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Several studies showed sex differences in spatial ability in the Morris water maze. Most often there was a "superiority" of males (Jonasson, 2005; Blokland et al., 2006; Forcano et al., 2009; Roof et al., 1999), however this was not systematic, depending mostly on specific experimental conditions influencing male and female performance (Faraji et al., 2010; Jonasson, 2005; Blokland et

al., 2006; Forcano et al., 2009; Roof et al., 1999) such as pre-training, cue type and/or position, etc. In the present study we analysed spatial navigation abilities in adult male and female Wistar rats in the Morris Water maze to better qualify and contrast possible strategies used by both sexes. Several observations showed that males and females rely on different cues to solve spatial problems.

One commonly accepted generalization is that females depend more closely on configurations of proximal cues (i.e., directly explored objects) than on distant relational cues. According to the parallel map theory (Jacobs & Schenk, 2003), we hypothesise that males rely more heavily on directional bearing maps and females on sketch maps.

## SPATIAL NAVIGATION: THE PARALLEL MAP THEORY

When navigating, information of different nature are used to build an integrated cognitive map:

- **Directional cues** polarize the environment rather than identifying specific positions. Too distant to provide accurate positional information, they can nonetheless provide accurate directions and are integrated in a *Bearing Map*.
- **Positional landmarks**, defined by local objects, allow localisation from the relative distances and positions within an array. This arrangement of positional cues are the basis of *Sketch Maps*.

The *bearing map* allows to maintain a representation of its position even in unknown territory and over long-distance navigation but doesn't provide accurate positional information, while the *sketch map* allows accurate localisation, but no extrapolation or generalization across novel terrain.

In the Water Maze, different indicators of spatial memory can be measured:

- The precision or accuracy, conveyed by the time spent in the exact training zone.
- The performance, conveyed by the time spent to reach the escape hidden platform.

We consider that accuracy might reflect sketch map discrimination, while escape performance might depend on bearing map.

## WORKING HYPOTHESIS

We hypothesise that males rely more on bearing maps, while females rely on sketch maps. However, we do not know how different environmental conditions affect specific map components.

When the complete visual panorama is available, both strategies are expected to provide accurate spatial navigation. But when visual information is partially or totally restricted, will female-like strategy or male-like strategy be supported? Or in other terms can we expect a dominance of male-like bearing maps in an impoverished environment?

## CONCLUSION

Three main observations resulted from these different conditions:

- A higher weight of sketch map allows animals to accurately localise the platform position, an observation confirmed by a better performance of female in probe trials
- Bearing map allow platform localisation nonetheless with less accuracy as observed in male probe trials
- When a rich visual panorama is available, sketch and bearing strategies are efficient, but when access to visual environment is totally restricted, only male-like strategy allowed effective navigation. We consider that this capacity is conditioned to a pretraining familiarization with directional information (i.e., pretraining in the complete panorama)

## Materials and method

### Subjects

#### WIS rats

A total of 34 naive Wistar Han rats (15 male, 19 female) were used in the different experiments. 1st Group: 10 male and 10 female from PND 95-102 until PND 120-127 were trained successively in experiment 1 (1st condition), experiment 2 (1st, 2nd and 3rd condition) and experiment 3 (1st

condition) 2nd Group: 5 male and 9 female were tested at 15 month in experiment 1 (1st and 2nd condition). 3rd Group: 7 male and 6 female were tested at 7 month in experiment 3 (1st and 2nd condition).

#### ODS

A total of 14 ODS naive mutant rats (7 Female and 7 Male) (ODS: lacking ascorbic acid synthesis) rats were used in experiment 1 (1st and 2nd condition). All rats were tested when adult.

#### Water maze

A 160 cm diameter grey water tank with a 14 cm diameter transparent plexiglass escape platform (1 cm below the water surface). Water (25 ± 1 °C) was opacified by 0.5 l of milk. The same water maze was used in the three experiments.

## Experiment 1

### Classical place learning – Open view Procedure

- 1st condition:**
- Training in a classical water maze task – place only, unique escape location.
  - Seven or three daily sessions of 4 trials
  - Discrimination of the training zone assessed by a first probe trial occurring directly after the last session



- 2nd condition:**
- Delayed match to sample (DMTS) with a daily changed platform position.
  - Working memory version of the Morris water maze
  - Four daily session of 4 trials, starting with a probe trial



### Acquisition

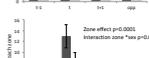
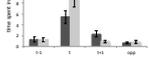
#### WIS 1st group



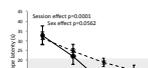
#### WIS 2nd group



#### ODS



### DMTS



When the whole visual panorama is available

- No sex differences were observed in acquisition latency.
- Performances in place discrimination were not consistent. Male WIS rats were slightly impaired in the 1st group while the contrary occurred in the 2nd group. Furthermore, ODS rats did not show sex differences.
- In delayed match-to-sample design both sexes of WIS and ODS rats expressed similar retention of the new position.
- Female WIS were slightly slower to reach the platform in comparison to WIS male, but no sex differences were found in ODS group.

## Experiment 2

### Restricted panorama - Procedure

- 1st condition:**
- **Restricted panorama design**
  - Pool surrounded by three curtains with different « Opening » orientation for each daily session
  - Same familiar escape location learned previously in a classical place learning (see experiment1)
  - Four daily sessions of 4 trials followed by 1 PT



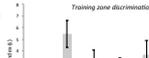
- 2nd condition:**
- **Full access to testing room panorama**
  - Same familiar escape location
  - One session of 4 trials followed by 1 PT



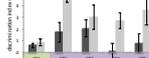
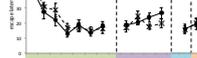
- 3rd condition:**
- **Pool completely surrounded by curtains**
  - Same familiar escape location
  - One session of 4 trials followed by 1 PT



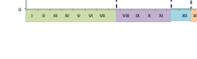
#### WIS 1st group



#### WIS 2nd group



#### WIS 3rd group



When visual cue availability was reduced with stability partially preserved

- Males were generally impaired in spatial discrimination in comparison to females but had no significant impairment in escape latency.
  - Females showed preserved performances in spatial discrimination (training zone discrimination index) despite partial masking
- When the whole visual panorama was restored
- No differences were observed both in escape latency and in place discrimination.

When the whole visual panorama was totally restricted

- Females did not discriminate anymore the training zone. Males were not apparently affected.

## Experiment 3

### Controlled environment - Procedure

- 1st condition:**
- **Controlled environment**
  - Pool completely surrounded by curtains
  - Proximal cues (ball+triangle)
  - Three or 7 sessions of 4 trials followed by a PT

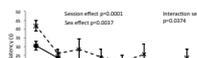


- 2nd condition:**
- **Full access to testing room panorama**
  - Same escape location
  - Two daily sessions of 4 trials including 1 PT

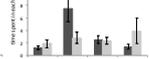
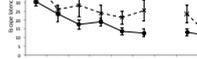


### Limited number of cues

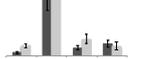
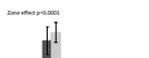
#### WIS 3rd group



#### WIS 1st group



### Full access to testing room panorama



When landmarks were restricted to proximal salient visual cues

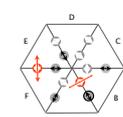
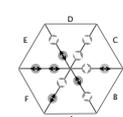
- When rats were naive, females were slower to reach the platform and severely impaired in spatial discrimination (3rd group).
- When rats had previous experiences in the water maze, no sex difference was observed

When the whole visual panorama was again available

- For naive rats, the capacity of female in reaching the platform and in spatial discrimination was restored to male level

## Experiment 4

### Compartmented arena - Procedure



- 1st condition:**
- Three sessions of 5 minutes habituation
  - Free exploration of the six compartments connected by one, two or no doors

- 2nd condition:**
- Changes in the configuration of two walls through the opening of the inversion of doors
  - Free exploration
  - One session

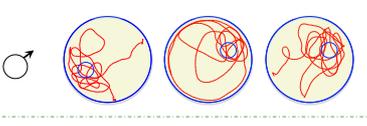
#### WIS 1st group



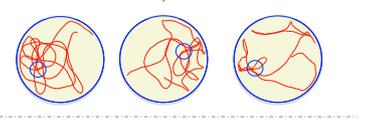
#### Globally:

- Females were more active than males.
- No habituation was observed as a reduction in exploration over sessions 1-3
- Both groups showed increased activity in session IV following connection change

### PT2 – 1st session partially curtained



### PT7 – totally curtained



Qualitative differences in swimming throughout the platform position account for the differences in time spent in this area by males and females

A marked concentration of swimming through the training area is evident in males in spite of the complete masking of the visual panorama