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## Spatial Reorientation: Effects of Verbal and Spatial Shadowing

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### ABSTRACT

Spatially disoriented adults flexibly conjoin geometric information (macroscopic shape) and nongeometric information (e.g., the color of a wall) to re-establish their bearings. It has been proposed that non-geometric information is incorporated into a geometric frame of reference through the use of spatial language. Support for this assumption comes from dual-task studies in which participants failed to use non-geometric features when they shadowed a verbal message concurrent to the reorientation task. These studies were performed in small rectangular spaces. In contrast, our study was performed in a large square room. Experiment 1 showed that verbal shadowing did not disrupt non-geometric feature use in this environment. In Experiment 2, we found that a spatial shadowing task that required the encoding of frequently changing spatial directions impaired reorientation behavior. Our study shows that nongeometric information can be used for reorientation without recourse to linguistic processes, and suggests that the use of non-geometric features is dependent upon a spatial coding process.

**Keywords:** spatial orientation, spatial memory, verbal shadowing, geometric module

### INTRODUCTION

Mobile organisms use a variety of cognitive mechanisms to orient in space. Path integration (or dead reckoning), cue and response learning, and cognitive mapping can all contribute to locating food, avoiding dangerous places,

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relocating the nest etc. Under normal conditions, these mechanisms work in concert, correcting and minimizing errors resulting from the use of each mechanism alone. In path integration, for instance, an animal computes a vector pointing towards its starting location by continuously updating its linear and directional displacement from that starting location while moving around. Path integration is prone to the slow accumulation of error, and animals use external cues to periodically update their path with respect to their target, for example when they return to their starting position. But what happens when an animal loses its sense of direction and its bearings? What processes and cues do organisms use to reorient themselves?

Cheng (1986) found that disoriented rats relied solely upon geometric features of the environment when trying to relocate a previously visited food source in a rectangular box despite the presence of various salient nongeometric features such as odor, texture and color. The shape of a rectangle provides ambiguous information about an object's location because the two diagonally opposite corners share the same geometric information. Because disoriented rats failed to use available non-geometric information to resolve this ambiguity, Cheng concluded that rats represent space in a modular fashion, relying on a "geometric module," a featureless metric frame that "records the geometric relations in the arrangement of surfaces as surfaces" (Cheng, 1986, p. 175; for the concept of modules, see Fodor, 1983). By this account, information about other features of the environment, such as odor, color, etc. is processed in separate modules, and does not penetrate the geometric module. Attempts to replicate this finding in other species have yielded mixed results (for a review, see Cheng & Newcombe, 2005).

Herner and Spelke (1994, 1996) proposed that the geometric module is a phylogenetically old spatial system shared by a variety of species including humans. They showed that disoriented children also rely upon geometric information and are incapable of integrating salient non-geometric features such as a colored wall when retrieving an object hidden prior to the disorientation procedure. Human adults, however, overcome the constraints of the geometric module and are able to flexibly integrate nongeometric features in solving the disorientation problem. Herner-Vazquez and colleagues (Herner-Vazquez, Spelke, & Katsnelson, 1999; Herner-Vazquez, Moffet, & Munkholm, 2001) hypothesized that language is the medium by which information from different encapsulated systems can be combined. This hypothesis is based on two empirical observations: First, young children behave like Cheng's rats when trying to relocate a hidden object in a small rectangular chamber containing nongeometric features (Herner & Spelke, 1994, 1996). Around 5 years of age, when most children are able to correctly apply the terms "left" and "right," they start to use these nongeometric features and commit fewer rotational errors, i.e., incorrect searches at the diagonally opposite corner. Additionally, the successful production of the terms "left" and "right" correlates with the use of nongeometric information in the reorientation task (Herner-Vazquez et al., 2001). Second, when adults were asked to

continuously repeat an auditory recording (verbal shadowing) while performing the reorientation task, they failed to incorporate nongeometric features and showed similar search patterns as young children and rats (Herner-Vazquez et al., 1999). In contrast, a concurrent rhythm-clapping task did not have the same disrupting effect.

There are, however, several issues that complicate the interpretation of these findings. While the study with children (Herner-Vazquez et al., 2001) revealed a correlation between the production of the spatial terms "left" and "right" and the successful use of nongeometric features, it is unclear whether there is a causal relationship between the development of spatial language and integration of non-geometric information or whether it is a spurious correlation, i.e. spatial language production and nongeometric feature use are unrelated and simply emerge around the same age. Indeed, Hupbach and Nadel (2005) found that when age was statistically controlled for, the correlation between spatial language production and successful reorientation was reduced and no longer significant.

Newcombe (2005) argued that verbal shadowing could engage brain structures that are also needed for feature integration. For instance, both verbal encoding and categorical coding of features are accompanied by left-lateralized activation of the medial-temporal lobe. Hence activation of similar neuronal circuits could have caused the verbal task to interfere with feature use.

Another critical aspect of Herner-Vazquez et al.'s (1999, 2001) studies is that they were performed in small rectangular spaces (1.22 × 1.83 m, 1.68 × 2.32 m). Participants were embedded in the space (in comparison to viewing it from outside), but given the size, could hardly move around. Studies by Learmonth and colleagues (Learmonth, Newcombe, & Huttenlocher, 2001; Learmonth, Nadel, & Newcombe, 2002) and Hupbach and Nadel (2005) have shown that room size, and probably the ability to freely move within a space, critically influence reorientation behavior. Young children can combine geometric and non-geometric information to reorient in larger spaces.<sup>1</sup> This could imply that a verbal process is not critical for feature use in large spaces. This is what we sought to test.

In Experiment 1, we asked whether a verbal shadowing task would interfere with feature use in a large space in which participants could freely move and walk around. To further simplify the task situation, we used a square

<sup>1</sup>In the present article, we refer to small spaces as spaces with a floor space less than 1.7 × 2.4 m (Herner-Vazquez et al., 1999, 2001). Spaces of this size make it hard for participants to move around. We refer to larger spaces as spaces with a floor plan varying between 2.4 × 3.7 m (Learmonth et al., 2001, 2002; Ratliff & Newcombe, submitted) and 5.0 × 5.0 m (present study). This classification is solely based on the various room sizes that have been used in empirical studies and is not at all meant to be a classification with external validity. For a topology of geographic space based on manipulability, locomotion, and size, see Freundschuh and Egenhofer (1997).

instead of a rectangular room. In a rectangular room, two corners share the same geometric information (e.g., located on the left side of the long and the right side of the short wall), and participants using just geometric information have a 50% chance of finding the correct corner. In a square room, all four corners share the same geometrical information and participants using just geometric information have only a 25% chance of finding the actual hiding place.

## EXPERIMENT 1

### Methods

*Design & Participants.* A within-subject design, modeled after Experiment 1 of Hermer-Vazquez et al.'s (1999) study was used. During the first eight trials, one wall of the test room provided a landmark. Participants were asked to find a hidden object in one of the four corners of the room. On the first four trials participants performed a secondary task during which they continuously repeated a verbal message. On trials 5–8, they did not perform this secondary task. After the landmark condition, a no-landmark condition (trials: 9–12) followed in which all four walls were colored a uniform yellow and participants did not perform a secondary task. This condition served as a control to show that the room itself could not provide any information about the target corner.

Thirteen participants (7 females, 6 males) took part in the experiment. They were undergraduate students and employees who were affiliated with the Douglas Hospital Research Center or McGill University. Two females were excluded from the analyses, because they reported keeping track of their position by counting turns during the disorientation procedure, i.e., they did not allow themselves to become disoriented as was also revealed by their nearly perfect search patterns in the all-yellow room.

*Material.* The experimental apparatus consisted of a 5.0 × 5.0 m square room. The walls and the ceiling were painted black. The floor was covered with a featureless gray carpet. Two doors were located on each wall at an equal distance from the left and right corners. Lighting came from several small lamps symmetrically distributed across the ceiling. A large screen, displaying a single color, was located in the center of each wall. In the no-landmark condition, all screens were yellow. In the landmark condition, one screen was blue. Eight speakers, also symmetrically distributed, were mounted to the ceiling. A small featureless coffee cup was placed upside down on the floor in each corner and served as the hiding location. A small sugar packet served as the hidden object. The message that was used for the verbal shadowing task was a fairy tale (human-read audio book). All eight speakers simultaneously broadcast the message.

*Procedure.* Participants were brought into the middle of the experimental room, where they remained throughout the study. They started by practicing the verbal shadowing task. Participants were asked to continuously repeat the spoken narrative syllable by syllable and not to wait for words or sentences to be completed. After they were able to continuously shadow for about two minutes without pausing for more than two seconds, instructions for the reorientation task were given. As in Hermer-Vazquez et al.'s (1999) study, participants received the following rather unspecific instruction: "You will see something happening during the experiment that you should try to notice. You will be asked about what you saw."

Additionally, participants were told that they would be asked to spin themselves around and that they should allow themselves to get disoriented rather than attempting to maintain their sense of orientation. A trial started with having the participants shadow the verbal message. After 1 minute, the experimenter directed the participants' attention to the sugar packet and hid it under one of the cups. Then, participants were asked to close their eyes and turn themselves around. After about 5 to 7 turns, the experimenter asked participants to change their turning direction. After an additional 5 to 7 turns, the experimenter stopped participants by touching their shoulders. For every trial, they were stopped at a predefined facing direction such that each wall was faced once in all three conditions. The sequence of facing directions was randomized for each participant. When the experimenter stopped the participant, s/he always stood behind him/her facing the same direction as the participant. On each trial, participants were allowed only one attempt to retrieve the sugar packet by pointing to one of the cups. The experimenter made note of the location and retrieved the sugar packet while participants were watching. Immediately after that, the next trial started. Across the four trials in each condition all four possible hiding locations were used once, and the order of locations was randomized. The four trials of the verbal shadowing condition were followed by a short break during which the sound was turned off. Then, the four trials of the no-shadowing landmark condition were administered. After another short break during which the blue screen was changed to yellow, the four trials of the no-landmark condition were administered.

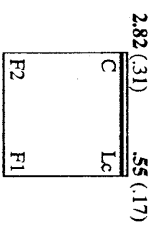
### Results

The mean number of searches in each corner averaged over the four trials served as the dependent variable (see Figure 1, top row).

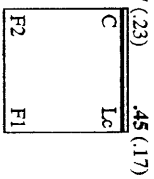
#### Landmark Conditions: Verbal Shadowing vs. No Shadowing

During the first 8 trials, one of the walls had a landmark (blue screen), and on the first 4 of these trials participants shadowed the verbal message.

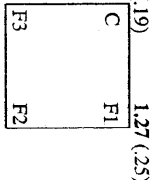
## EXPERIMENT 1

Landmark Condition:  
Verbal Shadowing

.83 (.19) 1.27 (.25)

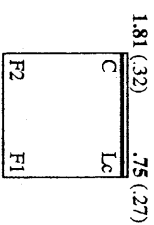
Landmark Condition:  
No Shadowing

.83 (.19) 1.27 (.25)

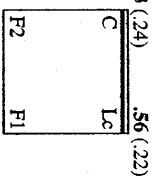
No-landmark  
condition

.83 (.19) 1.27 (.25)

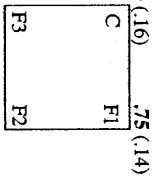
## EXPERIMENT 2

Landmark Condition:  
Spatial Shadowing

.81 (.20) .56 (.19)

Landmark Condition:  
No Shadowing

.81 (.20) .56 (.19)

No-landmark  
condition

.81 (.20) .56 (.19)

**Figure 1.** Mean number of searches (and standard errors) summed over 4 trials for Experiment 1 (verbal shadowing) and 2 (spatial shadowing). Note: For the purpose of simplicity, the upper left corner is displayed as the hiding location. In the experiment, the hiding location varied from trial to trial such that each hiding location was used for each participant and condition (shadowing, no-shadowing, control) once.

Behavioral responses were characterized in 3 ways: (1) *correct corner (C)*; (2) *incorrect corner in a correct place relative to the landmark, but mirror reverse (landmark-congruent, Lc)*; (3) *incorrect corner relative to the landmark (false-1, F1, and false-2, F2)*.

First, we compared landmark-congruent searches (C and Lc) to landmark-incongruent searches (F1 and F2) with a 2 (landmark-congruent vs. landmark-incongruent)  $\times$  2 (verbal shadowing vs. no shadowing) repeated-measures ANOVA. The ANOVA revealed only a significant main effect of landmark-congruency [ $F(1, 10) = 96.33, MSE = 1.09, p < .01$ ; all other effects were nonsignificant,  $F \leq 1.46$ ]. Participants searched significantly more often in the landmark congruent than in the landmark incongruent corners. Performance under the shadowing condition did not differ from that of the non-shadowing condition.

Second, we compared searches at the two landmark-congruent corners with a 2 (correct vs. adjacent landmark-congruent)  $\times$  2 (verbal shadowing vs. no shadowing) repeated-measures ANOVA. We found a main effect of

corner [ $F(1, 10) = 34.39, MSE = 2.07, p < .01$ ; all other effects were nonsignificant  $F \leq 1.32$ ]. The correct corner was searched significantly more often than the adjacent, but incorrect, landmark-congruent corner. Performance under the shadowing condition did not differ from that of the non-shadowing condition.

### No-Landmark Condition

In the no-landmark condition, corners were searched randomly [ $F(3, 56) = 1.30, MSE = .89, p = .29$ ] thus confirming that the apparatus itself did not provide any hints about the target location.

### Discussion

Participants used the distinctively colored wall in both the verbal shadowing and the no-shadowing condition: landmark-congruent corners were searched more often than landmark-incongruent corners. Additionally, participants mostly searched at the correct corner and made few incorrect choices of the adjacent-landmark congruent corner. Most importantly, there was no difference between the shadowing and the no-shadowing condition. Participants used the unique color of the blue screen and sense information (e.g., "The sugar is hidden on the left side of the blue wall") in both conditions. The finding that verbal shadowing did not interfere with successful object retrieval is in direct contrast to Hermer-Vazquez et al.'s (1999) finding and argues against the view that a verbal coding process is responsible for landmark use, at least in a large square room.

The numerical difference between correct searches in the verbal shadowing and no-shadowing condition could reflect an unspecific training effect: All participants started with the shadowing condition and received a rather unspecific general instruction ("... something will happen that you should try to notice"). They might have needed some time to realize that the task at hand involved object retrieval. This interpretation finds support in recent work by Ratliff and Newcombe (submitted). They studied verbal shadowing effects in a small rectangular space and found significant differences between an unspecific instruction and an explicit explanation of the object retrieval task that was paired with practice trials. No effects of verbal shadowing were found for the explicit condition, but verbal shadowing impaired object retrieval in the unspecific condition.

Our results could have differed from those reported by Hermer-Vazquez et al. (1999) either because we used a larger room or because we used a square room in which geometry did not provide hints about the target corner. We would argue that room size is responsible for the discrepant results, because Ratliff and Newcombe (submitted) found verbal shadowing effects in