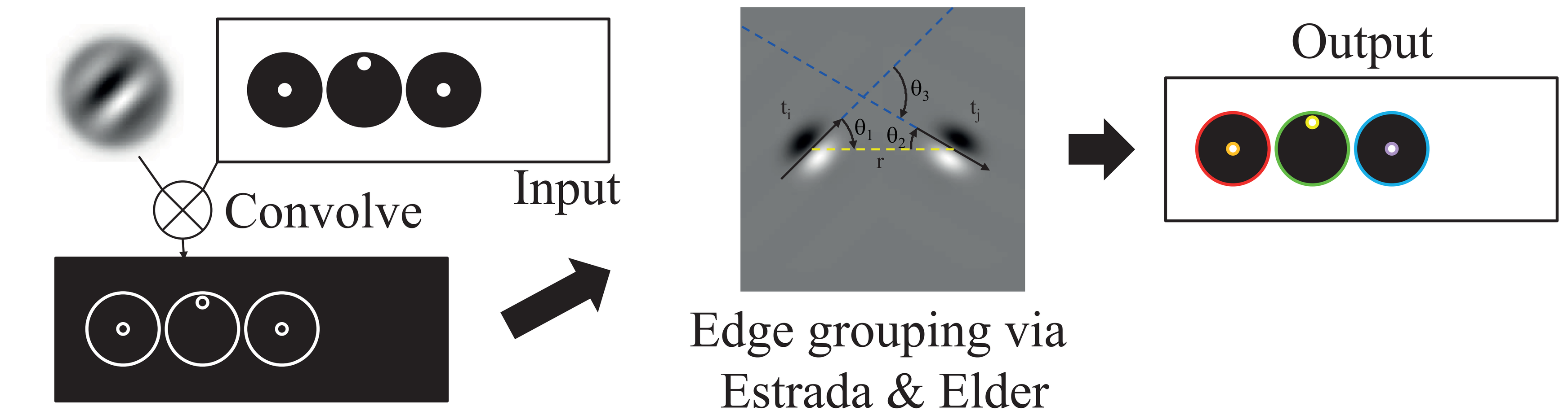
- How can non-retinotopic motion perception be modeled?
- Pooresmaeili, Cicchini, Morrone and Burr, (2012) proposed a one-stage model based on spatio-temporal filtering. However, their model has methodological problems and lacks generalizability (Clarke, Repnow, Öğmen and Herzog, 2013).
- Here, we propose a two-stage model that first establishes a dynamic, motion-based reference frame and then estimates motion signals within this reference frame.
- This approach conforms to the subjective notion that part-motions are perceived relative to their objects, and explains a broad range of illusions.

Overview:

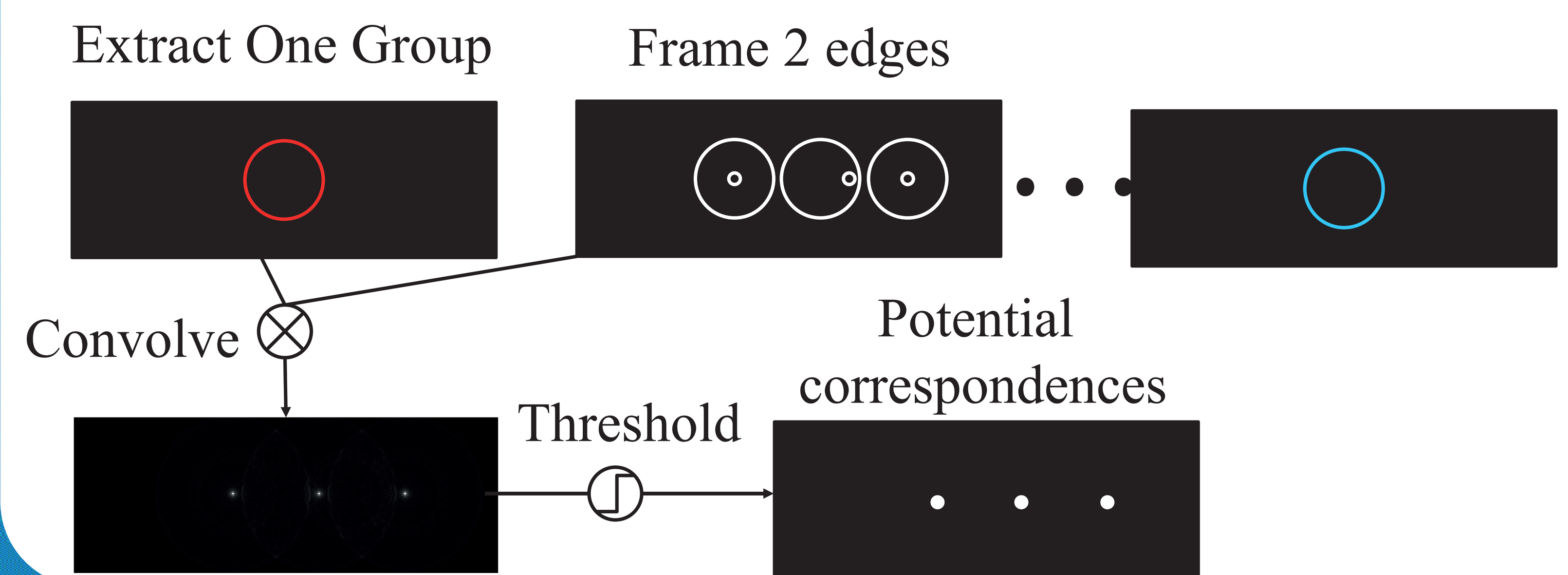
- In the first step we combined three standard techniques in a novel way – a) edge filtering & grouping leading to object segmentation, b) identifying temporal correspondence matches, and c) determining unique correspondences.
- In the second step, object motions are re-referenced, similarly to how the reflector's motion is re-referenced to the bicycle's reference frame.

1. A) Edge filtering and grouping:

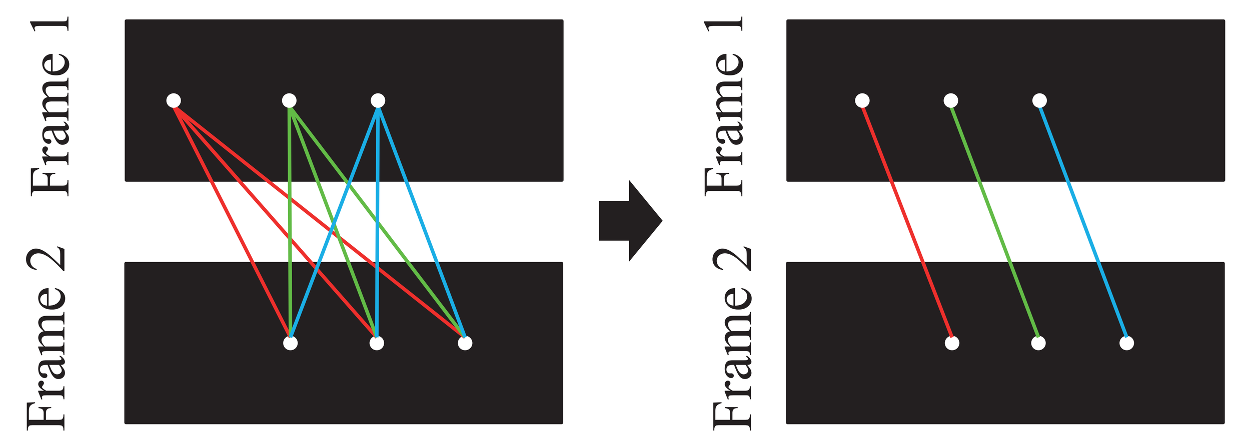
- First, edges are extracted by standard procedures, i.e., the image is convolved with an array of Gabor filters and the results are thresholded.
- Next, the edges are grouped based on proximity and good continuation.



1. B) Identifying temporal correspondence matches:



1. C) Determine unique matches using Dawson (1991):



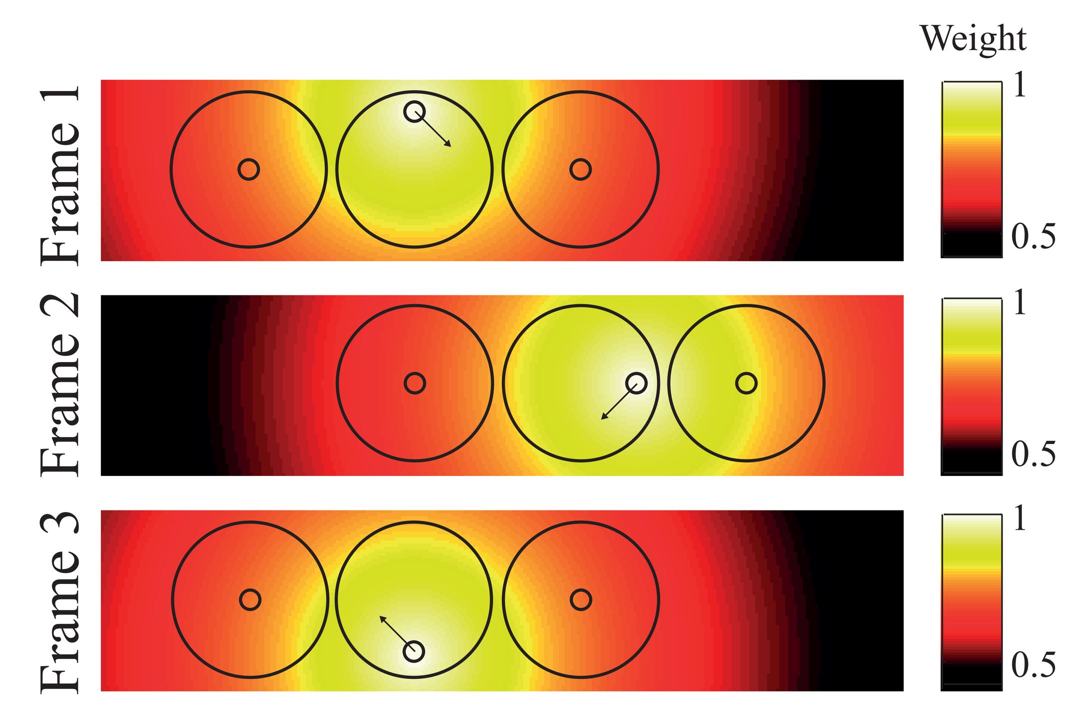
$$\omega_{NN}(ISI) = \mathrm{erf}((\mathrm{ISI}-41.47)) \cdot 0.12) \cdot 0.5+0.5$$

$$C = \delta \cdot (\omega_{NN} \cdot NN + \omega_{RV} \cdot RV + \omega_{EI} \cdot EI)$$

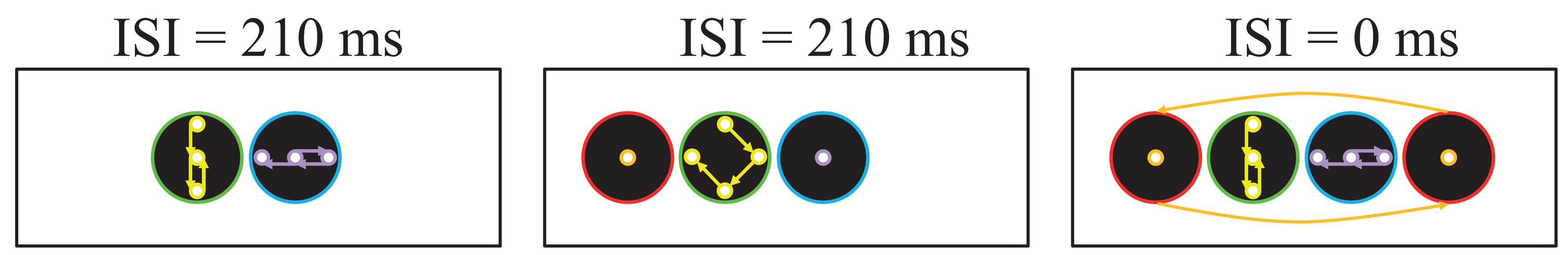
Connectivity matrix; Nearest Neighbour; Relative Velocity; Element Integrity

2. Take weighted motion vector averages around each object:

- Next we use the motion vectors created by solving the temporal correspondence problem.
- A weighting field around each motion vector is used to calculate a local-average reference.
- This average is then subtracted from the individual motion vectors to yield the final non-retinotopic percept.



Output:



The model does a good job at reproducing the human percepts. Left and Right: the model produces up-down and left-right dot percepts (yellow and purple arrows respectively). Center: the model produces a circular dot motion percept (yellow arrows).

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