Title
An ACT-R Model of Human Object-Location Memory

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 25(25)

ISSN
1069-7977

Authors
Johnson, Todd R.
Wang, Hongbin
Zhang, Jiajie

Publication Date
2003

Peer reviewed

An ACT-R Model of Human Object-Location Memory

Todd R. Johnson, Hongbin Wang, Jiajie Zhang
(todd.r.johnson@uth.tmc.edu, hongbin.wang@uth.tmc.edu, jiajie.zhang@uth.tmc.edu)
University of Texas Health Science Center Houston
7000 Fannin, suite 600, Houston, TX 77030

One important aspect of human spatial memory is the ability to remember the location of objects. Such locations are represented in multiple frames of reference, including eye-centered, body-centered, and object-based (world-centered) frames. The viewer-centered representations appear to require attention to encode; however, encoding object-to-object relations presents a computational problem. It seems unlikely that all object-to-object relations in the field of attention could be encoded, raising the question of which relations, if any, are available automatically, through early computation, and which may need to be generated later.

To address this issue, we adopted an experimental paradigm developed by Milner and colleagues in the 1990s, (e.g., Owen, Milner, Petrides, & Evans, 1996). There are two phases in the Milner paradigm. In the encoding phase, eight black-and-white drawings (objects) are presented, one at a time, on a computer screen, with each accompanied by two solid black squares as *landmark*s. Participants are asked to remember the locations of these drawings, relative to the landmarks. In the retrieval phase, participants are presented a pair of identical study drawings (say, two *chair*s), together with some retrieval cues. However, the two identical drawings are presented at different locations, with one (the target), in its original location relative to the retrieval cues, and the other one (the distracter) in a different location. Participants must select the target out of the target-distracter pair. Milner varied the retrieval cues and whether the array of objects were presented in the same screen position as during encoding (fixed array) or shifted to one of the four corners of the display (shifted array). Retrieval cues were either the two landmarks or two of the drawings. This resulted in four conditions: fixed-landmark, fixed-object, shifted-landmark, and shifted-object. In fixed conditions, the target could be identified using absolute screen location. In shifted conditions, object to object relationships were required. Furthermore, shifted-object required object-to-object relationships among drawings that were never simultaneously displayed during study.

To test the effect of retrieval cues, we modified the Milner paradigm by adding a fixed-nocue condition, in which only the target and distractor were present. The results of the experiment are shown as red lines in Figure 1. The main effects of cue-type and array-type, as well as their interaction were significant. There was no difference between fixed-no-cue and fixed-landmark.

To model this data we extended ACT-R to automatically encode object-to-object relations between the previously and currently attended objects. Attending to an object produces an encoding of that object that includes its visual features and its screen-based location. Shifting attention to a second object builds a relation between the two objects.

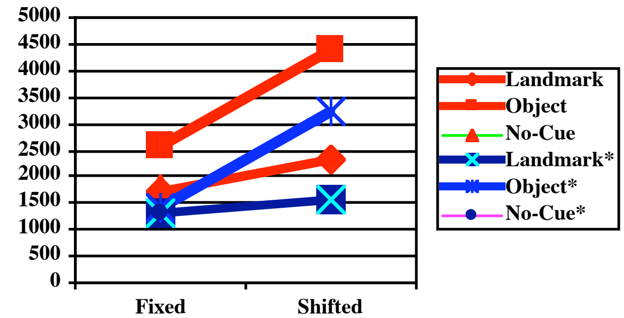

Figure 1. RT as a function of array-type and cue-type.

These relations are stored in declarative memory where they may later be retrieved. In all fixed conditions, the model attends to a drawing (either target or distractor), retrieves the screen-based study location of the object, and compares it to the current screen location. If the locations match, the model selects the drawing, otherwise the model chooses the alternative drawing. In shifted-landmark, the model attends to one of the drawings, then attends to one of the landmarks, resulting in a relation between the test drawing and landmark. It then tries to retrieve a study relation that matches the test relation. If one can be retrieved, it selects the current drawing, otherwise, it selects the other. All object-cue conditions first require a visual search for the pair of drawings that are the target and distractor. In shifted-object, the model locates the target-distractor pair, then retrieves a study relation between one of the drawings and a landmark. It then uses this relation to shift attention to where the landmark would be if the test drawing were in its correct location. It then determines whether this hypothesized landmark location is in the same relative location to one of the cue drawings as it was during study. Using all of ACT-R's default parameters, the model produces a good fit (R2 = 0.92) to the data.

Acknowledgments

This research was supported by the Grant N00014-01-1-0074 from the Office of Naval Research Cognitive Science Program.

References

Owen, A. M., Milner, B., Petrides, M., & Evans, A. C. (1996). A specific role for the right parahippocampal gyrus in the retrieval of object-location: A positron emission tomography study. *Journal of Cognitive Neuroscience, 8*, 588-602.