Sex Differences in Rodent Optimal Spatial Navigation: Influences of Estrous Cycle and Object Cues in the Traveling Salesperson Problem

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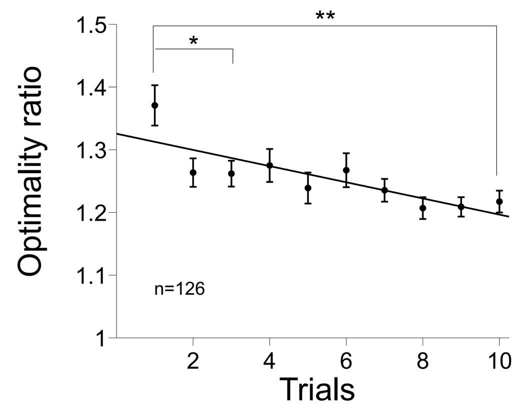
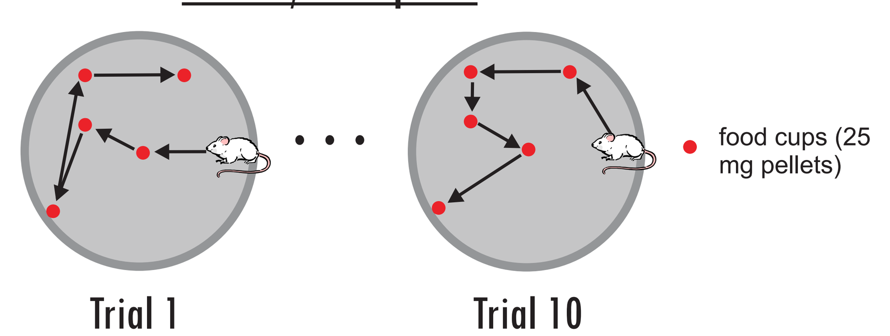
INTRODUCTION

- In humans, men and women rely on different spatial navigation strategies. Women rely on landmark cues and men rely on gradient and self-motion cues [1].
- In rodents, females rely on place or response-based strategies at different phases of the estrous cycle [2].
- We use the framework of the traveling salesperson problem (TSP) to study how these navigation strategies depend on both sex and the estrous cycle.
- TSP is a classical Artificial Intelligence problem in which an agent must visit a set of locations using the shortest route.
- We have previously shown that males rats can find near-optimal routes after only a few trials [3].

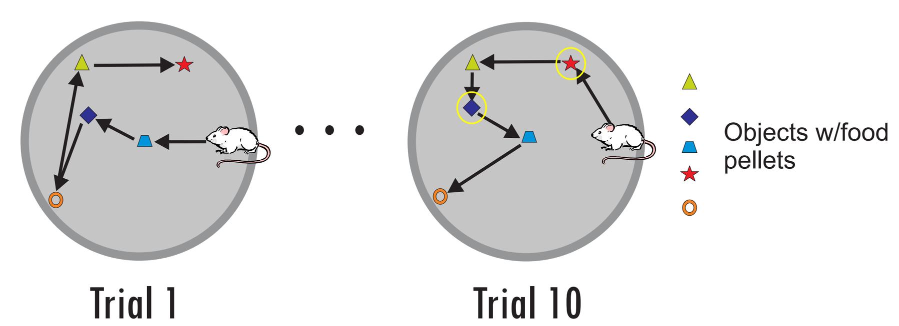


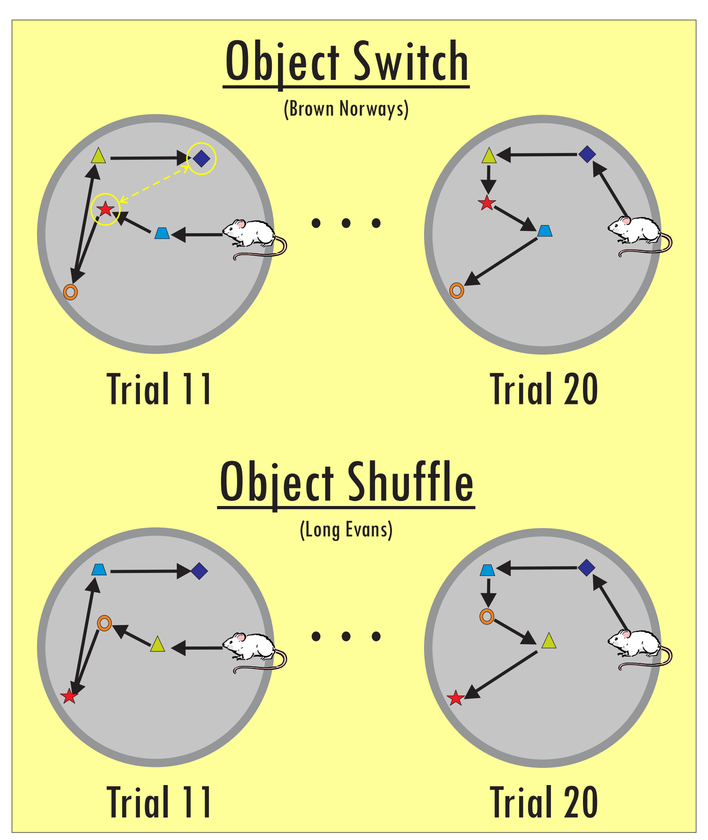
METHODS

TSP w/o Objects



TSP with Objects

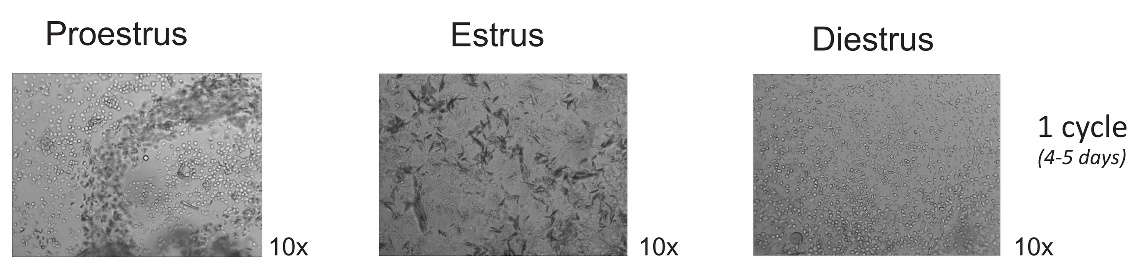


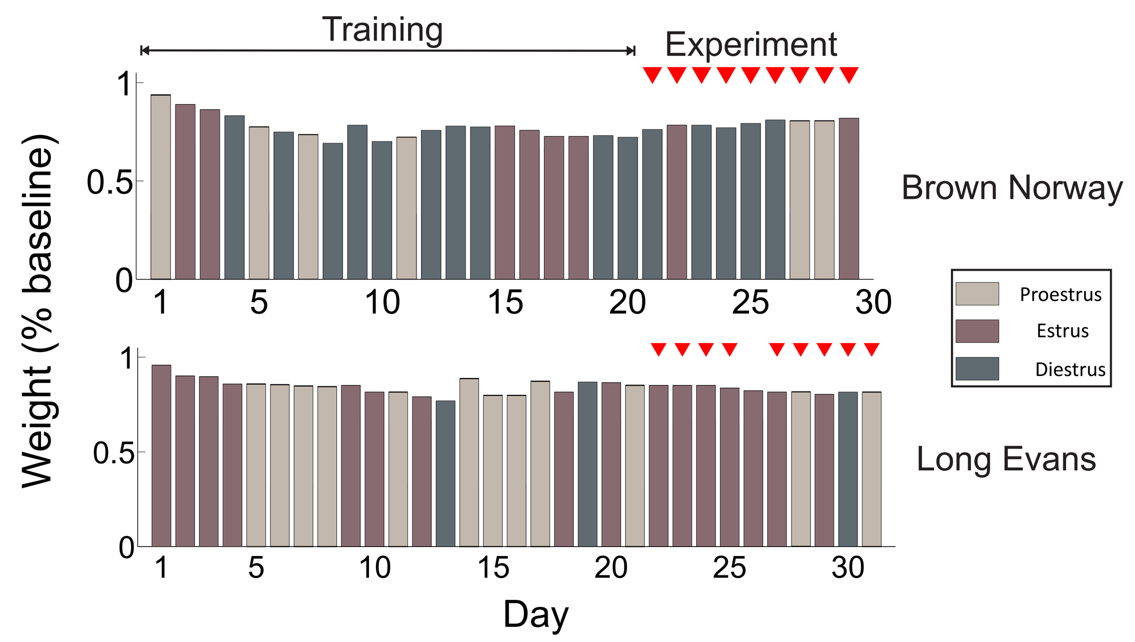


Data Analysis and Statistics

Based on 7 male Brown Norways (2 w/objects 5 w/o), 4 female Brown Norways, 3 male Long Evans and 4 female Long Evans. In all statistical analyses (repeated measures ANOVA), ## = p (between subjects) < 0.01, # = p (between subjects) < 0.05, ** = p (within subjects) < 0.01, * = p (within subjects) < 0.05, ^^ = p (interaction) < 0.001, and ^ = p (interaction) < 0.05. For all figures, error bars are standard error.

Estrous Cycle Determination

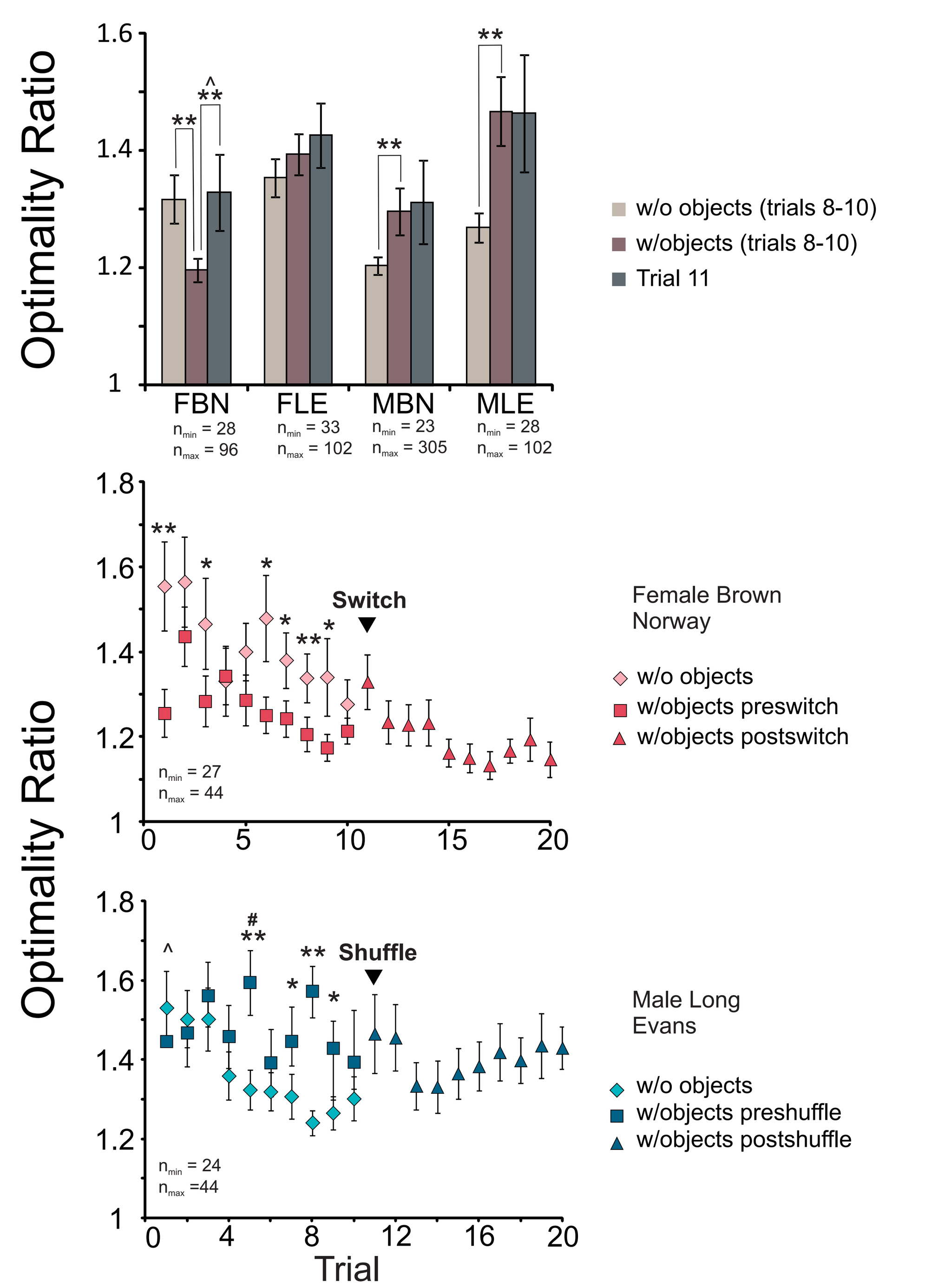




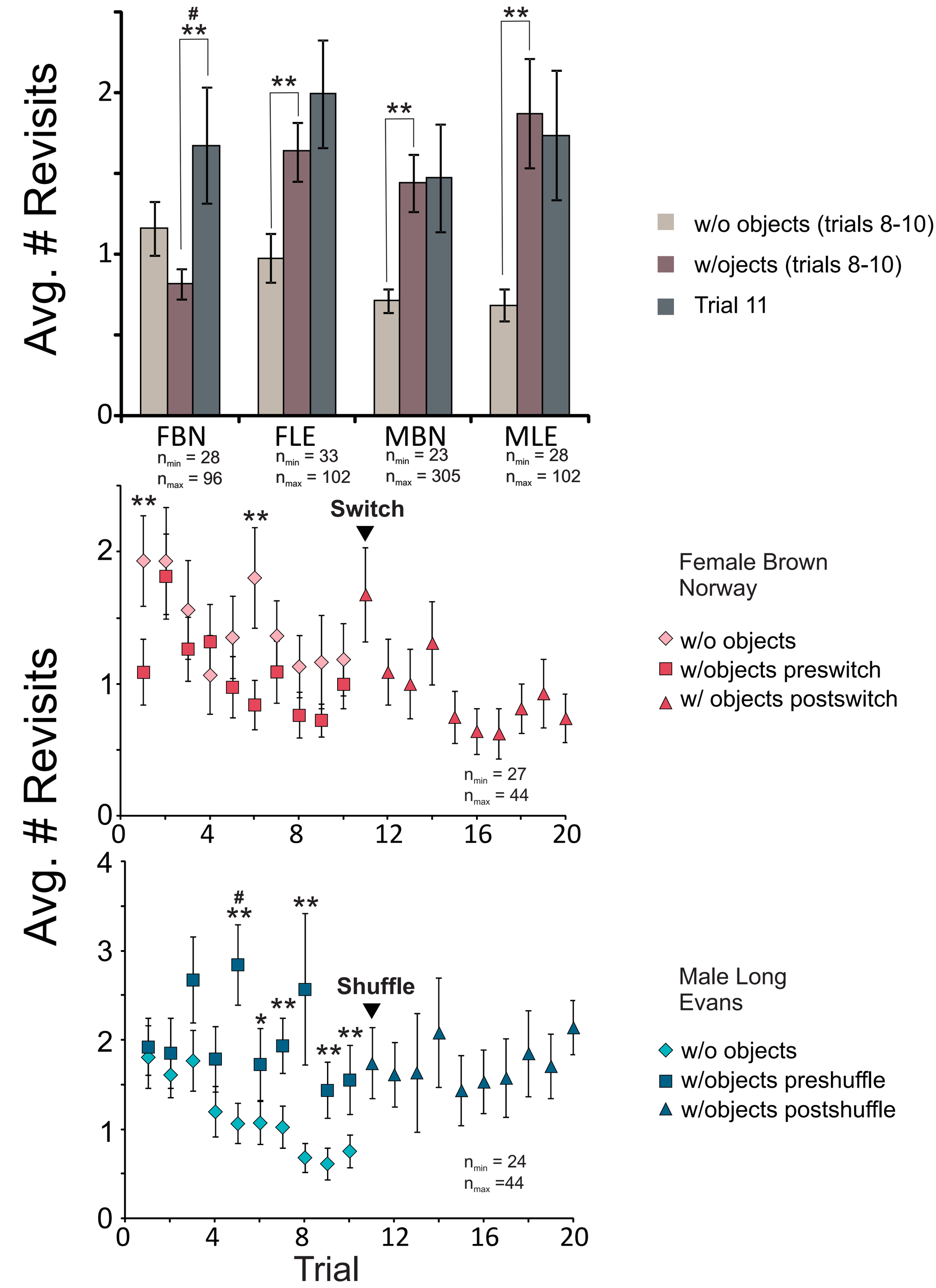
RESULTS

Optimality Ratio: Compared to males, female Brown Norway rats perform better with objects than without.

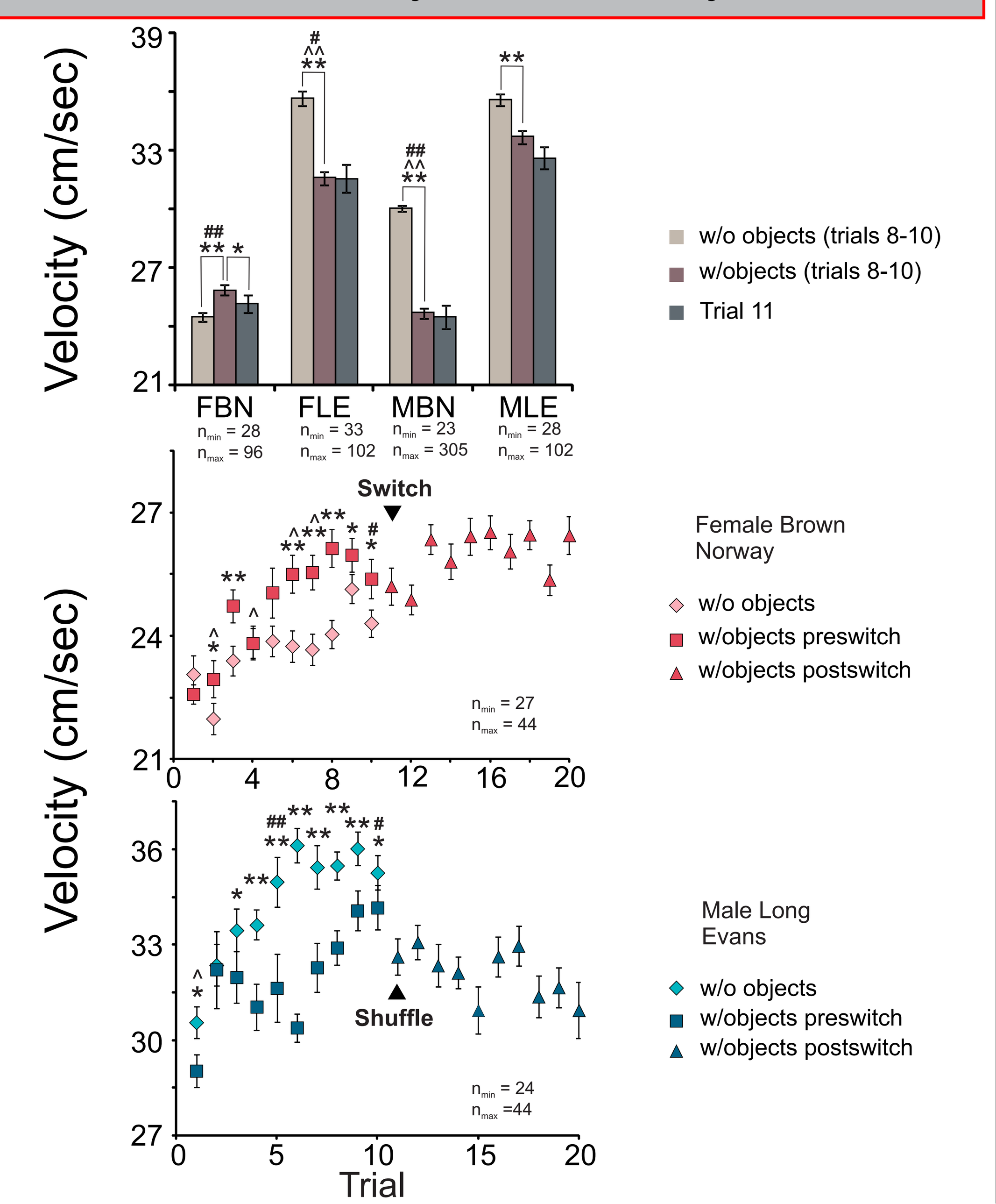
$$\text{Optimality Ratio} = \frac{\|\text{Path Sequence Chosen}\|}{\min(\|\text{Path Sequences}\|)}$$



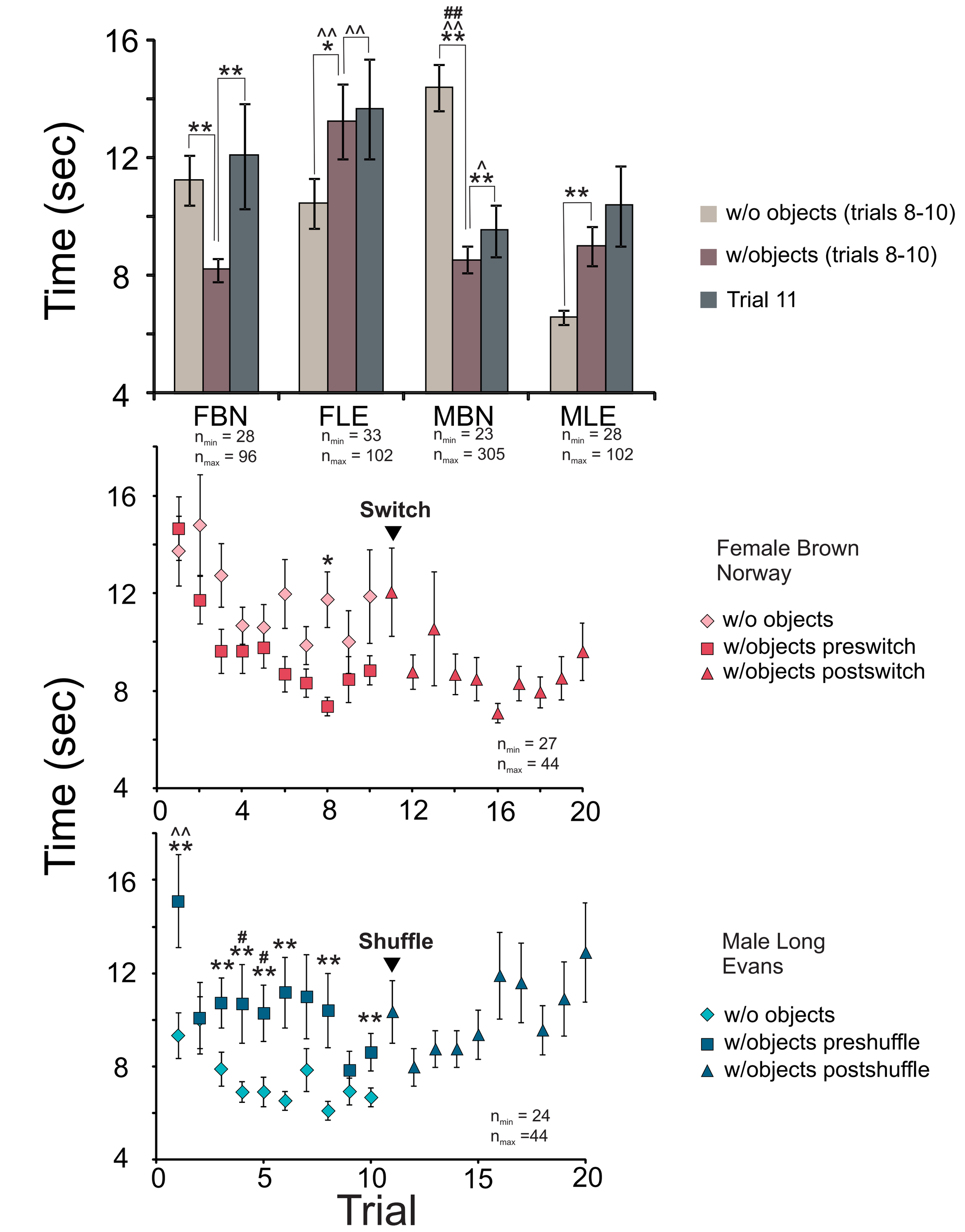
Revisits: Compared to males, female Brown Norway rats show more revisits without objects than with objects.



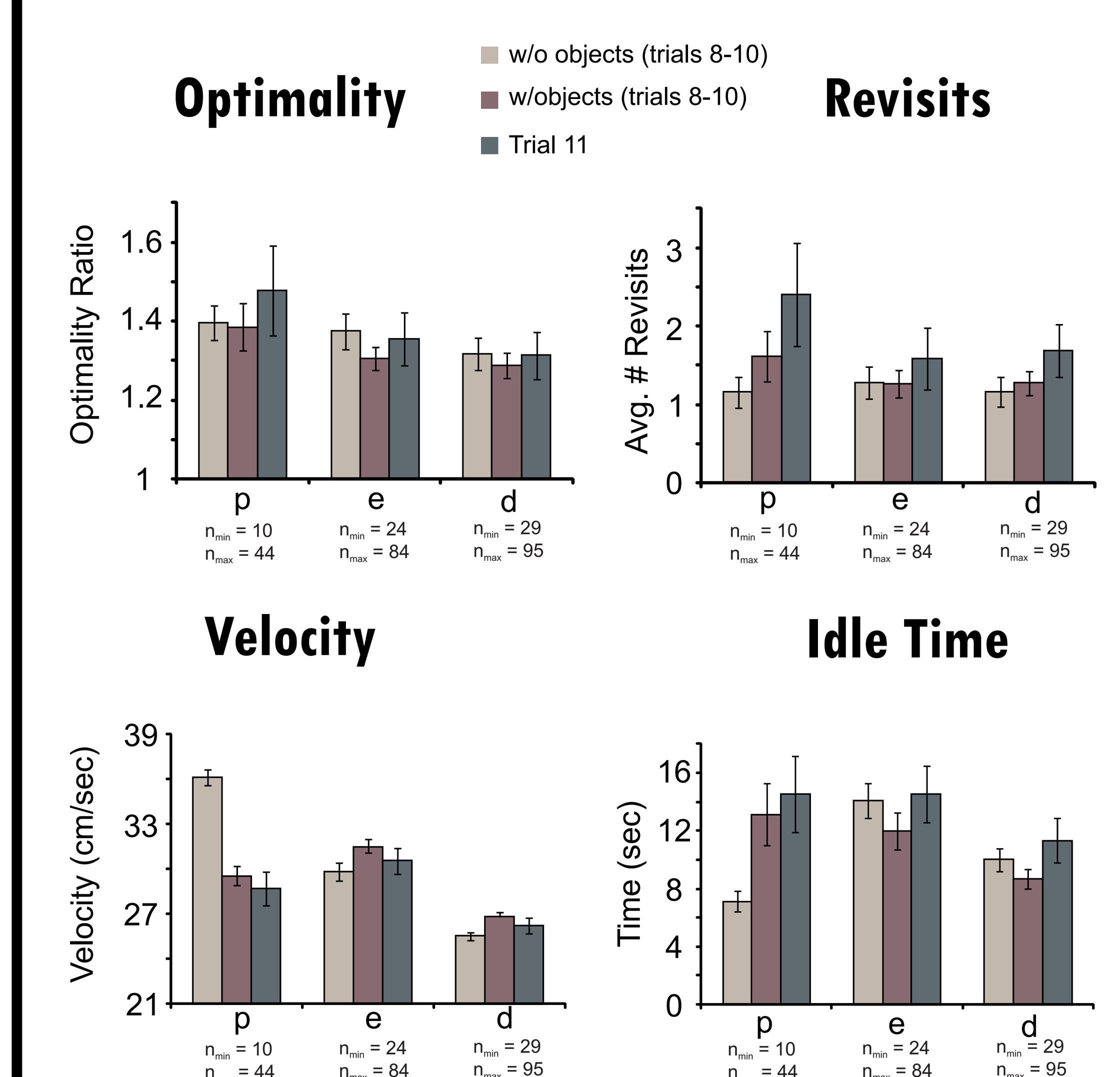
Velocity: Compared to female Brown Norways, males are faster without objects than with objects.



Idle Time: Compared to Long Evans, Brown Norways are less idle with objects than without objects.



Preliminary Estrous Cycle Results



CONCLUSIONS

- Female Brown Norways navigate more efficiently when object cues are available whereas males are more efficient without objects.
- Female Brown Norways have less revisits with objects whereas males and female Long Evans have less without. This could be explained by female rats displaying better object location memory [4].
- Female Brown Norways move faster with objects whereas males and female Long Evans are faster without.
- Brown Norways spend less total time completing the task with objects whereas Long Evans spend less time without.
- Together these results suggest that, in some cases, females can optimize using object cues whereas objects may interfere with optimization in males.

FUTURE DIRECTIONS

- More work is required to determine a possible role for the different phases of the estrous cycle.
- Objects have been shown to influence place field expression in the hippocampus of male rats [5], and running speed modulates cell assembly dynamics which are thought to generate short time scale predictions of future events [6].
- To our knowledge, electrophysiological studies of the hippocampus have not been performed in female rats in the context of a challenging spatial optimization task such as the TSP. This could give insights into the relative contributions of the Medial and Lateral entorhinal cortex.

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