



Competition in Female Rats: Dynamics and Stability

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Introduction

Social hierarchies are a fundamental aspect in the behavior of social animals, providing a framework through which animals organize group dynamics, communicate, reduce conflict, and allocate resources. In many species, from primates to rodents, these hierarchies can determine which individuals gain access to food, mates, and safe spaces.

Understanding how hierarchies form and sustain themselves may allow for the interpretation of broader patterns of social organization and can offer valuable insight into the importance of dominance and submissiveness across species, while also enabling the investigation of evolutionary parallels between animal and human behavior hierarchies. Previous research on male rats highlights the strong influence of social hierarchies on cognitive and motivational processes, with dominant individuals exhibiting a higher motivation for food rewards and lower levels of anxiety when compared to subordinate individuals, who face significant social stress (Barker et al., 2017).

This project aims to observe the establishment and persistence of social hierarchies among female rats.

We hypothesize:

- When the rats are placed into a competitive scenario, distinct roles of dominance and submission will become apparent across encounter sessions.
- Dominance profiles will remain consistent across distinct competitive contexts.
- The dominance/submission hierarchy will remain stable even over long periods of time (months).

Methods

Subjects: 10 Female F344 3m old rats at the start of the experiment. Each rat was paired with every other rat for at least 24 hours prior to performing the tasks.

Tower Competition Task



Figure 2: Tower apparatus in which food pellets were placed. Only one rat's head could fit at a time to feed (modified from Costa et al., 2021).

Tube Competition Task

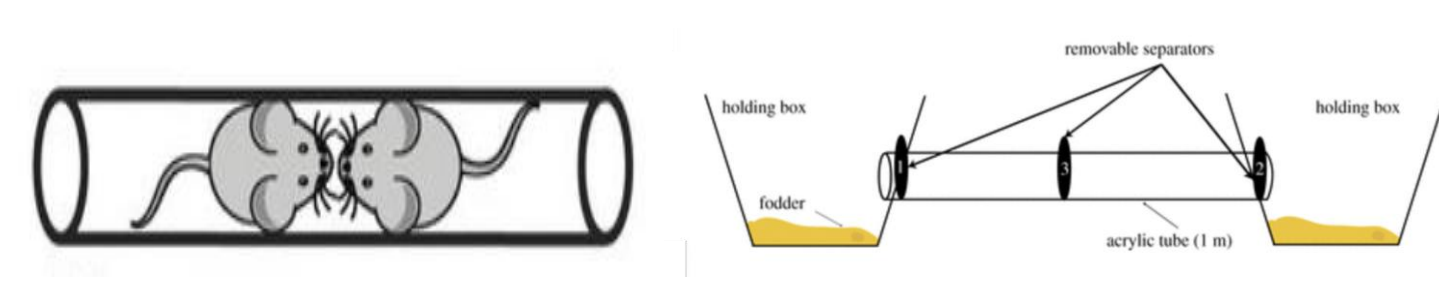


Figure 3: Schematic depiction of the passage competition apparatus. Two clear-sided holding cages are connected by an acrylic tube (~1 meter long). A removable middle barrier ensures synchronized trial starts (Lindzey et al. 1961).

Procedure: Restricted rats were first be introduced to a food cup with 3 pellets (BioServe, Frenchtown, NJ), access to the cup was through an opening with room for one "rat head". During testing, a pair of rats was placed in the chamber and which of the pair retrieved the pellets was recorded. Each rat was paired with the other 9 animals.

Procedure: Following the Food Competition task, rats were each placed in a holding box connected to a second box via a narrow tube. The tube only allowed the passage of a single animal. One rat was placed in each side, and the rat that pushes through to the other box was given a reward of chocolate sprinkles (UCONN Dairy Bar). Each rat was paired with the other 9 animals.

Water Maze

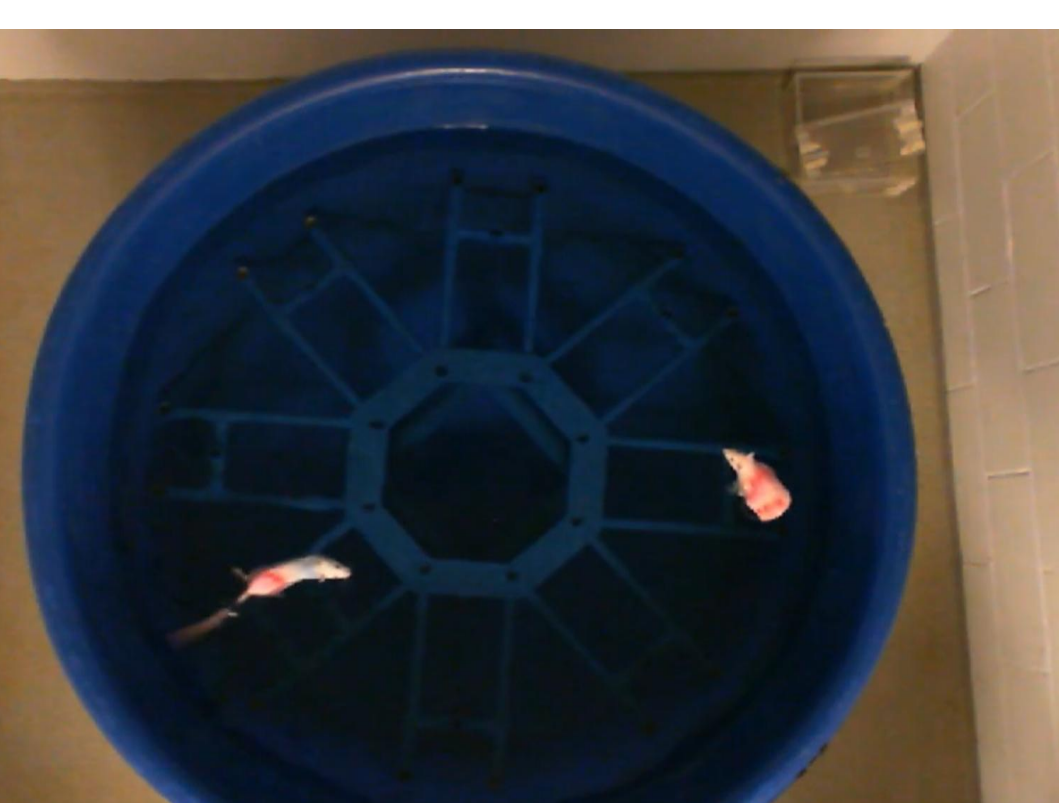


Figure 1: An example of dominance/submissive behavior during the water maze test, in which one rat is comfortably seated on the platform while the other maintains her distance.

Procedure: Visible platform in consistent location within the maze. Platform can only fit one rat at a time. After training rats singly to reach the platform in 10sec or less, each rat was paired with all other rats (n=9 pairings). After each test they were removed from the maze, dried and placed into a heated chamber. **Dominance:** Assessed 3 times per encounter: First rat on the platform, once again at 10sec and 20sec. Therefore, each encounter provided 3 assessments of dominance, and provided a score between 0 (no platform) and 1 (all 3 times on platform). **Competitive/Submissive Behavior:** In addition to the above assessment of dominance, experimenters noted the overall interaction between the pair. The interaction was coded as "competitive" if the rats engaged in continuous pushing/attempts to remove the rat on the platform. The interaction was dominant/submissive if the rat not on the platform did not attempt to remove the rat on the platform, but alternatively, remained in the water or hung off of the platform's side.

Timeline

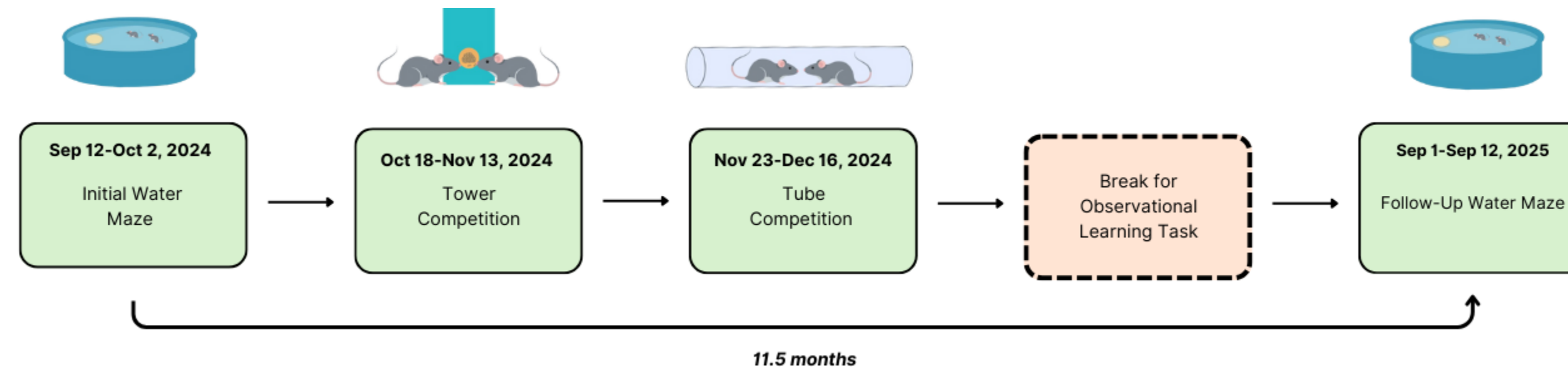


Figure 4: Schematic depicting the sequence of tasks. There was a break consisting of 8 months and 2 weeks between the tube competition and the follow-up water maze, during which the same subjects completed an observational learning task (see poster 64). The training for the follow-up water maze occurred approximately 11 months and 2 weeks apart from the initial water maze's training.

Results

Initial Water Maze

	day1	day2	day3	day4	day5	day6	day7	day8
129	4.3	6.0	6.0	2.3	1.0	2.7	1.0	2.0
130	3.7	3.0	2.0	2.3	1.0	2.7	1.0	2.0
131	1.7	2.7	2.3	1.3	4.3	5.7	4.0	2.7
132	3.0	3.3	4.3	5.7	4.7	4.0	4.7	7.0
133	5.7	4.7	3.7	4.7	3.3	3.7	1.7	3.3
134	5.3	4.3	3.3	4.3	4.7	5.7	6.3	6.0
135	5.3	1.7	3.0	5.0	4.3	3.0	5.0	3.0
136	6.3	6.3	4.7	4.3	3.7	3.7	3.3	3.0
137	4.7	6.0	6.7	7.0	8.3	6.7	7.7	6.3
138	5.7	6.7	7.0	3.0	3.0	5.0	4.7	6.0

Table 1: Average number of wins per day for each rat. Daily scores were calculated by summing the total number of wins across all three win categories: *First to Platform*, *After 10 Seconds*, and *After 20 Seconds*. Each win, regardless of category, was assigned a value of 0.33. Therefore, if a rat won in all three categories during a single encounter with another rat, the total score for that encounter was 1.0 (0.33 × 3). Because each rat encountered every other rat once per day (10 rats total → 9 encounters per rat), the maximum possible daily win score was 9.0. Higher scores (blue cells) indicate more dominant behavioral patterns, while lower scores (red cells) indicate more submissive interaction profiles.

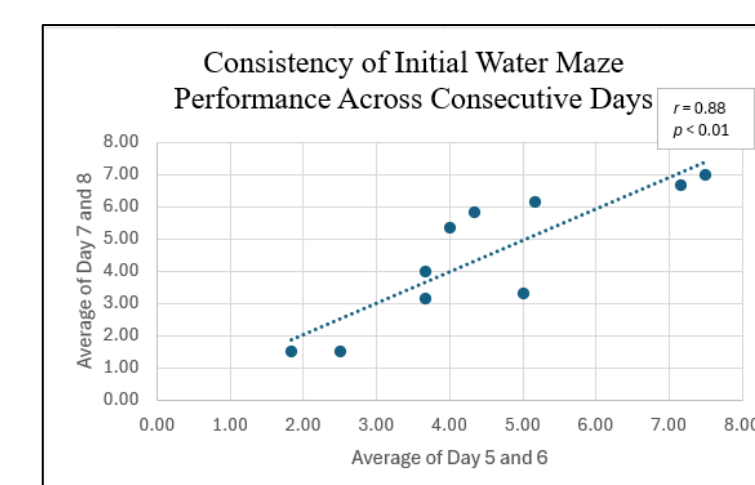


Figure 5: Consistency of initial water maze performance across consecutive days. Average Day 5 and 6 and Average Day 7 and performance showed a significant positive correlation, indicating stable individual performance across sessions ($r = 0.88, p < 0.01$).

Tower Competition

	day1	day2	day3	day4	day5	day6	day7	day8
130	2.0	2.0	0.0	2.5	5.0	4.0	1.0	7.0
131	7.0	8.0	5.0	7.0	5.0	7.0	7.0	7.0
132	2.0	5.0	3.0	2.0	3.0	4.0	3.0	2.0
133	5.0	1.0	4.0	8.0	3.0	6.0	7.0	6.0
134	6.0	6.0	7.0	4.0	7.0	4.0	4.0	4.0
135	2.0	4.0	6.0	4.0	3.0	6.0	5.0	3.0
136	3.0	1.0	3.0	1.0	0.0	0.0	3.0	0.0
137	2.0	4.0	6.0	5.0	4.0	2.0	3.0	3.0
138	7.0	5.0	2.0	3.0	3.0	4.0	3.0	4.0

Table 2: Average number of wins per rat across 8 days of food competition tasks. Win scores were determined by assigning a value of 1 to the rat that was first to consume the food in the tower during each encounter. Each rat faced every other rat once per day (10 rats total → 9 encounters per rat per day), resulting in a maximum possible daily win score of 9. Across the 8-day testing period, some rats (e.g., 131, 134) consistently achieved high win rates, indicating stable competitive dominance, whereas others (e.g., 136) displayed low or decreasing win frequencies. 129 was excluded from this task due to health-related issues that prevented participation.

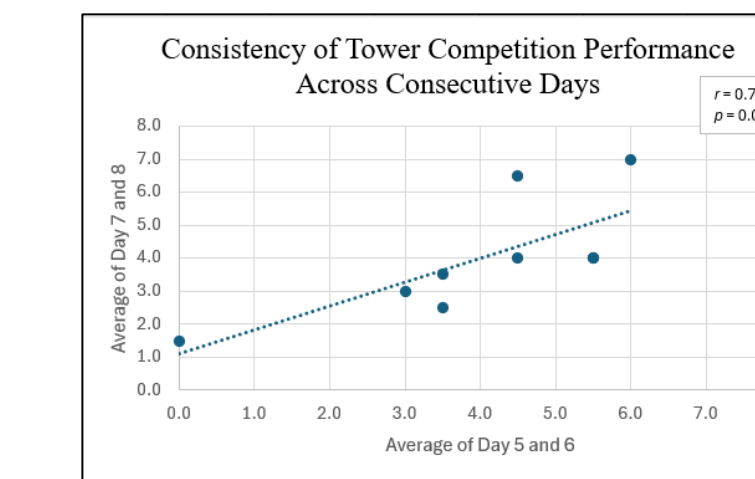


Figure 6: Consistency of tower competition performance across consecutive days. Average Day 5 and 6 and Average Day 7 and performance showed no significant correlation, suggesting unstable performance across sessions ($r = 0.32, p = 0.402$).

Tube Competition

	day1	day2	day3	day4	day5	day6	day7	day8
129	1.0	3.5	2.5	5.0	4.0	4.0	2.5	2.0
130	2.5	2.5	5.0	5.0	5.5	3.0	6.5	2.5
131	4.5	4.5	6.0	5.0	6.0	4.5	3.0	3.5
132	6.5	4.5	7.5	3.5	5.5	4.0	5.5	5.0
133	4.5	5.0	4.0	4.0	6.0	6.0	5.5	6.0
134	5.5	5.0	4.5	6.5	5.5	4.0	6.0	7.0
135	7.0	5.0	3.5	5.0	3.5	4.0	4.0	5.0
136	7.5	5.0	5.5	5.0	4.5	6.0	5.5	6.0
137	3.0	7.5	7.0	8.0	2.0	6.5	4.5	5.5
138	3.0	0.5	0.0	0.0	2.5	3.5	4.0	2.5

Figure 7: Frequency of the encounters on Day 1 and Day 8. A paired t test indicated a significant difference in mean tie frequency between Day 1 and Day 8, $t(44) = 2.93, p < 0.01$, with more ties occurring on Day 8.

Table 3: Average win scores for each rat across 8 testing days. Scoring same as Table 2, with each rat competing against all other rats. A score of 1.0 was assigned for a win (defined as rat pushing another back into its home cage), while a tie was coded as 0.5. Each rat encountered every other rat once per day (10 rats total → 9 encounters), yielding a maximum possible daily score of 9.0.

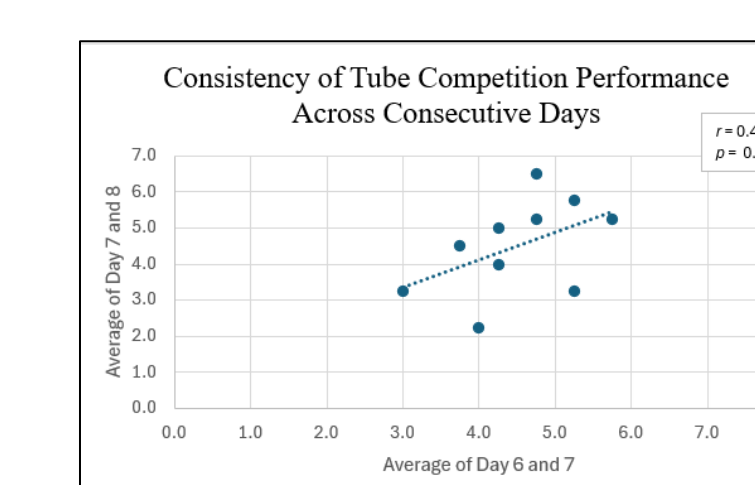


Figure 8: Consistency of passage competition performance across consecutive days. Average Day 6 and 7 and Average Day 7 and 8 performance showed no significant correlation, suggesting unstable performance across sessions ($r = 0.48, p = 0.15$).

Follow-Up Water Maze

	day1	day2	day3	day4	day5	day6	day7	day8
129	5.0	6.3	6.7	8.3	7.7	7.7	6.7	2.8
130	1.0	3.0	5.3	5.0	2.7	0.0	1.7	2.0
131	4.0	4.3	4.7	5.3	5.0	4.3	4.0	6.7
132	8.0	6.7	4.3	3.3	4.7	6.7	5.3	6.3
133	2.3	1.0	6.8	3.3	3.3	2.7	4.0	1.7
134	4.3	7.7	5.7	7.0	7.7	6.0	6.3	6.7
135	2.3	3.7	3.0	0.7	3.0	5.3	4.0	2.7
136	5.3	3.7	6.3	2.0	3.3	4.0	7.0	4.7
137	7.3	7.0	5.7	7.0	6.7	5.3	6.7	6.0
138	3.7	1.3	3.0	3.0	2.0	2.7	0.3	1.0

Table 4: The average number of wins per day for a given rat, calculated by combining the total counts of each win type (First to Platform, After 10 Seconds, After 20 Seconds). Higher scores, represented by bluer cells, indicate more dominant behavioral patterns, whereas lower scores, represented by redder cells, indicate more submissive interactions.

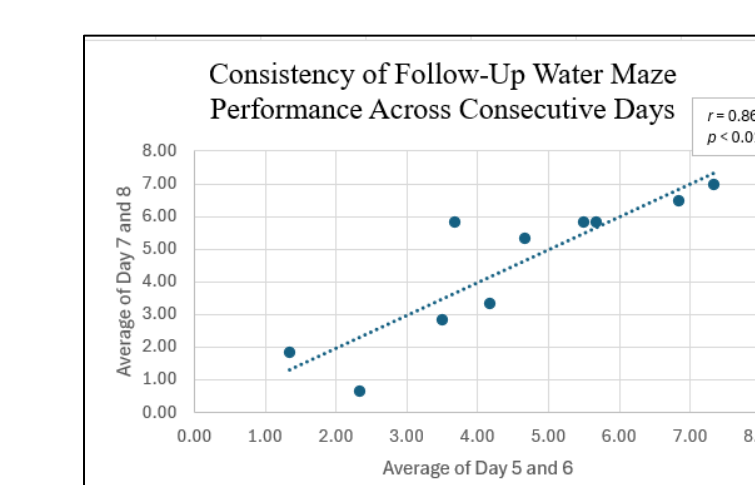


Figure 9: Consistency of follow-up water maze performance across consecutive days. Average Day 5 and 6 and Average Day 7 and 8 performance showed a positive correlation, indicating stable individual performance across sessions ($r = 0.86, p < 0.01$).

Comparing Dominance Stability In the Water Maze: Competitive Interactions

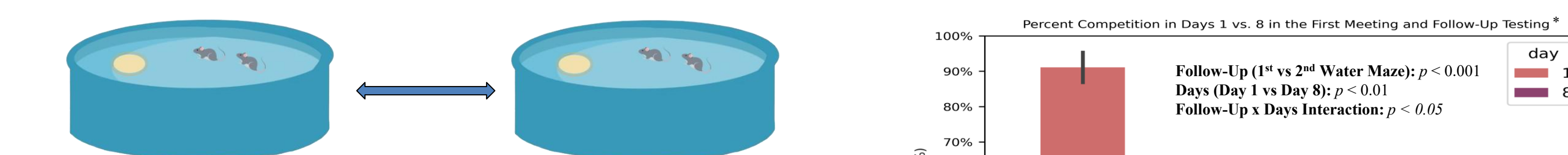


Figure 10: Histogram displaying the percentage of competitive interactions (out of 45 total trials) observed on **Initial Day 1**, **Initial Day 8**, **Follow-Up Day 1**, and **Follow-Up Day 8**. Following a Repeated Measures ANOVA, a significant main effect was found for time elapsed as a function of **follow-up** (Initial vs. Follow-Up) ($F(1,44) = 36.67, p < 0.001$) and **day** (day 1 vs 8) ($F(1,44) = 16.00, p < 0.01$). Additionally, a significant interaction effect was observed between **follow-up** and **day** ($F(1,44) = 6.53, p < 0.05$).

Cross-Task Correlations



Figure 11: Scatter plots depicting pairwise correlations between average win scores across four behavioral tasks: initial water maze (WM1), follow-up water maze (WM2), tower food competition, and tube competition. Six scatter plots are shown, each representing the relationship between two tasks. A significant positive correlation was observed between initial and follow-up water maze performance ($r = 0.73, p = 0.02$). All other task pairings were not statistically significant: Initial Water Maze (WM1) vs. Tower ($r = -0.21, p = 0.60$), Tube vs. Initial Water Maze ($r = -0.25, p = 0.49$), Follow-up Water Maze (WM2) vs. Tower ($r = -0.09, p = 0.82$), Tube vs. Tower ($r = -0.16, p = 0.67$), and Tube vs. Follow-up Water Maze ($r = -0.09, p = 0.82$).

Summary and Discussion

- Social hierarchy in female rats was examined used 3 different types of tasks: water maze; food competition and passage competition.
- The water maze and tower tasks showed more reliable results than the tube task.
- In the tube task there was an increase in cooperative behavior with experience.
- In the water maze after the initial encounter, there was a tendency for some animals to show an overall dominance or submissive profile.
- Competition showed a significant decline over time, both across days and between the initial and follow-up water maze (11.5 month interval).
- Dominance expressed in food-motivated tasks may differ from dominance expressed in aversive tasks like the water maze.

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