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# Using perceptrons to explore the reorientation task

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ABSTRACT

The reorientation task is a paradigm that has been used extensively to study the types of information used by humans and animals to navigate in their environment. In this task, subjects are reinforced for going to a particular location in an arena that is typically rectangular in shape. The subject then has to find that location again after being disoriented, and possibly after changes have been made to the arena. This task is used to determine the geometric and featural cues that can be used to reorient the agent in the arena. The purpose of the present paper is to present several simulation results that show that a simple neural network, a perceptron, can be used to generate many of the traditional findings that have been obtained using the reorientation task. These results suggest that reorientation task regularities can be explained without appealing to a geometric module that is a component of spatial processing.



## 1. The reorientation task

The ability to orient and navigate in space is critical for the survival of humans and animals. Studies of navigation in indoor environments have found that humans and other animals can use available external cues to determine direction (Cheng & Newcombe, 2005). Such cues can include the overall shape of the environment (geometric cues), as well as other available landmarks or local elements that might also be placed in the environment (feature cues). Geometric cues are presumed to be relational, while feature cues are not: "A geometric property of a surface, line, or point is a property it possesses by virtue of its position relative to other surfaces, lines, and points within the same space. A non-geometric property is any property that cannot be described by relative position alone" (Gallistel, 1990, p. 212). One question of considerable interest is the extent to which either geometric or feature cues are used to govern navigation.

One approach that has been used extensively to answer this question is the reorientation task, first introduced by Cheng (1986). In this paradigm, an agent is placed within an enclosure or arena that is usually rectangular in shape. The metric properties of the arena (i.e., length of walls, angles between walls) combined with the distinction between left and right (e.g., the long wall is to the left of the short wall) provide geometric cues. Colors of walls, or the visual properties of additional objects added to the arena (e.g., placed at each corner of a rectangular enclosure) can be used to provide feature cues (see Fig. 1). In the reorientation task, an agent learns that a particular place – usually a corner of a rectangular arena – is a goal location. The agent is then removed from the arena, disoriented, and returned to an arena, with the task of using the available cues to relocate the goal. The agent can, of course, be placed back into the original, unaltered arena. Of more interest are experimental conditions in which the arena has been changed in some way.

For example, after training in one arena (e.g., Fig. 1B or D) the subject might be placed back into an arena after the feature cues have been moved to different locations (e.g., Fig. 1C or E). This manipulation places feature cues in conflict with geometric cues. Will the agent move to a location defined by geometric information, or will it move to a different location indicated by feature information? Extensive

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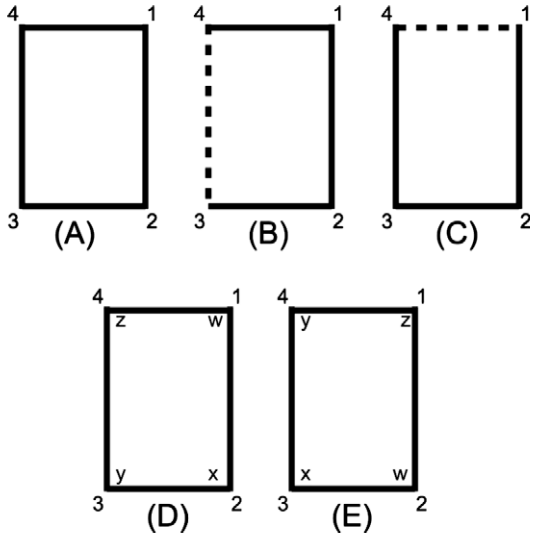


**Fig. 1.** Examples of rectangular arenas that can be used to study spatial reorientation. (A) A rectangular arena with no feature cues. The corners (Locations 1 through 4) are potential locations for reinforcement. Note that the corners at Locations 4 and 2 are geometrically equivalent to one another, as are the corners at Locations 1 and 3. (B) Wall color used as a feature cue. The wall indicated by the dashed line would be one color (e.g., white) while the other three walls would be a different color (e.g., black). (C) An affine transformation of (B), usually described as a conflict test when an animal is trained in an arena like that in (B), and then placed in this arena. In this conflict test, Locations 4 and 2 have correct geometry, but incorrect features. Location 1 has correct features, but incorrect geometry. Location 3 has incorrect geometry and incorrect features. (D) Feature cues as landmarks at each location. Each letter stands for a unique object (e.g., a colored or patterned panel) that can be used to identify the location. (E) An affine transformation of (D).

use of the reorientation task has uncovered a wealth of empirical evidence about animal navigation and the relative relevance of geometric and feature cues. These results have revealed some striking regularities in the reorientation task.

First, consider the case in which animals must perform the reorientation task in a rectangular arena using only geometric cues (Fig. 1A). This occurs when no unique feature cues are present in the arena. One consequence of this condition is that geometric cues do not specify a single target location in such an arena. For instance, the geometric cues available at Location 4 of Fig. 1A are identical to those available at Location 2 of the same figure: 90° angle, longer wall to the left and shorter wall to the right. As a result, these two corners are geometrically indistinguishable. When agents are trained on the reorientation task under such conditions, one of the basic findings is rotational error (Cheng, 1986, 2005). When rotational error occurs, the trained animal goes to the reinforced corner, as well as the corner located at a 180° rotation through the center of the arena, at above chance levels. That is, the agent cannot, and should not be able to, distinguish the reinforced corner from another corner that has identical geometric properties. This is usually taken as evidence that the animal is relying upon the geometric properties of the environment. Rotational error has been found in numerous studies with species ranging from ants (Wystrach & Beugnon, 2009) to humans (see Cheng and Newcombe (2005) for a review).

The second main regularity that governs the reorientation task occurs when feature cues (e.g., distinct objects) are added to the arena. These cues can be used by agents to uniquely relocate the reinforced location. For instance, feature cues can be added by making one of the arena walls a distinctive color (Fig. 1B), or by placing a unique landmark at each corner of the arena (Fig. 1D). The addition of such information can eliminate the response indeterminacy that is observed when only geometric cues are available.

Third, even though unique objects may be sufficient to correctly relocate a reinforced place in the arena, it would appear that in most cases agents use both feature and geometric cues. That is, geometric cues can influence behavior even when such cues are not required to solve the task. This claim is supported by several pieces of evidence. First, in some cases subjects continue to make some rotational errors even when a feature disambiguates the correct corner (Cheng, 1986; Hermer & Spelke, 1994). Second, when features are removed following training, subjects typically revert to choosing both of the geometrically correct locations (Kelly, Spetch, & Heth, 1998; Sovrano, Bisazza, & Vallortigara, 2003). Third, when the features are moved after training so as to create a conflict between geometric and feature cues, control by both types of information is often observed (Brown, Spetch, & Hurd, 2007; Kelly et al., 1998; Ratliff & Newcombe, 2008); the extent of control by geometric information on such tests appears to depend on several factors, including species, prior experience, and size of arena (Cheng & Newcombe, 2005). Thus, even when feature cues provide the most reliable indicator of the goal location, geometric information is typically also encoded.

Early theories of the regularities governing the reorientation task proposed that geometric features were encoded by modular processes that were dedicated to this kind of information (Cheng, 1986; Gallistel, 1990). For example, Gallistel (1990) viewed the solution of the reorientation task as a two stage process. The first stage occurs when an agent is first placed in an arena: it encodes the shape of the arena by attending to metric cues, such as wall lengths and angles between walls, as well as to sense cues (i.e., the distinction between left and right). The purpose of encoding the arena's shape is that this information is then used by the agent to determine its heading: that is, the arena's shape provides the reference frame for the agent's ability to orient itself. The second stage occurs when an agent is disoriented, and then placed in an arena once again. In this stage, the agent uses a representation of the shape of the previously encountered arena as a mental map. The agent "gets its heading and position on its map by finding the rotation and translation required to produce a congruence (shape match) between the currently perceived shape of the environment and a corresponding region of its map" (p. 220). If the only sources of information used to create such maps are sense and geometric cues, one consequence of this theory is rotational error in rectangular arenas.

A key assumption of the Gallistel (1990) model is that the processing of environmental shape is modular (Fodor,