Landmarks are Used to Perform Shortcuts During Navigation

P. Foo, W. H. Warren, Jr. & M. Tarr

Department of Cognitive and Linguistic Sciences
Brown University
Do humans integrate routes into a "cognitive map"?

The layout of an environment must be learned from experience with particular routes.

Does path integration serve to link environmental locations together into a metric "cognitive map," thus enabling new short-cuts?

Dyer (1991) found that this was not the case in honeybees, who depend on global visual landmarks to find a shortcut between known locations. Can humans do any better?
Virtual Environment (VENLab)

- SGI Onyx 2
  - 2 VGA Signals
  - L-R Audio
  - Position, Orientation

- sonic beacons
- inertial unit & mics
- HMD: LCDs & earphones

(12m X 12m Walking Area)
Conditions

Ground Plane Only  Colored Poles

Training

Testing
Dependent Measures

I. Start of Trial
   (Initial Orientation & Look Time)

II. Travel
   (Distance, Straightness of Path)

III. End of Trial
     (Final Orientation & Position)
Can humans combine their known routes to perform a short-cut task, or will they require landmarks like honeybees?

I. Train 16 subjects on legs
II. Test leg and shortcut performance
III. Compare ground alone with colored poles
Example Paths

**Ground Plane Only**

- First leg test
- Second leg test

**Colored Poles**

- First shortcut test
- Second shortcut test

Increasing variability as trials progress

Decreasing variability at trial end
Results: Start of Trial

Subjects in the Colored Pole Condition left the start position demonstrating less error magnitudes than those subjects in the Ground Plane Only Condition ($p < 0.01$).

No Significant Differences for Look Time, $p > 0.05$.

Note: Error bars represent standard error (SE) in all plots.
Results: Travel

All Subjects undershot the required target distances with the exception of subjects in the Colored Pole/Shortcut condition, $p < 0.01$.

No differences for straightness of path between the conditions, $p > 0.05$. 

![Travel Distance Graph](image)
Results: End of Trial

Final Position

Subjects in the Colored Poles Condition arrived on target accurately while those in the Ground Plane/Leg erred more, and Ground Plane/Shortcut erred most, $p < 0.01$.

![Error Distance (cm) Graph](image)

Final Orientation

Subjects in the Colored Pole Condition demonstrated better final orientation than those subjects in the Ground Plane Only Condition, $p < 0.01$.

![Error Angle (deg) Graph](image)
Conclusions

Subjects do not seem to build up an accurate metric “cognitive map” from path integration, rather they rely on landmarks when available.

• Subjects in Ground Plane Only conditions demonstrate initial orientation errors that increase in magnitude across the length of the trial, and large final position errors consistent with theories of path integration.

• The addition of local landmarks (Colored Pole conditions) help reduce initial errors, and appear to help subjects successfully home in on the final target.
Experiment II

Can we show direct evidence that local landmarks are guiding navigation?

I. Train 12 subjects on legs (e.g., Home-Red, Home-Blue)
II. Test normal shortcut performance (e.g., Red Blue)
III. Probe trials (poles shifted 1.5m left or right)
Example Paths

Away from Landmarks

- Left Shift
  - Normal

- Right Shift
  - Normal

Toward Landmarks

- Left Shift
  - Normal

- Right Shift
  - Normal

Increasing variability as subjects travel away from landmarks

Low variability at trial end for targets w/landmarks.

Subjects shift to follow the landmarks regardless of direction
Results: Start of Trial

Subjects traveling towards the local landmarks demonstrated less angle error than those subjects traveling away from landmarks, $p < 0.01$.

In addition, those same subjects (towards the landmarks) hesitated less before leaving the start position, $p < 0.01$. 
Results: Travel

**Travel Distance**

Subjects traveling towards the landmarks walked the correct distance while their counterparts undershot the **required target distance**, $p < 0.01$.

**Straightness of Path**

Subjects walking towards the landmarks also traveled a more direct path ($p < 0.01$).
Results: End of Trial

Final Position

Subjects traveling towards the landmarks that were not shifted completed the task closer to the target \((p < 0.01)\), and pointed in the right direction \((p < 0.01)\), better than any of the subjects travelling away from the landmarks.

Final Orientation

Those subjects in the perturbed conditions were pulled to the shifted landmark position both in position and orientation, \(p < 0.01\).
Conclusions

We show direct evidence that subjects use local landmarks to modify final orientation and position as well as initial orientation and travel towards the target.

Humans appear to:

1.) Ballpark the initial target position and orientation

2.) If global landmarks are present, use them to estimate the initial orientation

3.) When close to the target, subjects home in using local landmarks if available.