Path analysis and feature extraction

Avgoustinos Vouros[1]

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Supervised by Prof Eleni Vasilaki

The University Of Sheffield.

The story so far...

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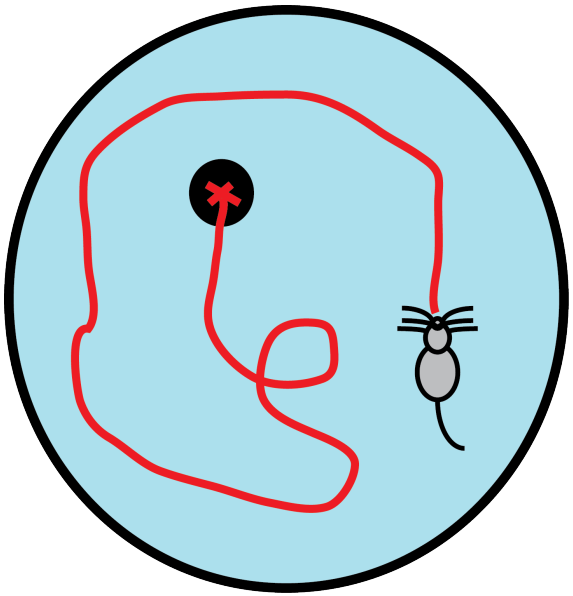

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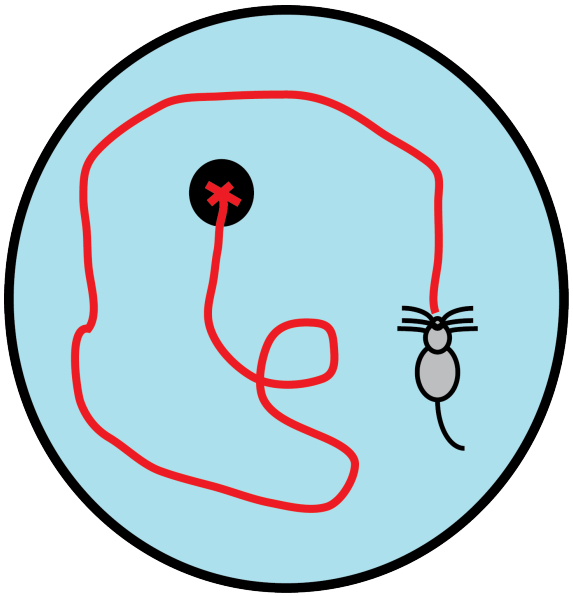

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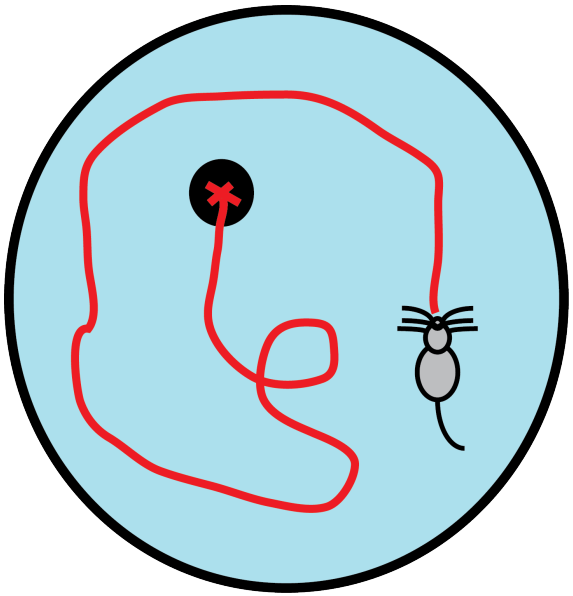

Thigmotaxis

Self Orienting

Scanning

Focused Search

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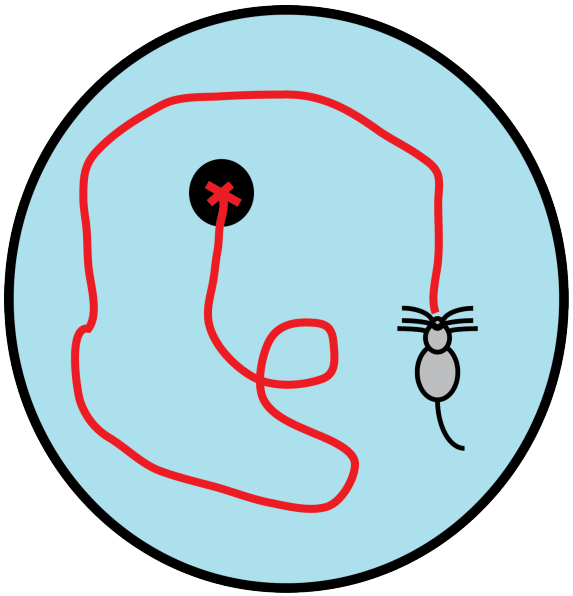
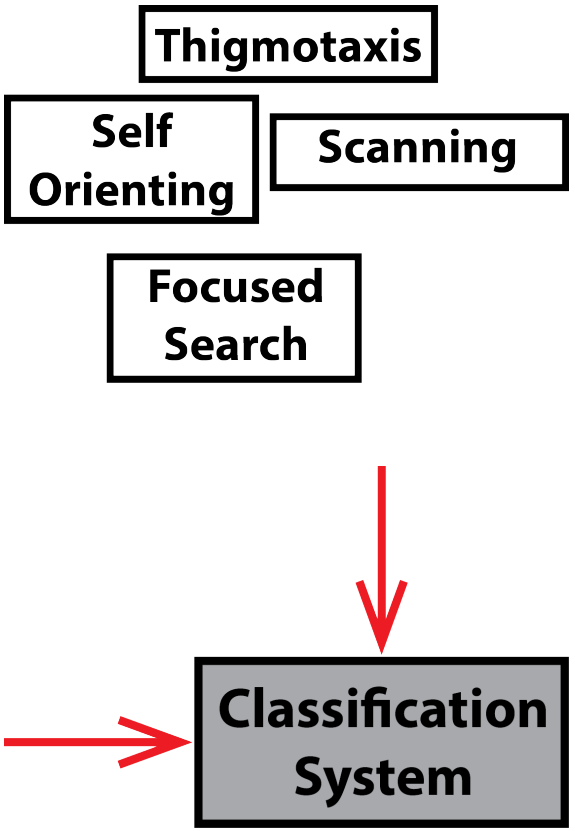
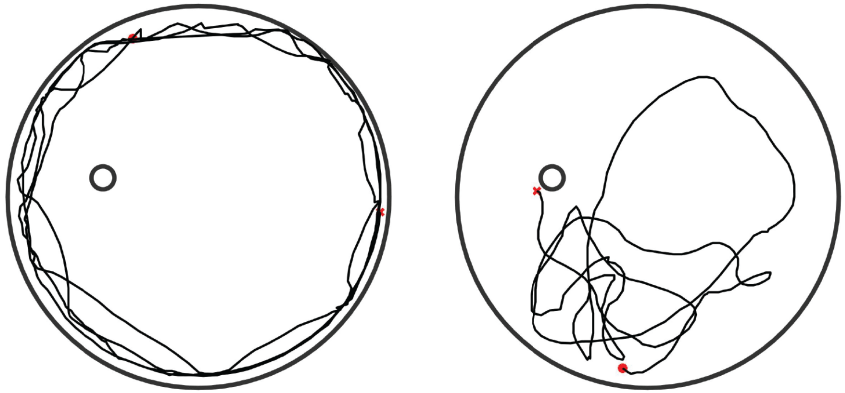




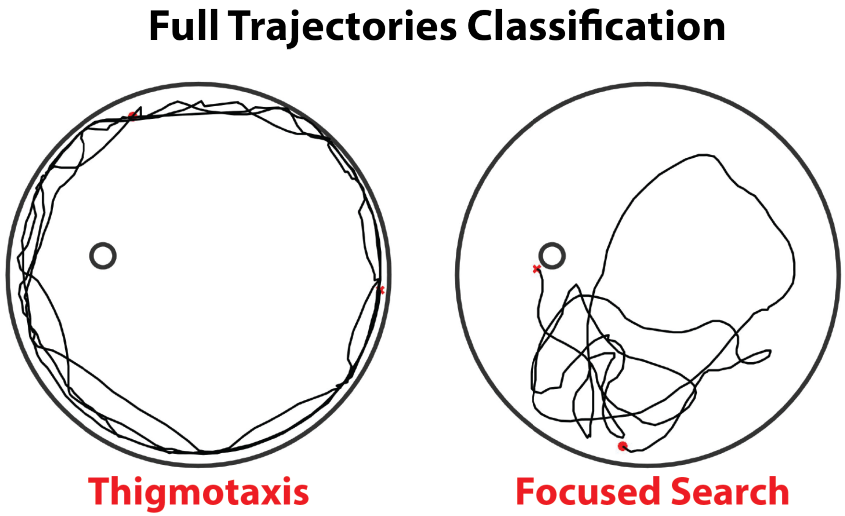
The story so far...

Full Trajectories Classification



Thigmotaxis **Focused Search**

The story so far...



- Dalm, S., Grootendorst, J., De Kloet, E. R. (2000).
- Wolfer, D. P. & Lipp, H.-P. (2000).
- Wolfer, D. P., Madani, R., Valenti, P. & Lipp, H.-P. (2001).
- Graziano, A., Petrosini, L. & Bartoletti, A. (2003)
- Illouz, T., Madar, R., Louzon, Y., Griffioen, K. J. & Okun, E. (2016).
- Rogers, Jake, et al. (2017).
- Higaki, Akinori, et al. (2018).

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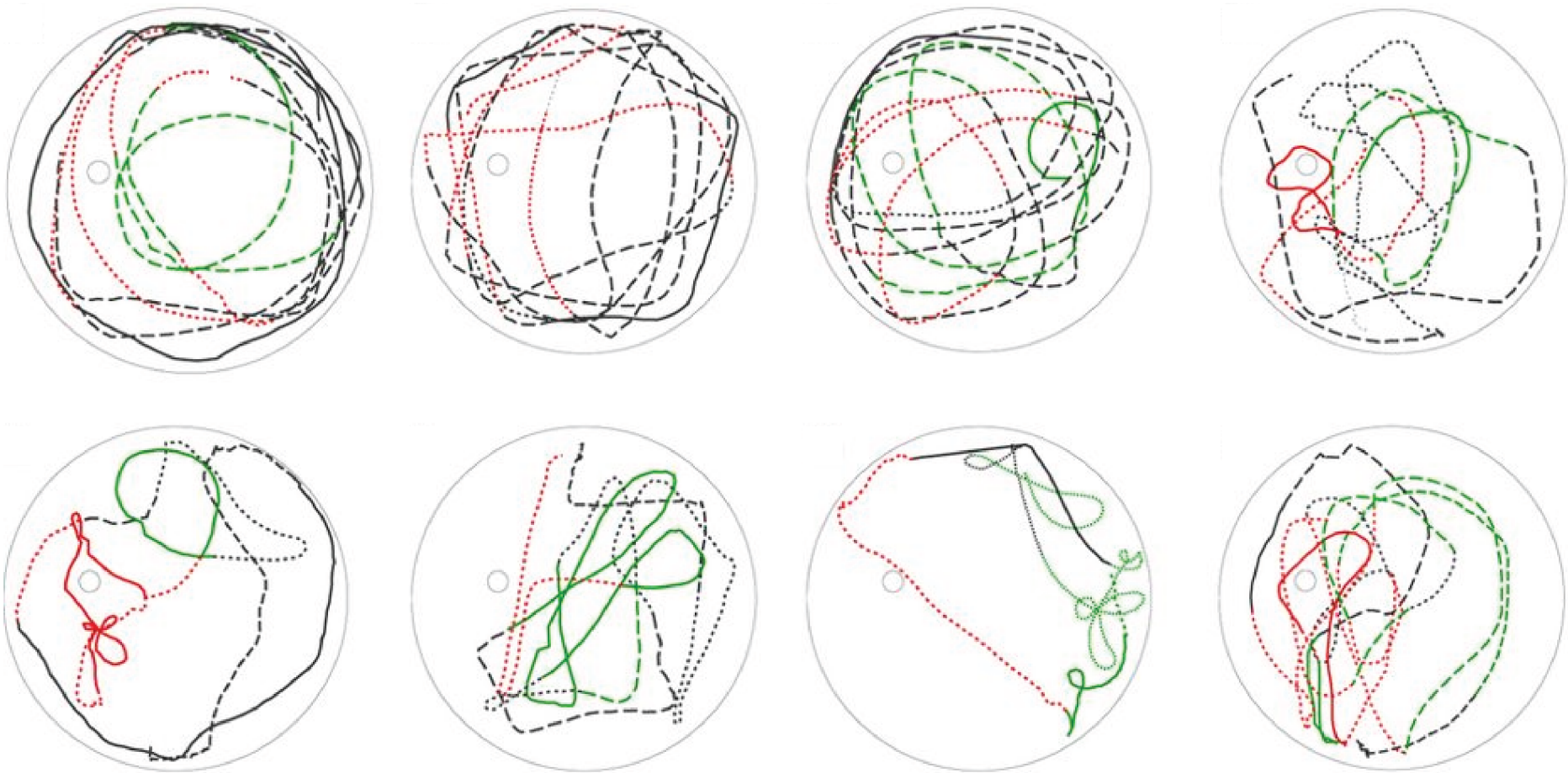

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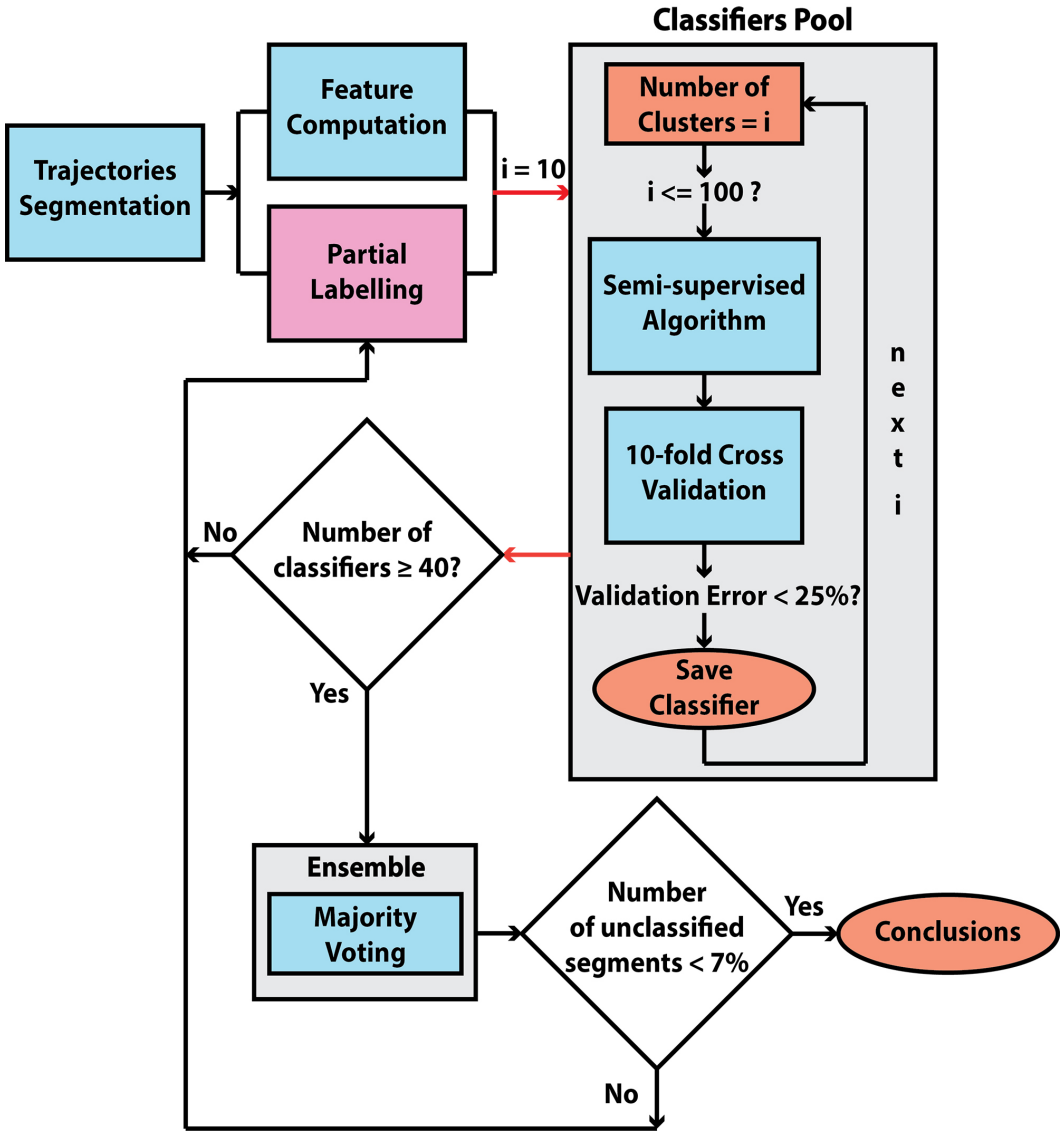
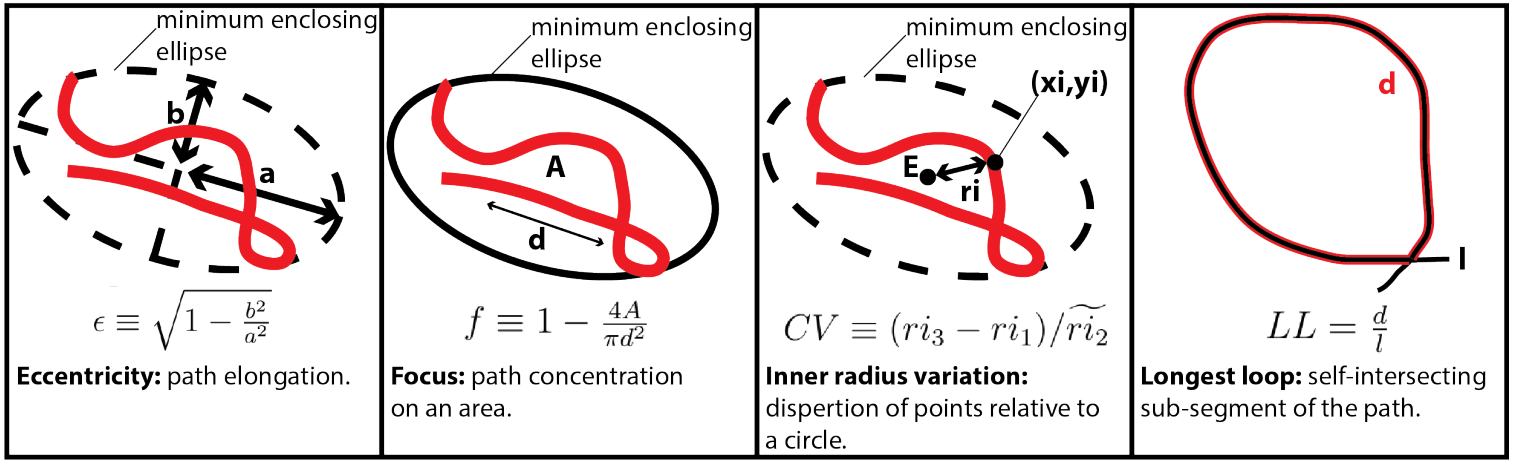


Vouros, Avgoustinos, et al. "A generalised framework for detailed classification of swimming paths inside the Morris Water Maze." Scientific reports 8.1 (2018): 15089.

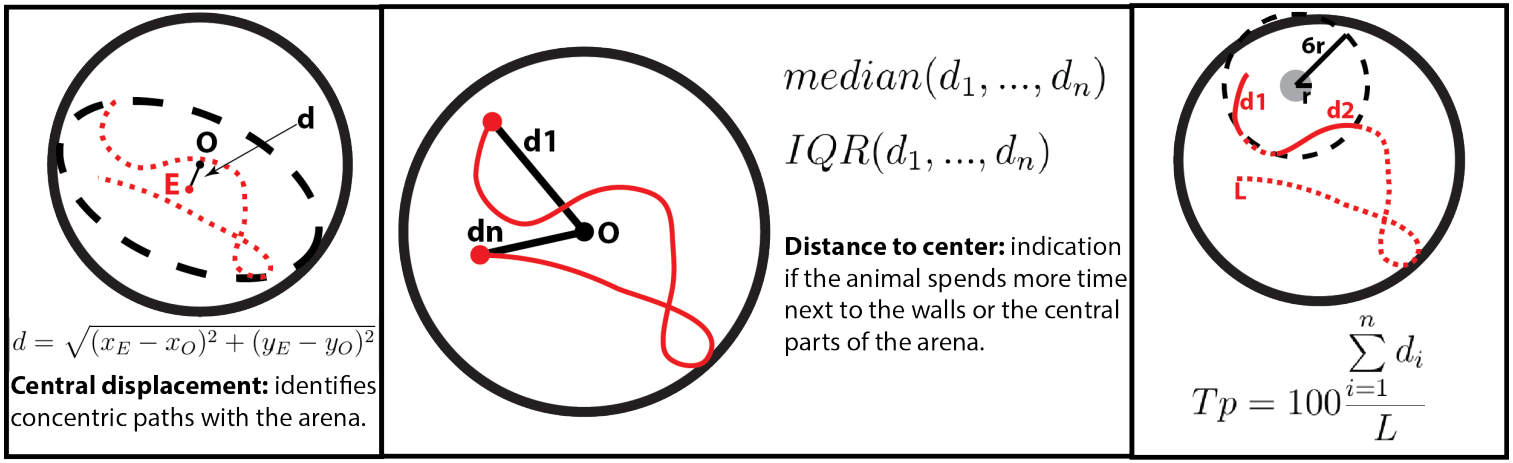
What about the path features?

Geometric



Spatial

ArenaSpecific



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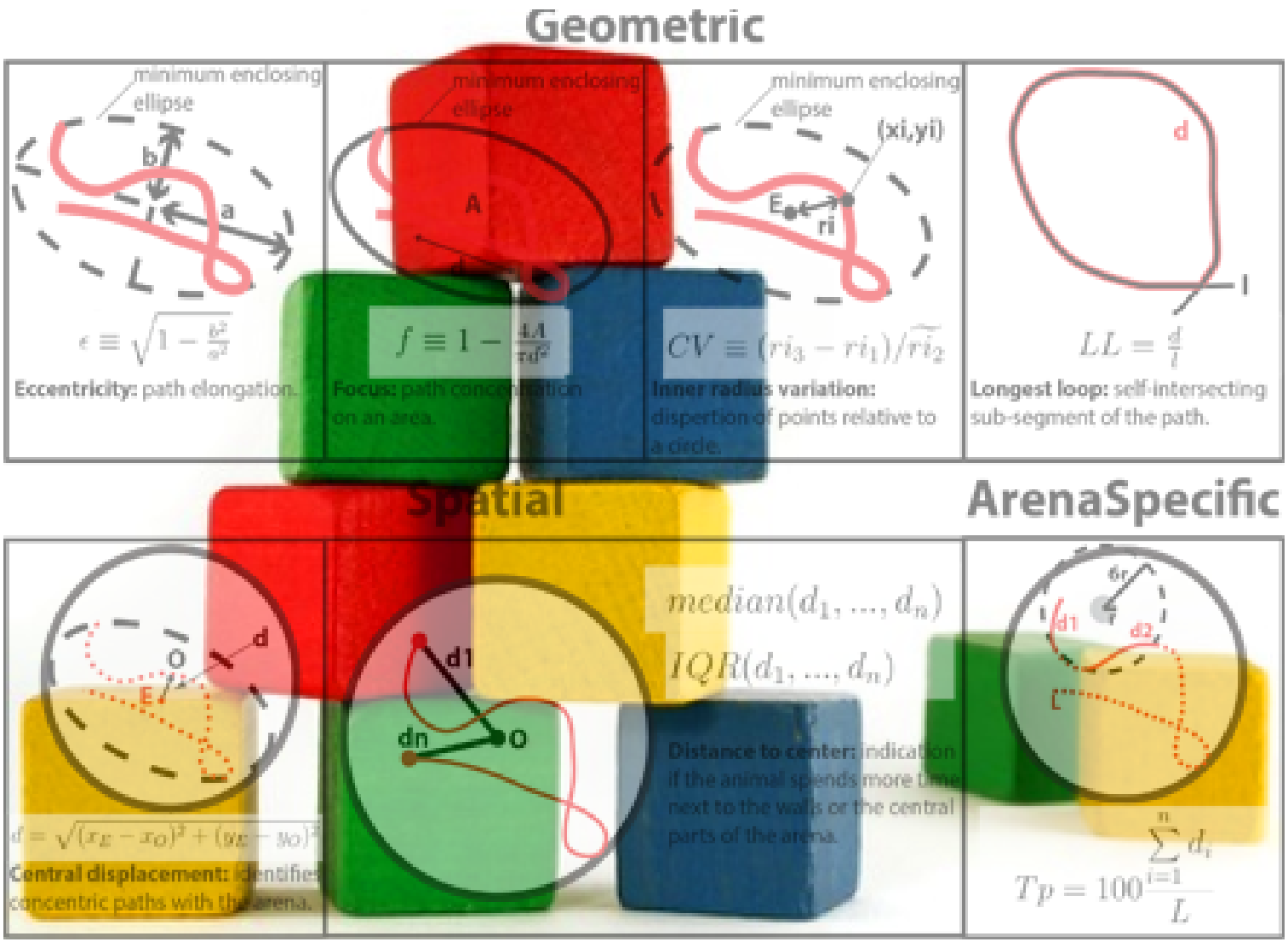
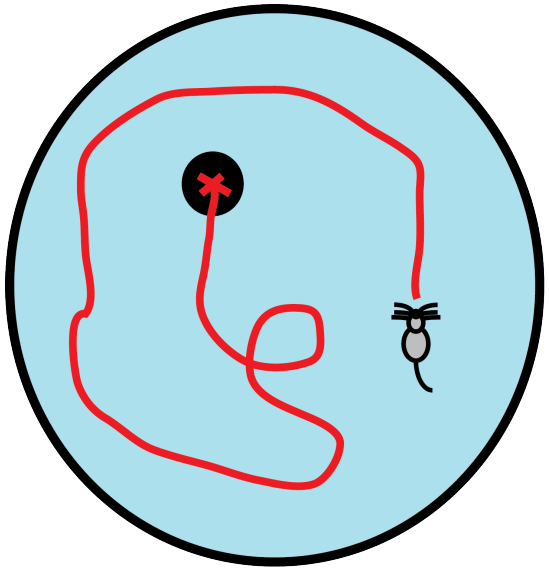
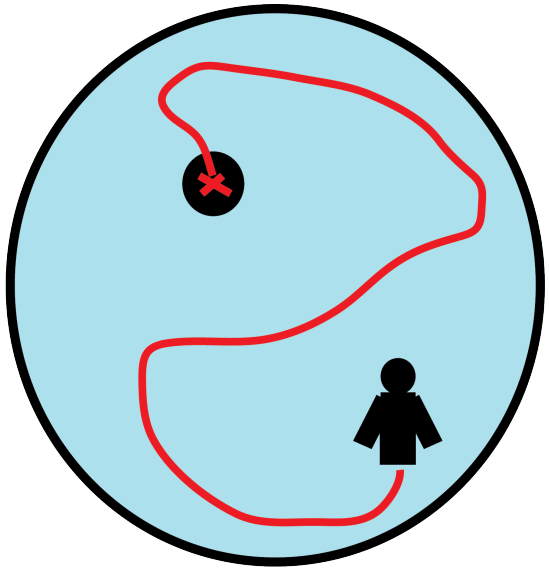
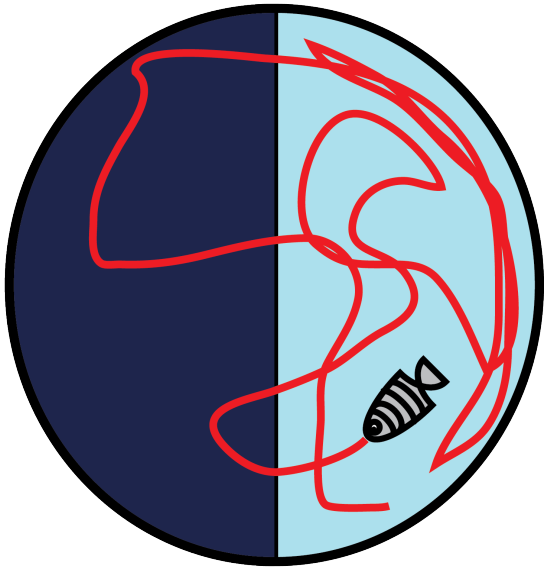
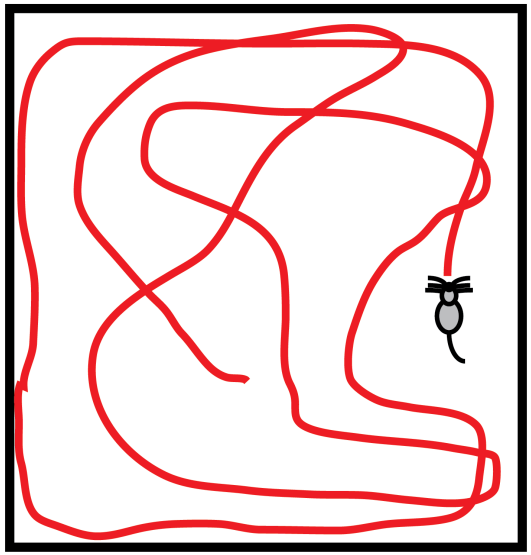


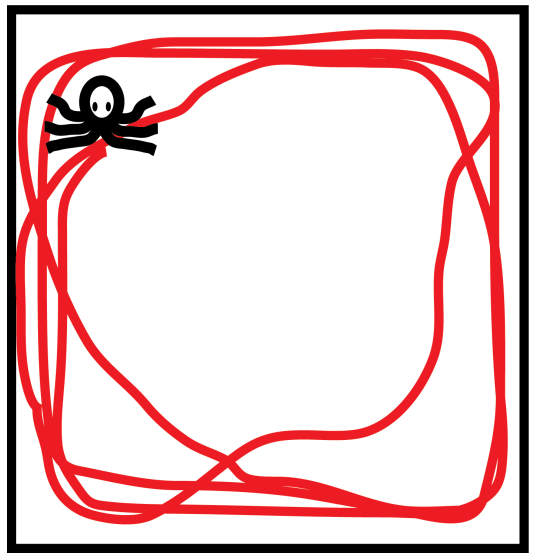
Different experimental procedures



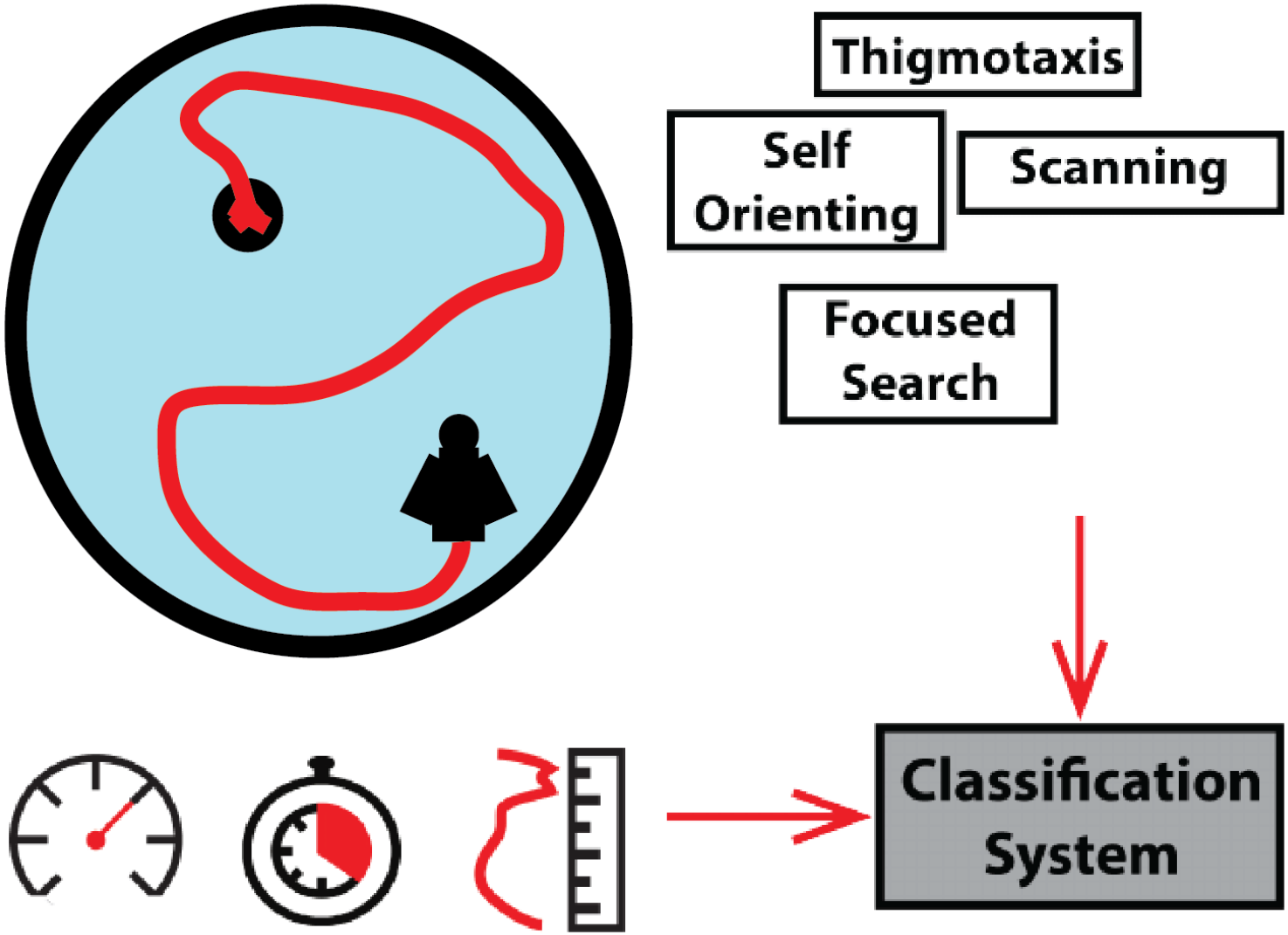








Why don't we just apply the same frameworks?



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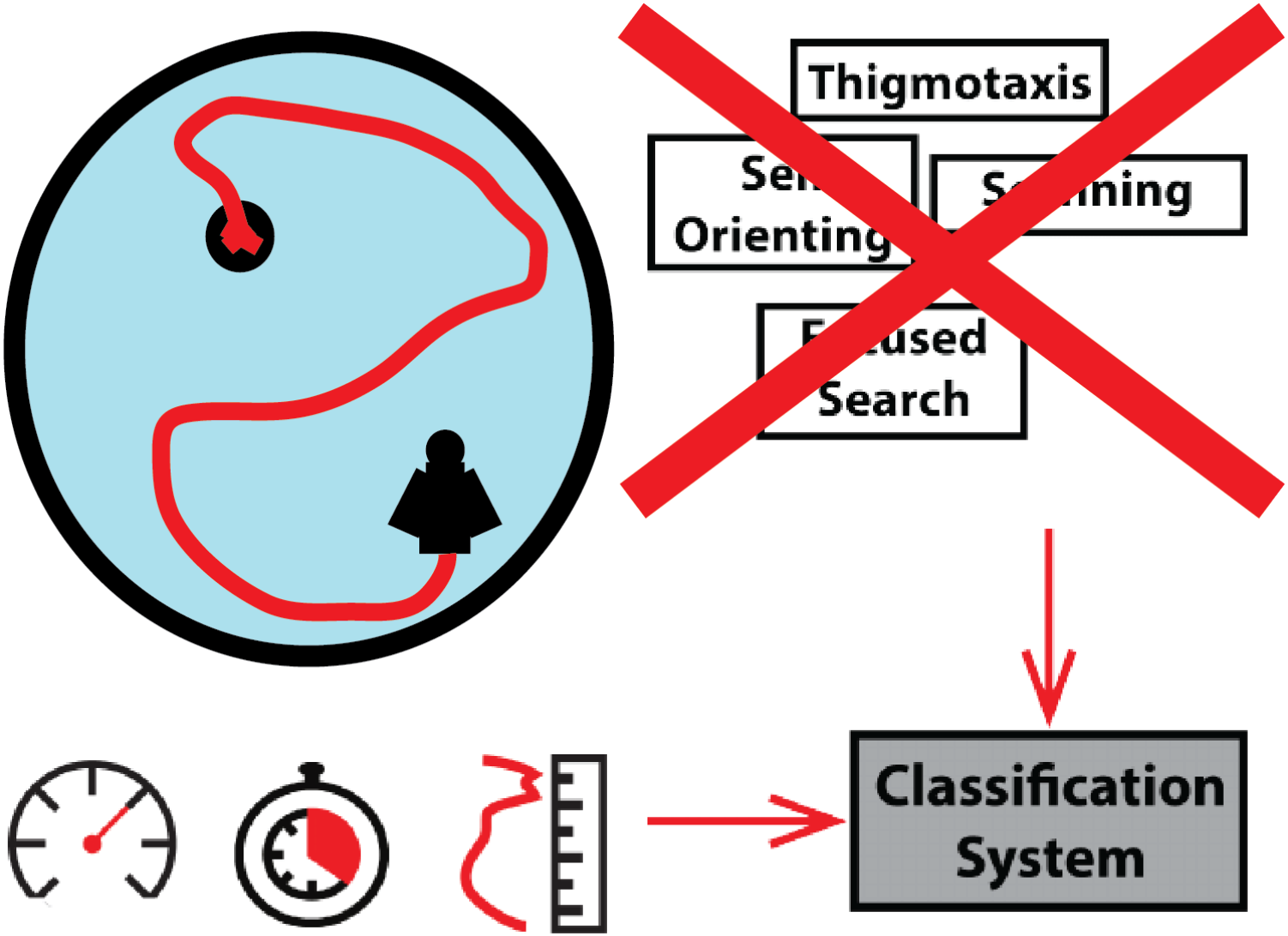

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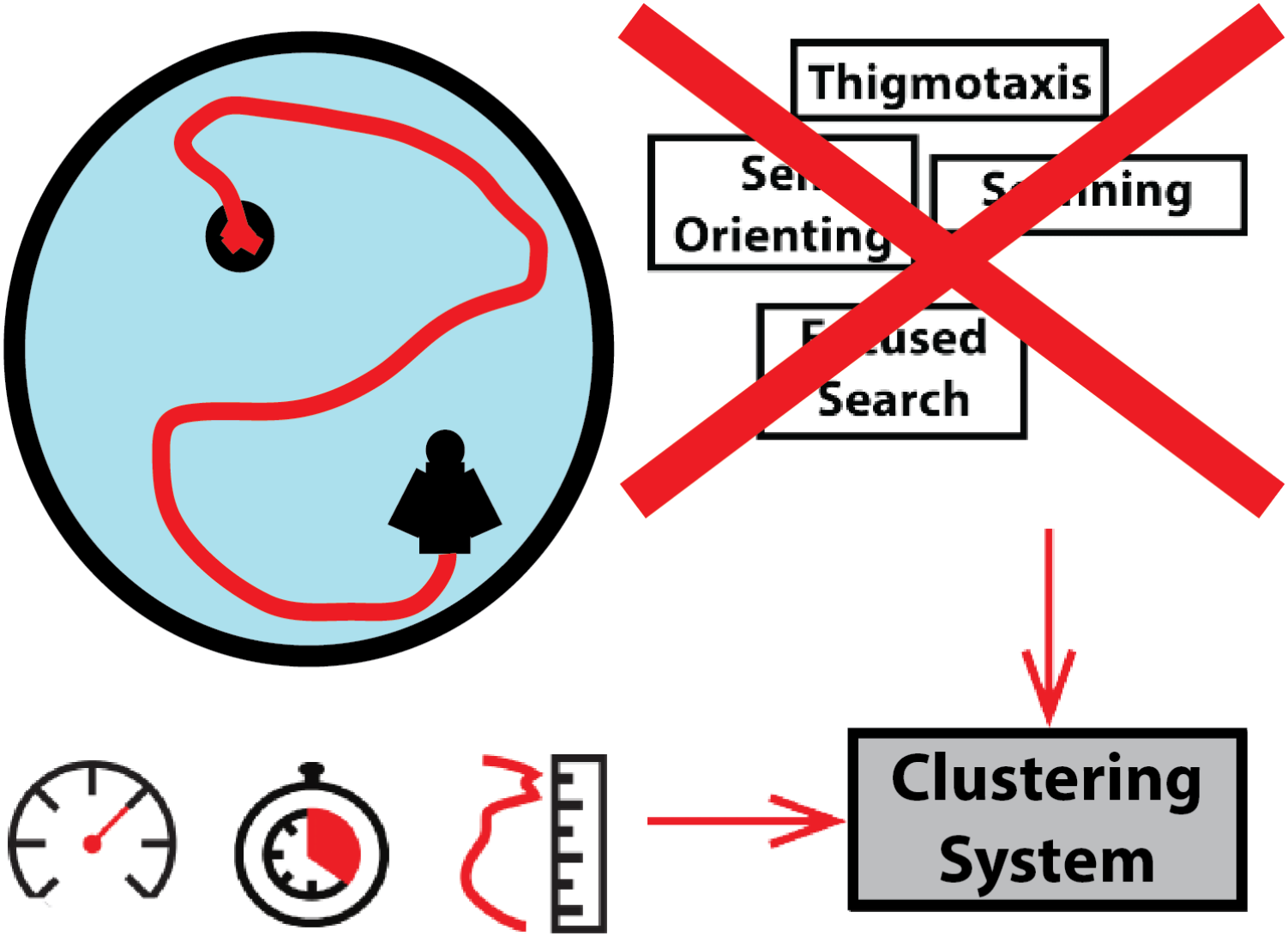

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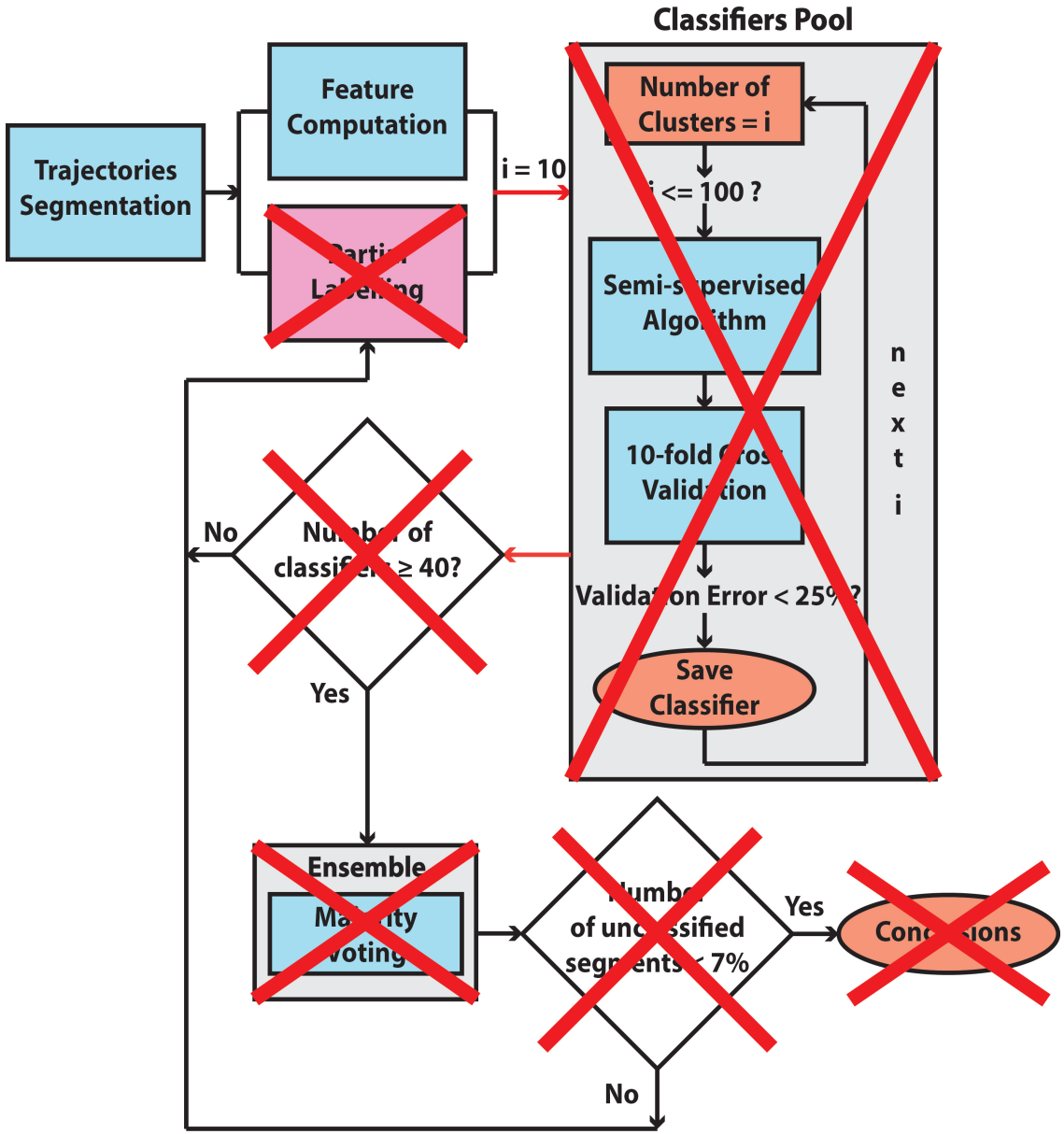

Let's just do clustering

The K-Means Algorithm (Lloyd's)

Advantages:

- Simple and easy to implement.
- Versatile.
- Guaranteed to converge.
- Invariant to data ordering.

Disadvantages:

- Detects only spherical and well-separated clusters.
- Sensitive to noise and outliers (Euclidean).
- Converges to a local minimum.

In general:

- Sensitive to initial centroids location.
- Sensitive to features (variables/attributes).

[1] Celebi, M. Emre, Hassan A. Kingravi, and Patricio A. Vela. "A comparative study of efficient initialization methods for the k-means clustering algorithm." Expert systems with applications 40.1 (2013): 200-210.

Let's just do clustering

- **ROBIN [1] or DK-Means++ [2]:** Make K-Means deterministic.
- **Sparse K-Means [3]:** Auto-assess the feature quality and discard the ones that do not contribute to the overall clustering.
- **Auto-tunable:** Ability to find optimal parameters automatically.
- **Ability to detect redundant features.**

[1] Al Hasan, Mohammad, et al. "Robust partitional clustering by outlier and density insensitive seeding." Pattern Recognition Letters 30.11 (2009): 994-1002.
[2] Nidheesh, N., KA Abdul Nazeer, and P. M. Ameer. "An enhanced deterministic K-Means clustering algorithm for cancer subtype prediction from gene expression data." Computers in biology and medicine 91 (2017): 213-221.
[3] Witten, Daniela M., and Robert Tibshirani. "A framework for feature selection in clustering." Journal of the American Statistical Association 105.490 (2010): 713-726.

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Can you make sense of abstract path features?

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Sodium nitroprusside ameliorates hyperglycemia-induced anatomical, neurovascular, and behavioural defects in zebrafish larvae

Dr Karishma Chhabria

Sodium nitroprusside ameliorates hyperglycemia-induced anatomical, neurovascular, and behavioural defects in zebrafish larvae

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Chhabria, Karishma, et al. "The effect of hyperglycemia on neurovascular coupling and cerebrovascular patterning in zebrafish." Journal of Cerebral Blood Flow & Metabolism (2018): 0271678X18810615.

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- The current work examines the effects of glucose exposure to the components of the neurovascular unit (NVU).

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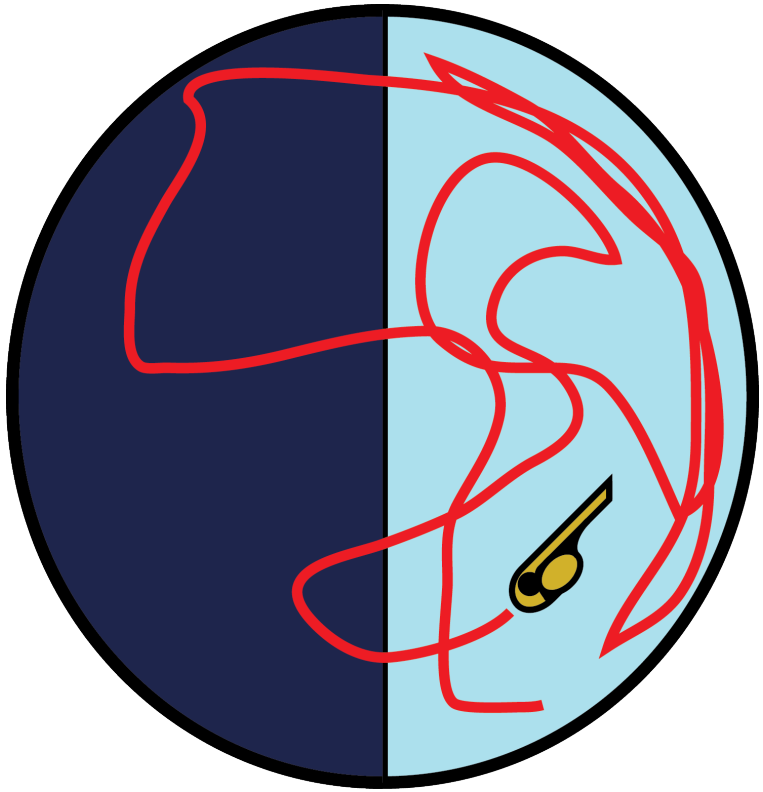
Behavioural analysis: Sodium nitroprusside ameliorates hyperglycemia-induced anatomical, neurovascular, and behavioural defects in zebrafish larvae



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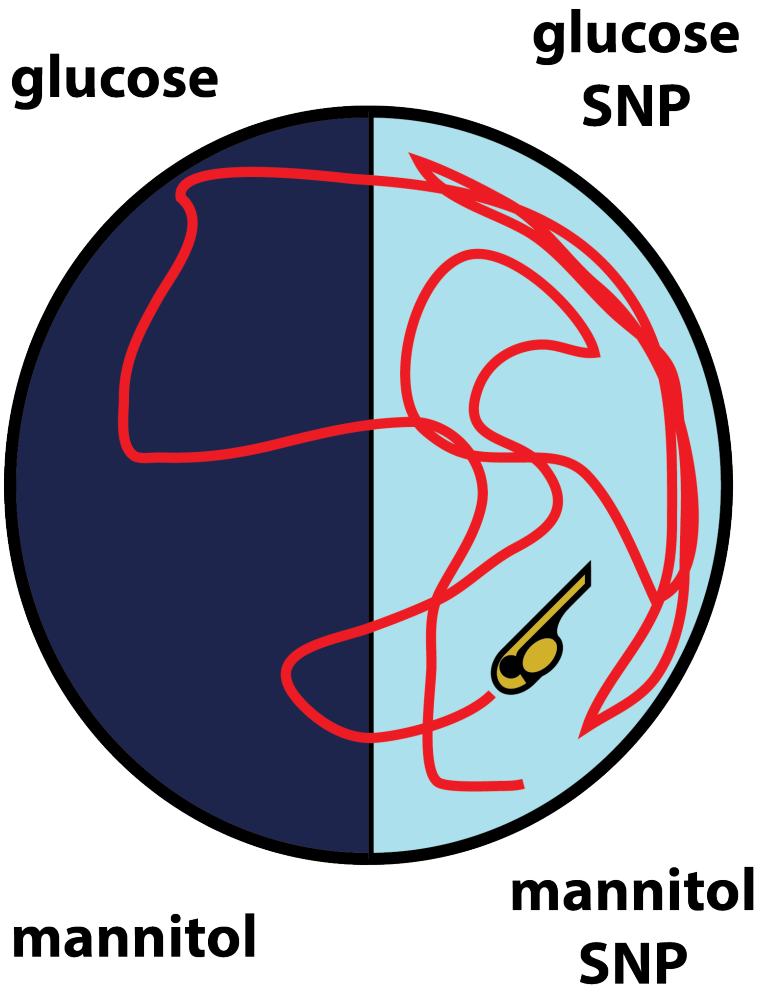
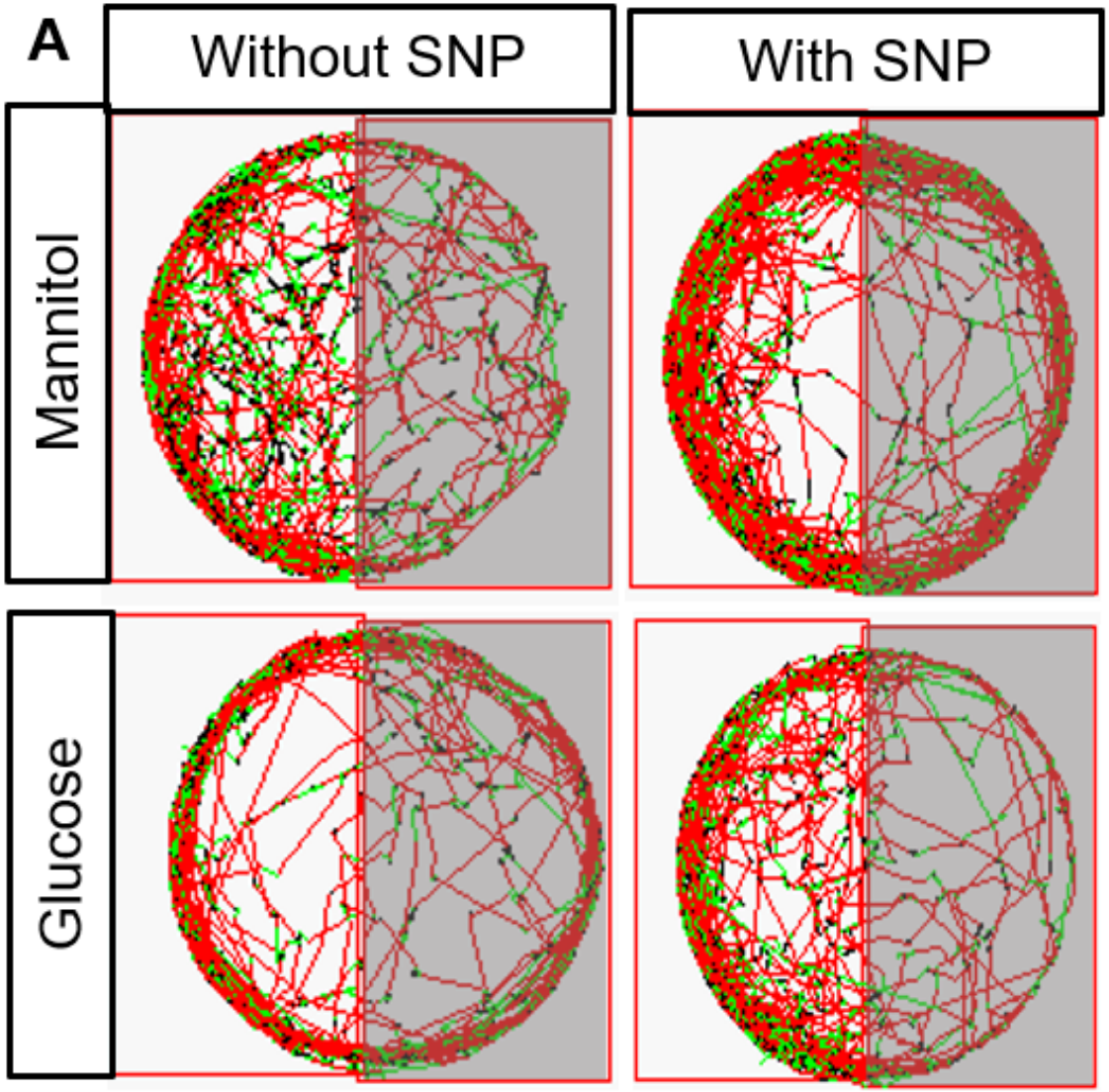


Behavioural analysis: Segmentation



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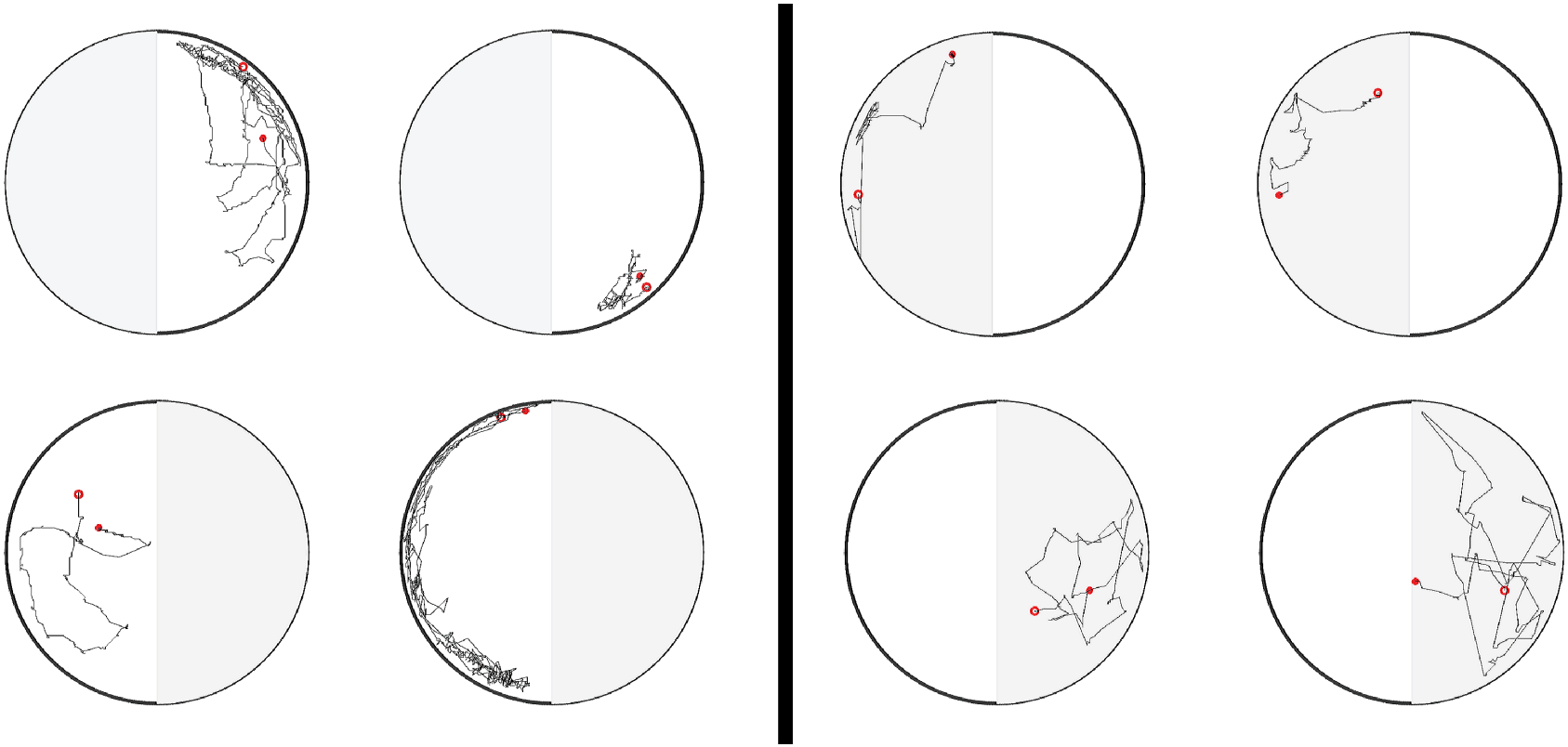
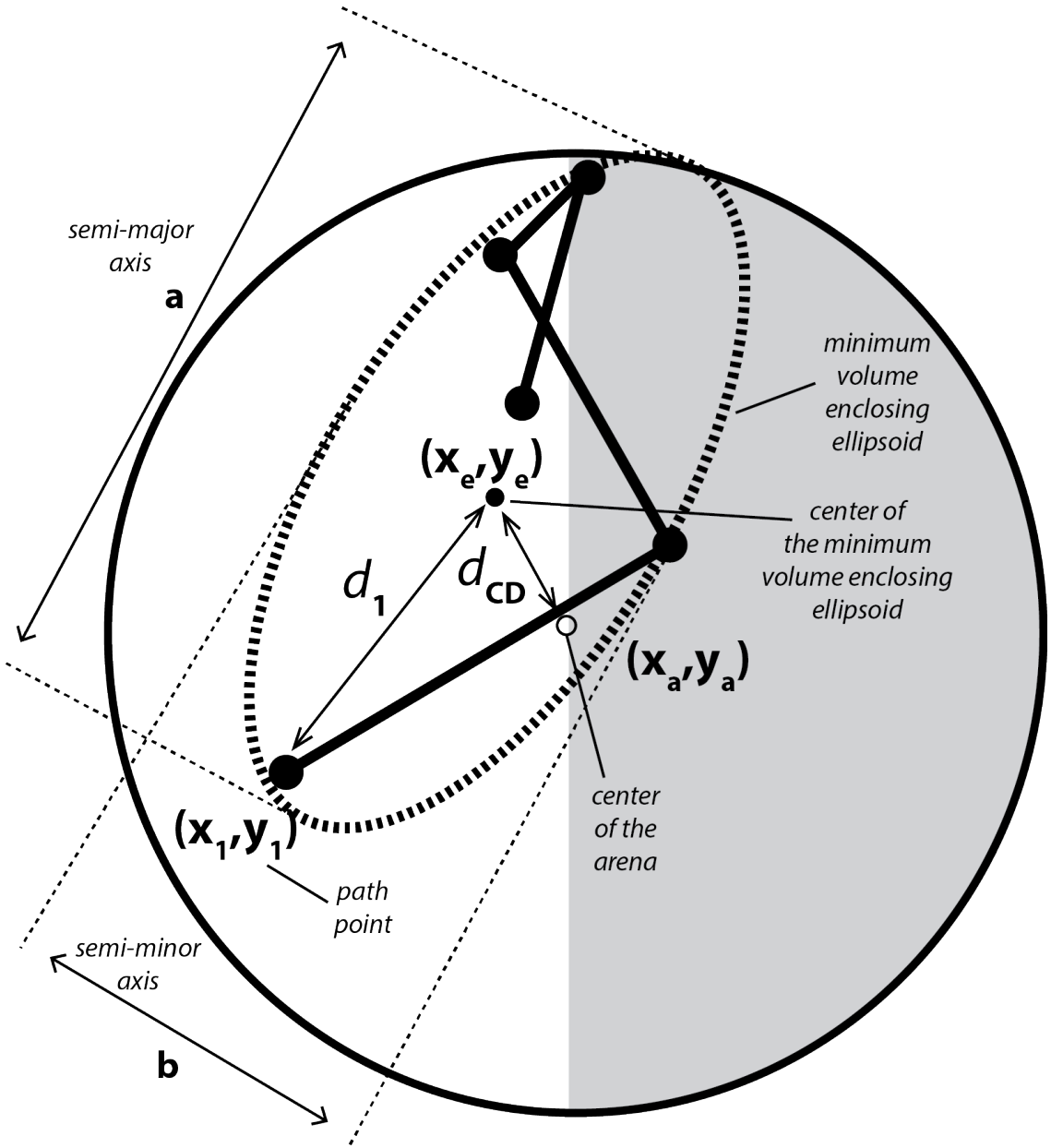


Behavioural analysis: Path features



Behavioural analysis: Path features

- **Eccentricity [1]:** $\epsilon = \sqrt{(1 - \frac{b^2}{a^2})}$
- **Mean path point distance from ellipsoid:**
  $MPP = \frac{\sum_{i=1}^{n} \sqrt{(x_i - x_e)^2 + (y_i - y_e)^2}}{n}$
- **Central displacement [1]:** $d_{CD} = \sqrt{(x_e - x_a)^2 + (y_e - y_a)^2}$
- **Number of entrances/exits:** number of transitions between light and dark side of the arena.

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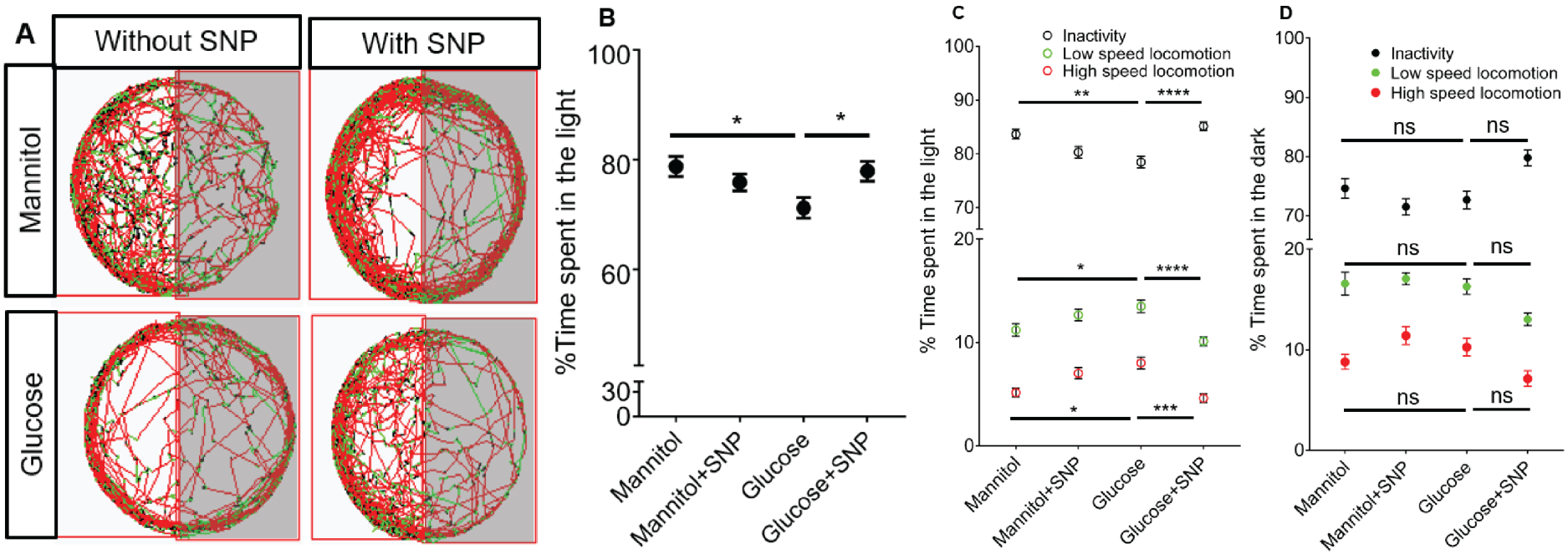

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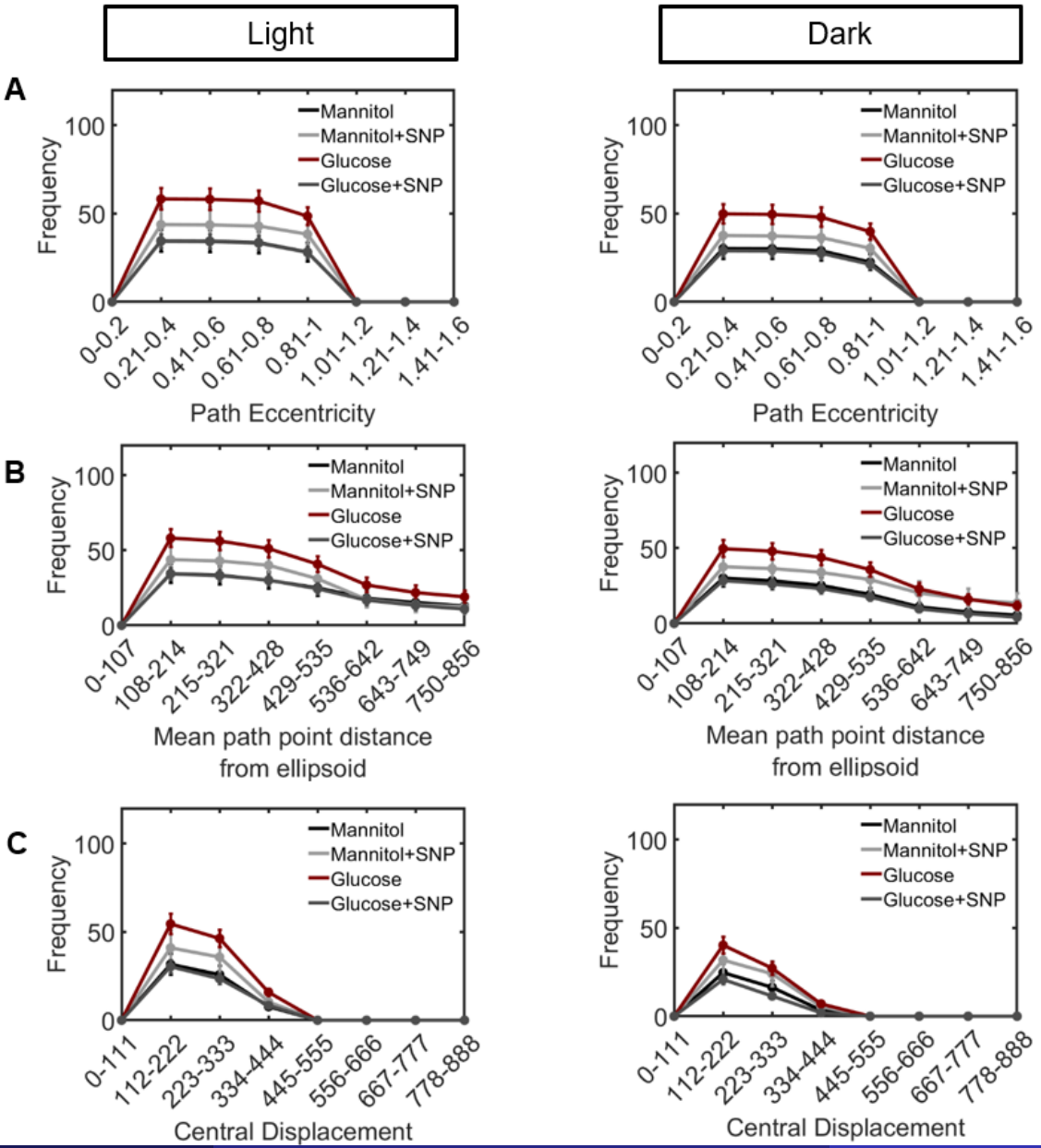
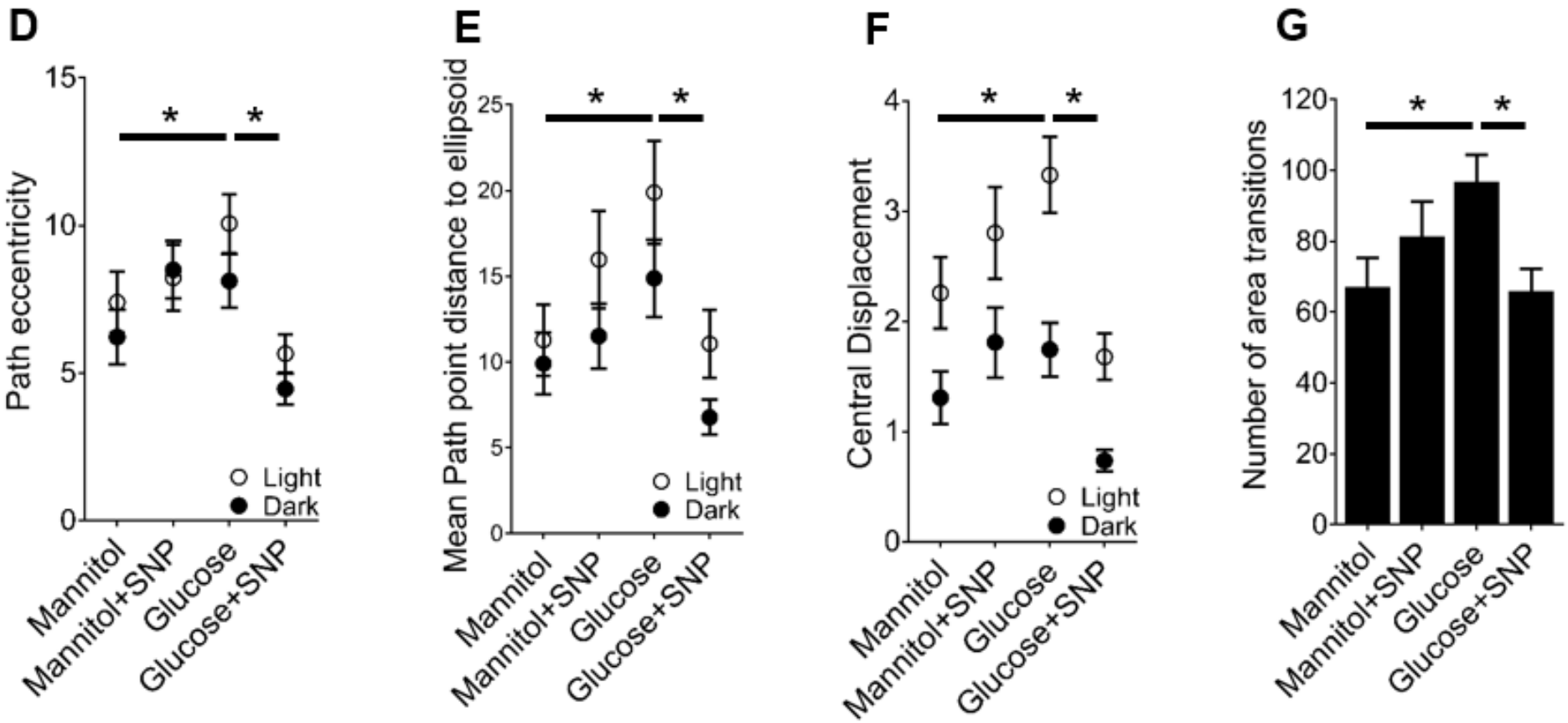


Behavioural analysis



Behavioural analysis: Results

- Glucose exposure reduced light-dark preference which was rescued by co-treatment with SNP.

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- Glucose exposure resulted in a significant increase in the time larvae spent undertaking both low and high speed locomotion while in the light region of the well, with an associated reduction in the time spent inactive. SNP co-treatment reversed this effect.

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- Glucose exposure reduced light-dark preference which was rescued by co-treatment with SNP.
- Glucose exposure resulted in a significant increase in the time larvae spent undertaking both low and high speed locomotion while in the light region of the well, with an associated reduction in the time spent inactive. SNP co-treatment reversed this effect.
- Quantifying the same measures for the dark region of the well, we found similar trends to that seen in light area but these were non-significant.

Behavioural analysis: Results

- Glucose exposed larvae showed an increase in path eccentricities, mean PPDE and central displacement compared to mannitol exposed larvae and co-treatment with SNP rescued all these features in the light side of the well.

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- We did not observe significant differences in these features between glucose and mannitol with or without SNP in the dark side of the well.

Behavioural analysis: Results

- Glucose exposed larvae showed an increase in path eccentricities, mean PPDE and central displacement compared to mannitol exposed larvae and co-treatment with SNP rescued all these features in the light side of the well.
- We did not observe significant differences in these features between glucose and mannitol with or without SNP in the dark side of the well.
- We found that glucose exposure increased the number of transitions between these areas compared to mannitol treated larvae and this was rescued by co-treatment with SNP.

Behavioural analysis: Discussion

- This is the first study characterizing the effect of hyperglycemia on geometrical and positional characteristics of zebrafish locomotion.

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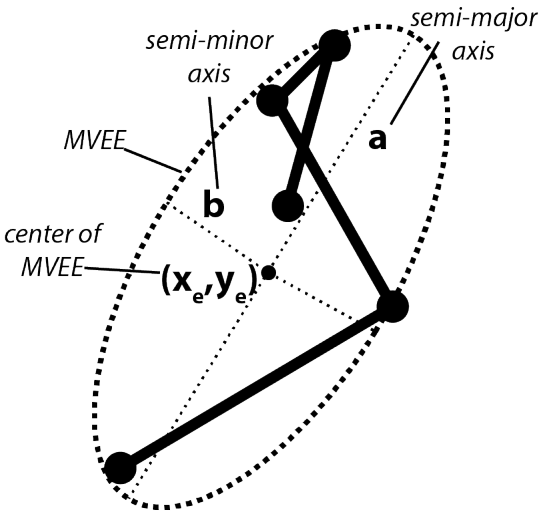
- Increase in positional and geometric features with glucose exposure implies an altered behaviour such as increased exploration and thigmotaxis.
- Various zebrafish studies have shown increased exploration and thigmotaxis with anxiogenic drug treatments (Egan, Bergner et al. 2009, Blaser, Chadwick et al. 2010). This further points to the associated of glucose exposure and diabetes to anxiety related brain activation and needs further investigation.

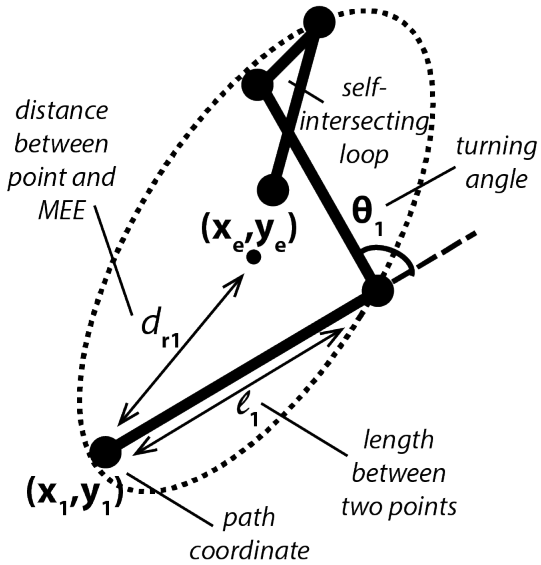
Future work on features

Future work

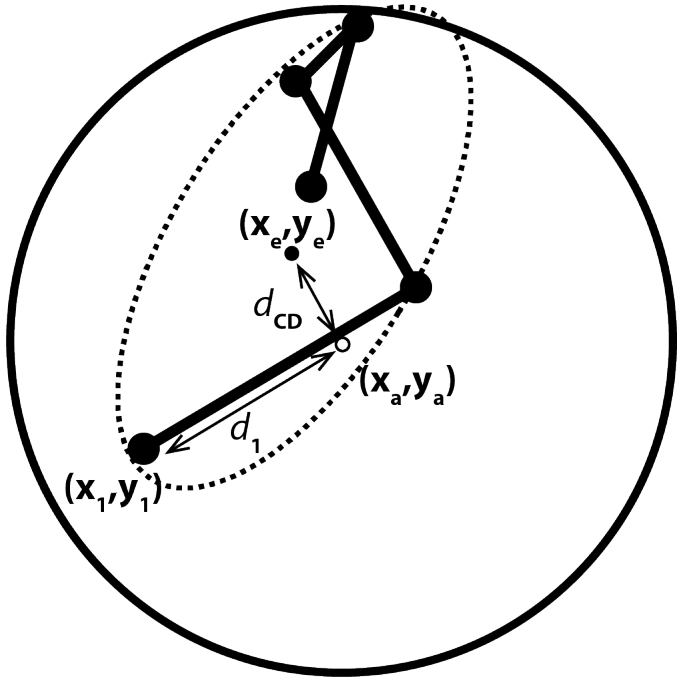
Minimum Volume Enclosing Ellipsoid (MVEE)



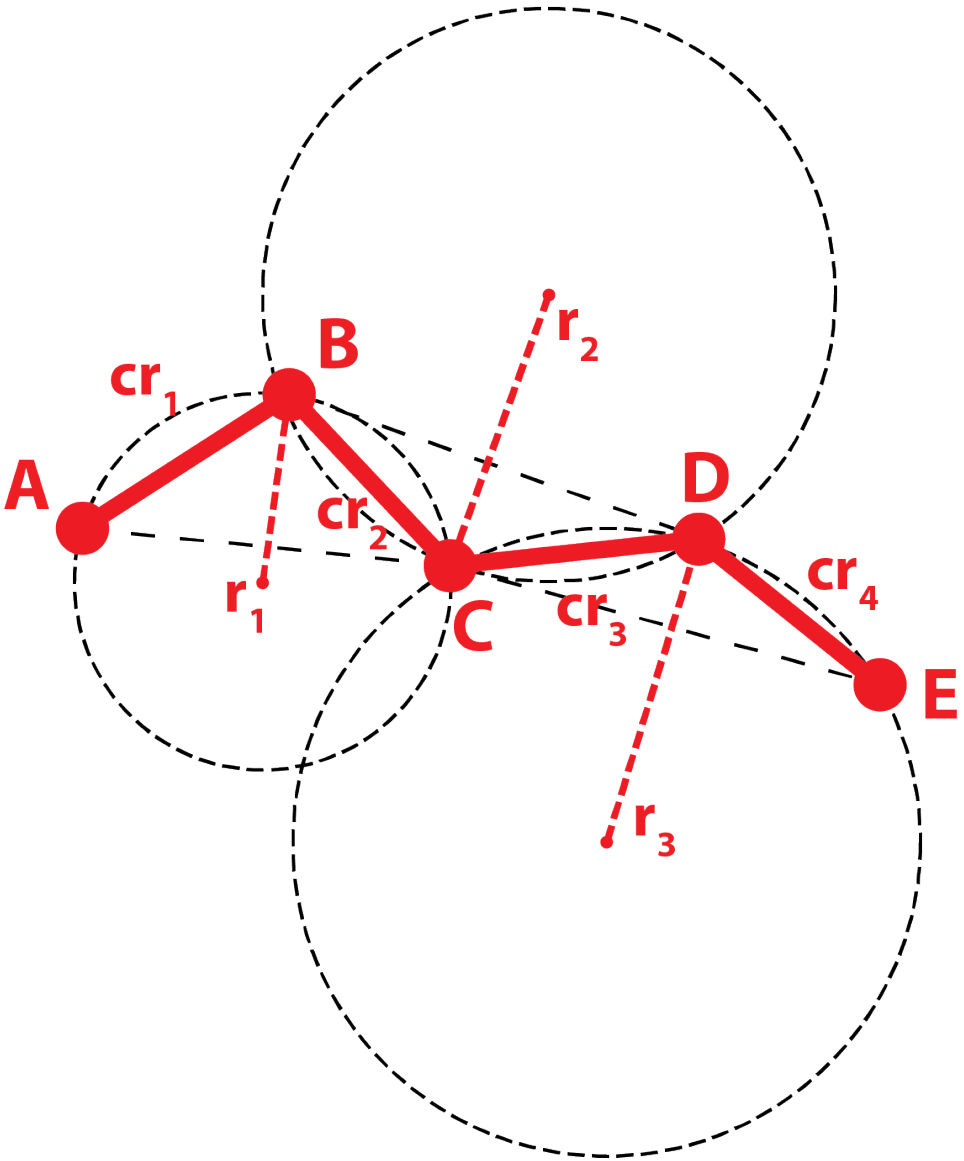
Geometric Measurements

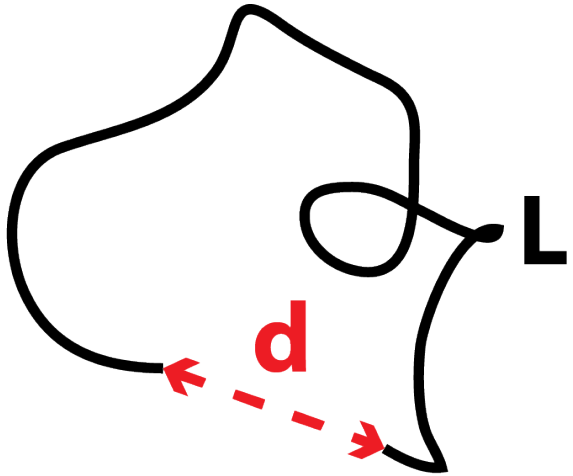


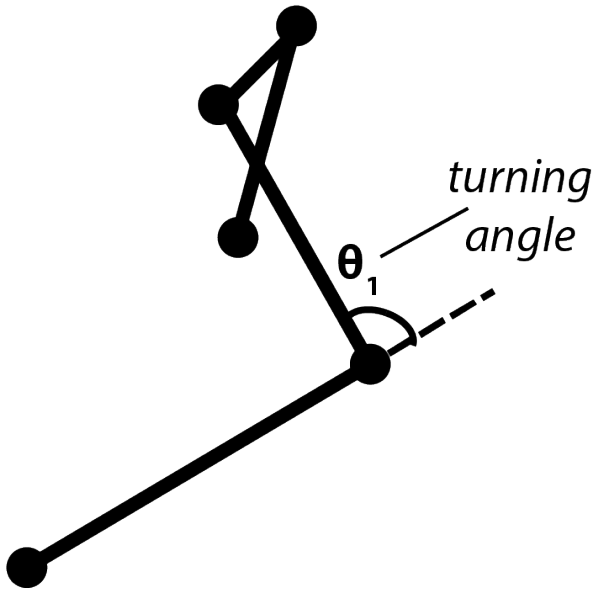
Positional Measurements



Future work







Future work

$$S1 = \frac{d}{L} \tag{1}$$

$$S2 = 2\sqrt{p_m \frac{1+c}{1-c} + p_{cv}^2} \tag{2}$$

$$S3 = 2\sqrt{p_m \frac{1+c^2-s^2}{(1-c)^2+s^2} + p_{cv}^2} \tag{3}$$

[1] Benhamou, Simon. "How to reliably estimate the tortuosity of an animal's path:: straightness, sinuosity, or fractal dimension?." Journal of theoretical biology 229.2 (2004): 209-220.

[2] Almeida, Paulo JAL, et al. "Indices of movement behaviour: conceptual background, effects of scale and location errors." Zoologia 27.5 (2010).

Thank you for your attention!

Any questions?