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Internal and External Spatial Frameworks for Representing Described Scenes

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Four experiments explored readers' mental models of described scenes. Environments were described from one of two perspectives, an *internal* perspective of an observer within the scene, surrounded by objects, or an *external* perspective of an observer outside the scene, with objects in front. Subjects read narratives describing a scene and were probed for locations of objects. In the general case, reaction times to identify objects were fastest for the head/feet (above/below) axis, then the front/back (front/behind) axis, and then the left/right axis, conforming to the spatial framework analysis which reflects people's conceptions of space based on typical interactions in space. For the internal spatial framework, readers were faster to questions of front than back, reflecting the perceptual and biological asymmetries that favor an observer's front. For the external spatial framework, all objects were in front of the observer and readers were equally fast to questions of front and behind. The difference between internal and external spatial framework reflects the different perceptual experience of observers in the two perspectives. The two variants of the spatial framework allowed us to infer readers' spatial perspective for narratives with unspecified perspectives.

Suppose you are reading a story about Jim, who has become separated from his group in the jungles of Africa. "Seeing a snake, Jim quickly pulls himself onto a branch directly above the snake. Behind him, in a hole in the trunk, Jim notices a nest filled with buzzing insects. Above him, on another branch, a colorful bird is perched. . . ." Researchers investigating memory for discourse have proposed that, in order to comprehend such prose, readers construct mental or situation models embodying the spatial relations explicitly given in the text as well as those inferable from the text (e.g., Bransford, Barclay, & Franks, 1972; Johnson-Laird, 1983; van Dijk & Kintsch, 1983). Evidence for such mental models comes from several sources. Perrig and Kintsch (1985), for example, demonstrated that although subjects may be unable to recall the surface structure of a text, they perform quite well on a verification task of explicit and inferred spatial relations. Furthermore, people spontaneously make spatial inferences, and incorrectly recognize such inferences as having been presented in the text (Bransford et al., 1972). Other evidence suggests that spatial mental models derived from text are similar to those derived from direct experience. Mental models may include information about spatial properties such as relative po-

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sition (Mani & Johnson-Laird, 1982 Perrig & Kintsch, 1985; Taylor & Tversky, 1991), and relative distance (Franklin, 1991; Glenberg, Meyer, & Lindem, 1987; Morrow, Bower, & Greenspan, 1989; Morrow, Greenspan, & Bower, 1987; Wagener-Wender & Wender, 1990).

Recently, Franklin and Tversky (1990b) sought to characterize the spatial qualities of mental representations acquired from text describing a particular common spatial situation. Their subjects read narratives written in the second person describing a simple environment around themselves, locating objects beyond their head, feet, front, back, left, or right. For example, subjects read a story that described them standing on a ladder in the center of a barn with a saddle hanging on the wall directly in front of them, a lantern hanging directly above their head, and so on. After describing the locations of objects around the second-person observer (the reader), the narrative oriented him or her to face a particular object. The reader was then probed by egocentric direction names (head, feet, front, back, left, right) for the objects in those positions, then reoriented toward another object, probed by direction names, and so on. Response times varied systematically with the direction of the object from the observer and the posture of the observer, upright or reclining, revealing that subjects' spatial mental models were organized in terms of their three orthogonal body axes, and their position in space.

Spatial frameworks. A number of theorists have suggested that spatial language reflects the way we typically perceive and interact with the world (e.g., Clark, 1973; Fillmore, 1982; Levelt, 1984; Miller & Johnson-Laird, 1976; Shepard & Hurwitz, 1984). Although these writers were primarily concerned with the way people use and comprehend spatial terms, many of their arguments are derived from the way people conceive of space. Influenced by these analyses, Franklin and Tversky (1990b) hypothesized that readers of their narratives would construct a three-dimensional *spatial framework,* a mental model, or knowledge structure used to store, retrieve, and verify locations of objects relative to their own bodies. A spatial framework reflects the way people normally conceive of their perceptual world, based on their interactions with it.

The perceptual world of a human observer can be described in terms of three orthogonal body axes, one vertical and two horizontal. For the canonically oriented upright observer, the head/feet axis corresponds to the vertical, and the front/back and left/right axes are horizontal. According to the spatial framework analysis, objects located on the vertical head/feet axis should be more accessible to upright observers because of both properties of the world and properties of the body. The head/feet axis is physically asymmetric and normally correlated with the vertical gravitational axis of the world. As observers navigate the world, vertical spatial relations among objects remain largely constant with respect to the observer whereas spatial relations in the horizontal plane change. Both the biological asymmetry and the correlation with gravity impart a special status to the head/feet axis leading to easy and rapid access from memory of objects beyond the head and feet. The front/back axis is physically asymmetric, and the observer is perceptually and behaviorally oriented frontwards. However, the front/back axis is not correlated with an environmentally defined axis. What objects are located along this axis depend on the direction currently faced by the observer. Finally, the left/right axis is derived from the front/back axis of the observer and lacks both asymmetry and correlation with an environmental axis, making it the least salient spatial organizer. Thus, for the upright observer, the spatial framework analysis predicts that subjects' responses should be fastest to objects at the head or feet, followed by those to the front or back, followed by those to the left or right. This prediction was confirmed in four experiments by Franklin and Tversky (1990b). Subjects were also faster to respond to front than back, reflecting the perceptual and biological asymmetries that favor front over back.

For a reclining observer, the situation changes; the head/feet axis is no longer correlated with gravity and loses its predominance. In this case, the spatial framework analysis predicts that subjects should be fastest to respond to questions of front/back because of its perceptual, biological, and behavioral asymmetries. Head/feet should still be faster than left/right because of its biological asymmetry. In addition, subjects should be slower overall for a reclining than upright observer because people do not typically interact with the world in a reclining posture. This pattern of response times was observed by Franklin and Tversky (1990b) in two experiments.

Internal spatial viewpoint. Thus far, the spatial framework analysis has been developed and tested with a single narrative perspective. All of Franklin and Tversky's (1990b) narratives were written in the second person and described an array of five objects surrounding "you" the reader, locating objects with respect to "your" various body sides. The direction questions used to probe subjects, too, referred to objects located at specific directions from "your" body. This use of deictic terminology (e.g., Fillmore, 1975; Levelt, 1984; Miller & Johnson-Laird, 1976) in the narrative perspective specified what we will call an *internal* perspective for the reader, the point of view of an observer at the center of an array of objects. Although that situation may be prototypical of spatial cognition, other narrative perspectives, spatial viewpoints, and spatial arrays are possible.

External spatial viewpoint. It is possible to specify other spatial points of view, notably, one where the observer is looking toward an array of objects all located in front of the observer. We call this point of view an *external* perspective. In Experiment 1, subjects read narratives describing an array of objects external to an observer. The external viewpoint was specified by using deictic spatial terminology, just as the internal viewpoint was specified by deictic terminology by Franklin and Tversky (1990b). In the external case, for example, when the "mask" was described as being *behind* the "camera," and the "pumpkin" as being to the *right* of the "bowl," the terms *behind* and *right* were with respect to the external observer, and not with respect to the intrinsic sides of the camera or pumpkin. The direction questions probing for subjects' knowledge of the described scenes were also presented from the point of view of an external observer. A new variation of the spatial framework needs to be developed to account for keeping track of objects in an external array. In the external case, all of the array was in the observer's field of view, unlike the internal case where the objects surrounded the observer, and most were not in the observer's field of view. Because the array does not surround the observer, considerations of body symmetry are no longer relevant for predicting response times to access locations of objects in a scene. Rather, asymmetries in the typical visual field of the observer determine the relative accessibility of the three dimensions.

Narratives without a specified spatial viewpoint. Although some narratives specify a spatial viewpoint through the use deictic terminology, such as the internal viewpoint of Franklin and Tversky and external viewpoint of Experiment 1, other narratives do not specify a viewpoint. Going back to our description of Jim lost in the jungle, for example, readers could take an external point of view on the scene, "seeing" Jim in the tree with the snake below and the buzzing insects behind. Alternatively, readers could take the point of view of Jim, an internal perspective, and instead of "seeing" Jim, would "see" the snake below them and the insects behind. Such narratives, typical of fiction, describe spatial relations with respect to the intrinsic sides of the current main character, but it is up to the reader to decide whether to adopt an internal or external perspective. In Experiments 2 and 3, narratives described an array of objects around a central person or around a central inanimate object, respectively, but the narratives did not specify a perspective. The question of interest is whether readers would adopt the perspective of an observer inside an array of objects, or that of an observer outside the scene, looking onto it. The results of the first experiment, in contrast to those of Franklin and Tversky (1990b), allow us to distinguish the spatial perspective readers adopt for such narratives.

The research reported here investigates two common spatial frames of reference, one viewer-centered or egocentric or deictic and one subject-centered or intrinsic (e.g., Garnham, 1989; Levelt, 1984; Marr & Nishihara, 1978; Pinker, 1984; Shepard & Hurwitz, 1984). In the first case, the referent for all locations of objects is "you" and, in the second case, the referent for all locations of objects is a central figure or object. Yet another spatial frame of reference, the extrinsic frame of reference, is commonly used to locate objects in space. In an extrinsic frame of reference, locations of objects are described with reference to some external set of coordinates, such as longitude, latitude, and altitude, or the floor, walls, and ceiling of a room, but exploration of environments described this way is left for future research.

Experiment 1: Specified External Perspective

In Experiment 1, subjects read narratives that described an array of objects from the point of view of an implied observer *external* to the array. The array consisted of eight objects arranged at the corners of an imaginary cube. Subjects read an initial description which located objects with reference to the location of another object and to the location in the imaginary cube, from the point of view of the external observer. After learning the array, subjects were probed for their knowledge of the relative locations of objects in the scene. Object location probes were also from the point of view of the external observer, in terms of *front, behind, above, below, left,* and *right.*[1]

Here, because the observer is outside the array, considerations of asymmetries of the observer's body are less relevant to understanding the spatial terms and conceptualizing the spatial array. From an external viewpoint, the above/below axis is the most salient because of the pervasive asymmetries of the perceptual world due to gravity. Gravity defines an environmental axis that does not depend on the orientation of the observer. Moreover, under typical horizontal navigating, the vertical locations of objects relative to observers do not change. The front/behind axis, projecting out from the observer, is also asymmetric, but the asymmetry depends on the observer's field of view. From the observer's point of view, objects that are toward the front of an array are closer and appear larger and clearer than those toward the back, and objects toward the front may occlude or partially occlude those at the back. As before, the left/right axis has little or no asymmetry. Thus, subjects should be fastest to respond to questions of above/below, followed by front/behind, followed by left/right.

The overall ordering of the accessibility of the three dimensions is the same for the external as for the internal spatial framework analysis, though for different reasons. What should differ between the two viewpoints is the relative accessibility of the poles within the front/behind axis. In all four of Franklin and Tversky's (1990b) experiments with upright observers, response times to front were considerably faster than those to back (by roughly 200 ms). This was accounted for in terms of the strong percep-

[1] From Franklin and Tversky (1990b), we know that the same results are obtained for the terms above/below and head/feet, as well as for front/back and ahead/behind.

tual and behavioral asymmetries of the human figure that favor front. Both the perceptual apparatus and most forms of behavior are directed frontwards. This asymmetry of the body is not relevant to the external viewpoint, where both front and behind refer to objects in front of the observer. Although there is an asymmetry of front/behind, it is not nearly as strong an asymmetry as the internal front/back asymmetry, and we do not expect a difference in response times favoring front over behind for the external perspective.

Method

Subjects

Subjects were five male and seven female Stanford University undergraduates who participated in exchange for credit in an introductory psychology class.

Narratives

Seven narratives, one a practice story, each described, from an external perspective, a different "cube" environment, consisting of eight objects at the eight corners of an imaginary cube. An observer and array are depicted in Fig. 1 to illustrate the nature of the scenes described by the narratives, but subjects never viewed this or any diagram. The scenes and objects were selected to be familiar and common to the environment being described. The objects were also selected to be approximately the same size and equally plausible in any location in the array. The locations of objects

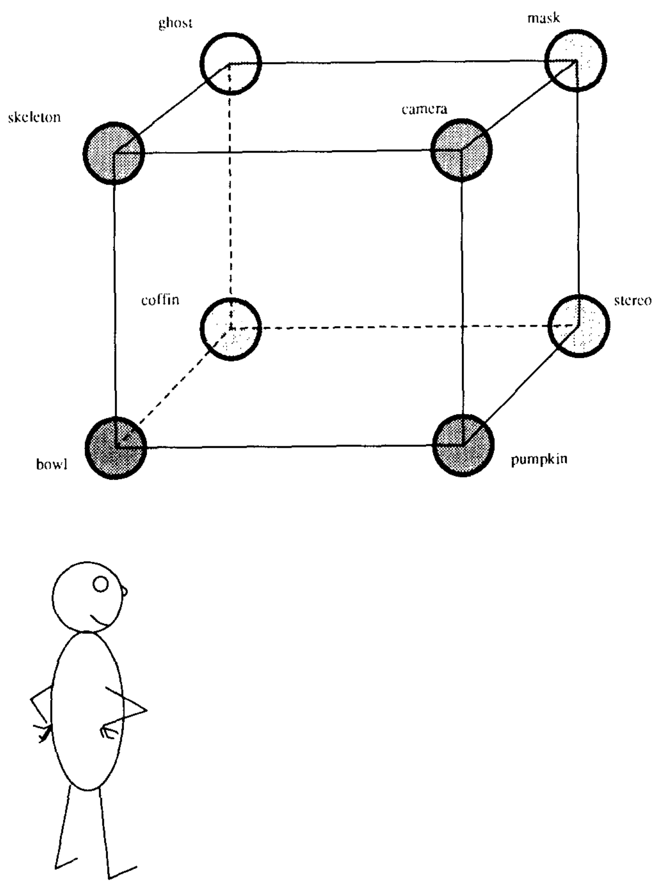

FIG. 1. A depiction of the *Halloween Party* external array (Experiment 1). The reader's implied point of view is that of the figure shown outside the cube, looking at it. The dashed lines represent spatial relations in depth.

in a scene were randomly selected. Scenes and objects are listed in Table 1.

Narratives were given to subjects in two parts. The first, printed on a single sheet of paper, provided the name of the setting and a list of the eight objects in the scene. It then described the environment from the perspective of an implied observer outside the environment. The first part of *Halloween Party* narrative used in Experiment 1 follows as an example. Objects are italicized here, but were not in the version read by subjects.

The Joneses are having a Halloween party this evening in their backyard. The yard is fifteen feet on all sides and is covered by a large colorful tent which is supported by thick beams at all four corners. The Joneses have brought out all the things they will need for a successful party and have put them in the corners to keep the yard clear for dancing. In the lower left front corner of the yard, a plastic punch *bowl* has been placed on the ground. It is filled with a dark red punch for the party. To the right of the bowl, in the lower right front corner, a *pumpkin* is resting on the ground. It has yet to be carved, but a menacing jack-o-lantern face has been drawn on it with a black marker. Directly above the pumpkin, in the upper right front corner, a video *camera* has been fastened to the tent pole. The hosts think it will be fun to show a tape of the party at some future event. Directly behind the camera, in the upper right rear corner, a horrifying witch *mask* has been mounted on the tent pole. It has beady red eyes and leers evilly down on the yard. Below the mask, in the lower right rear corner, a *stereo* has been set up on the ground. The Joneses plan to have a lot of dancing at their party and want their guests to be able to select their favorite music. To the left of the stereo, in the lower left rear corner, there is a life size *coffin* resting on the ground. This is the most gruesome decoration at the party, as it was borrowed from a local funeral parlor. Above the coffin, in the upper left rear corner, a *ghost* doll has been hung from the rafters of the tent by a few thin wires. It is made mostly from a billowing white sheet with a round bulbous head. In front of the ghost, in the upper left front corner, a papierma-che *skeleton* is also hanging from the rafters. It has a strange lipless grin on its face, giving it a disturbing and threatening air.

TABLE 1
SCENES AND OBJECTS OF EXPERIMENT 1

Scene	Objects
Halloween party	Bowl, camera, coffin, ghost, mask, pumpkin, skeleton, stereo
Hotel lobby	Banner, barbershop, desk, escalator, fountain, giftshop, pushcart, tavern
Construction site	Bucket, concrete, cord, jackhammer, ladder, lunchbox, shovel, wheelbarrow
Opera theatre	Bouquet, chair, sprinkler, lamp, loudspeaker, plaque, sculpture, table
Space exhibit	Computer, map, meteorite, moonrover, rocket, satellite, spacesuit, trashcan
Barn	Bag, barrel, footstool, lantern, pail, rake, saddle, shears
Work shed	Basket, bench, engine, fan, hammer, saw, tirepump, yardstick

The second part of each narrative was divided into eight blocks and presented sentence-by-sentence on an IBM-XT computer screen. A block consisted of, first, one orienting sentence, followed by two filler sentences, then three direction probe questions. The orienting sentence of each block named an object and gave some detail information about it. This object served as the referent object for the direction probes of that block. The next two sentences were fillers to focus attention on the object; they provided additional details about the object, such as its visual appearance, but did not mention it by name. The three probes in a block were separated by two such filler sentences each. An example of orienting and filler sentences from the Halloween narrative follow:

The Joneses have decided to use a plastic BOWL at the party for practical reasons.

Plastic is difficult to break, but the container looks very much like a crystal one.

The rim, instead of being smooth, is serrated in order to give it a more stylish appearance.

Procedure

Subjects were given detailed instructions about the experimental procedure before beginning. They were instructed to read each narrative for understanding and told that they would be asked questions about the directions of objects with respect to each other. They were allowed to study the printed portion of the narrative for as long as they wished and then returned it to the experimenter. Subjects then proceeded to the second portion of the narrative which was presented on the computer. They read at their own pace, striking the space bar to advance to the next sentence. Subjects were not allowed to return to previous sentences.

Following the filler sentences, subjects were probed with a direction term for an object located in that direction from the current referent object. Each question had the following format. The name of the referent object appeared on the screen in capital letters. After striking the space bar, the subject was probed with one of six directions, indicated by a single word, "front," "behind," "above," "below," "left," or "right." Only three directions were occupied for any particular referent object (see Fig. 1), so only three directions were probed in any given block. Subjects were instructed at the beginning of the experiment that they were to interpret probes with respect to the referent object; e.g., "which object is in front of the referent object?" Subjects were told to press the space bar as soon as they were certain which object was located in that direction, without sacrificing accuracy. The time subjects took to do this was the critical response time, RT1. After subjects pressed the space bar, the names of six objects in the environment (excluding the referent object and the object located diagonally opposed to it in the cube) appeared on a line on the screen in random order, numbered 1 to 6. Subjects were told to press the number corresponding to the correct object as quickly as they could, without sacrificing accuracy. This was the second response time, RT2, which served as an accuracy check. Ideally, RT2 should only be affected by list position. The narrative continued with two more filler sentences pertaining to the referent object. Then the next question about the same referent object appeared, until all three occupied directions with respect to that referent object had been probed. Following this, a new block began and subjects answered questions about another referent object. The first narrative was for practice, during which subjects received feedback about their accuracy on questions. No feedback was given during experimental trials.

Design

The independent variable in this experiment was direction (front, behind, above, below, left, and right). The dependent variable was the time subjects took to decide which object in an environment was in a probed direction with respect to a specified referent object (RT1). Three subjects were assigned to four random orders of presentation of the narratives. Half the narratives located objects along the above/below, followed by left/right, then front/back axes (as in example above), and half along the front/back, then left/right, then above/below axes. These versions were alternated and half the subjects began with the first version and half with the second. There were three versions of the computer portion of each narrative, one for each possible order of direction probes within a block, and four subjects received each order of probes. The order of blocks was random.

Results

The second part of each question (RT2) was intended to serve as a check that subjects complied with the experimental instructions to decide which object was in the stipulated direction before asking for the alternatives. A repeated-measures analysis of variance on RT2 revealed a significant effect of direction, $F(5,55) = 32.20$, $p < .001$, indicating that subjects did not strictly follow instructions. The RT2 data, however, displayed the same pattern as the RT1 data alone. The RT2 data, where they deviated from equality, did so in the same direction as the RT1 data, but less reliably. Consequently, only RT1 data were used in subsequent analyses.

The RT1 data were adjusted according to the following criteria. Subjects made errors on 2.1% of the questions and these response times were discarded from analysis. Outliers, defined as response times more than two standard deviations greater than the subject's direction cell mean, accounted for 5.1% of the data and were also discarded from analysis. One subject failed to complete three stories in the allotted 2-h experimental session and this subject's means were based only on the narratives completed. Response times were collapsed across narratives within each subject to form mean response times for each direction. Mean response times to each direction are shown in Table 2. The subject means in this, and all subsequent experiments, were subjected to a log transformation because variability was positively correlated with mean response time. The natural log was taken for each subject mean and this served as the data point in the appropriate cell.

Effect of direction. Direction had a significant effect on subjects' response times, $F(5,55) = 15.67$, $p < .001$, and the pattern of results conformed to the predictions of the spatial framework. Subjects responded faster to questions of above/below than front/behind, $t(11) = 5.89$, $p < .001$, and faster to front/behind than left/right, $t(11) = 2.48$, $p < .05$.

Ordering of directions. The ordering of individual directions was below < above < front = behind = left = right, where "<" indicates a significant difference at or beyond the .05 level and "=" indicates no significant difference. (For below vs. above, $t(11) = 2.36$, $p < .05$; for above vs. left, $t(11) = 4.16$, $p < .01$; for front vs. behind, $t(11) = 0.02$, n.s.; for behind vs. left, $t(11) = 0.70$, n.s.; for left vs. right, $t(11) = 0.50$, n.s.) This pattern is predicted by the external spatial framework, except that response times to left were unexpectedly fast.

Explicitly vs. implicitly defined relations. Some of the spatial relations between objects in the cubic array were explicitly stated in the narrative, whereas others had to be inferred by the subject. One claim about mental models that distinguishes them from text representations is that explicit and implicit relations are equally accessible (Byrne & Johnson-Laird, 1989; Johnson-Laird, 1983). Subjects were not significantly faster when probed for explicit relations (2.33 s) than implicit relations (2.49 s), $F(1,11) = 2.83$, n.s., and this factor did not interact with direction, $F(5,55) = 1.17$, n.s. This result offers further evidence that subjects employed mental models to represent the described scenes.

Individual patterns and item effects. In order to assess whether individual subjects tended to display the pattern of response times predicted by the spatial framework, we treated subjects' response times as the product of a random binomial process. There were six possible orders of response times to the three dimensions, so that the spatial framework pattern (above/below < front/behind < left/right) had a 1/6 probability of occurring by chance. Nine of the 12

TABLE 2
MEAN RESPONSE TIMES (IN SECONDS) FOR EXTERNAL PERSPECTIVE NARRATIVES (EXPERIMENT 1)

<table>
<tr><th colspan="6">Direction</th></tr>
<tr><th>Above</th><th>Below</th><th>Front</th><th>Behind</th><th>Left</th><th>Right</th></tr>
<tr><td>2.05</td><td>1.75</td><td>2.57</td><td>2.57</td><td>2.57</td><td>2.89</td></tr>
<tr><td colspan="2">1.90</td><td colspan="2">2.57</td><td colspan="2">2.73</td></tr>
</table>

subjects exhibited the spatial framework pattern (binomial probability < .0001). Six of the 12 subjects responded faster to front than behind, and the remaining six responded faster to behind than front (binomial probability >.05). Thus, there was no difference between front and behind on the level of individual subjects. Females, in general, responded more quickly than males, $F(1,10) = 12.83, p < .01$, but subject gender did not interact with direction, $F(5,50) = 2.15$, n.s., and males and females exhibited the same pattern of response times.

In order to test for item effects, mean response times were calculated for each narrative by collapsing across subjects. The overall spatial framework pattern was evident in all six narratives (binomial probability <.00001), and response times were faster to front than behind in only two narratives (binomial probability >.05). Thus, the overall results of this experiment do not depend on any particular subset of items.

Discussion

In this experiment, subjects read narratives with a specified external perspective that described an array of objects arranged at the corners of an imaginary cube. Subjects responded as fast to inferred spatial relations as to spatial relations explicitly stated in the narrative, indicating the use of mental models. The external spatial framework analysis, based on the perceptual world of the observer, predicts that the vertical axis will dominate due to the asymmetric effects of gravity on the perceptual world and to the preservation of vertical spatial relations under typical horizontal navigation. Of the two horizontal dimensions, front/back should dominate left/right because it is the axis the observer is primarily oriented along and is perceptually asymmetric, with objects toward the front of the viewer being relatively larger, closer, and perhaps occluding more distant objects. These predictions were confirmed by the data. The results, however, contrast with those of Franklin and Tversky (1991b). Whereas response times for front were faster than times for back in Franklin and Tversky's experiments, with the observer internal to the array, response times to front and behind did not differ in the current experiment. This is consistent with predictions of the external spatial framework. Given an external viewpoint, properties of the observer's front/back body axis are not relevant to judgments of front and behind, and objects are equally accessible at either pole.

Experiment 2: Unspecified Perspective: Central Person

The narratives of the first experiment and of Franklin and Tversky (1990b) specified the point of view of the reader by describing the spatial arrays, and probing locations of objects deictically with respect to the reader. Another way to describe a spatial array is with reference to the intrinsic sides of an object or a third-person observer in the scene. In the next two experiments, narratives describe spatial situations quite similar to those of Franklin and Tversky (1990b) except that they locate objects with respect to a central person (Experiment 2) or a central inanimate object (Experiment 3). Narratives written in this way afford the reader more than one point of view on the scene. The reader can either adopt an external perspective, "looking" at the character surrounded by objects, or an internal perspective, that of the central character or object. These two viewpoints correspond to the internal viewpoint specified by the narratives of Franklin and Tversky and the external viewpoint specified in Experiment 1, respectively.

A priori, it seems reasonable to expect that a narrative describing a character in the third person would evoke an external perspective, much like a play or movie, or, for that matter, life, where we frequently find ourselves in the position of an external observer looking at others and their surroundings. On the other hand, if readers adopt external viewpoints on such scenes, they would have to keep in mind two viewpoints in order to respond to direction probes, their external point of view and the point of view of the central person/object, because the probes refer to the intrinsic sides of the central figure. Adopting the viewpoint of the central figure would simplify the readers' mental world by allowing them to keep in mind only one point of view. Whether readers adopt an internal or an external viewpoint can be determined by their response times to "front" and "back" questions. Specifically, if response times to front are faster than those to back, an internal viewpoint is indicated; if not, an external viewpoint is indicated.

Method

Subjects

Subjects were nine male and eight female Stanford undergraduates who participated for credit in an introductory psychology class, or for pay.

Narratives

Nine narratives (one of which was a practice story) were adapted from Franklin and Tversky (1990b). Each narrative described, in the third person, a different setting containing a character surrounded by five objects. Each narrative had two versions, one with a male character and the other with a female character. The settings and the objects were selected to be familiar and common (see Table 3), and the sizes of objects and the distances between them were all roughly equal within a narrative. The locations of objects were selected randomly. An example of a scene used in this experiment is depicted in Fig. 2, but subjects never saw this or any other diagram.

Narratives were presented to subjects in two parts. The first, printed on paper, provided the name of the setting and a list of the five objects, in the scene, then described the environment with respect to the character of the narrative. The first part of the *Space Museum* narrative used in Experiment 2 follows as an example. The key objects are italicized here, but were not in the narratives subjects read.

TABLE 3
SCENES AND OBJECTS OF EXPERIMENT 2

Scene	Objects
Navy ship	Anchor, antenna, cannon, flag, lifeboat
Halloween party	Bowl, ghost, mask, pumpkin, skeleton
Hotel lobby	Banner, barbershop, fountain, giftshop, tavern
Construction site	Bucket, jackhammer, ladder, shovel, wheelbarrow
Opera theatre	Bouquet, lamp, loudspeaker, plaque, sculpture
Space exhibit	Map, meteorite, portrait, satellite, spacesuit
Barn	Lantern, pail, rake, saddle, shears
At the lagoon	Bottle, frisbee, paddle, snorkel, towel
Work shed	Basket, fan, hammer, saw, yardstick

> Sue is at the local Museum of Natural History, visiting the Space Exhibit, which occupies two stories of the building. Except for a narrow circular walkway, the second-story floor is missing so that large objects can be displayed in an open area spanning the two floors. Sue is currently standing on this walkway, looking around at the many fascinating displays. As she stands at the edge, Sue looks directly in front of her and sees a *map* of the solar system, including the orbit paths of all the planets. The map covers many square feet of wall space and is large enough for Sue to easily read from where she stands. Directly to her right, a full-sized *spacesuit* hangs by a thin wire from the ceiling. It is shiny and white, and it looks like it was never used. Next, Sue twists her neck to look directly behind her at a life-sized *portrait* of John Glenn. The portrait is a bright watercolor painting that makes the famous astronaut look very dashing. Peering downward toward the first floor, Sue sees a large rocky *meteorite* resting on a pedestal on the floor of the museum. The meteorite is about the size of a small boulder, but it looks to Sue to be dense enough to weigh a ton. Stretching her neck to look directly above her head, she sees a communications *satellite* suspended from the ceiling. It consists of a metal ball, about 2 feet in diameter, with a metal dish attached to it.

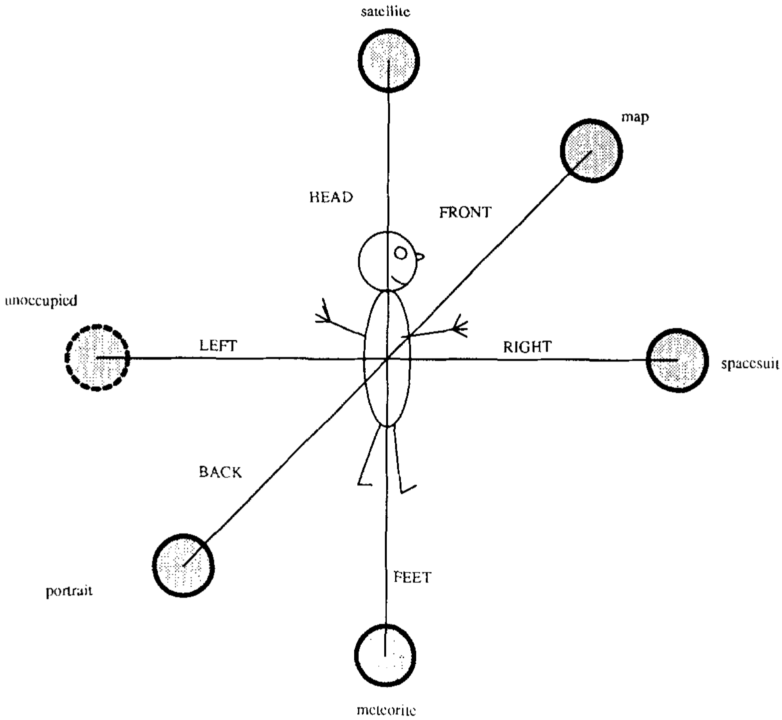

FIG. 2. A depiction of the *Space Museum* person-centered array (Experiment 2). Objects were located with respect to the intrinsic sides of the character shown at the center of the array.

The second part of each narrative was divided into six blocks and presented sentence-by-sentence by computer. Each block began with two sentences orienting the character toward one of the five objects in the environment while either standing upright or reclining. This was followed by two filler sentences that described the object currently to the character's front, without mentioning it by name. The dual purposes of the filler sentences were to focus attention on the object and to prevent priming of the object's name when subjects responded to direction probes. A description of one of the orientations along with the associated detail and filler sentences of the *Space Museum* narrative follows as an example:

After a while, Sue becomes bored and decides to study a different exhibit.

So she turns to her right and faces the spacesuit.

By looking carefully, she can read the insignia on one arm.

The patches identify the astronaut, his rank, and the mission on which he served.

Following the filler sentences, subjects were given direction terms and probed for the objects lying in those directions, and then reoriented toward another object. Direction probes were separated by three filler sentences each. After three reorientations, the character changed posture from upright to reclining, or vice versa, and had two subsequent reorientations in that posture. When reclining, characters lay on their back, front, or sides, and turned along their head/feet axis.

Procedure

The procedure was similar to that of Experiment 1. Subjects read an initial portion of narratives for understanding, then proceeded sentence by sentence through the second portion. Following the filler sentences, subjects were probed with one of six directions, indicated by a single word, "front," "back," "head," "feet," "left," or "right," which referred to a particular side of the central figure (RT1), and then selected the number corresponding to the correct object as quickly as possible, without sacrificing accuracy (RT2). Questions appeared after every two such sentences until all five occupied directions for a particular orientation had been probed. Following this, a new block began with two sentences orienting the character to a new object. The subject was then probed for the five occupied directions in this orientation. The narrative reoriented the character six times, including the change in posture. The first narrative subjects completed was for practice and subjects received feedback about their accuracy on questions. No feedback was given during experimental trials.

Design

The independent variables were direction (front, back, head, feet, left, and right) and posture of the character (upright or reclining), and the dependent variable was RT1.

Approximately equal numbers of subjects were assigned to four random orders of presentation of the eight narratives. In half of the narratives, the character was initially reclining and in the other half, upright. Likewise, half the narratives had a male character, and the other half a female character. Both factors were counterbalanced. The first object faced during the second portion of a narrative was randomly selected and independent of the object faced during the printed portion. Within a block, the order of probes was random. In half the narratives, the character turned clockwise, and in the other half counterclockwise, both in the upright and reclining postures.

Results

The RT2 data were analyzed in a repeated-measures analysis of variance. Posture did not affect RT2 times, $F(1,16) = 0.08$, n.s., but there was a significant effect of direction, $F(5,80) = 5.01$, $p < .001$. Posture and direction did not interact, $F(5,80) = 2.23$, n.s. Although the effect of direction indicates that subjects were not following instructions perfectly, the RT2 data displayed the same general pattern as the RT1 data alone. As before, the RT2 pattern, where it differed from equality, did so in the direction of the RT1 data, but more weakly. The analyses reported were performed on RT1 data.

Subjects made errors on 2.0% of the questions and those were discarded from analysis. Outliers, defined as in Experiment 1, accounted for 5.3% of the data and were also discarded. All response times from a total of 11 stores from five subjects were discarded due to experimenter error, and the response times of a total of four other stories from three subjects were discarded because subjects made more than six errors (average of one per block) during the course of each of these narratives. Six subjects were unable to complete a total of 12 stories in the two hours allotted to the experimental session. As in the first experiment, a log transformation was applied to all data points prior to analysis.

Gender of character. The gender of the character in relation to that of the subject had no impact on subjects' response times. The three-way interaction of direction, posture and match/mismatch between subject and character gender was not significant, $F(5,75) = 1.43$, n.s., indicating that the gender of the character did not influence subjects' performance. In addition there was no main effect of the match of subject and character gender, $F(1,15) = 0.39$, n.s., so subjects were neither slower nor faster when the character was of the same or opposite sex. Consequently, subjects' data were collapsed across character gender for all subsequent analyses.

Effect of direction and posture. Mean direction by posture response times are shown in Table 4. Subjects responded faster when the character was upright than reclining. A two-factor analysis of variance with repeated measures revealed main effects of posture, $F(1,16) = 60.99$, $p < .001$,

TABLE 4
MEAN RESPONSE TIMES (IN SECONDS) FOR NARRATIVES WITH UNSPECIFIED PERSPECTIVE AND A CENTRAL PERSON (EXPERIMENT 2)

	Direction								
Posture	Head		Feet	Front		Back	Left		Right
Upright	1.59		1.41	1.53		1.69	2.27		2.40
Mean		1.50			1.61			2.34	
Reclining	2.22		2.05	1.67		1.87	3.07		2.46
Mean		2.14			1.77			2.76	

direction, $F(5,80) = 20.71$, $p < .001$, and their interaction, $F(5,80) = 3.86$, $p < .01$. When the character was upright, head/feet was faster than front/back, $t(16) = 2.95$, $p < .01$, which was faster than left/right $t(16) = 3.86$, $p < .01$. For reclining characters, however, front/back was faster than head/feet, $t(16) = 4.11$, $p < .001$, which was faster than left/right, $t(16) = 3.82$, $p < .01$.

Ordering of directions. When the character was upright, the ordering of directions was feet < front = head = back < left = right (for feet vs. front, $t(16) = 2.83$, $p < .05$; for front vs. head, $t(16) = 1.11$, n.s.; for head vs. back, $t(16) = 1.28$, n.s.; for back vs. left, $t(16) = 3.11$, $p < .01$; for left vs. right, $t(16) = 0.14$, n.s.). Front was unexpectedly fast, or head unexpectedly slow, in the upright posture. As in Franklin and Tversky's (1990b) second person narratives, subjects were significantly faster to front than to back in the upright posture, $t(16) = 2.08$, $p < .05$, one-tailed test. When the character was reclining, the ordering was front = back = feet < head = right < left (for front vs. back, $t(16) = 1.97$, n.s.; for back vs. feet, $t(16) = 1.88$, n.s.; for feet vs. head, $t(16) = 2.52$, $p < .05$; for head vs. right, $t(16) = 1.69$, n.s.; for right vs. left, $t(16) = 2.39$, $p < .05$).

Constant and vertical dimensions. In the upright posture, the objects located above the head and below the feet did not change with reorientations, and subjects were fastest to answer questions along this axis. In the reclining posture, the objects at the head and feet were also constant, but subjects were faster to respond to front/back than head/feet. Thus, constancy of objects in and of itself did not make objects at the head and feet more accessible. In the reclining posture, all directions except head and feet were sometimes associated with the gravitational axis of the environment, depending on which side of the body on which the character was reclining; however, the mean vertical response time (2.01 s) was slower than that of front/back (1.77 s).

Effect of initial posture. In half the narratives, the character began upright and in the other half reclining, but initial posture did not affect response times. In a repeated-measures analysis of variance, the three-way interaction of direction, posture, and initial posture was not significant, $F(5,80) = 1.94$, n.s.

Individual patterns and item effects. Individual subjects' response times were tested as random binomial processes and found to be consistent with the overall pattern. There are six possible orders of the three dimensions within a given posture. Nine of the 17 subjects exhibited the spatial framework pattern of means in both the reclining and upright postures (binomial probability <.0001), and all 17 subjects displayed the spatial framework pattern in at least one of the two postures. In the upright posture, front could either be faster or slower than back by chance. Twelve of the 17 subjects responded faster to front than back (binomial probability <.05), replicating the mean advantage of front over back at the level of individual subjects. There was no effect of subject gender, $F(1,15) = 0.23$, n.s., nor did gender interact with direction or posture. Item effects were investigated by collapsing across subjects to form direction by posture means for each narrative. The predicted spatial framework pattern was evident in both postures of seven of the eight narratives (binomial probability <.0001). Response times were faster to front than back in the upright posture of seven of the eight narratives (binomial probability <.05).

Discussion

In this experiment, subjects read narratives that described an array of objects with respect to the intrinsic sides of a central person. Unlike the narratives used in Experiment 1, these narratives allowed readers to adopt a viewpoint that was either external or internal to the object array. The latter perspective (that of the central person) is less cognitively demanding and seems to be the viewpoint adopted by readers. Response times were faster to front than back for an upright character, in correspondence with the internal spatial framework analysis. Readers appear to spontaneously take the internal spatial viewpoint of protagonists in narratives describing spatial arrays surrounding the protagonist, even when other viewpoints are possible. This finding is consistent with previous research showing that subjects' memory for described scenes is affected by the psychological and spatial perspective adopted (Abelson, 1975; Owens, Dafoe, & Bower, cited in Bower, 1978).

Experiment 3: Unspecified Perspective: Central Object

In the second experiment, readers adopted the viewpoint of a person internal to a spatial scene when reading narratives that allowed either internal or external viewpoints. In Experiment 3, subjects read narratives that described an array of objects located around a passive central inanimate object. The central object always had an intrinsic front, back, top, and so on, and objects in the described scenes were located with respect to the central object's sides. As in Experiment 2, the narrative perspective was unspecified and subjects could choose to take an external perspective on the array or the perspective of the central object in the array.

Will readers adopt an internal viewpoint when the central figure is an inanimate object rather than a person? On the one hand, readers are not usually induced to identify with objects in narratives, especially passive objects that do not act in the world. Also, many objects do not have intrinsic sides, and even for those that do, the mapping from human intrinsic sides to object intrinsic sides is awkward. In particular, people have heads and feet whereas objects have tops and bottoms. Moreover, the asymmetries of the human body that lead to the predictions of the internal spatial framework are largely perceptual in nature and do not apply to inanimate objects. It is unclear whether readers will extend differential salience of dimensions of the body to the sides of an object. On the other hand, subjects will be probed from an internal perspective, and the claims about cognitive simplicity of keeping a single, as opposed to a double, viewpoint in mind hold for central objects as well as for central human beings.

Method

Subjects

Ten male and four female Stanford undergraduates participated in this experiment for credit in an introductory psychology course.

Narratives

Subjects read seven narratives, one of which was for practice. These narratives differed from those described in the Method section of Experiment 2 in the following respects. First, the narratives described scenes with respect to a central inanimate object rather than a person. These objects, listed in Table 5, had intrinsic fronts, backs, tops, and bottoms. Second, a total of six objects were located around the central object. Subjects in Experiment 2 had little difficulty in keeping track of five objects, so a sixth was added to balance the design of the experiment. Third, the central object was reoriented to face a new object a total of eight times in the second part of each story. Reorientations of the central object were accomplished by external forces explained in the story (e.g., by actions of the work crew). This was done to ensure that subjects did not personify the central object or think of it as animate. The second part of each narrative, presented by computer, contained eight blocks of questions, four concerning an upright and four a reclining central object. Questions were separated by orienting and filler sentences as in Experiment 2. Once reclined, objects were reoriented by turning them along their top/bottom axes, a motion analogous to human characters turning along their head/feet axes.

Procedure

The procedure differed from that of Experiment 2 only in that two directions were referred to as top and bottom, as opposed to head and feet, in the narratives and questions.

Results

A repeated-measures analysis of variance on RT2 revealed no significant effects of direction, posture, or their interaction, indicating that subjects followed instructions to select an object before striking the space bar. Only RT1 data were used in subsequent analyses.

Data from three subjects, two men and one woman, were discarded because these subjects made more than eight errors (average of one per block) in each story they completed. A total of 10 stories from six subjects were also discarded because subjects made eight or more errors in each. Seven subjects were unable to complete a total of 15 stories in the 2-h experimental session. Of the remaining data, 4.4% were errors and 3.5% were outliers. Response times were collapsed across narratives within each subject to form direction by posture means. A log transformation was applied to data points prior to analysis.

Effect of direction and posture. Mean response times are shown in Table 6. A two-factor analysis of variance with repeated measures revealed main effects of direction, $F(5,50) = 6.65$, $p < .001$, posture, $F(1,10) = 44.85$, $p < .001$, and their interaction, $F(5,50) = 9.74$, $p < .001$. Subjects responded more slowly when the central object was reclining. The pattern of response times in the upright posture conformed to the spatial framework pattern, with top/bottom faster than front/back, $t(10) = 6.90$, $p < .001$, which was faster than left/right, $t(10) = 2.34$, $p < .05$. The pattern in the reclining posture, however, did not conform to the spatial framework, with front/back faster than left/right, $t(10)$

TABLE 5
SCENES AND OBJECTS OF EXPERIMENT 3

Scene	Central object	Objects
Navy ship	Weather vane	Anchor, antenna, cannon, flag, lifeboat, warning light
Hotel lobby	Push cart	Banner, barbershop, fountain, giftshop, office, tavern
Construction site	Tool box	Boards, bucket, jackhammer, ladder, shovel, wheelbarrow
Opera theatre	Chair	Bouquet, lamp, loudspeaker, plaque, sculpture, table
Space exhibit	Moon rover	Map, meteorite, portrait, rocket, satellite, spacesuit
Barn	Saddle	Bag of feed, brush, lantern, pail, rake, shears
Work shed	Engine	Basket, fan, hammer, saw, tire pump, yardstick

TABLE 6
MEAN RESPONSE TIMES (IN SECONDS) FOR NARRATIVES WITH UNSPECIFIED PERSPECTIVE AND A CENTRAL OBJECT (EXPERIMENT 3)

	Direction								
Posture	Top		Bottom	Front		Back	Left		Right
Upright	1.63		1.67	2.05		2.56	3.02		2.49
Mean		1.65			2.30			2.76	
Reclining	3.16		3.89	2.59		3.33	3.58		2.98
Mean		3.52			2.96			3.28	

= 2.21, $p < .05$ one-tailed, which was somewhat faster than top/bottom, although this difference was not significant, $t(10) = 0.35$, n.s.

Ordering of directions. The ordering of directions within the upright posture was consistent with the internal spatial framework, with top = bottom < front < back = right = left (for top vs. bottom, $t(10) = 0.15$, n.s.; for bottom vs. front, $t(10) = 1.84$, $p < .05$ one-tailed; for front vs. back, $t(10) = 2.43$, $p < .05$; for back vs. right, $t(10) = 0.57$, n.s.; for right vs. left, $t(10) = 1.69$, n.s.). The order of directions in the reclining posture were generally not consistent with the predictions of the spatial framework, with front < right = top = back = left = bottom (for front vs. right, $t(10) = 2.57$, $p < .05$; for right vs. top, $t(10) = 0.32$, n.s.; for top vs. back, $t(10) = 1.39$, n.s.; for back vs. left, $t(10) = 0.98$, n.s.; for left vs. bottom, $t(10) = 0.99$, n.s.).

Constant and vertical dimensions. As in Experiment 1, the response times for the constant dimension (3.49 s) and the vertical dimension (3.28 s) in the reclining posture were slower than the response times for front/back (2.96 s).

Effect of initial posture. In half the narratives, the central object was initially upright and in the other half, reclining, but this had no effect on subjects' response times. A repeated-measure analysis of variance revealed that the three-way interaction of direction, posture, and initial posture was not significant, $F(5,50) = 0.94$, n.s.

Individual patterns and item effects. Eight of the 11 subjects displayed the spatial framework pattern in the upright posture (binomial probability <.0001). Moreover, 10 of the 11 subjects responded faster to front than back in the upright posture (binomial probability <.01). Five of the 11 subjects exhibited the observed pattern of means for the reclining posture (front/back < left/right < top/bottom) (binomial probability < .01), but only two of the 11 subjects exhibited the pattern predicted by the spatial framework (front/back < top/bottom < left/right) (binomial probability >.05). Individual subjects' response times for the reclining posture were not ordered as predicted by the spatial framework, but were consistent with the observed mean data. It should be noted, though, that two of the 11 subjects exhibited the predicted patterns in both the upright and reclining postures (binomial probability <.04). These subjects may have been able to represent the environments according to the spatial framework, even for reclining central objects. Subject gender was not examined as a factor because only four female subjects participated in this experiment and this factor was not found to affect subjects' response times in previous experiments.

Mean response times were calculated for each narrative, and the spatial framework pattern for the upright posture was evident in all six narratives (binomial probability <.00001). The observed pattern in the reclining posture was evident in three of the six narratives (binomial probability <.06), whereas the pattern predicted by the spatial framework was evident in only two of the six narratives (binomial probability >.05). These two narratives involved a chair and moon rover as central objects, and it is possible that subjects found it easier to resolve the terms top and bottom for these objects than others.

Discussion

Subjects read narratives with an unspecified spatial perspective describing an array of objects around a central object. The pattern of response times indicated that readers took the internal viewpoint of the central object rather than an external viewpoint, but not without difficulty. When the central object of a narrative was upright, the pattern of response times was that of the internal spatial framework. In addition, subjects tended to respond as quickly overall to questions in the upright posture as subjects in Experiment 2 with a central person. When the central object was reclining, however, response times were considerably slower than those in the reclining condition of Experiment 2 and deviated somewhat from the spatial framework pattern. Thus, subjects appeared to have difficulty answering questions about relative directions from a noncanonically oriented central object.

When the central object reclined, the top/bottom questions took longer than front/back or left/right. This seems to be due to the fact that, for a reclining object, two senses of the terms "top" and "bottom" are in conflict. "Top" refers to a particular surface of an object that has an intrinsic top and bottom, but for objects that do not, it refers to the part of the object that is currently upwards. When the object is upright, the two senses of "top" coincide, and there is no conflict in interpreting its meaning, but when the object is reclining the term is ambiguous. The same argument holds for "bottom."

Nevertheless, except for the slow response times to top and bottom when the central object reclined, the pattern of response times corresponds to the internal spatial framework. This is evidence that readers take the point of view of an inanimate object in reading narratives and answering questions about the spatial relations of objects to the central object, even when other points of view are possible. Readers even seem willing to extend an analysis of the human body in space to inanimate objects.

EXPERIMENT 4: INTERNAL VERSUS EXTERNAL PERSPECTIVES

The first three experiments have presented evidence of two subclasses of the spatial framework. The external framework reflects the spatial regularities of an observer outside an array of objects, primarily those of the typical field of view, and the internal framework reflects the regularities of an observer inside an array, those of the body as well as the perceptual world. One way narratives induce a perspective is by the use of deictic terminology, by describing locations of objects with respect to the point of view of "you," the reader, and by querying locations with respect to "you" as well. The experiments of Franklin and Tversky (1990b) induced an internal perspective by the use of deictic spatial terms, in the same way that the first experiment induced an external perspective. In contrast, Experiments 2 and 3 indicated that when a narrative uses intrinsic rather than deictic spatial terms and readers are free to assume either an external or an internal perspective, readers prefer to adopt the internal point of view of the figure/object that serves as the spatial referent.

The spatial situation used to verify the external spatial framework was, however, slightly different from that used to demonstrate the internal spatial framework. It would be both more elegant and more convincing to induce readers to form either an internal or external framework of the *same* scene, depending on the perspective from which it was described. For this, we constructed two types of narratives that described the identical objective situation, one written from an internal perspective and the other from an external perspective. The narratives described "you," the reader, standing in a setting, facing another person surrounded by six objects on all sides (see Fig. 3). The external version of the narrative located these objects with respect to "you" the reader looking at the character, whereas the internal version located the objects with respect to the intrinsic sides of the character. Each subject read both types of narratives during the experimental session. If subjects assume an external perspective when deictic language specifies it, and an internal perspective when intrinsic spatial language is used, then subjects should take different points of view on the same array depending on the spatial terminology. If, on the other hand, the spatial array itself dictates perspective, the same perspective should be adopted for both narrative versions. The relative times for front and back (behind) indicate whether an internal or external perspective has been taken.

A second goal of this experiment was to replicate the results of Experiment 1 with narratives that described scenes like those used in Experiments 2 and 3 and Franklin and Tversky (1990b). Those narratives described an array of objects surrounding a central figure. The lack of a central figure in the cube-like arrays of the first experiment

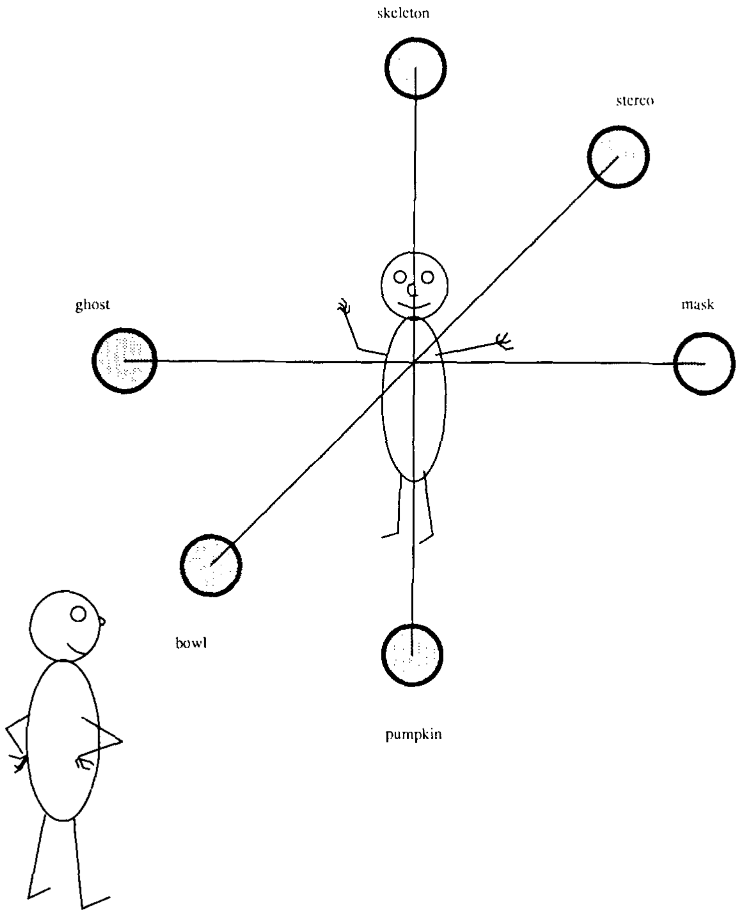

FIG. 3. An example of the type of scene described by narratives in Experiment 4. The reader is the figure outside the array and the individual inside the array another character.

may have influenced subjects' strategies. Specifically, the absence of a difference between response times to front and behind may have reflected the lack of an internal figure whose front and back would imply an asymmetry along that dimension.

Method

Subjects

Subjects were seven male and nine female Stanford undergraduates who participated for credit in an introductory psychology class.

Narratives

Nine narratives, one of which was a practice story, were adapted from the scenes used in Experiment 2. Each narrative addressed the reader in the second person and described an environment in which the reader was standing facing another person. The character was surrounded by six objects. A diagram of one of the settings is shown in Fig. 3, but subjects never saw this or any other diagram.

There were two versions of each narrative: one written from an internal perspective and another from an external perspective. The internal versions described the locations of objects with respect to the character inside the array of objects, as in Experiment 2. Question probes were also with respect to the central character. The external versions described the locations of objects with respect to the reader's perspective outside the array, as in Experiment 1. Questions were also from the external point of view of the reader. Thus, the external perspective was prescribed by the deictic use of spatial terms, and the internal point of view was induced as in Experiments 2 and 3. In all other respects, the two versions of a narrative were identical.

Narratives were again given to subjects in two parts. The first, printed on paper, provided the name of the setting and a list of the six objects in the scene and then described the environment either with respect to the reader's perspective or that of the other character in the story. The second part of each narrative was divided into three blocks and presented sentence-by-sentence by computer. Each block began with four filler sentences that described details about an object in the scene. Then all six directional probes were presented, each separated by two filler sentences. This pattern was repeated twice more so that each direction was probed a total of three times during the course of a narrative. Neither the reader nor the character centered in the array of objects was reoriented during the course of the narrative.

Procedure

The procedure followed that of previous experiments. Subjects were first given detailed instructions about the experiment. They were allowed to read the first part of each narrative as long as they wished and turned to the computer for the second part containing filler sentences and direction probes. Feedback was provided during the practice narrative.

Design

The independent variables were direction (front, back/behind, head/above, feet/below, left, and right), and narrative perspective (internal or external). The dependent variable was the time to decide which object in an environment was in the direction indicated by a question (RT1). Directions were probed three times per narrative in order to provide stable subject means in each condition.

An equal number of subjects was assigned to four random orders of presentation of the eight narratives. Half the subjects initially completed four narratives written from an internal perspective before completing four external narratives. The other half completed the two perspective conditions in the opposite order. Subjects were always probed for locations of objects from the same perspective as the narrative they had just read. In half of the narratives, the character in the scene was male, and in the other half female. Character gender was counterbalanced with narrative perspective. Each direction appeared as a probe once per block. The order of probes within a block was randomly determined.

Results

The data of one subject were discarded because this subject made more than 12 errors (average of one per block) in the narratives that the subject completed. The RT2 data were subjected to a repeated measures analysis of variance. Narrative perspective did not affect RT2 times, $F(1,14) = 0.18$, n.s., but there was a significant effect of direction, $F(5,70) = 8.38$, $p < .01$. The interaction of perspective and direction was not significant, $F(5,70) = 0.80$, n.s. The RT2 data displayed the same but a weaker pattern as the RT1 data alone, and all subsequent analyses were performed on RT1.

RT1 data were analyzed separately for the internal and external perspective conditions. In the internal perspective narratives, 4.8% of the responses were errors and 3.4% were outliers. In the external perspective narratives, 5.6% of the responses were errors and 4.9% were outliers. Response times were collapsed across narratives to compute direction by perspective means for each subject. A log transformation was applied to data points prior to analysis.

Effect of perspective and direction. Table 7 presents mean direction by perspective response times. The general spatial framework pattern was replicated in both the internal and external conditions. A two-factor analysis of variance with repeated measures revealed a main effect of direction, $F(5,70) = 32.27$, $p < .001$. In the internal condition, head/feet was only marginally faster than front/back, $t(14) = 2.06$, $p < .06$, which was significantly faster than left/right, $t(14) = 4.95$, $p < .001$. In the external condition, above/below was faster than front/behind, $t(14) = 3.74$, $p < .01$, which was faster than left/right, $t(14) = 3.88$, $p < .01$. Subjects were somewhat faster, overall, to respond to probes in the external than internal condition. Although this effect only achieved marginal significance, $F(1,14) = 4.12$, $p < .07$, it was supported by analysis of individual subjects' response times (see below). The interaction of perspective and direction was not significant, $F(5,70) = 1.31$, n.s.

Ordering of directions. The ordering of individual directions was consistent with the predictions of the spatial framework for both the internal and external perspectives. In the internal condition, the ordering was feet = head = front < back < right = left (for feet vs. head, $t(14) = 1.84$, n.s.; for head vs. front, $t(14) = 0.15$, n.s.; for front vs. back, $t(14) = 1.89$, $p < .05$, one-tailed; for back vs. right, $t(14) = 3.59$, $p < .01$; for right vs. left, $t(14) = 0.26$, n.s.). As predicted by the internal spatial framework analysis, subjects were faster to respond to questions of front than back. In the external condition, the ordering was below = above < behind = front < right = left (for below

TABLE 7
MEAN RESPONSE TIMES (IN SECONDS) FOR NARRATIVES WITH AN INTERNAL OR EXTERNAL PERSPECTIVE (EXPERIMENT 4)

	Direction								
Perspective	Head/above		Feet/below	Front		Back/behind	Left		Right
Internal	1.51		1.42	1.55		1.68	1.93		1.91
Mean		1.46			1.62			1.92	
External	1.34		1.27	1.54		1.49	1.83		1.70
Mean		1.30			1.52			1.76	

vs. above, $t(14) = 2.06$, n.s.; for above vs. behind, $t(14) = 2.11, p < .06$; for behind vs. front, $t(14) = 0.73$, n.s.; for front vs. right, $t(14) = 2.06, p < .06$; for right vs. left, $t(14) = 1.65$, n.s.). As predicted by the external spatial framework, there was no difference in subjects' response times to questions of front and behind. The critical finding is that front is faster than back in the internal condition, but equally fast as behind in the external. This finding was confirmed by a significant interaction effect of direction and perspective, $F(1,14) = 6.03, p < .05$, found in an analysis of variance performed on the front/back (behind) data as a function of perspective.

Effects of initial perspective. Half of the subjects received the internal perspective versions of narratives first, followed by the external ones; the other half had the opposite order. The initial perspective had no effect on subjects' performance, $F(1,13) = 3.78$, n.s. The three-way interaction of initial perspective, direction, and narrative perspective also was not significant, $F(5,65) = 1.11$, n.s., indicating that subjects displayed the same pattern of response times regardless of the order in which they received perspective conditions.

Individual patterns and item effects. Individual subjects' patterns of response times were consistent with the predictions of the spatial framework within each perspective condition. In the internal condition, 12 of 15 subjects produced the expected general pattern (i.e., head/feet < front/back < left/right) (binomial probability <.0001), and 12 of 15 subjects were faster to front than back (binomial probability <.02). In the external condition, nine of 15 subjects displayed the general pattern (binomial probability <.001), and only nine of 15 subjects were faster to front than behind, not more than expected by chance (binomial probability >.05). Subjects tended to be faster, overall, to probes in the external than internal conditions, with 11 of 15 subjects displaying this pattern (binomial probability <.05). There was no effect of subject gender on response times, $F(1,13) = 1.25$, n.s., and this factor did not interact with any other.

The predicted spatial framework pattern was evident in both the internal and external versions of all eight narratives (binomial probability <.00001). Front was faster than back in six of the eight internal narratives (binomial probability >.05), failing to support the mean data. Front was faster than behind in only five of the eight external narratives (binomial probability >.05).

Discussion

Experiment 4 demonstrates that, for the identical spatial array, readers will employ an internal spatial framework when the narrative perspective is that of an inside observer, and an external framework when the narrative perspective is that of an outside observer. Subjects responded faster to questions of front than back in the internal perspective condition, a prediction of the internal spatial framework. The same subjects were no faster to front than behind in the external perspective condition, a prediction of the external spatial framework. Thus, adopting the external spatial framework does not depend on the particular "cube" array described in the narratives of Experiment 1. The external spatial framework has been replicated on spatial arrays surrounding a central person or object, identical to the arrays used in experiments demonstrating the internal framework.

An interesting finding was that subjects responded faster overall to questions in the external than in the internal condition. Although not predicted, this finding is understandable. In the internal condition, objects are located on all sides of the observer, some not in the field of vision. In the external condition, however, all the objects were located in front of the observer. That situation may be easier to hold in mind, yielding the faster response times. Objects in an external framework may all gain a degree of salience by being associated with the observer's frontward direction which yields a high degree of perceptual and spatial availability.

General Discussion

Internal spatial framework analysis. In earlier work, Franklin and Tversky (1990b) proposed that in order to keep track of locations of objects in narratives, people form three-dimensional mental spatial frameworks based on their conceptions of space from interactions with the perceptual world. In the current set of experiments, we have found that there are at least two classes of spatial frameworks. One, the internal spatial framework explored by Franklin and Tversky, refers to the mental model readers adopt for spatial situations that are associated with a viewpoint within the described environment. In this framework, spatial relations are conceptualized with respect to the sides of a central figure (i.e., front, back, head, feet, left, and right). Accessibility of information from the spatial framework depends on the particular axis probed and the posture of the central figure.

Rejecting other explanations. According to an imagery/transformation theory (cf. Finke & Shepard, 1986; Kosslyn, 1980; Podgorny & Shepard, 1978), readers would imagine themselves in the described scene, facing the selected object. In order to decide which object is currently located in a particular direction, readers would imagine themselves turning to that direction and inspecting it. In this case, response times should increase with the angle of difference between the direction faced (front) and the probed direction, and subjects should have been slowest to back (180° rotation), and equally fast to head, feet, left, and right (90° rotation). This prediction was not supported by either Franklin and Tversky's experiments or the present ones.

A possible artifact can also be rejected by the data. Objects located at the head and feet did not change with reorientations of the upright observer, in contrast to those located at the front, back, left, and right, perhaps accounting for the finding that subjects were fastest to head/feet. However, when the observer reclined, objects located at the head and feet were still constant because observers turned along that axis, but subjects were fastest to questions of front and back rather than head and feet.

Extensions of the Spatial Framework Analysis

External spatial framework. The present studies extended the spatial framework analysis to a narrative perspective external to a spatial array. In the first experiment, narratives located each object in a particular direction from another object with respect to an implied observer (you) outside the array. For example, when the pumpkin was described as in front of the stereo, that meant that the pumpkin was closer to the observer than the stereo. When the viewpoint is external, considerations of body axis asymmetries are no longer relevant to predicting response times to access spatial information. Rather, predictions are made on the basis of asymmetries in the perceptual world of the external observer.

In the external case, spatial relations are defined by an above/below axis corresponding to the gravitational axis of the world, a front/behind axis projecting from the implied observer at the assumed point of view, and a left/right axis defined by the observer's left and right. Asymmetries due to gravity and constancy under typical horizontal navigation render the vertical axis the dominant one. The front/behind axis is the next most salient, because of asymmetries of size, clarity, and occlusion of objects produced by relative nearness. No such asymmetries exist for the left/right dimension. Thus, the global predictions for the external viewpoint (above/below fastest, followed by front/behind, then left/right) are identical to those of the upright internal viewpoint, though for different reasons.

One prediction distinguishes the external from the internal spatial framework. In all of the previous studies with upright internal viewpoints, responses to *front* were considerably faster than those to *back*. This makes sense for objects in front of and behind the viewer because the perceptual apparatus and behavior are oriented primarily frontwards. For the external viewpoint, however, both objects are in front of the viewer, and the terms front and behind merely refer to the relative nearness of objects to the observer along this dimension. Thus, for the external viewpoint, the reaction time advantage to *front* over *behind* should disappear, and in fact, it did.

Experiment 4 produced evidence for both external and internal spatial frameworks for the same spatial array, that of a central figure surrounded by objects. The external spatial framework was induced by narratives that used deictic spatial terms to give an explicit external perspective. The internal spatial framework was induced by narratives that used intrinsic spatial terms with the central figure as the spatial referent. Thus, the external spatial framework does not reflect the difference in the spatial arrays of Experiment 1 and of Franklin and Tversky (1990b). In particular, the presence of a figure in the array did not induce an advantage of front over behind.

Narratives with unspecified perspective. Franklin and Tversky's (1990b) use of the second person and deictic spatial terms was meant to draw the readers into the spatial situation. Indeed, in many conversations, speakers describe events as if they happened to "you," the listener, presumably to induce the listener to identify with the speaker's experience. Most narratives, however, do not employ this device, but are written with an intrinsic perspective about a third-person character. When reading and answering questions about an array of objects around another person, the reader can adopt either an external viewpoint or, with some minor alterations, an internal viewpoint, essentially in the place of the character. The results of Experiments 2 and 3 reveal that readers prefer to adopt the internal perspective of a central person or object in order to represent a scene described from that person's point of view, although an external perspective might be a more familiar and natural way of experiencing such a situation. Adopting an internal perspective presumably makes it easier to comprehend such narratives because only a single viewpoint needs to be kept in mind.

It is not difficult to reinterpret object-centered narratives and direction questions to enable an internal point of view, and that is what readers seemed to do. Where "Sue" or "the saddle" appear, a reader can substitute "you." The advantage of doing so is in reducing the number of points of view that have to be kept in mind. If the reader takes the point of view of the central figure, then the reader no longer has to keep in mind an external point of view, which is irrelevant to the task at hand. Where both internal and external perspectives are relevant, a reader might keep both in mind, or switch back and forth between them. Adopting the internal viewpoint did not seem to be costly in the case of narratives describing a central person; the pattern and speed of responding was comparable to that of second-person narratives. Although we did not use first-person narratives, we expect that readers could just as easily adopt the perspective of a first-person central character for similar reasons.

Adopting the point of view of a central object was more difficult, but probably not because readers had difficulty thinking of themselves in the place of a saddle or a chair, as readers had little difficulty with the upright case. The difficulties readers had assuming the perspective of objects occurred only when the objects reclined, and they seem to be attributable to the conflicting senses of "top" and "bottom" for reclining objects.

The Theory of Spatial Frameworks

The four experiments reported here extend the scope of the spatial framework analysis to account for external viewpoints, where properties of the perceptual world alone determine the pattern of response times. For narratives without a specified spatial perspective that describe an array around a central person or object, readers chose to take an internal rather than an external viewpoint, presumably to simplify the mental spatial framework that had to be kept in mind. However, readers' mental models of described scenes can incorporate either an internal or an external point of view, depending on the narrative perspective. In both cases, and in other cases investigated elsewhere (Franklin & Tversky, 1990a), the spatial framework has a particular perspective. Indeed, it is the observer's perspective relative to the array and the world that confers the asymmetries underlying differential accessibility. In the sense of having a defined perspective, spatial frameworks are more like images or Marr and Nishihara's (1978) 2½D sketch than abstract mental models (Johnson-Laird, 1983) or Marr and Nishihara's object-centered representation.

Although we have talked about "the" spatial framework, there appears to be a family of spatial frameworks that depend on the spatial array to be represented, the viewpoint of the observer, and other factors as well. As a family of mental spatial models, spatial frameworks resemble what Lakoff calls "image schemas" (Lakoff, 1987). Image schemas are sets of related spatial mental models meant to represent the various senses of spatial terms, such as *over* and *up*. Like image schemas, spatial frameworks differ from conventional images (see Kosslyn, 1980) in that they are not rich or detailed, and do not have specific knowledge attached to them. Once a spatial framework is invoked to represent a particular scene, it contains specific information but not necessarily as concretely or richly as in an image. Spatial frameworks are memory structures or schemas or frames; they are somewhere between networks and images in abstractness. Because they represent spatial relations, they are more structured than networks, and that structure derives from human interactions with the perceptual world. A spatial framework forms a mental scaffolding on which specific information can be arranged and rearranged, information drawn from the world or from discourse about the world. For the internal spatial framework, the scaffolding is formed from the observer's body axes and for the external framework from a set of axes projected from the observer.

The accessibility of relations from an observer's viewpoint is accounted for by characteristics of the body and perceptual world of the observer. That space is similarly organized around the body rather than around other referents in space was observed in a little known and largely ignored essay published in 1768, "The First Ground of Distinction of Regions in Space." Kant wrote:

> In physical space, on account of its three dimensions, we can conceive three planes which intersect one another at right angles. Since through the senses we know what is outside us only insofar as it stands in relation to ourselves, it is not surprising that we find in the relation of these intersecting planes to our body the first ground from which to derive the concept of regions in space. . . . The plane to which the length of our body stands perpendicular is called, in reference to us, horizontal; it gives rise to the distinction of the regions we indicate by *above* and *below*. Two other planes, also intersecting at right angles, can stand perpendicular to this horizontal plane, in such a manner that the length of the human body is conceived as lying in the line of their intersection. One of these vertical planes divides the body into two outwardly similar parts and supplies the ground for the distinction between *right* and *left;* the other, which is perpendicular to it, makes it possible for us to have the concept of *before* and *after* (Kant, pp. 21–22, cited by Casey, 1991).

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