Dependence on path integration and landmarks when learning a new environment

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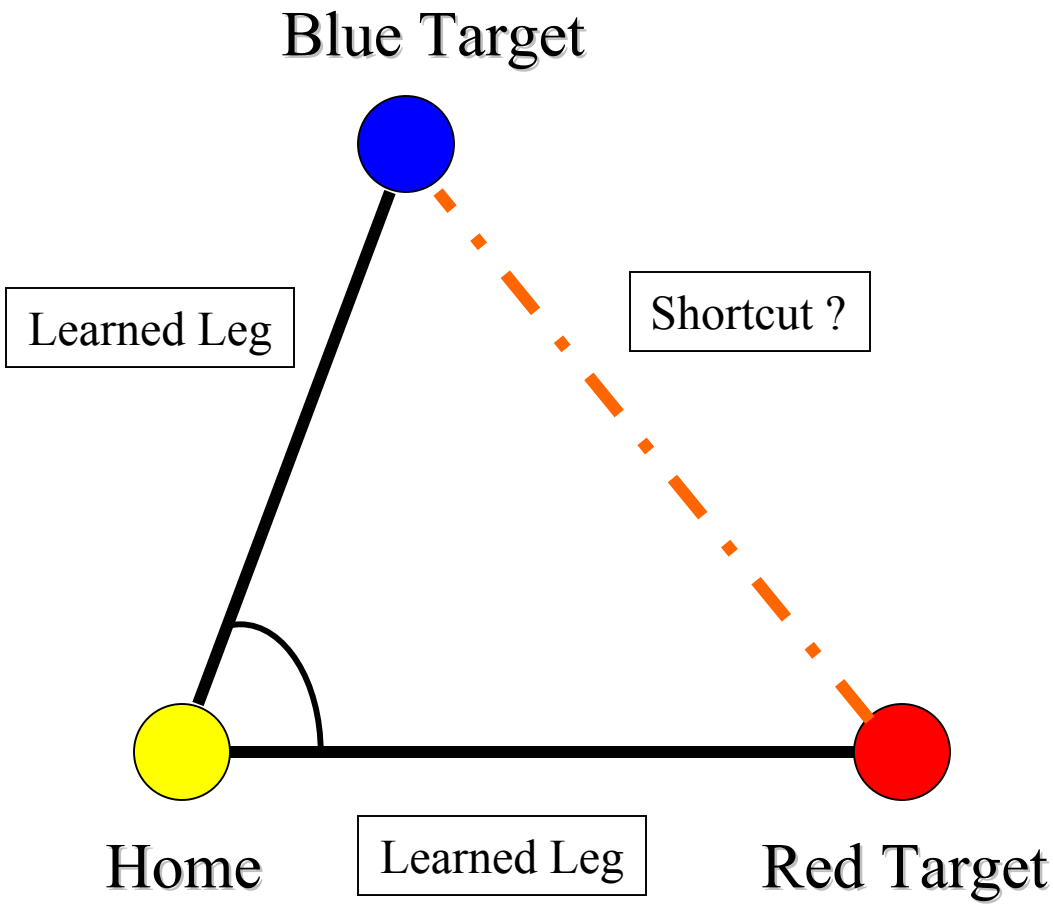
How do humans learn new environments from known routes?

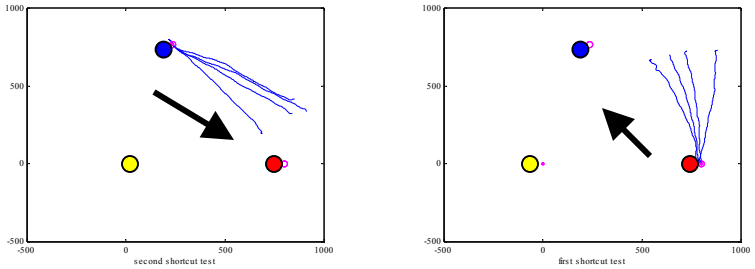


- The vector subtraction task requires rich spatial knowledge (more complex than topological geometry)

- Subjects learn the legs, then are tested on the direct, novel, shortcut

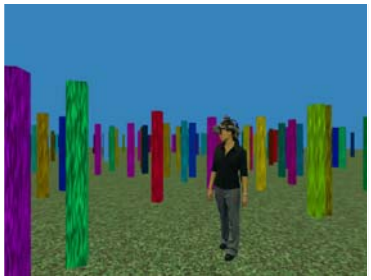
Humans use landmarks to perform novel shortcuts (Foo et al., 2001a)

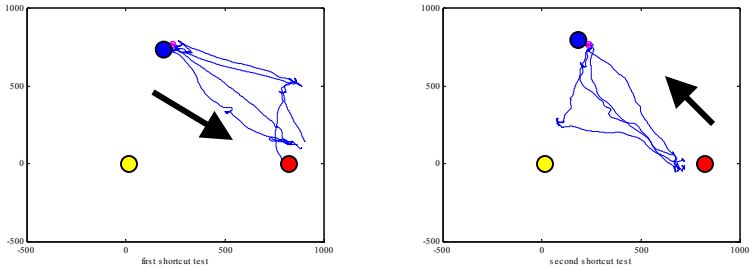
Path Integration



Poor shortcut performance

Landmarks

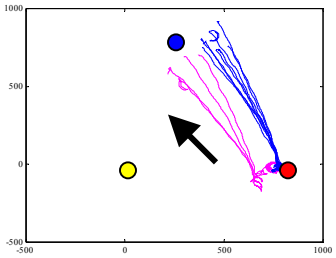




Successful shortcut completion

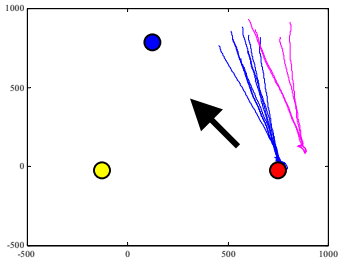
Humans follow perturbed landmarks completely (Foo et al., 2001b)

Landmarks at Start



Left Shift

Normal

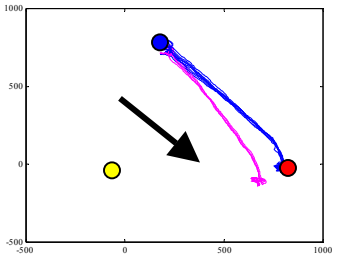


Right Shift

Normal

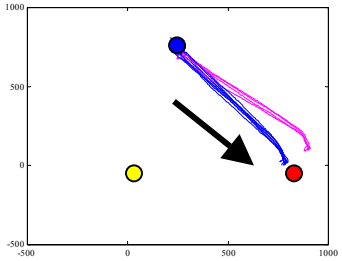
Improved initial orientation

Landmarks at Target



Left Shift

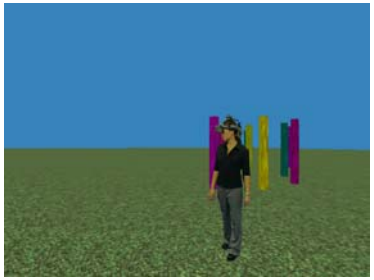
Normal

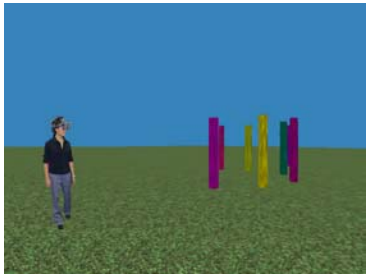


Right Shift

Normal

Subjects use landmarks throughout





Motivation

Other results (Kearns et al., 2002, Aginsky et al., 2001) suggest that humans follow path integration and visual landmarks equally during virtual navigation tasks that do not include learning sessions.

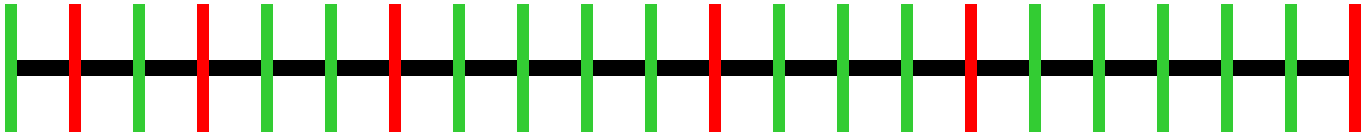
Do humans, like ants (Collett, et al., 1999), first rely on path integration, then shift to landmarks when learning a new environment?

Method

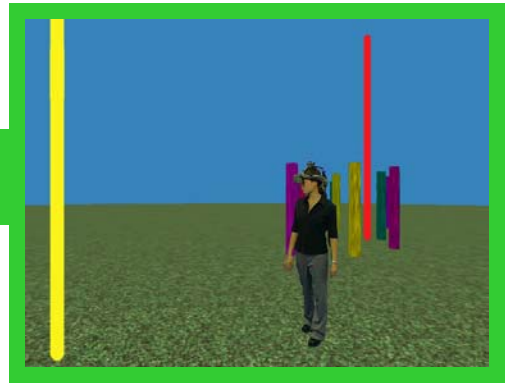
24 participants

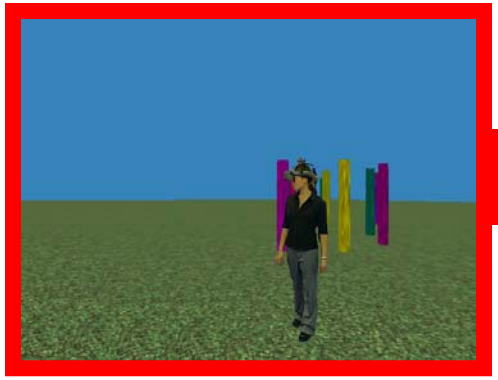
2 paths (toward landmarks, away from landmarks) x 3 conditions (control, translate, rotate) x 6 learning trials

Trial number: 1 2 3 4 …



Training





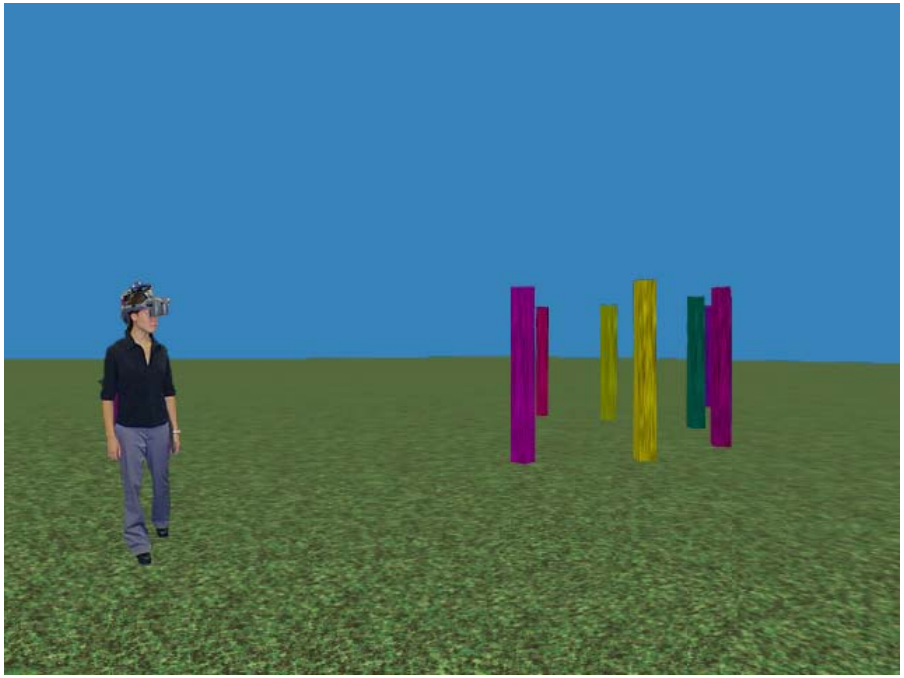
Test

VENLab

Sonic/inertial tracker

HMD (80 deg FOV)

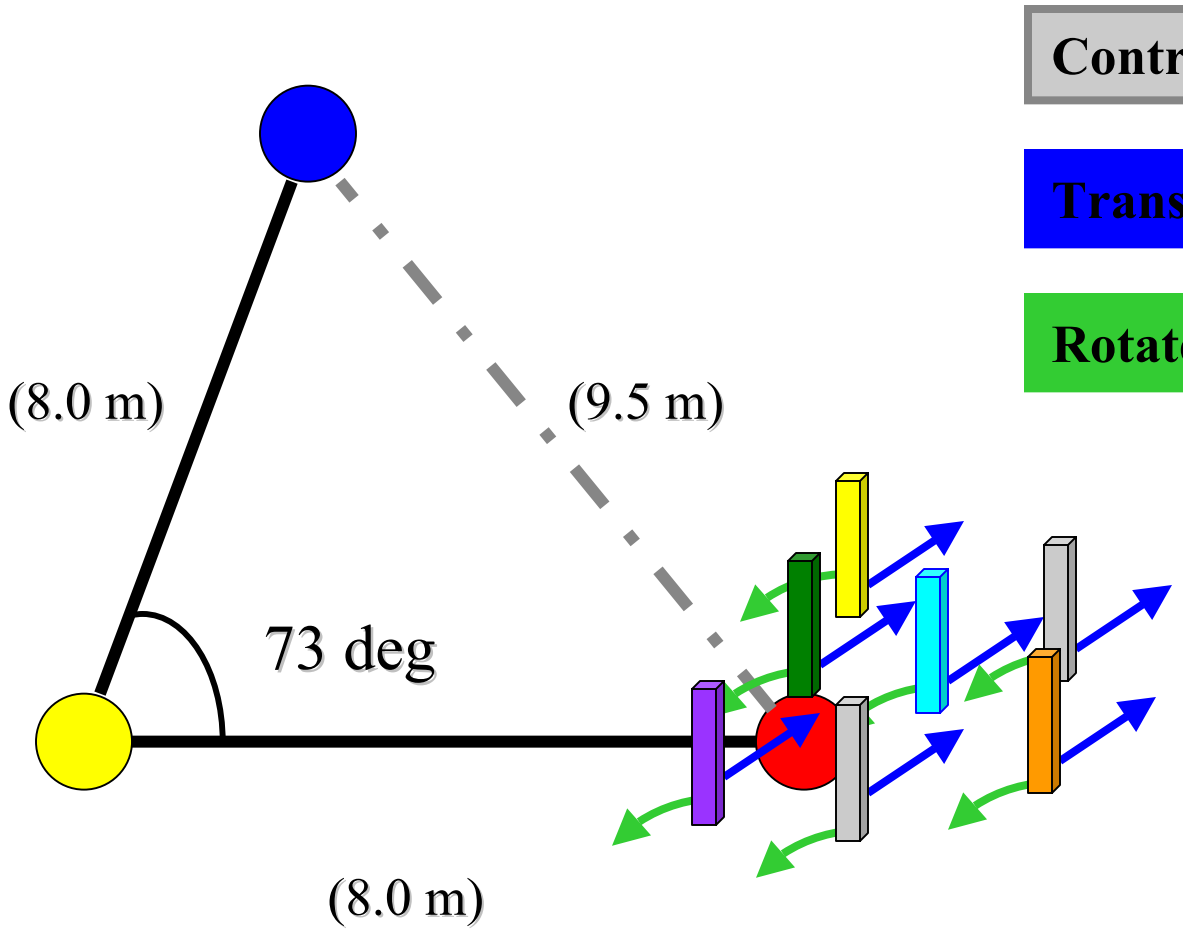
Virtual Environment



Position & orientation recorded at 60 Hz

12m X 12m Walking Area

Conditions



Dependent Measures

I. Start of Trial

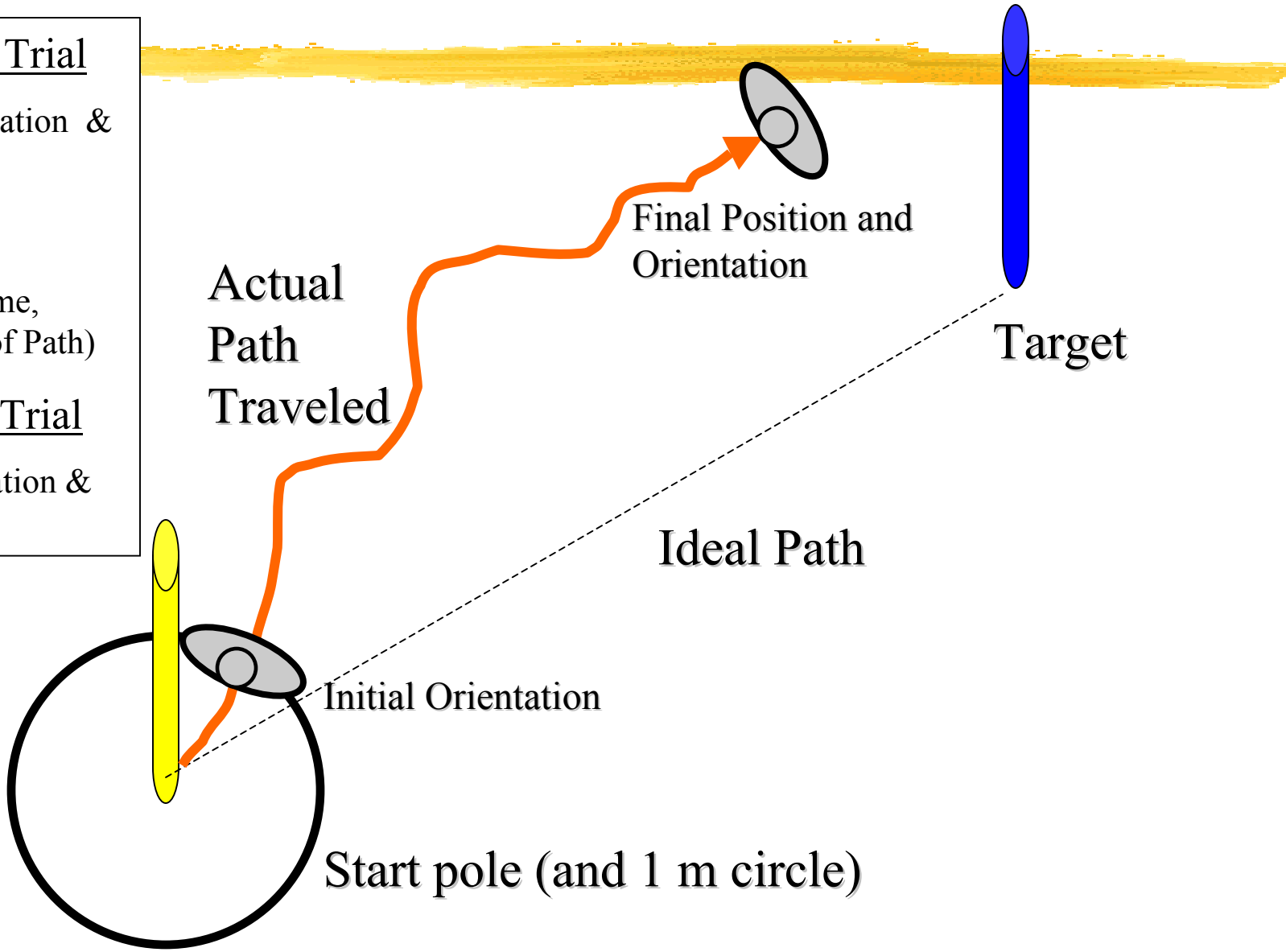
(Initial Orientation & Look Time)

II. Travel

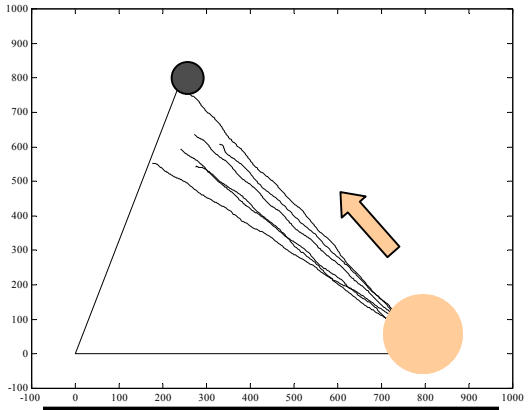
(Distance, Time, Straightness of Path)

III. End of Trial

(Final Orientation & Position)



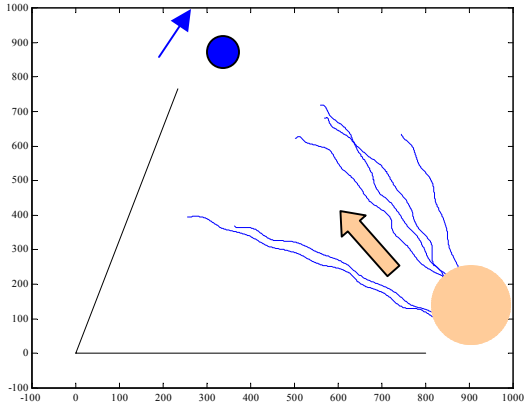
Sample Learning Trials: Landmarks at Start



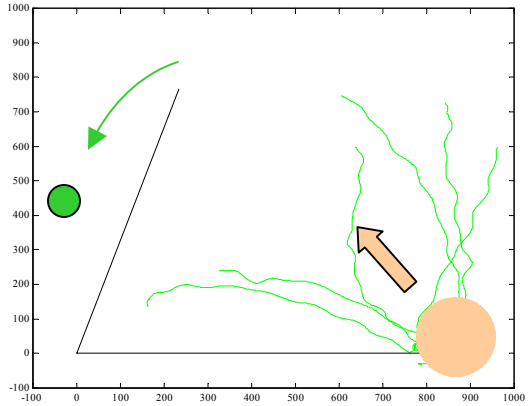
Control

landmarks

- Subjects hesitated more and walked slower on the first test trial, $p < .01$
- Otherwise, no systematic changes with learning, $p > .05$

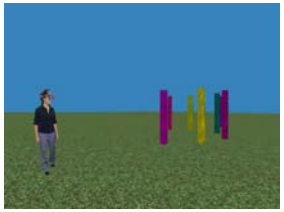


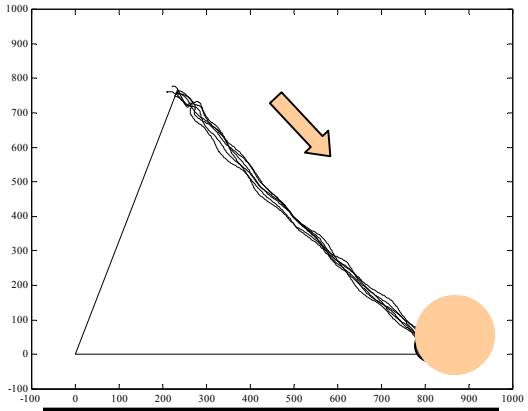
Translated



Rotated

Sample Learning Trials: Landmarks at Target

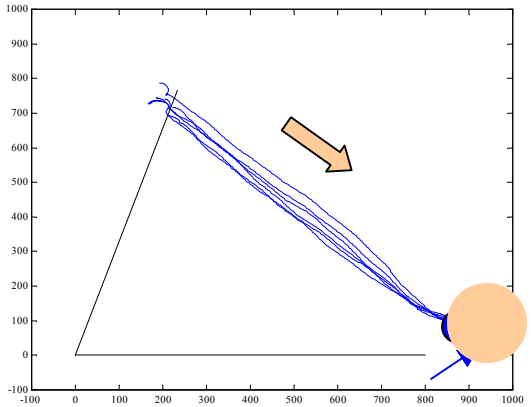




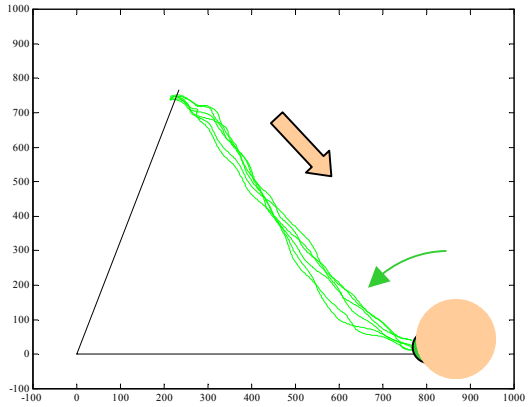
Control

landmarks

- Subjects perform so accurately that no systematic changes were observed across learning trials, $p > .05$

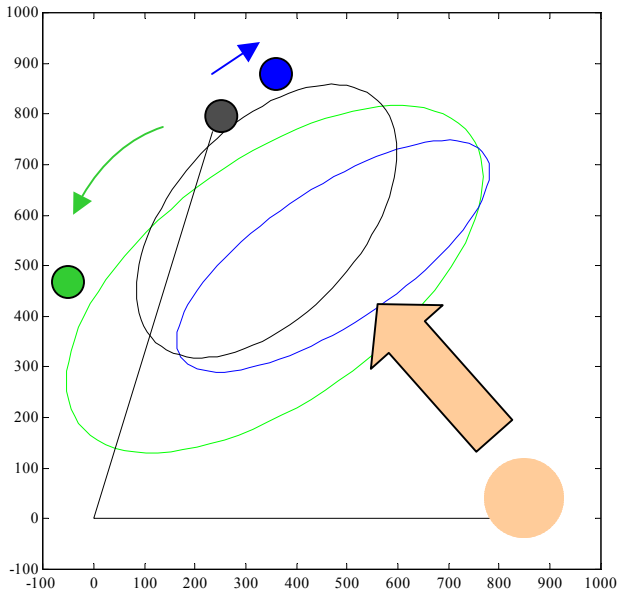


Translated



Rotated

Final Position: Landmarks at Start



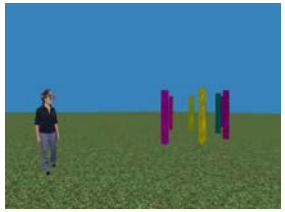
95% Confidence Ellipses

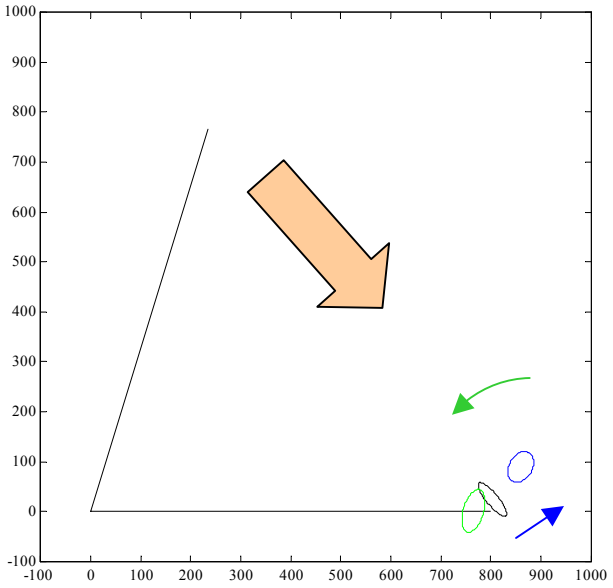
landmarks

Subjects are not sensitive to the rotated or translated visual landmarks, $p > .05$

Instead, subjects use a path integration strategy to navigate

Final Position: Landmarks at Target





95% Confidence Ellipses

landmarks

Subjects are extremely sensitive to the rotated and translated landmarks, consistent with a visual landmark based strategy, $p < .01$

Subjects perform exceptionally well. Mean initial error is 4 deg, and subjects walk to within 50 cm of shifted targets, $p < .03$

Conclusions

- When landmarks surround the start position, humans rely on path integration to perform metric navigation
- When landmarks surround the target position, they dominate navigation behavior, acting as beacons
- Unlike ants, humans do not switch between strategies as they learn (Collett et al., 1999)
- When given the choice, humans consistently use the simpler place-recognition-triggered response, instead of metric navigation (see Trullier & Berthoz, 1996).

Acknowledgements

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http://www.cog.brown.edu/Research/ven_lab/