An ideal navigator model of human wayfinding: Learning one's way around a new town

Jeremy R. Manning*, Michael J. Kahana*, and Robert Sekuler**

*University of Pennsylvania, **Brandeis University

I. Approach

- We study goal-directed wayfinding in humans using a virtual reality (VR) taxicab driving task.

Figure 1. Screen capture of VR taxicab task. Subjects deliver passengers to stores in the virtual town. **Butcher Shop**, one such store, is shown, along with several office buildings. Deliveries are never made to office buildings.

- We developed an **ideal navigator** as a performance benchmark
- We degrade the ideal navigator's **vision** and **cognitive map** (memory) modules to estimate:
  - how much information subjects **acquire** and **retain**
  - the state of the subject's **cognitive map**
  - how quickly subjects will **learn** to generate efficient delivery paths in novel VR environments

II. Ideal navigator

- The ideal navigator (i) sees and (ii) permanently stores everything on screen. It (iii) makes efficient use of stored information.
- Algorithm (executed when passenger is picked up):

  COGNITIVE MAP := {estimated subject cognitive map}
  while PASSENGER not delivered to GOAL store:
      if isKnown(GOAL): {take a one-block step towards GOAL}
      else: {take a one-block step towards nearest unexplored block}

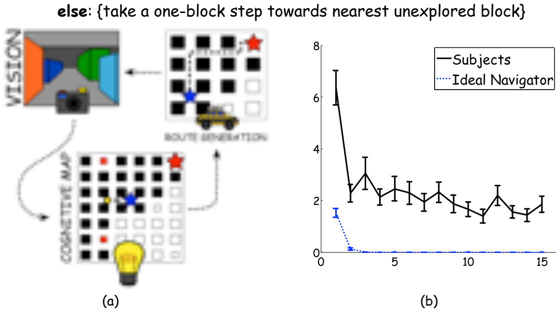

Figure 2. (a) Ideal navigator modules. Office buildings are represented as white (unknown) and black (known) boxes. Stores are represented as smaller white (unknown) and red (known) boxes. (b) Learning curves: ideal navigator vs. subject performance. The ideal navigator out-performs human subjects.

III. Degraded ideal navigator

- We degrade the **vision** and **cognitive map** modules of the ideal navigator according to the **V** and **M** parameters, respectively.
- The ideal navigator **algorithm** and **route generation** module are not

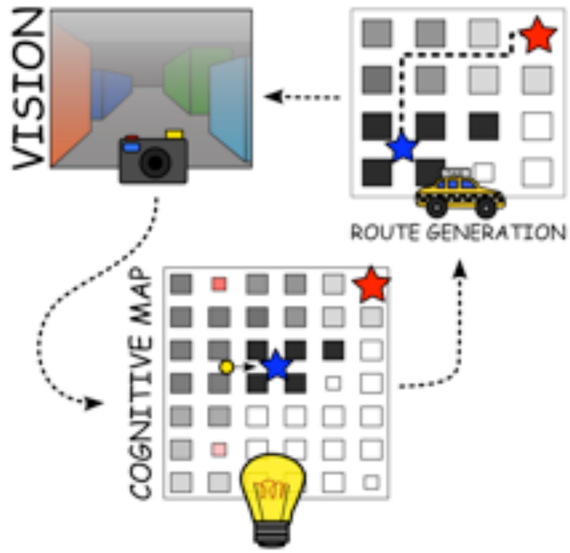

Figure 3. Degraded ideal navigator modules. The **vision** and **cognitive map** modules are degraded, while the **route generation** module is kept intact. Landmarks taking up more than V% of the screen are added to the cognitive map. Memories added to the cognitive map remain viable for **M** steps. Landmarks added recently are drawn darker for illustrative purposes. Unknown or forgotten landmarks are drawn in white.

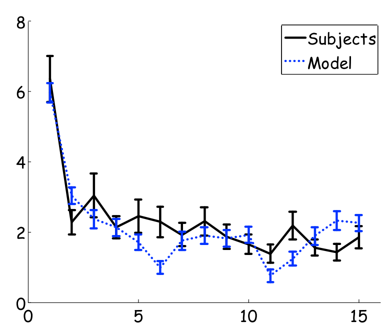

Figure 4. Learning curves: degraded ideal navigator vs. subject performance. The best-fitting parameters are (**M,V**) = (32, 0.08). RMSD = 0. 6357. Note that the average number of steps taken between deliveries was 11.45, and so on average, landmark memories remain viable for 2.79 deliveries.

IV. Validation

- To test the robustness of our model, we fit learning curves collected from a previous version of the VR taxicab driving task[1].

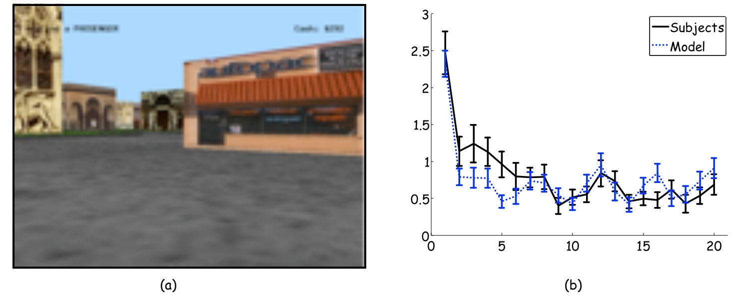

Figure 5. (a) Screen capture of previous version of VR taxicab task. The tasks differed in town size, texture graphics, store placement constraints, controller, movement and turning speeds, fields of view, screen resolution, and screen refresh rates. (b) Learning curves: degraded ideal navigator vs. subject performance. The best-fitting parameters are (**M,V**) = (36, 0.3). RMSD = 0.2434. Note that the average number of steps taken between deliveries was 13.91, and so on average, landmark memories remain viable for 2.59 deliveries (compare to 2.79 deliveries for the newer version of the task).

V. Conclusions and future directions

- Our degraded ideal navigator is able to account for mean performance over a series of deliveries in two related VR taxicab tasks with only two free parameters.
- Collecting eye-tracker data would aid in validating the **V** parameter.
- Future experiments will be designed to explicitly test the state of the subject's cognitive map during each delivery in order to further validate our model's **M** parameter.

Figure 6. Flowchart of proposed experiment to test degraded ideal navigator's ability to predict the state of subjects' cognitive map during each delivery.

- Our model assumes that subjects make use of explicit cognitive maps[2]. Alternative representations of navigationally-relevant information[3] would be interesting to study.

VI. References

1. Newman, E. L., Caplan, J. B., Kirschen, M. P., Korolev, I. O., Sekuler, R., & Kahana, M. J. (2006). Learning your way around town: How virtual taxicab drivers learn to use both layout and landmark information. Cognition (in press).
2. Tolman, E. C. (1948). Cognitive maps in rats and men. The Psychological Review, 55(4), 189-208.
3. Montello, D. R. (2005). Navigation. In P. Shah & A. Miyake (Eds.), The Cambridge Handbook of Visuospatial Thinking (p. 257-294). Cambridge University Press.