A Model for Non-Retinotopic Processing

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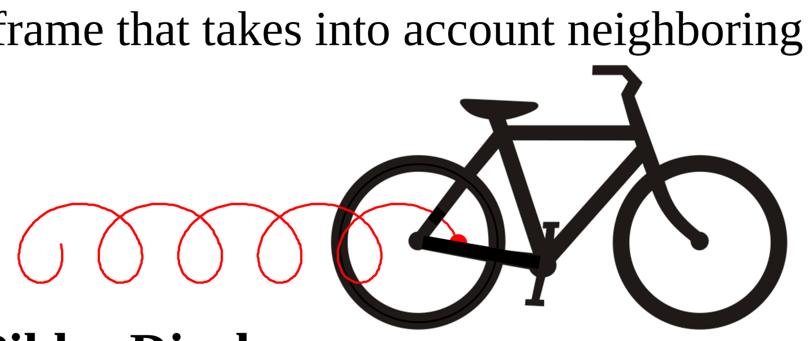
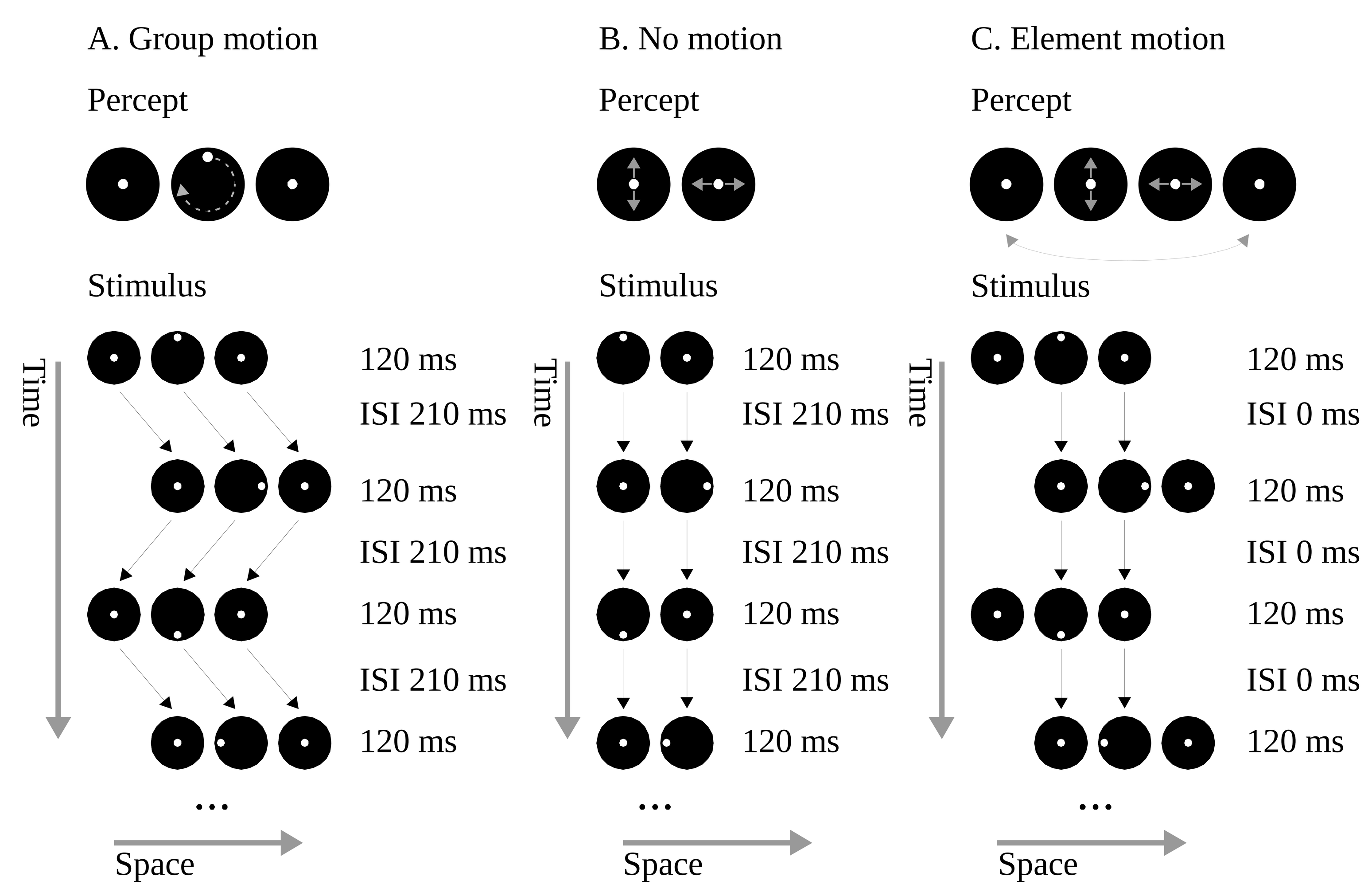
Introduction:

A reflector on a moving bicycle wheel appears to follow a circular path even though its physical trajectory is actually cycloidal. The cycloidal trajectory is perceived only when the bicycle is invisible. Hence, the brain interprets motion not in a purely retinotopic manner but according to a non-retinotopic reference frame that takes into account neighboring motion patterns.



Ternus-Pikler Display:

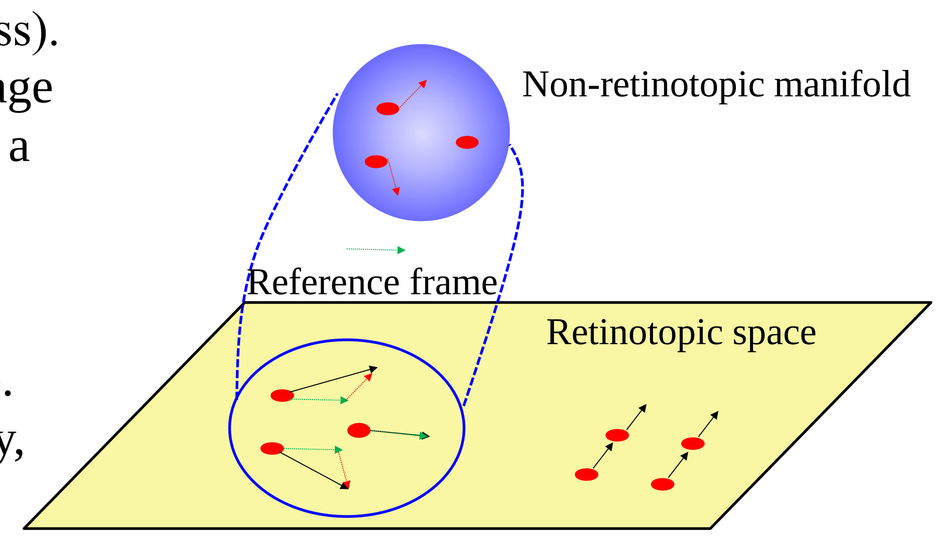
- How can non-retinotopic motion perception be studied experimentally?
- The Ternus-Pikler display directly pits retinotopic and non-retinotopic processes against each other and thus provides a useful probe for testing retinotopic versus non-retinotopic processing.



A. With an ISI of 210 ms, the three black disks appear to move back and forth as a group. The central disk's white dot appears to rotate. **B**. Removing the outer disks yields the percept of two stationary disks whose dots move up-down and left-right. **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.

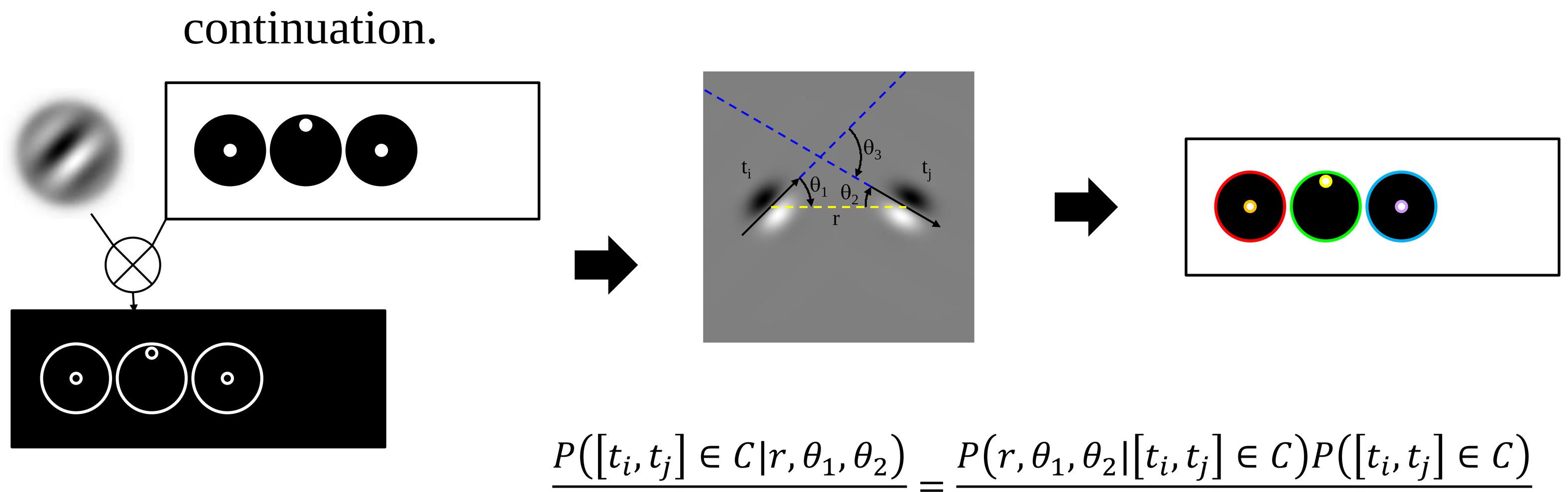
Model:

- 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, the model has some methodological problems and lacks generalizability (Clarke, Repnow, Öğmen and Herzog, in press).
- Here, we propose a two-stage model that first establishes a motion-based dynamic reference frame and then estimates motion signals within this reference frame.
- In the Ternus-Pikler display, non-retinotopic motion percepts are explained by establishing a reference frame based on the motions of the disks and then determining the dot motions within this reference frame.



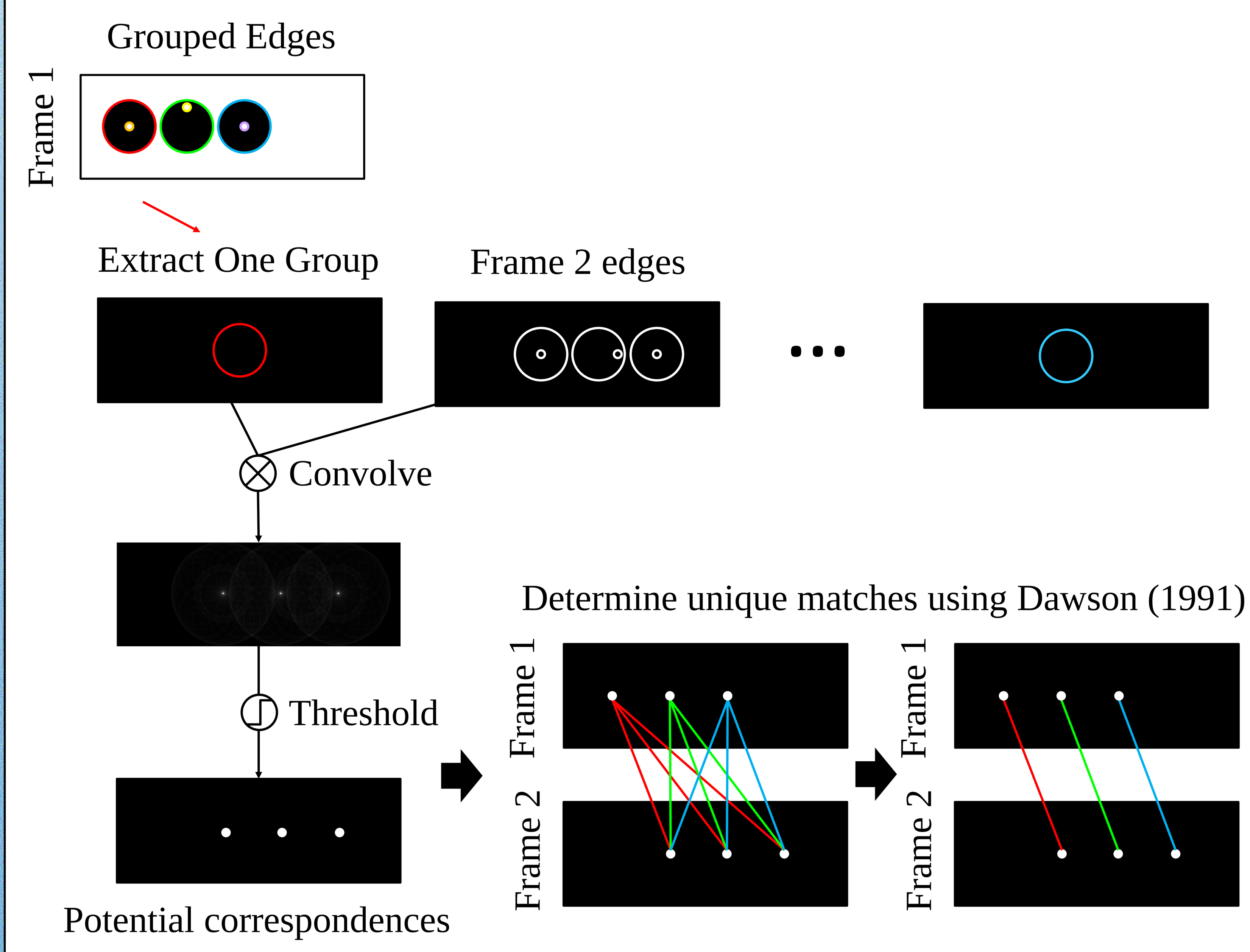
Edge filtering and grouping:

- First, edges are extracted by standard procedures.
- Next, the edges are grouped based on proximity and good continuation.



$$\frac{P([t_i,t_j]\in C\,|\,r,\theta_1,\theta_2)}{P([t_i,t_j]\in \tilde{C}\,|\,r,\theta_1,\theta_2)} = \frac{P(r,\theta_1,\theta_2\,|\,[t_i,t_j]\in C)\,P([t_i,t_j]\in C)}{P(r,\theta_1,\theta_2\,|\,[t_i,t_j]\in \tilde{C})\,P([t_i,t_j]\in \tilde{C})}$$

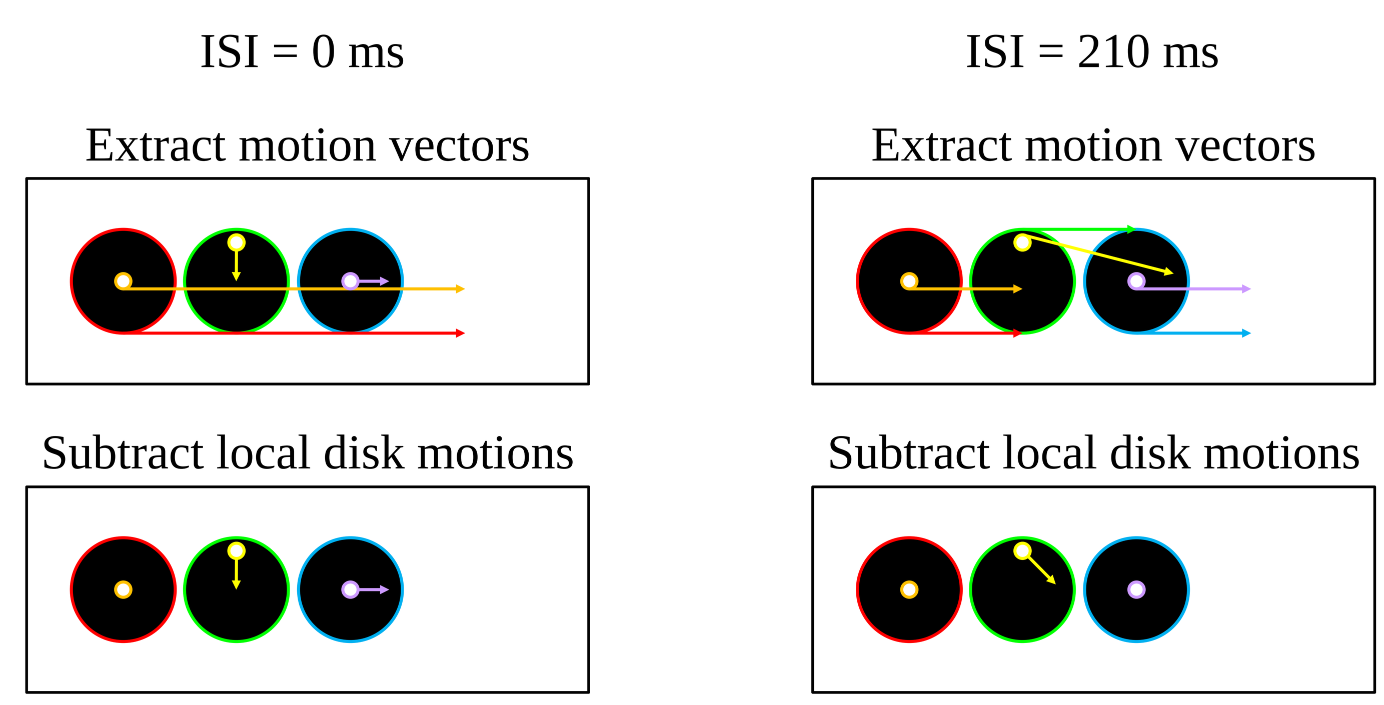
Next, the temporal correspondence problem is solved:



$C = \delta \cdot (\omega_{NN} \cdot NN + \omega_{RV} \cdot RV + \omega_{EI} \cdot EI)$ $\omega_{NN}(ISI) =$ erf((ISI−41.47)) · 0.12) · 0.5+0.5

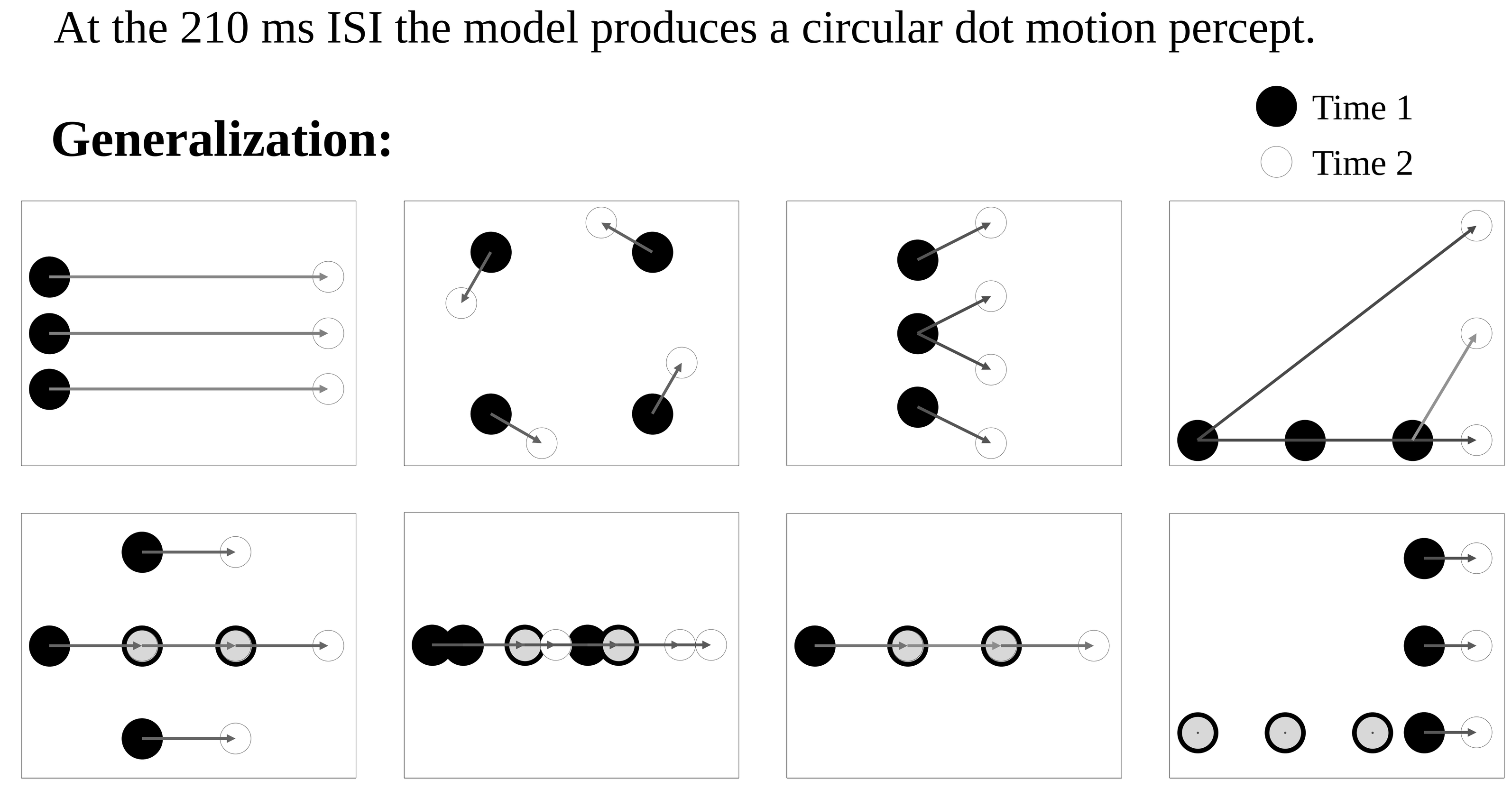
Connectivity matrix | Relative Velocity | Nearest Neighbour | Element Integrity

Results:



The model does a good job at reproducing the human percepts. At the 0 ms ISI, the model produces up-down and left-right dot percepts (see arrows). At the 210 ms ISI the model produces a circular dot motion percept.

Generalization:



The model also nicely handles other conditions established by Ternus (1926). Black disks mark time 1 positions, while white transparent disks mark time 2 positions. Arrows denote correspondence matches. All correspondence matches are consistent with human percepts, except for the top-left sub-plot.

References:

- Clarke, A. M., Repnow, M., Öğmen, H. & Herzog, M. H. (in press). Does Spatio-Temporal Filtering Account for Non-Retinotopic Motion Perception? Comment on Pooresmaeili, Cicchini, Morrone, and Burr (2012). *Journal of Vision*.
- Pooresmaeili, A., Cicchini, G. M., Morrone, M. C., & Burr, D. (2012). "Non-retinotopic processing" in ternus motion displays modeled by spatiotemporal filters. *Journal of Vision*, 12(1), 1-15.

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