Active and Passive Spatial Learning in Human Navigation: Acquisition of Survey and Graph Knowledge

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CONCEPTS

COMPONENTS OF ACTIVE AND PASSIVE LEARNING:

Active learning:

1. Efferent motor commands to determine path of locomotion
2. Proprioceptive information about displacement with respect to the substrate
3. Vestibular information about head movement
4. Cognitive decision making about direction of travel or selected route
5. Attention allocation to relevant spatial properties of the environment
6. Mental manipulation of spatial information

(* items 1–2; ** items 1–3)

Passive learning:

Exposure to visual information about environmental layout and path of self-motion, including optic flow, binocular disparity, and surface texture

* known together as podokinetic information

** known together as idiothetic information

EXPLORATION-SPECIFIC LEARNING HYPOTHESIS

Do specific components of active learning differentially contribute to particular forms of spatial knowledge?

Results from both papers:

Decision making is the primary component of active learning for the acquisition of topological graph knowledge, and idiothetic information is the primary component for metric survey knowledge. These findings support the exploration-specific learning hypothesis.

KNOWN FROM PREVIOUS STUDIES

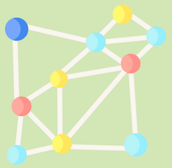
forms of spatial knowledge and graph terms:

Successful navigation between known locations might involve place recognition, reliance on beacons or landmarks (prominent features in an environment acting as location markers), knowledge of routes or pathways between places, and survey knowledge of their spatial layout.

Route knowledge: series of place-action associations, detailing a sequence of turns at each identifiable location or decision point

Survey knowledge: map-like knowledge including metric distances and directions between locations, information can be provided by podokinetic and vestibular systems

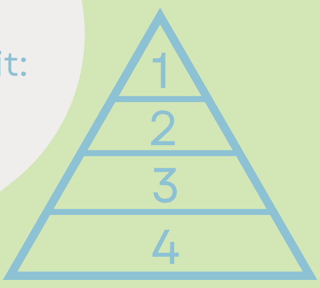
Graph knowledge: stronger than route knowledge but weaker than survey knowledge, expresses known connectivity of environment



Landmark knowledge: knowledge about the identities of discrete objects that are salient and recognizable

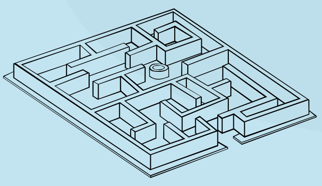
Logical hierarchy, where each level encompasses the level below it:

1. Survey knowledge
2. Graph knowledge
3. Route knowledge
4. Landmark knowledge



suggestions and findings from other survey learning papers:

Idiothetic information does not contribute much to survey learning on simple paths (visual information may), and more complex paths reveal a significant podokinetic contribution



Motor, proprioceptive, and vestibular information all contribute to path integration

Idiothetic information contributes to distance learning in a small-extent grid environment and to both distance and direction learning in a larger environment

Spatial updating during physical self-motion is a fairly automatic process

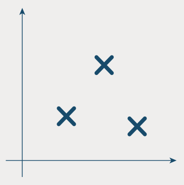
Combined idiothetic information about both translation and rotation is important for learning object locations

inconsistencies in other survey/graph learning papers:

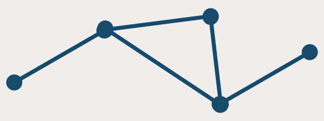
- Influence of decision making and idiothetic information on the acquisition of route and graph knowledge has inconclusive results from the few studies that have tested it
- Results from graph learning papers differ from those on survey knowledge about the importance of podokinetic and vestibular information

PRESENT STUDIES

acquisition of survey knowledge



acquisition of graph knowledge



Purpose

test the contributions of **4 components** (visual, vestibular, and podokinetic information and cognitive decision making) **to metric survey knowledge**

test the contributions of **3 components** (visual information, idiothetic information, and cognitive decision making) **to topological graph and route knowledge**

topological graph structure: network of nodes linked by edges that have been traveled

Experimental design

information	decision: Yes	decision: No
Visual + vestibular + podokinetic	Free walk	Guided walk
Visual + vestibular	Free wheelchair	Guided wheelchair
Visual	Free video	Guided video

information	decision: Yes	decision: No
Visual + idiothetic	Free walk	Guided walk
Visual	Free video	Guided video

Procedures

Participants were informed that they would be traveling through a virtual maze and that the task was to find all objects and learn their locations.

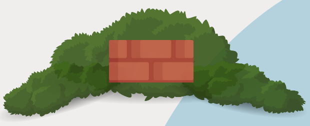
Practice phase:

A few minutes given in assigned exploration condition to become familiar with the VR system, different layout from test phase

Learning phase:

Explored environment for 10 minutes, guided to one out of six start locations and maze appeared, four landmarks (famous paintings on hedge walls) and objects included, based on participant assigned conditions (free walk, guided walk, etc.)

Testing phase


example of barrier

After the learning phase was complete, participants walked a **novel shortcut** from a starting object to the remembered location of a test object, with the maze removed.

After the learning phase was complete, participants had to take the **shortest route between two learned locations** by walking in the maze corridors; on 40% of the trials, barriers were added to promote novel detours to test route and graph knowledge.

Test phases:

The participant was wheeled to the entrance of the branch hallway with the starting object and, when the maze appeared, told to walk towards the starting object.

Everything in the environment was then replaced with the ground plane. The starting point of the shortcut was marked, and they walked until they thought they had reached the target's location.

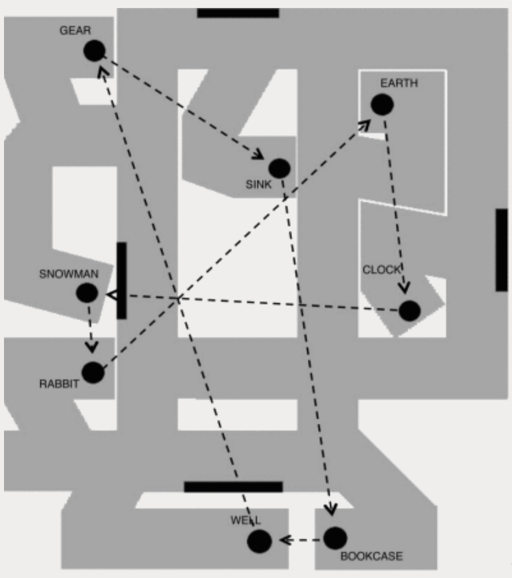
After the target was named by the instructor on the headphones, all objects were replaced with red blocks but the landmarks were still present. The participant was then given 30 seconds to walk to the location of the target object and click the mouse, taking the shortest route possible in the maze corridors.

The trial then ended, and a new one began at another location in a circuitous route in the environment. Full visual, vestibular, and podokinetic information was present during the test phase (to avoid testing condition differences).

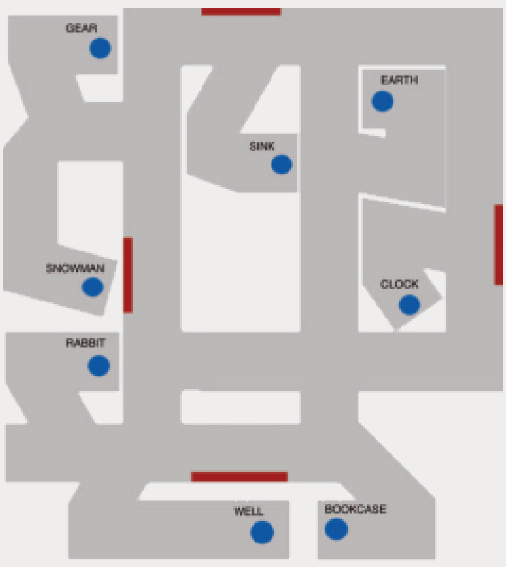
Follow-up tests:

After the test phases were completed, participants completed a sketch map of the maze, described strategies used in the task, a questionnaire about video game usage, the Santa Barbara Sense of Direction Scale, Road Map Test, and Perspective-Taking Test.

Map layouts



Experiment map
● = objects
▬ = landmarks
----- = shortcuts



Experiment map
● = objects
▬ = landmarks

Landmark painting

Well object

Views from inside the maze (participant's perspective)

DEPENDENT MEASURES AND ANALYSIS

SURVEY KNOWLEDGE PAPER

Initial angular error:

Definition: difference between actual target direction and initial walking direction when the participant left the starting object

Estimated using linear measures (absolute angular error) and circular measures (signed angular error)

2 separate analyses performed to remove circularity of data

Path length:

Definition: linear distance from the starting point to the stopping point of the shortcut

Path length error: signed difference between path length and actual distance from the starting object to the target object

Overshoot = positive value
Undershoot = negative value

Measures of exploration:

Total distance traveled, total angular rotation, mean number of visits per object

GRAPH KNOWLEDGE PAPER

Proportion of correct trials:

Definition: trial considered correct if the participant ended anywhere in branch hallway containing target object. Chance performance: 1/8 probability of randomly ending at one of the objects

Proportion of novel routes:

Definition: proportion of correct test trials on which observed route was not previously taken during free exploration (if sequence previously observed, route counted as familiar, but if not previously observed, counted as novel)

Proportion of shortest paths:

Definition: proportion of correct test trials in which participant took shortest-length path between start and target locations

RESULTS + DISCUSSION

Main conclusions:

- Podokinetic information is primary contributor to active learning of metric survey knowledge
- Decision making during exploration significantly contributes to graph learning
- Both results support the Exploration-Specific Hypothesis