An Investigation of Path Integration: Humans in a Maze

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Path integration (PI) is navigation done without the help of landmarks.

The successive positions in relation to a starting-point are known by taking account of the lengths and directions of each of the segments of displacement.

The vector to the starting-point is the inverse of the vector compacting the various segments.

Lengths and directions are calculated with the help of external and internal information.
Studies of PI

- with blind or blindfolded participants (e.g., Loomis et al., 1993)
  - sight is, per definition, precluded

- in virtual reality (e.g., Riecke et al., 2002)
  - situation is not natural
  - proprioception and vestibular stimulation are precluded

- in natural settings (e.g., Sholl et al., 2000)
  - environment is not controlled
  - path cannot be varied
Our study

→ in a maze

+ all senses can be used
+ paths can be varied
+ environment is controlled
- only point-to-origin task
Issue of the study

Is human PI realised within an egocentric or allocentric coordinate system?

If PI is carried out in an allocentric reference system, the direction of each segment is necessarily anchored to a reference (allocentric) direction.

If PI is carried out in an egocentric reference system, the direction of every new segment is referenced to the previous segment.
Issue of the study

Basis of reflection:

If PI is carried out in an allocentric reference system, then a reference direction given at the beginning of trajectory (= allocentric direction) should be easy to recover at the end of trajectory (as easy or easier than doing PI).

If this is not the case, that is, if the recovering of a reference direction is difficult (more difficult than doing PI), it precludes that PI is carried out with its help. If so, one can suppose that PI is carried out in an egocentric reference system.
Issue of the study

In order to determine what holds true for humans, we designed an experiment composed of two tasks:

**Task DR (Direction Recovering):** at the end of a trajectory, participants must recover a reference direction (= allocentric direction) given at the beginning of trajectory.

**Task PI:** at the end of a trajectory, participants must point to origin.

Results in DR and PI are compared.

→ Which task is easier?

→ Is the *same* task easier for women and men?
Participants

48 participants (28 women and 20 men)
Mean age: 28 years (ranging from 19 to 56, $SD = 8$)
The Maze

Surface on floor: 5.70 x 3.50 m

Height: 2 m

Width of corridors: 0.63 m

Ceiling (closed-up envir.); lit from inside

3 entry/exit spaces (curtained, with 2 slits)

Mobile double-panel shuts off one arm
When one arm is shut off, the remaining arms produce 3 submazes (AB, AC, BC).

3 Submazes in 2 directions $\Rightarrow$ 6 paths.
The tasks

**DR:** Participants see a large orange arrow on the floor of the entry-space (called “north”); when arriving in the exit-space, they have to point in the same (i.e., parallel) direction.

**PI:** Participants see a large orange circle on the floor of the entry-space; when arriving in the exit-space, they have to point towards this circle.
Experimental design

Participants made 3 trials with task DR, then 3 trials with task PI (or vice versa); each trial was done with another path.

Paths were maximally varied. For example: Task DR → AB, CA, BC / Task PI → AC, BA, CB.

Order of tasks and order of paths were counterbalanced.
Upon arriving in the exit-space, participants had to point towards “north” in task DR and towards the starting-point in task PI.

The dependent measure was the pointing error.

In the exit-space, participants were filmed from above.

Example:
The red arrow represents the correct direction; the participant points with an angular error of -30°.
Procedure

The first task (DR or PI) was explained to participants in an adjacent room (they could not see the maze).

Participants were blindfolded and led along a circuitous route to the entry-space. Once in the entry-space, they removed their blindfold. Task was explained again; participants performed the task...

... procedure was the same for the second task.
Task PI on path AC (24 trials)
General Results

Signed errors for tasks DR and PI (all paths considered together):

Individual responses = radial lines
(For each task, 3 responses per participant).

The long arrows stand for the correct directions, and the open arrows show the mean vectors.

**DR:** mean direction = $0.9^\circ$; vector length = $0.61$;
**PI:** mean direction = $-8.9^\circ$; vector length = $0.75$;

Directional bias is stronger in PI than in DR. There is more scatter in DR than in PI.
Results: gender differences

Task: $F(1,46) = 2.14$  \( p = .15 \)

Gender: $F(1,46) = 7.20$  \( p = .01 \)

Task*Gender: $F(1,46) = 1.45$  \( p = .23 \)

Task(Women): $F(1,27) = 4.49$  \( p = .04 \)
Discussion

The basis of reflection:
If PI is carried out in an allocentric reference system, then task DR will give rise to smaller errors (or, at least, not larger errors) than PI.
If this is not the case, i.e., if DR gives rise to larger errors than PI, it precludes that PI is carried out in an allocentric reference system and it indicates that PI is carried out in an egocentric reference system.

Results:
Men: difficulty DR = PI
Women: difficulty DR > PI
**Discussion**

**Men: difficulty DR = PI**

The pattern of results indicates that, for men, PI could be carried out in an allocentric reference frame: Errors in DR are not larger than errors in PI, so the ability to do DR (using a reference direction) could be the core capacity upon which PI rests.

**Women: difficulty DR > PI**

In contrast, women made more errors in DR than in PI. So, for women (at least, for some women), doing DR cannot be the core capacity that is used to carry out PI. So women (at least, some women) do certainly not use an allocentric reference frame when carrying out PI.
Thank you!

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