Costs of Switching Perspectives in Route and Survey Descriptions

Paul U. Lee (pauly@psych.stanford.edu)
Department of Psychology, Bldg. 420
Stanford, CA 94305 USA

Barbara Tversky (bt@psych.stanford.edu)
Department of Psychology, Bldg. 420
Stanford, CA 94305 USA

Abstract

Two experiments examined perspective switching in comprehension and retrieval of spatial information. Participants read route or survey descriptions of environments line by line. Reading times were recorded. For half of the descriptions, the perspective of the last sentence was switched. True/false verification of sentences from both perspectives followed the descriptions. Switching perspective increased reading times but increased verification times only for survey sentences. This suggests that perspective switching exacts a cost in comprehension, but that the cost dissipates after information retrieval, especially for route descriptions. The second study examined which aspects of perspective, viewpoint or terms of reference, accounted for switching costs by using hybrid descriptions. Switching terms of reference slowed reading times more than switching viewpoint. Together, the experiments suggest that switching perspective plays a role in comprehension that diminishes with repeated retrieval. They also point to a fundamental asymmetry between route and survey perspectives, one that depends on orientation.

Introduction

All animals, human or otherwise, must be able to gain knowledge about their surroundings in order to survive. Like other animals, humans often gain this knowledge first-hand by navigating through their immediate surroundings. However, unlike other animals, humans also have the ability to transmit this knowledge to others by language.

Whether the world is experienced first-hand or through descriptions, the world is viewed from a particular perspective. In text comprehension, maintaining a consistent perspective makes the text more coherent and comprehensible to the readers (Black, Turner, & Bower, 1979).

Although there is a general agreement that we perceive the world from specific viewpoints, the role of perspectives on spatial memory is less certain. In particular, there is a considerable debate about whether or when spatial relations are encoded independently of perspective.

If spatial memory is formed in a perspective-dependent manner, it should be more accessible from one perspective over the others. Therefore, when people describe spatial layouts from memory, they should prefer to maintain a consistent perspective in their descriptions since memory associated with a specific perspective is more accessible than others (Levelt, 1982). There is some evidence that supports this view. When readers take a particular viewpoint during text comprehension, they later remember the information better from that viewpoint (Black, Turner, and Bower, 1979; Abelson, 1975).

Other evidence suggests that for constrained well-learned environments, spatial memory can equally be accessible from multiple perspectives. Taylor and Tversky (1992) demonstrated that when people learned route or survey descriptions of spatial layouts and later were asked inference questions about them, they were as fast and accurate to questions from the read perspective as from the new perspective. In spontaneous descriptions of naturalistic environments, people mixed route and survey perspectives about half the time (Taylor & Tversky, 1996). The choice of a perspective also seems to depend on the pragmatics of the situation much more than an inherent bias toward any particular perspective. During a conversation, speakers often use not only their own perspective, but also the perspective of their addressee's or some perspective independent of both (Schober 1993; Tversky, Lee, & Mainwaring, 1999).

In visual cognition, there is a similar inquiry about the nature of spatial memory derived from perception and navigation. There is some evidence that spatial relations are encoded in a viewpoint-dependent manner (Diwadkar & McNamara, 1997; Shelton & McNamara; Rieser, 1989). For example, Diwadkar and McNamara (1997) had participants study the locations of objects in a room from a single perspective and then learn to recognize the layout from three other views. A recognition test of the layout from different viewpoints showed faster response times for the learned viewpoints than the novel viewpoints. However, memories of large-scale spaces seem to encode spatial relations in a viewpoint-independent manner, in which familiar and

novel views of spatial layouts are equally accessible (Evans & Pezdek, 1980; Presson, DeLange, & Hazelrigg, 1989).

So far, the evidence seems to suggest that maintaining a consistent perspective is important when learning a new environment, but the effect of perspective is less clear for retrieving well-learned environments. The present study is an attempt to understand the role of perspectives in spatial descriptions during both on-line comprehension and subsequent retrieval of the layouts from memory.

As an extension to Taylor and Tversky study (1992), we studied acquisition of environments by text that maintained a consistent perspective or switched perspectives. Testing was from same or switched perspective. We expected that the cost of switching perspective be large when under construction of spatial mental models but diminished after repeated retrieval.

Experiment 1

Method

Subjects. Thirty-nine undergraduates, 18 male and 21 female, from Stanford University participated individually in partial fulfillment of a course requirement. The criterion of 67% correct response eliminated the data of three men and four women.

Materials. Descriptive texts were prepared for sixteen fictitious environments. Each environment consisted of two intersecting roads and three adjacent landmarks. The descriptions were given either in a route or a survey perspective.

Route Description

Go east on High St and you will intersect with a much narrower Green Ave.
Turn right on Green Ave and on your right, you will see the stock market.
Past the stock market, on your right on Green Ave, you will see the mortgage bank.
On your right on Green Ave, past the mortgage bank is the legal firm.

Survey Description

High St runs east-west, intersecting a much narrower Green Ave, which runs north-south.
South of High St on the west side of Green Ave is the stock market.
South of the stock market on the west side of Green Ave is the mortgage bank.
On the west side of Green Ave, south of the mortgage bank is the legal firm.

Figure 1: Route and Survey Descriptions

A route perspective takes an imagined navigator through an environment describing landmarks relative to the navigator in terms of *left* and *right*. A survey perspective takes bird's eye view of the environment describing landmarks relative to each other in terms of cardinal directions.

Each description consisted of two introduction sentences, followed by four sentences that described the spatial layout of the environment. Figure 1 shows examples of the spatial descriptions.

In order to examine the perspective switching cost during on-line comprehension, the last sentence of the study phase was presented either in the same perspective as the preceding descriptions or in a new perspective. Figure 2 shows the perspective switch in both directions for the target sentence.

Perspective Switch: Route to Survey

Past the stock market, on your right on Green Ave, you will see the mortgage bank.
On the west side of Green Ave, south of the mortgage bank is the legal firm.

Perspective Switch: Survey to Route

South of the stock market on the west side of Green Ave is the mortgage bank.
On your right on Green Ave, past the mortgage bank is the legal firm.

Figure 2: Perspective Switch during On-line Comprehension

Four statements (i.e. two statements each for route and survey perspective) followed the target sentences for true/false verification. These questions provided assurance that participants formed accurate mental models of the spatial layouts. Since the questions used in both perspectives, half required perspective switching with respect to the study perspective. All of the questions were inference questions, querying the spatial relations that could be inferred but were not directly specified in the descriptions. An example of route inference statement is "The stock market is on your right when you face the mortgage bank from Green Ave.", and an example of a urvey statement is "The mortgage bank is north of the legal firm and west of Green Ave.".

Design and Procedure. Subjects were told that they would read descriptions of various environments. They were asked to study and remember them because after each scene, they will be given true/false questions to test their memory of the scene. They were then given a practice trial, so that they would be familiar with the overall nature of the experiment. The trial consisted of a route and a survey environment followed by four test questions.

For the actual trial, subjects read sixteen texts, i.e. eight route and eight survey descriptions, and then answered four true/false questions for each description. The order of presentation and the assignment of experimental condition to environments were randomized across subjects. The texts appeared on the screen one sentence at a time. Each sentence remained on the screen until participants pressed a key to indicate that they were ready to move on to the next sentence. The reading time for each sentence was recorded. After reading a description, participants answered four test questions by pressing assigned keys for true and false. Both

response time and accuracy were recorded for each question. The question order was randomized across subjects. The experiment was conducted on a Apple PowerMac computer controlled by PsyScope software package (J.D. Cohen, MacWhinney, Flatt, & Provost, 1993).

Results

The reading time during the study phase indicates the amount of time that subjects needed to comprehend the descriptions. Using repeated measures design, reading times (RT) per syllable were compared between route and survey perspective for all study sentences except for target sentences. Subjects studied survey texts longer (351 msec/syllable) than route texts (311 msec/syllable). $F(1, 31) = 12.39$, $p < 0.001$.

The target sentence was the last sentence in the study phase. Half of the target sentences switched perspective from preceding study descriptions and the other half kept the same perspective. Target sentences were analyzed for two factors: perspective of the target sentence and perspective consistency.

On the average, subjects read route targets marginally faster (456 msec/syllable) than survey targets (513 msec/syllable; $F(1,31) = 3.02$, $p < 0.10$). They read targets that kept the same perspective much faster (397 msec/syllable) than the targets with a new perspective (572 msec/syllable; $F(1,31) = 30.89$, $p < 0.00001$.

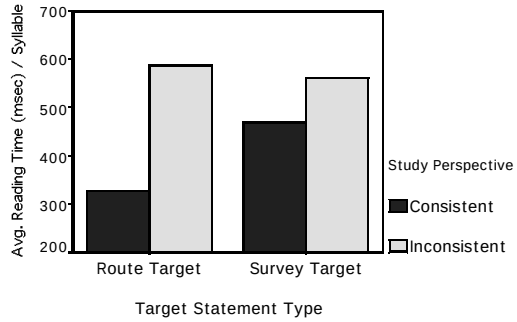

Figure 3: RT/syllable for Target Sentences: Effects of Perspective Switch during On-line Comprehension

Furthermore, there was an interaction between target perspective and perspective consistency ($F(1,31) = 10.43$, $p < 0.003$). Figure 3 illustrates that on the average, reading a route target sentence that was preceded by a description with a consistent route perspective was much faster (0.33 s/syl) than reading a route target sentence preceded by a survey description (0.59 s/syl). Although a same general pattern holds for survey target sentences, the difference in RTs is smaller (0.47 s/syl and 0.56 s/syl for consistent and inconsistent perspectives respectively).

For the true/false verification statements, we collected both response time (RT) and accuracy data. We analyzed response times for question perspective and study perspective. We also checked for effects of target perspective since it differed from study perspective half the trials. These analyses are reported for correct RTs to true questions, since RT analyses for incorrect answers or false questions yielded no significant results. It seems that subjects needed to correctly verify an accurate mental model to produce a consistent perspective effect.

Route questions were verified faster and more accurately than the survey questions (423 ms/syl for route, 476 ms/syl for survey; $F(1,31) = 9.02$, $p < 0.005$; 83% for route, 75% for survey, $F(1,31) = 7.90$, $p < 0.008$). There was no effect of target perspective on the response time ($F(1,31) = 0.0005$; $p > 0.98$).

The effect of perspective consistency was also significant but this was due only to survey questions, as there was a significant interaction between the question perspective and its consistency with the study perspective. $F(1,31) = 9.71$, $p < 0.004$. Subjects responded equally fast to route statements, regardless of perspective (426 ms/syl for route vs. 419 ms/syl for survey) but were faster to survey questions when they had studied from survey perspective (429 ms/syl; 523 ms/syl for route) (see Figure 6). Accuracy data for this interaction was not significant but was consistent with the RT results, assuring us that there is no speed-accuracy tradeoff.

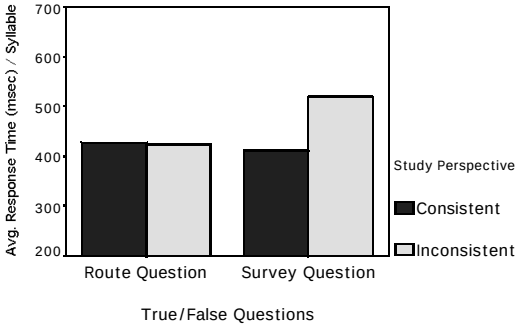

Figure 4: RT/syllable for T/F Questions: Effects of Perspective Switch during Memory Retrieval

Discussion

As predicted, switching perspective during on-line text comprehension resulted in a longer reading time, supporting cognitive costs for perspective switching during acquisition.

The interaction between target type and perspective consistency suggests that perspective consistency is more important for route descriptions. Since a route perspective is relative to a moving referent, the knowledge of current location and orientation of the

referent is crucial to processing the incoming route information. Switching from survey to route descriptions forces the reader to establish the current orientation of the referent without the benefit of inferring this knowledge from the previous text. Since survey descriptions are based on a fixed orientation perspective, consistency has no advantage over switched perspective in establishing the orientation information.

For the true/false verification statements, there was an effect of perspective switch, but the effect size was diminished from that of on-line comprehension. Furthermore, the effect completely disappeared for the route statements. The results indicate that retrieval from spatial memory is less perspective-dependent than on-line comprehension. The diminished effects of perspective for memory together with previous findings of perspective-independent memory (Taylor & Tversky, 1992) suggest that conversion from perspective-dependent to perspective-independent spatial memory may be a gradual process. If so, the present results indicate that route and survey perspective have different timetable for this conversion.

Finally, subjects took longer to study survey descriptions than route descriptions. This result is opposite that of Taylor and Tversky (1992). Although readers of route perspectives may have had greater cognitive loads due to continual updates and integration of changing location and orientation of the referent, they still read the description faster. It may be that any such difficulty is compensated by other factors, such as greater familiarity with intrinsic spatial terms (e.g. left/right) than extrinsic terms (e.g. north/south) in everyday route descriptions.

Experiment 2

We have established that switching between route and survey perspectives during study has cognitive costs. The nature of these costs seems different for route and survey perspectives. What are some of the factors that might account for these differences?

Route and survey descriptions differ in at least two ways. One is the way orientation is described. Route descriptions use intrinsic spatial terms, such as *left* and *right*, which change with the changing orientation of the navigator. Thus, they adopt a person-centered reference frame. Survey descriptions use extrinsic spatial terms, such as *north* and *south*, which fix the orientation in space, adopting an environment-centered reference frame.

Another difference is the viewpoint of the observer. Route perspectives are embedded within the environment, whereas survey perspective are external and above the environment.

In this experiment, we created hybrid descriptions that take route-like viewpoints but update its orientation using extrinsic terms. For example, a route description such as "Go down the street, turn right, and the building will be on your right" can be converted to a hybrid description like "Go north on the street, turn east, and the building will be south of you."

Using hybrid descriptions, we can examine if the perspective switching costs are due to changes in orientation terms or changes in viewpoint. If orientation terms are crucial, we expect hybrid results to mirror the survey results. If viewpoint is important, we expect hybrid results to mirror the route results.

Method

Subjects. Sixty-four undergraduates, 30 male and 34 female, from Stanford University participated individually in partial fulfillment of a course requirement. 67% accuracy criterion eliminated two men and eight women.

Materials. The stimuli were similar to those used in Experiment 1 with few changes. In addition to route and survey descriptions, hybrid descriptions were added for the study and the test phase. Figure 5 shows an example of a hybrid description.

Hybrid Description

Go east on High St and you will intersect with a much narrower Green Ave.
Turn south on Green Ave and west of you, you will see the stock market.
Past the stock market, on the west side of Green Ave, you will see the mortgage bank.
West of you on Green Ave, south of you past the mortgage bank is the legal firm.

Figure 5: Description in Hybrid Perspective

Both descriptions and targets were given in each of three perspectives. Two fictitious environments were added to the sixteen environments in Experiment 1 to match the number of environments with the experimental conditions. In addition, four true/false questions per environment were reduced to three, one each from route, survey, and hybrid perspective. Finally, the number of practice trials was increased to three, one for each description type.

Design and Procedure. Except for the changes in the materials described in the previous section, the procedure is identical to Experiment 1.

Results

The reading time results replicated those of Experiment 1. The new results for this experiment show how switching perspectives with hybrid descriptions affect on-line comprehension and memory.

We analyzed reading times for the target sentences for two factors: perspective of the target sentence and perspective consistency with study. Each factor has three perspectives: route, hybrid, and survey.

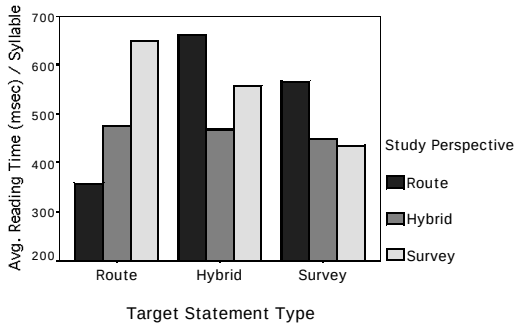

Figure 6: RT/syllable for Target Sentences: Effects of Perspective Switch during On-line Comprehension

There was an interaction between target perspective and study perspective (see Figure 6). $F(4,212) = 20.55$, $p < 2e\text{-}11$). Planned contrasts on hybrid target sentences showed faster reading times for hybrid (468 msec/syl) than route descriptions (661 msec/syl; $t(212) = 4.89$, $p < 1e\text{-}6$), and reading times for hybrid was marginally faster than survey descriptions (556 msec/syl; $t(212) = 2.16$, $p < 0.02$; Bonferroni group $p_{crit} = 0.0025$). Direct comparison between route and survey descriptions showed that a perspective switch from route to hybrid took marginally longer than a switch from survey to hybrid ($t(212) = 2.73$, $p < 0.004$; $p_{crit} = 0.0025$).

Similarly, route target sentences were read faster after route (357 msec/syl) than either hybrid (474 msec/syl; $t(212) = 3.04$, $p < 0.0015$) or survey descriptions (649 msec/syl; $t(212) = 4.55$, $p < 5e\text{-}6$). In addition, a perspective switch from survey to route took significantly longer to understand than a switch from hybrid to route ($t(212) = 7.60$, $p < 1e\text{-}11$).

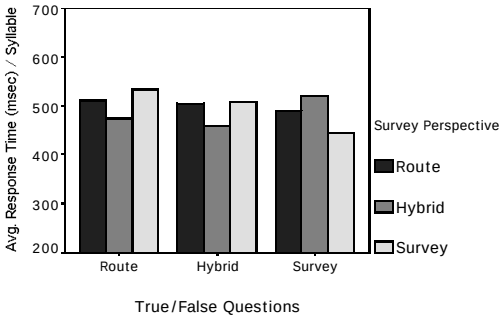

Figure 7: RT/syllable for T/F Questions: Effects of Perspective Switch during Memory Retrieval

Finally, survey target sentences were read faster when preceded by survey descriptions (435 msec/syl) than by route descriptions (566 msec/syl; $t(212) = 3.41$, $p < 0.0004$), but not by hybrid descriptions (448 msec/syl; $t(212) = 0.34$, $p > 0.35$). A direct comparison between route and hybrid descriptions showed a perspective switch from route to survey to take longer than a switch from hybrid to survey ($t(212) = 3.07$, $p < 0.0015$). Overall, hybrid statements behaved more like survey statements than like route statements.

True/false verification statements failed to replicate the results from Experiment 1, as there was no significant main or interaction effects (see Figure 7).

Discussion

The hybrid perspective provided an "intermediate" perspective between route and survey perspective. Its viewpoint was embedded like a route perspective but its reference terms were like survey perspective (i.e. north, south, east, and west). Which of these two factors would play a role in exacting cognitive costs during comprehension? The answer turned out to be both.

Reading times for target sentences were longer when the perspective was switched from route to hybrid than when consistent. Since the route and the hybrid descriptions were identical except for orientation terms, orientation terms contributed to the perspective switching costs. Similarly, when perspective was switched from survey to hybrid, longer reading times resulted. Since a survey description differs from a hybrid in the viewpoint of the observer, viewpoint also contributed to the perspective switching costs, although the effect size was much smaller than that of the orientation terms.

Target reading times for the route statements confirmed this hypothesis. Switching from the hybrid to route perspective increased the reading times, implicating orientation terms or reference frames. Since a switch from survey to route required a change in both orientation terms and the viewpoint, reading times were even longer than for a switch from hybrid to route. The advantage of hybrid over survey study perspectives for reading route targets further supported the significance of the viewpoint in the perspective switching costs.

For the survey targets, the overall results corroborated the other findings, except that there was no perspective cost when readers switched from hybrid to survey perspective. This suggests that orientation terms exact a greater cost than viewpoint.

Overall, there were strong and consistent effects of perspective switching costs due to changes in orientation terms. The effects due to viewpoint changes were weaker, since there was a significant effect for the route targets, a marginal effect for the hybrid targets, and no effects for the survey targets.

During the sentence verification, all effects between conditions disappeared. These results were consistent with Taylor and Tversky (1992) but differed slightly

from the results of Experiment 1. Both experiments are consistent with the claim that perspective effects diminish during the retrieval phase compared to the study phase, especially when the retrieval is done repeatedly from multiple perspectives. Answering true/false questions from three different perspectives might have accelerated the process.

Conclusion

When people describe a large-scale environment, they typically adopt route or survey perspectives, or a combination of both (Taylor & Tversky, 1996). These two perspectives are also readily understood, suggesting that they capture a natural way of understanding the world.

Previous work suggested that mental representations of constrained, well-learned environment acquired from descriptions are perspective-free, that is, statements about the environments from either perspective are verified equally quickly and accurately, irrespective of study perspective (Taylor & Tversky, 1992). However, other studies have suggested perspective-dependent representations (Diwadkar & McNamara, 1997).

The present experiment provided evidence that maintaining a consistent perspective during learning facilitates acquisition of new environments, that is, switching perspective exacts a cost in reading times. However, after acquisition and during testing for memory of the environment, costs of switching perspectives diminish considerably (Exp 1) or disappear (Exp 2). Perspective-independent responding could indicate that the mental representations are more abstract than any particular perspective, allowing equally efficient retrieval from either perspective. Alternatively, it could indicate multiple representations or increased efficiency of comprehending various perspectives.

Spatial perspectives include both viewpoints and terms of reference, as well as other factors, such as referent object. In particular, survey descriptions take an overhead viewpoint and use the cardinal direction terms of reference. Route descriptions take viewpoints within environments and use intrinsic direction terms, *left, right, front,* and *back.* In the second experiment, a hybrid description was constructed using a route viewpoint and survey reference terms. Switching reference terms exacted a greater cognitive cost than switching viewpoint, suggesting that overall reference frame is more critical in spatial descriptions than viewpoint.

Acknowledgments

This research was supported by Stanford Graduate Fellowship to the first author and by Office of Naval Research, Grant Number NOOO14-PP-1-O649, to the second author. We are grateful to Herb Clark and Gordon Bower for helpful discussion.

References

Abelson, R. (1975). Does a story understander need a point of view? In R. Schank & B. L. Nash-Webber (Eds.), *Theoretical issues in natural language processing.* Washington, DC: Association for Computational Linguistics.

Black, J. B., Turner, T. J., & Bower, G. H. (1979). Point of view in narrative comprehension, memory and production. *Journal of Verbal Learning and Verbal Behavior, 18,* 187-198.

Cohen, D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavior Research Methods, Instruments, & Computers. 25,* 257-271.

Diwadkar, V. A., & McNamara, T. P. (1997). Viewpoint dependence in scene recognition. *Psychological Science, 8(4),* 302-307.

Evans, G. W., & Pezdek, K. (1980). Cognitive mapping: Knowledge of real-world distance and location information. *Journal of Experimental Psychology: Human Learning & Memory, 6,* 13-24.

Levelt, W. J. M. (1982). Linearization in describing spatial networks. In S. Peters & E. Saarinen (Eds.), *Processes, beliefs, and questions.* Dordrecht: Reidel.

Presson, C. C., DeLange, N., & Hazelrigg, M. D. (1989). Orientation specificity in spatial memory: What makes a path different from a map of the path? *Journal of Experimental Psychology: Learning, Memory, & Cognition, 15,* 225-229.

Rieser, J. J. (1989). Access to knowledge of spatial structure at novel points of observation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 887-897.

Schober, M. F. (1993). Spatial perspective-taking in conversation. *Cognition, 47(1),* 1-24.

Shelton, A. L., & McNamara, T. P. (1997). Multiple views of spatial memory. *Psychonomic Bulletin & Review, 4(1),* 102-106.

Taylor, H. A., & Tversky, B. (1992). Spatial mental models derived from survey and route descriptions. *Journal of Memory & Language, 31(2),* 261-292.

Taylor, H. A., & Tversky, B. (1996). Perspective in spatial descriptions. *Journal of Memory & Language, 35(3),* 371-391.

Tversky, B., Lee, P., & Mainwaring, S. (1999). Why do speakers mix perspectives?.*Spatial Cognition and Computation, 1,* 399-412.