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Brief article

Changing perspective within and across environments

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Abstract

Perspective change within a single environment is a slow and effortful process. However, little research has addressed perspective change across multiple environments. Using a task-set switching paradigm, subjects judged spatial relationships between target locations from differing perspectives. Response times were longer when successive trials probed different perspectives. However, this cost was greater when perspective was changed within a single environment compared to when it was changed across two environments. This result indicates that the processing of perspective change, and perhaps general spatial reasoning, differs in these two cases. Implications for theories of perspective change and environmental knowledge are discussed.

Keywords: Environmental representations; Spatial reasoning; Perspective change

1. Introduction

Imagine you are in the center of your kitchen facing your stove. Where is your sink in relation to you? Turn to face your refrigerator. Now where is your sink? To answer the first question, information about your kitchen had to be accessed from memory. This information is referred to as an "environmental representation". Moreover, you had to adopt a certain perspective within that environment, according to a particular heading. To answer the second question, you had to change your perspective by changing your heading within the environment. The adoption of a new perspective within an environment requires one to engage in "spatial reasoning" whereby the relationship of the objects relative to the viewer has to be realigned.

A variety of experiments have demonstrated that spatial reasoning requires time. For

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example, Rieser (1989) showed that response time (RT) and errors in estimated viewer-to-object direction judgments increase as a viewer changes perspective by imagined turning to face new objects (see also Farrell & Robertson, 1998). Imagining an array of targets rotate around a stationary observer can be even more difficult and time consuming (e.g. Huttenlocher & Presson, 1979; Wraga, Creem, & Proffitt, 1999, 2000; see also Presson, 1982). Similar costs have also been observed with imagined change in self location (Easton & Scholl, 1995).

Research on perspective change has primarily dealt with target locations within a single, well-defined environment, as in the kitchen example above. However, research on environmental representations has suggested that humans do not maintain a single representation of all known environmental space. Rather, humans maintain a series of multiple, separable representations. The dominant view is that these representations are hierarchically organized, such that we may, for example, maintain separate interconnected representations of a city block, the buildings on that block, and the rooms in a particular building (e.g. Hirtle & Jonides, 1985; McNamara, 1986; McNamara, Hardy, & Hirtle, 1989; Stevens & Coupe, 1978; Taylor & Tversky, 1992).

A system of multiple representations provides cognitive economy – we can consider only the relevant local aspects of the world required by a particular situation. A disadvantage exists, however, in that we must often consider the relationship between locations that may be stored in separate representations, thereby requiring the access of several representations. This process is non-trivial. Brockmole and Wang (2002) recently showed that only one representation can be accessed at a time, and that changing the mentally active representation entails a temporal cost.

Because environmental knowledge is distributed across separable representations in memory, it may be fruitful to consider perspective change not only within a single environment, but also across environments. The manner in which a change in perspective influences spatial task performance may vary depending on whether that change occurs within (where one representation is considered) or across (where multiple representations are considered) environmental representations. Any differences in the way in which perspective change influences performance in these two cases could shed light on the structure of the environmental memory system and the cognitive processes underlying spatial reasoning.

The present study compared the perspective change process within a single environment and across two nested environments. On any given trial, subjects judged whether a real-world target was presented correctly relative to an imagined location and perspective. For example, on one trial a subject may have imagined being in his office (i.e. accessed an environmental representation) facing the window (i.e. adopting a particular perspective) and been asked if his desk was to his right. Thus, two factors could be manipulated: the environmental representation and the adopted perspective. In the present study, trials either required a change in perspective only, or a change of both environment and perspective.

The logic of the experimental design follows that of a cued task-set switching paradigm (e.g. Allport, Styles, & Hsieh, 1994; Jersild, 1927; Rogers & Monsell, 1995; Spector & Biederman, 1976). In this paradigm, subjects are presented with a continuous set of trials. On a particular trial subjects are engaged in some task. On the subsequent trial, subjects may execute the identical task (no-switch trial) or engage in a different task (switch trial). If changing task requires additional time, then RT for the switch trials will be longer than that for no-switch trials. This conclusion is strengthened if a pre-cue indicating the identity of the nature of the upcoming trial reduces this switch cost, since it should allow subjects time to become prepared for the next task before the start of the trial. If no additional time is needed to respond on the switch trials, then it is inferred that no additional processing was required during the switch in task.

In the context of the present study, in an unpredictable order, subjects evaluated the correctness of target placement from two different perspectives. Thus, on some trials, perspective was held constant between successive trials (no-switch trials) and on other trials perspective was changed (switch trials). A cue indicated what perspective to adopt for that trial. The elapsed time between the cue and target presentations, the cue-to-target interval (CTI), was 0 or 2000 ms. If changing perspective requires time to complete, then RT to switch trials should be longer than for no-switch trials. Furthermore, the magnitude of this cost should be smaller at the longer CTI as it provides subjects a head-start to change their perspective prior to the presentation of the target.

In separate conditions, perspective change occurred either within a single environment (within condition), or across two nested environments (across condition). In the within condition, subjects changed perspective between facing north and facing east in the middle of the psychology building. In the across condition, they changed perspective between facing west in the middle of the psychology building and facing north in the middle of their office.

Note that compared to the within condition, which only requires a change in perspective, the across condition requires two processes that potentially take time. One is perspective change (e.g. Rieser, 1989). The other is an environmental representation switch (Brockmole & Wang, 2002).[1] Thus, there are three potential ways the costs associated with changing perspective could differ when perspective is changed across environments compared to when it is changed within an environment. First, switching environment and changing perspective may occur sequentially; thus, the time required to complete both processes is additive. This hypothesis predicts that the cost in the across condition should be longer than in the within condition. Second, switching environment and changing perspective could be accomplished in parallel. In this case, the time required to change both perspective and environment would simply be the duration of the longer of the two processes. Based on past research, it is expected that the perspective change will require more time than switching environment, and thus it would be predicted that the switch cost in the across condition should equal that in the within condition. Finally, the switch cost in the across condition could be smaller than that in the within condition. This most interesting of possibilities would suggest that the processing that underlies perspective change across environments is different than perspective change within a single environment. The experiment reported here was designed to examine these possibilities. Therefore, the

[1] Using the same testing procedure, Brockmole and Wang (2002) showed that switching from the psychology building to the subject's office without an accompanying change in perspective entailed a switch cost, indicating that the two environments are represented separately and cannot be accessed or held active in memory simultaneously. The cost of this switch was approximately 110 ms.

critical comparison concerns the switch cost in the within condition and the across condition.

2. Method

2.1. Subjects

Eight professors at the University of Illinois participated after providing informed consent. Subjects were compensated with gift certificates to a local coffee shop.

2.2. Stimuli

Stimuli consisted of a circle with eight equally spaced dots around its perimeter presented on a computer screen. The perimeter of the circle represented the 360 degrees of space surrounding the subject in an imagined location (i.e. the top dot represented the area of space directly in front of the subject in the imagined environment, etc.). For each perspective in each environment probed, only one target was selected to occupy any given position.

For each trial, one dot was replaced by the name of a target. Targets were selected from the psychology building at the University of Illinois and the subjects' individual offices in that building. Building targets were selected a priori and included the lecture hall, library, patio, stairs, elevators, planter bed, and workshop. Six office targets were selected by the individual subjects. Typical office targets included desks, file cabinets, computers, chairs, tables, pictures, windows, blackboards, doors, and bookshelves. No targets were presented in the uppermost dot to avoid confusion with respect to heading. Thus, each target could be presented in seven locations.

On each trial, in the center of the circle, a cue was presented indicating the perspective and environment according to which the subject was to judge the placement of the target. In the within condition, because perspective, but not environment, changed, the cue named a location to face and was either the word "patio" when subjects were to face north or "elevators" when subjects were to face east. In the across condition, perspective was specific to each environment so the cue only had to indicate the environment from which the next target would be selected. The cue was either the word "building" when subjects were to face north or "office" when subjects were to face west.

2.3. Design

All subjects participated in the within and across conditions in counterbalanced order. In the within condition, subjects imagined facing either north (patio) or east (elevators). While imagining facing the patio, the elevators were never used as a target, and vice versa. Thus, of the seven building targets that appeared throughout the experiment, for any particular perspective only six were presented. In the across condition, subjects imagined facing west (the lecture hall) while assessing building targets and north while assessing office targets. Thus, in each condition, a 90 degree perspective change was required. The perspective in the building adopted in the across condition was different from either of the two perspectives used in the within condition in order to avoid practice effects with a given perspective.

Twelve trials were required to counterbalance each target with respect to position and response type: each target was presented in the correct position six times and once in each incorrect position (of which there were six). Each counterbalance (12 trials/target) was crossed with the number of targets (12: six in each perspective), CTI (two), and switch type (two), yielding 576 total trials. Trials were classified as either switch trials or no-switch trials based upon the perspective probed on the preceding trial. Trials were divided into 16 blocks of 36 trials. Within each block, the CTI was constant. For each subject, the blocks of trials were presented in a different random order. With the constraint that no target was probed on two successive trials, trial presentation was also randomized. Accuracy and RT for each judgment were recorded. Subjects were told to respond as quickly but as accurately as possible.

Prior to the experimental trials for each condition, subjects completed two sets of no-switch trials, counterbalanced across subjects. Prior to the within condition, one set probed the building from the perspective of facing north, and the other set probed the building while facing east. Prior to the across condition, one set probed the building from the perspective of facing west, and the other set probed the office while facing north. Each set consisted of 144 trials. The CTI was always 0 ms. The purpose of these trials was to ensure that subjects understood the task and knew the correct placements of each target (mean accuracy exceeded 95%). These trials were considered practice and no results obtained from them were entered into the analyses.

2.4. Procedure

The sequence of events across trials is illustrated in Fig. 1. The procedure for the within and across conditions was identical. At the start of each block the circular display was presented. Subjects were asked to acquaint themselves with the imagined location(s) and environmental surroundings. The first trial was presented following a keypress from the subject. Immediately, a cue was presented in the center of the circle. If the CTI was 0 ms, the target appeared simultaneously with the cue. If the CTI was 2000 ms, the target appeared 2000 ms later. Subjects indicated whether the target was presented in the proper spatial position with reference to their imagined location and perspective. The target remained on the screen until a response was registered. Responses were made by pressing one of two keys labeled "yes" and "no" which the subject used to signal a target's correct or incorrect placement. Immediately upon response, the next trial began (i.e. the intertrial interval was always 0 ms). This created a stream of trials the subject could not disrupt. Breaks were provided at the end of each block (every 36 trials).

3. Results

Trials were excluded if the response was incorrect or if RT was ± 3 standard deviations from the mean RT for correct trials, on a subject-by-subject and cell-by-cell basis. In the within condition, 4% of responses were incorrect; in the across condition, 3% of responses were incorrect. For both conditions, the RT trim discarded 2% of the remaining data. For

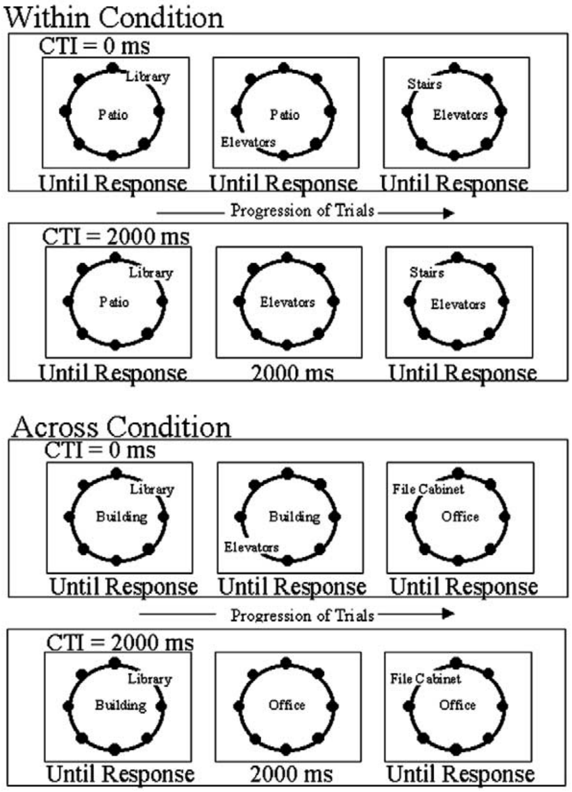

Fig. 1. Schematic illustration of the procedure.

all analyses, an alpha level of less than 0.05 was adopted as the criterion for statistical reliability.

Mean RT is summarized in Table 1, broken down by each factor. For each condition and CTI, the temporal cost of changing perspective was calculated by subtracting the RT for no-switch trials from that of switch trials. These costs are illustrated in Fig. 2.

Table 1
Mean RTs and standard errors (ms) by switch type, CTI, and condition

CTI	Switch type	
	Switch	No switch
Within-environment condition		
0 ms	2539 (212)	2029 (179)
2000 ms	1864 (172)	1688 (155)
Across-environment condition		
0 ms	1313 (77)	1144 (64)
2000 ms	1075 (69)	1024 (71)

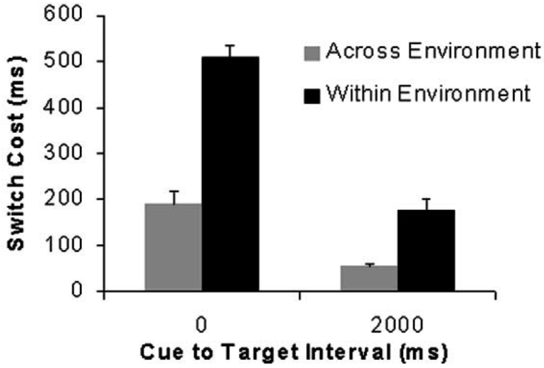

Fig. 2. Mean switch costs (with standard errors) by condition and CTI.

Switch costs were submitted to a 2 (condition) × 2 (CTI) repeated measures analysis of variance. Not surprisingly, a main effect of CTI was observed ($F(1,7) = 43.4$, $MSE = 9,417$). Switch costs when the CTI was 0 ms were 226 ms greater than those when the CTI was 2000 ms. More importantly, a main effect of condition was found ($F(1,7) = 52.0$, $MSE = 8,313$). Within-environment switch costs were 233 ms greater than the switch costs in the across-environment condition. This effect reliably interacted with CTI ($F(1,7) = 10.3$, $MSE = 9,136$). When the CTI was 0 ms, the within-environment switch cost was 341 ms greater than that in the across-environment condition. When the CTI was 2000 ms, this difference was 125 ms. Planned comparisons demonstrated that at both CTIs, the switch costs in the within-environment condition were reliably greater than in the across-environment condition.[2]

4. Discussion

Changing perspective across environments required *less* time than changing perspective within a single environment. This is surprising given that past research has shown that both changing perspective within a single environment (Rieser, 1989) and switching between different environmental representations in memory (Brockmole & Wang, 2002) require time. The non-additivity of these processes, however, indicates that switching environment and changing perspective do not occur sequentially. Strikingly, the results are also inconsistent with a parallel-process hypothesis which predicts that changing perspective

[2] The no-switch RTs in the within condition were overall longer than in the across condition. To control for this baseline difference, the same statistical analyses were conducted on the percentage of RT growth from the no-switch to switch trials in each condition and at each CTI. In short, the major results obtained by testing raw RT costs were also observed using this method. When the CTI was 0 ms, for the across condition RT for switch trials was 11% greater than for the no-switch trials whereas this growth was 26% in the within condition. When the CTI was 2000 ms, for the across condition RT for switch trials was 5% greater than for the no-switch trials whereas this difference was 15% in the within condition. The main effects of CTI and condition were reliable, although the factors did not interact. However, at both CTIs, the switch trial RT growth in the within condition was reliably greater than in the across condition.

requires equal time when it occurs within and across environments. Rather, it appears that the time required to change perspective when considering a single environment was not required when considering multiple environments. This result has implications for theories on the structure of environmental representations and the processing of environmental knowledge.

First, representations of environments at adjacent levels of a hierarchy (e.g. objects in a room and rooms in a building) seem to be independent of each other in terms of perspective. That is, the perspective adopted in one representation has no influence on the perspective adopted when a subsequent representation is accessed. This independence, however, contrasts with other research used to support hierarchical models. For example, Stevens and Coupe (1978) (see also Huttenlocher, Hedges, & Duncon, 1991; McNamara, 1986) demonstrated that the access of superordinate knowledge of the spatial relationship among target locations (e.g. among states) can bias spatial judgments at more subordinate levels (e.g. among cities). The lack of an influence of perspective between levels questions how closely related different representation are, and future conceptions of hierarchical models need modification to account for this inconsistency.

Second, our results help differentiate theories of perspective change. The predominant view of perspective change is that it reflects a process similar to mental rotation and translation (Huttenlocher & Presson, 1979; Rieser, 1989; Wraga et al., 2000). According to this hypothesis, perspective change across environments involves, for example, imagining oneself moving from the office to the building (translation) and turning 90 degrees (rotation), while perspective change within an environment merely involves turning 90 degrees. Thus, the across condition should be no less difficult than the within condition, a result not supported here. Instead, the results support an emerging alternative view which poses that perspective change is determined by a process that resolves the conflict between perspectives (May, 1996; Wang, in press; also see Presson, 1982). Perspective change within a single environment involves strong competition. For example, the planter is behind the subject when she is facing north but will be to her right if she is facing east. Thus, the two relationships (behind and right) will interfere with each other when she tries to make a judgment about the correct direction of the planter. Less competition, however, exists when both perspective and environment change because different targets are involved.

In summary, perspective change across environments is faster than perspective change within a single environment. This suggests that environmental representations are independent of each other in terms of perspective, and that perspective change involves a process that resolves the competition between representations of different perspectives.

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