Journal of Experimental Psychology:
Human Learning and Memory
1980, Vol. 6, No. 5, 516–528

Reference Points in Spatial Cognition

Edward K. Sadalla, W. Jeffrey Burroughs, and Lorin J. Staplin
Arizona State University

The present research investigates the hypothesis that cognitive representations of large scale space contain elements that may be termed reference points, and that these points are used to define the position of adjacent places. The nature and function of reference points is explored in five experiments. Experiments 1 and 2 consist of tasks during which subjects judged the distance between known locations. The subjective distance between reference points and nonreference points was found to be asymmetrical, with the latter ordered in relation to the former. Experiments 3 and 4 employ reaction time tasks in which subjects attempted to verify the distance or direction from an anchor location to target locations. The data indicate that the relative referentiality of anchor and target locations influences verification time. The results of Experiments 1–4 suggest that reference points occur in spatial cognition and that these points provide an organizational structure that facilitates the location of adjacent points in space. Experiment 5 consists of a multiple regression analysis designed to clarify the semantic attributes of spatial reference points.

The concept of *landmark* has been increasingly used to account for human navigational ability. Lynch (1960) suggested that navigation through cities is dependent on memory for landmarks. Siegel and White (1975) similarly argued that landmark knowledge is a necessary condition for "way finding" to occur; landmarks are described as the strategic foci to and from which an individual travels. Landmarks have also been found to play a rôle in the development and maintenance of spatial orientation. Acredolo (1977) found that landmarks facilitate children's transition from egocentric to coordinated frames of reference. Howard and Templeton (1966) suggested that adult geographical orientation is typically maintained through reference to landmarks. Allen, Siegel, and Rosinski (1978) concluded that the acquisition of spatial knowledge in a novel milieu begins with the perception of distinctive environmental features. The term has additionally been used to denote central elements in an individual's cognitive representation of a region; the most easily recalled attributes of a region are typically referred to as landmarks (Appleyard, 1969; Downs & Stea, 1973).

The literature previously cited indicates that the concept of landmark has multiple referents. The term has been used to denote (a) discriminable features of a route, which signal navigational decisions; (b) discriminable features of a region, which allow a subject to maintain a general geographical orientation; and (c) salient information in a memory task. These different referents suggest that landmarks may play a role in a variety of spatial abilities.

The present studies explore the function of landmarks as spatial reference points, points that serve as the basis for the spatial location of other (nonreference) points. Implicit in the concept of spatial reference point is the assumption that the position of a large set of (nonreference) locations in a particular region is defined in terms of the position of a smaller set of reference locations. It is assumed that the

The authors would like to thank Clark Presson for his thoughtful critique of an earlier version of this article and Larry Gregory for his suggestions regarding data analysis.

Requests for reprints should be sent to Edward K. Sadalla, Department of Psychology, Arizona State University, Tempe, Arizona 85281.

location of different places within a region is known with different degrees of certainty. Reference points are those places whose locations are relatively better known and that serve to define the location of adjacent points. This sort of organization could be expected from considerations involving cognitive economy (Stevens & Coupe, 1978). Rather than a system that stores the relationship between every known location, the relationship between reference points may be stored and the position of other points computed from the knowledge that they are proximate to specific spatial reference points.

The present research explores the possibility that spatial knowledge is organized in terms of reference points. Multiple operational definitions are employed in an attempt to establish the validity of the concept. The operational definitions employed in the first two experiments are similar to those developed by Rosch (1975) in her analysis of semantic reference points. Rosch demonstrated the existence of asymmetries in similarity judgments between semantic reference points and nonreference points. The present research seeks to establish whether an analogous phenomenon exists for spatial reference points. Such asymmetries may be expected if the spatial location of nonreference points is cognitively represented primarily in terms of proximity to specific reference points. Since a reference point is regarded as a place that defines the position of other adjacent places, it follows that other places should more easily be seen "in spatial relation to" a reference point than vice versa. The asymmetry hypothesis concerns the magnitude of the judged spatial relationship between reference points and adjacent places: Adjacent places should be judged closer to reference points than are reference points to adjacent places.

Additional evidence for reference points was sought in the context of reaction time studies. Following the logic that the location of nonreference points is encoded in terms of adjacent reference points, it was hypothesized that the verification of the distance from a given location to a spatial reference point would be faster than the verification of the distance to an equivalently spaced nonreference point. It was further assumed that in a reaction time task, verification of the orientation of a location in relation to a reference point should be faster than verification of the orientation of a location in relation to a nonreference point. The research reported here consists of four studies that were designed to test these assumptions. Data from a fifth study, concerned with the semantic attributes of spatial reference points, are also included.

Experiment 1

The first task used to test the asymmetry hypothesis was a cognitive-mapping task in which subjects located the relative positions of reference points and nonreference points on a grid. In this task the name of one location was anchored at the center of a line grid; the other stimulus was placed by the subject at a point that represented the subject's perception of the distance between the two locations. If the cognitive distance between reference points and adjacent (nonreference) points is symmetrical, then the judged distance between a reference point and a nonreference point when the reference point is the anchor should not differ from the judged distance between those same points when the nonreference point is the anchor. The asymmetry hypothesis, however, predicts that judged distance will differ under these two conditions. Specifically, this hypothesis leads to the prediction that judged distances between a reference point and a nonreference point will be less when reference points are anchors, since reference points are locations that other places are seen "in relation to."

Method

Subjects. This experiment consisted of a stimulus scaling phase that involved 50 male and female subjects, and a subsequent mapping task that involved a new sample of 40 male and female subjects. All subjects were students in an introductory psychology course, who participated in partial fulfillment of a course requirement.

Stimuli. The stimuli used in the cognitive-mapping task consisted of pairs of locations on the Arizona State University (ASU) campus and pairs of

Table 1
Mean Distance Placements of Subjects (mm) for Control and Experimental Conditions When Stimulus 1 was Fixed and When Stimulus 2 was Fixed

Stimulus condition	Control pairs	Experimental pairs
Stimulus 1 fixed	81.1	72.6
Stimulus 2 fixed	82.9	78.6
M diff between Stimulus 1 and Stimulus 2	1.8	6.0*

* $p < .05$.

locations in the greater Phoenix metropolitan area (the setting of ASU). Ten pairs of locations were employed as stimuli, 5 experimental pairs in which one of the locations was a hypothesized reference point and the other location was not, and 5 control pairs in which neither location was hypothesized to be a reference point.

Identification of potential reference points. To identify locations that served as reference points in the environment, 50 subjects were asked to rate 20 locations on the Arizona State University campus and in the greater Phoenix metropolitan area on three 9-point scales selected to measure the salience and importance of each location. The three dimensions employed were number of visits to a place (anchored on the 9-point scale by "never–very often"), knowledge of the place's location (anchored by "know very well–know very poorly"), and the historical and cultural importance of the location (anchored by "not important at all–very important"). By summing the score of each location over the three dimensions, an overall environmental salience score was constructed for each location.

It was hypothesized that a highly salient location, when paired with a location that was not salient, would serve as a reference point for the nonsalient location. Accordingly, based on the salience scores, locations were assigned to experimental and control pairs. The experimental pairs contained one location that was rated as highly salient and one location rated low in salience. The control pairs contained locations of equal salience.

Mapping task. The response instrument used to record distance placements in this experiment was designed after Rosch (1975). A 25.4-cm diameter, semicircular grid was placed on 21.6 cm × 28 cm sheets of paper; the grid was composed of semicircular lines 1.2 cm apart. A stimulus location was printed at the origin on each sheet, and an additional stimulus location was indicated, which the subjects were asked to place on the grid at a point that best represented the distance between the two stimuli. Subjects marked their responses so that each distance placement was made on a new semicircular grid; the sheets were combined into a response booklet.

Each subject performed the place task for the five experimental and five control pairs. Each stimulus pair was presented twice to each subject—once with Stimulus 1 of the pair fixed at the origin of the grid, and once with Stimulus 2 of the pair fixed at the origin of the grid. In counterbalancing the presentation order, the stimulus pairs were divided into two groups, one with Stimulus 1 fixed and the other with Stimulus 2 fixed. The order of presentation of the two groups was reversed for half of the subjects. Within these groups the presentation of the pairs was counterbalanced so that each distance placement appeared in each presentation order once.

Subjects were told that the experiment was concerned with the way people describe the relationships between physical locations. To eliminate the possibility of subjects comparing distance placements made early in the experiment with subsequent placements, subjects were not allowed to return to responses in their booklets once they had turned a page.

Results

The variable of primary interest in this phase of the study was the possible difference in distance judgments when the hypothesized reference location was the fixed point versus when it was the point located by the subject. The dependent variable was the distance between the origin of the grid (fixed stimulus location) and the point at which the subject placed the other member of a stimulus pair.

Presented in Table 1 are the mean distance estimations over location pairs for the condition when Stimulus 1 was fixed and for the condition when Stimulus 2 was fixed. These distance estimates and the differences between them were computed for experimental and control pairs. To determine if these differences were statistically significant, a one-way multivariate analysis of variance (MANOVA) was performed separately for experimental and control conditions. In the experimental condition Stimulus 1 refers to a hypothesized reference point location, whereas Stimulus 2 refers to a nonreference point location. In the control condition one member of a stimulus pair was randomly designated Stimulus 1; the other was designated Stimulus 2. In each MANOVA the experimental manipulation (Stimulus 1 fixed vs. Stimulus 2 fixed) was treated as a within-subjects factor with two levels, and the five location pairs were treated as five dependent variables.

The MANOVA for control pairs indicated that no significant differences existed between the distance placements made when Location 1 was fixed versus when Location 2 was fixed; by Wilks's lambda, multivariate $F(5, 15) = 1.53$, *ns*. Thus, when neither member of a pair of locations was more salient than the other, the distance between Stimulus 1 and Stimulus 2 was seen as equal to the distance between Stimulus 2 and Stimulus 1.

The MANOVA for experimental pairs indicated that when Stimulus 1 (the hypothesized reference location) was fixed at the origin of the grid, the distance between Stimulus 1 and Stimulus 2 was significantly less than when Stimulus 2 (the nonreference location) was fixed at the origin point, multivariate F by Wilks's lambda $(5, 15) = 3.13, p < .04$. Thus, when one member of a location pair was more salient than the other, the distance between Stimulus 1 (reference location) and Stimulus 2 (nonreference location) was seen as significantly less than the distance between Stimulus 2 and Stimulus 1. These results support the hypothesis of asymmetries in cognitive distance between spatial reference points and nonreference points.

Experiment 2

The second task that was used to evaluate the reference point hypothesis employed a procedure developed by Rosch (1975). Subjects were presented with a sentence frame of the form "____" is close to "____." They were then presented with two locations and were asked to place them in the appropriate positions in the sentence. If the perceived distance between two locations is symmetrical, then each location should be placed in each part of the sentence equally often. An asymmetry hypothesis, however, predicts that reference locations should be placed more frequently in the second position in the sentence. Using numbers as stimuli in a similar task, Rosch found that subjects would say that "48 is essentially 50" more frequently than "50 is essentially 48." In the present task we would expect subjects to choose the order "*the architecture building* [a nonreference point] is close to the *student union* [a reference point]" more often than the reverse order. Such asymmetry is not predicted for pairs of locations in which neither member is a reference point.

The purpose of the second experiment was twofold. First, it assessed whether asymmetries exist for pairs of spatial locations, and second, it used obtained asymmetries as the basis for quantifying the degree to which a given location is a spatial reference point.

Method

Subjects. This experiment was conducted in two parts, a preliminary stimulus identification phase and a subsequent linguistic task. Two groups of subjects were used. In the stimulus identification phase, 75 male and female students from an introductory psychology class participated in partial fulfillment of a course requirement. In the linguistic task, 42 male and female students from an introductory psychology class participated, again in partial fulfillment of a course requirement.

Stimuli. The sentence frame used in this experiment was constructed by using the phrase "is close to." Pilot data gathered prior to the present study indicated that this phrase produced the same judgments as the phrase "is essentially next to." The resulting sentence frame, then, was "_____ is close to _____."

The location names that subjects inserted into the sentence frames consisted of pairs of locations on the university campus. To ensure that subjects would be able to identify all of the locations presented to them in the task, 75 subjects were asked to rate 30 locations on the university campus on a 5-point scale anchored with "don't know at all" (1) and "know very well" (5). Only those locations with a mean familiarity rating of 2 or higher were considered for the final group of stimulus items. From the list of known locations, 14 stimulus items were selected that were of differential familiarity to subjects and that were spatially distributed over the university campus. Each of the 14 locations was then paired with every other location to yield 91 pairs of locations (all possible pairs). The pairs were then randomized and listed on sheets of paper in blocks of 10. To control for the effects of fatigue and boredom, the order of the blocks was counterbalanced.

Procedure. Subjects were informed that the present research was concerned with "the way people commonly use language to describe spatial relationships between physical locations." They were then presented with the sentence frame format and instructed that their task would be to complete the sentence frame by placing one of the locations in the first blank and the other location in the second blank. They were encouraged to take their time, try the locations in the sentences both ways, and to pick the way in which the sentence made the most sense to them.

Table 2
Number of Placements of Column Location in Rear (Reference) Slot when Paired with Row Location

Location	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Memorial union		11	6	4	17	16	8	18	4	6	4	5	6	7
2. Psychology bldg.	31		14	12	33	24	25	32	10	17	16	10	14	14
3. Business bldg.	36	28		16	34	21	22	37	8	27	22	23	18	15
4. Neeb lecture hall	38	30	26		37	31	33	38	20	25	23	21	15	18
5. Gammage auditorium	25	9	8	5		20	9	13	2	16	9	10	9	8
6. The fountain	26	18	21	10	22		12	24	13	15	17	17	9	13
7. Language & lit.bldg.	34	17	20	9	33	30		34	13	26	12	17	14	15
8. Hayden library	24	10	5	4	29	18	8		6	6	3	7	11	5
9. Mass communications bldg.	38	32	34	22	40	29	29	36		30	23	28	25	24
10. Social sciences bldg.	36	25	15	17	26	27	16	36	12		13	10	16	18
11. Men's P.E. bldg.	38	26	20	19	33	25	28	39	19	29		25	20	19
12. Manzanita dorm	37	32	19	21	32	25	25	35	14	32	17		17	15
13. Danforth chapel	36	28	24	27	33	33	28	31	17	26	22	25		19
14. Swimming pool	35	28	27	24	34	29	27	18	18	24	23	27	23	
Column sums	434	294	239	190	403	329	270	410	156	279	204	225	197	190

Results

The data were analyzed to determine if consistent asymmetries occurred in the placement of locations in the sentence frame task. To test this hypothesis, the number of times a given location was placed in the second (reference) slot was determined and tested for significance. Since 42 subjects fitted the 91 pairs of locations into the sentence frame, there were 42 independent observations made on each of the location pairs. If placements into the sentence frames were random, then a location would be placed into the two sentence frame slots equally often, and thus would have appeared in the second (reference) slot on 21 of the 42 observations. The actual number of times a location was placed into the reference slot is presented in Table 2. The cell values in the table indicate the number of times the column location was placed in the reference point slot.

The normal approximation to the binomial distribution was used to calculate the number of times one location in a pair would have had to be placed in the reference slot in order to deviate significantly from chance. For an alpha level of .05, with 42 subjects, the number of placements must be greater than or equal to 26, or less than or equal to 16. Significant differences in location placements were demonstrated for 62 of the 91 stimulus pairs (68%).

To test the effect of the presentation order of words within a pair (the tendency for subjects to place the top word of a location pair into the first slot of the sentence frame), the binomial test was applied to counts of the top location in the first slot for each location pair. None of these counts reached significance at the .05 level.

To test the reliability of responses to the sentence frame task, Pearson product-moment correlations were obtained between split halves of the sample of subjects divided at random. The number of times a location was placed in the reference point slot was determined for both groups of subjects, and the resulting matrices were subjected to a cell by cell correlation. Results indicated substantial agreement between halves of the subject sample ($r = .81$).

Inspection of data presented in Table 2 suggested a method for determining the relative degree of referentiality for each location. The sum of each column in the matrix indicated the number of times a location was placed in the reference point slot by all subjects over all locations. Locations frequently placed in the reference point slot when paired with others may be regarded as high referentiality locations; locations rarely placed in the reference point slot may be regarded as low referentiality locations.

The reliability of this ranking of locations presented in Table 2 was explored by randomly splitting the subject sample in half and computing the ranking of locations for each group. The rank-order correlation between each half of the subject sample was $r = .92$, indicating substantial agreement in rankings.

Experiment 3

In general, the results of Experiment 2 indicated that some locations are consistently placed in the second (reference point) slot in the sentence frame task. This asymmetry in placement is used as a method for indexing the degree to which a location may be regarded as a spatial reference point. The studies that follow were designed to futher validate this ranking through the use of reaction time (RT) tasks.

Based on the assumption that other locations are seen "in relation to" reference locations, it was assumed that verification of the distance from a given location to a proximate spatial reference point would be faster than verification of the distance to an equivalently spaced nonreference point. Experiment 3 was designed to test this hypothesis. Subjects were instructed to imagine that they were standing at a particular location on campus. A second location of either high or low referentiality was flashed on a screen; a timing device was started simultaneously. Subjects were asked to make a close/far judgment about the presented location. It was assumed that when initially asked to imaginally locate themselves on campus, subjects would be most likely to access information pertaining to the proximity between the imagined location and adjacent reference points. Consequently, it was predicted that positive verifications of proximity ("close" judgments) would be faster when reference points were presented than when nonreference points were presented.

Method

Subjects. Fifteen male and female undergraduates from Arizona State University participated in the experiment in partial satisfaction of course requirements. Only subjects who had attended Arizona State University for 2 yr. were employed in the experiment. Data from 3 additional potential subjects was not analyzed. Two of these subjects were excluded because of their inability to comply with the imagery instructions at least 75% of the time. An additional subject was excluded because of her lack of familiarity with the university campus.

Stimuli. Stimuli in this study consisted of location place names that were projected onto a screen in front of the subject. Three types of stimulus locations were used: five high referentiality locations (the five locations with the highest column means in Table 2), five low referentiality locations (the five locations with the lowest column means in Table 2), and five neutral locations. The set of locations was chosen so that no streets were crossed when going from one location to another. This procedure was employed, since previous research (Sadalla & Staplin, 1980) has indicated that crossing boundaries such as streets segments the experience of distance and increases the cognitive distance between locations. To control for this factor, only locations with no boundaries between them were used. From this set of stimuli, triads of location names were constructed. Each triad consisted of a neutral location that was geographically equidistant from a pair of high and low referentiality locations, and no more than 600 yd (548 m) from either location. The neutral stimulus always served as an anchor point in this experiment; the high and low referentiality locations served as targets. Subjects were required to verify the distance between the anchor and both target locations.

A second set of triads was also prepared, using the same set of neutral (anchor) stimuli and an additional five pairs of distractor stimuli that were located *more* than 600 yd (548 m) from the anchors.

Apparatus. The location names were projected onto a screen in front of the subjects by two Kodak Carousel slide projectors. One projector contained a Lafayette tachistoscopic shutter that actuated a Durwood-Brown clock. The projectors cast an image that was approximately 46 cm × 46 cm; the centers of the two images were 1 m apart. Subjects sat approximately 2 m from the screen. A response board containing two buttons labeled *close* and *far* was placed immediately in front of the subject. Depression of either response button stopped the timing device.

Procedure. Subjects were told that they were participating in a study to determine some of the factors involved in making distance estimates between familiar locations.

The subjects were first presented with a list of stimuli and were asked to rate each location on a 5-point scale, ranging from "don't know to all" (1) to "know very well" (5).

The subjects were told that a location would be presented on the left side of the screen, and that it would remain there until they were able to form an image that they were standing in front of the building. A subject was told to respond with "ready" when the image was firmly in mind. When the subject said "ready," the subject was instructed to immediately look at a fixation point on the right side of the screen,

Table 3
Mean Reaction Time (in sec) From Neutral Location to Verify High and Low Referentiality Target Locations

Neutral stimulus number	Target location: High referentiality *M*	*SD*	Low referentiality *M*	*SD*
1	1.226	.360	1.323	.390
2	1.282	.391	1.495**	.436
3	1.225	.477	1.726**	.626
4	1.345	.421	1.915*	1.049
5	1.179	.284	1.475*	.598

* Significantly different from high referentiality locations at the .05 level.
** Significantly different from high referentiality locations at the .01 level.

where another location name would appear in approximately 2 sec. The subject's task was to decide, as rapidly as possible, if the two locations presented were geographically close or far. Subjects used their dominant hand for the close button. Close was arbitrarily defined for the subjects as being less than 600 yd apart. Several examples were given of this distance using well-known campus locations, and subjects were repeatedly asked if they were able to conceptualize this distance. All subjects indicated that they could.

The dependent variable was the time required by the subjects to verify the close–far relationship. The reaction time clock was started when a target or distractor stimulus was onset following the ready signal, and was stopped by a subject's close or far button-press response.

Ten practice trials using locations not included in the actual experiment were allowed, during which subjects were questioned to ensure that they were performing the task as instructed. The experiment proceeded with each subject required to complete 20 reaction time responses. Five triads contained neutral (anchor) locations and high and low referentiality target (close) locations; responses to each neutral–high and neutral–low combination within each triad thus accounted for 10 responses. Another five triads each contained neutral (anchor) locations and two distractor (far) locations; responses to location pairs generated from this set of stimuli accounted for the other 10 responses. The 20 pairs of locations were randomized and grouped into blocks of five. The order of presentation of the blocks was then counterbalanced so that each block appeared in each presentation order an equal number of times.

At the conclusion of the experiment, each subject was interviewed and asked to estimate the percentage of the time he or she was able to follow the imagery instructions while performing the task.

Results

The data were analyzed to determine if the time to verify the distance between two locations differed significantly as a function of the referentiality of the stimuli involved. Accordingly, the time to verify the distance between the neutral location and the high referentiality location, and the neutral location and the low referentiality location, was tested for differences. Only correctly identified members of the target set of close locations were considered in the analysis. Subjects performed with acceptable accuracy on the tasks; the number of misses was 8% of the total possible positive responses, and the number of false alarms was 6% of the total possible negative responses.

Table 3 presents the means and standard deviations of the reaction times required to verify the distance between the neutral location and the high and low referentiality locations for each triad. As can be seen from Table 3, all of the means were in the predicted direction.

A MANOVA was performed to assess the effect of referentiality on reaction time. The experimental manipulation was treated as a within-subjects factor with two levels, and the reaction times for each pair of target locations were treated as five dependent variables. The overall multivariate F was significant, by Wilks's lambda, $F(5, 10) = 4.64$, $p < .02$, indicating that the time to verify the proximity of a high referentiality location was significantly shorter than the time to verify the proximity of a low referentiality location. The data from this study support the notion that a given location in the environment is seen in relation to adjacent reference points. Subjects were able to indicate the proximity of reference points faster than they could indicate the proximity of equidistant nonreference points.

Experiment 4

Experiment 4 explored the assumption that reference points function to enhance geographical orientation (Allen et al., 1978; Howard & Templeton, 1966). The study focused on the effect of being cognitively located at either a reference point or a nonreference point. Since other points in space are assumed to be seen in relation to reference locations, it was assumed that subjects could locate any given target location faster from a reference point than from a nonreference point. Subjects in this study were asked to verify the *direction* from an anchor location to a target location. It was hypothesized that such verifications would be faster when subjects were anchored at reference locations than when they were anchored at nonreference locations.

Method

Subjects. Sixteen male and female undergraduates enrolled at Arizona State University served as subjects in return for extra course credit. Two potential subjects were eliminated because of their failure to meet the criterion for familiarity with the university campus.

Stimuli. Stimuli for this study again consisted of slides depicting the names of campus locations. Two sets of stimuli were constructed—one set for positive and one set for negative responses. As in Experiment 3, three types of locations were employed in the study—high referentiality locations, low referentiality locations, and target locations. Triads of locations were constructed from this set of stimuli. Each triad consisted of one target location, one high referentiality location, and one low referentiality location. High and low referentiality locations were used as anchor points in this study, from which subjects estimated the direction of target locations. The comparison of interest in this study was the RT needed to verify the direction of a given target location from high versus low referentiality anchors. The mean distance between target locations and high and low referentiality locations was equal.

Twelve sets of triads were constructed for use in the study. Six triads were developed for true responses; 6 were developed for false responses. The stimuli used for false responses involved campus locations not used in previous studies. Since false responses were not analyzed in this experiment, referentiality data were not collected for these locations.

Apparatus. The slide projectors, timer, and response board used in Experiment 3 were also used in this study, with the two response buttons labeled *true* and *false*. In addition, a circular grid designed to resemble compass directions was constructed. This grid measured approximately ½ m in diameter and was divided into eight equivalent wedges. The wedges were in turn labeled (clockwise) with the numbers 1–8, and the top and bottom of the grid were labeled *north* and *south*, respectively.

Procedure. Subjects were seated approximately 2 m from a projection screen with the response board in front of them. They were informed that they were facing north, and that north was also indicated on the top of the circular grid (which was superimposed on the screen). The subjects were first presented with a list of the locations that were to serve as stimuli, and were asked to rate their familiarity with each of the locations on a 5-point scale. Two subjects who were not familiar with the majority of the locations were eliminated from the study.

Next, subjects were presented with a location name that was projected in the center of the circular grid. They were asked to imagine this location as if they were viewing a map with north at the top. Each subject was told to respond with "ready" when the image was firmly in mind. At the ready signal, a target stimulus was presented together with a number that referred to one of the wedges on the circular grid. The subject's task was to verify whether the target location was actually located in the wedge referred to by the number. If a correct target–wedge number combination was presented, subjects pressed the true response button; if an incorrect combination was shown, subjects pressed the false button. All subjects used their dominant hand for positive responses. Subjects were instructed to try to achieve error-free performance and to perform the task as quickly as possible. The principal dependent variable in this study was the time required by subjects to verify true relationships. The reaction time clock was started when the second (target) stimulus was shown and was stopped by a subject's response. Ten practice trials were allowed during which subjects were questioned to ensure that they were performing the task as instructed.

Each of the target locations in a triad was presented twice during the course of the experiment—once with a high referentiality location anchored in the center of the grid and once with a low referentiality location anchored in the center of the grid. Twelve pairs of true stimuli and 12 pairs of false stimuli were thus presented, so every subject was required to verify a total of 24 pairs. The 24 pairs were randomized and grouped into four blocks. The order of presentation of the blocks was then counterbalanced so that each block appeared in each presentation order an equal number of times.

Results

The data were analyzed to determine if the time to verify the direction of a target location varied as a function of the referentiality of the anchored location. It was hypothesized that the RT to verify the location of a target would be faster when reference locations were anchors than when nonreference locations were anchors. Table 4 presents the mean reaction times (in seconds) required by subjects to verify the

Table 4
Mean Reaction Time (in sec) to Verify the Direction of a Target Location From High and Low Referentiality Anchor Locations

Target location	Anchored location: High referentiality *M*	*SD*	Low referentiality *M*	*SD*
1	2.656	1.158	3.101	1.339
2	2.459	.762	2.950*	.779
3	2.725	.475	3.309*	.942
4	2.251	.511	3.098**	.829
5	2.734	.888	2.927	1.067
6	2.927	.999	3.330	.984

* Significantly different from high referentiality location at the .05 level.
** Significantly different from high referentiality location at the .01 level.

direction of target locations in the two conditions of this study. The data indicate that subjects verified the direction of target locations more rapidly when the high referentiality locations were anchored in the center of the circular grid than when the low referentiality locations were anchored. As noted previously, the reaction time means are based on the true instances, which were verified correctly. The subjects generally performed the task with acceptable accuracy. The number of misses was 10% of the total possible positive responses, and the number of false alarms was 8% of the total possible negative responses.

A MANOVA was performed on the high and low referentiality anchor locations to determine if the RT differences were statistically significant. In the MANOVA analysis, the experimental manipulation (high referentiality locations anchored in the center of the circular grid vs. low referentiality locations anchored in the center of the grid) was treated as a repeated measure with two levels, and the six location pairs were treated as six dependent variables.

The MANOVA indicated that the time to verify the location of target stimuli differed depending on the referentiality of the anchored stimuli. When a highly referential location was anchored, the time to verify the location of a target stimulus was significantly less than when a low referentiality anchor was employed; by Wilks's lambda multivariate $F(6, 10) = 5.57$, $p < .01$.

The results of this study further validate the referentiality index obtained in the sentence frame task in Experiment 2. The data also support the concept that other locations are seen in relation to reference points by demonstrating that the direction of particular target locations is more quickly verified relative to reference locations than relative to nonreference locations.

Experiment 5

Experiment 5 is concerned with the attributes of locations that are designated as reference points. The question of what determines the relative landmark status of a place has received some empirical attention (Levine, Note 1). Such factors as recognizability (Lynch, 1960), use (Appleyard, 1969), and cultural meaning (Moore, 1979) have been emphasized. In Experiment 5 each location used as a stimulus in Experiment 2 was rated on a number of descriptive scales. The referentiality index obtained in Experiment 2 was then used as the criterion in a multiple regression analysis of the attributes of reference points.

Method

Subjects. Ten male and female graduate students in psychology were used as judges. All of the judges had attended Arizona State University for at least 2 yr and were quite familiar with the campus.

Predictor scales. Eighteen 9-point bipolar scales were employed as location descriptors. These scales were based on scales developed by Appleyard (1969) to predict the salience of urban structures. The semantic scales were listed on sheets of paper, and the name of one of the 14 locations used in Experiment 2 was printed at the top of each sheet. The sheets were then compiled into 14-page booklets, each containing the complete set of locations used in Experiment 2. A different random order of locations was employed in each booklet to minimize fatigue and boredom effects.

Procedure. The judges rated each location on all 18 semantic scales. The responses were then collapsed over judges to yield a mean rating of each location on each semantic scale. These means then served as input to the multiple regression analysis.

Table 5
Results of Cluster Analysis of Semantic Differential Descriptors

Cluster a	Cluster d
Large–Small	Simple–Complex
Tall–Short	Cheap–Expensive
Dominates nearby places–Is dominated by nearby places	Disrepair–Well kept
High economic importance–Low economic importance	Old–New
Cluster b	Colorless–Colorful
Often used–Rarely used	Cluster e
Location well known–Location poorly known	Well labeled–Poorly labeled
Familiar–Unfamiliar	Near the center of a region–Near the border of a region
Cluster c	Cluster f
High cultural importance–Low cultural importance	On the beaten path–Off the beaten path
Aesthetics good–Aesthetics poor	Not visible from a distance–Visible from a distance

Results

The scales were first subjected to a hierarchical clustering analysis (Sokal & Sneath, 1973) that identified sets of scales that were highly intercorrelated. The cluster analysis yielded the six clusters listed in Table 5. These clusters have been labeled as follows: (a) size, (b) familiarity, (c) cultural value, (d) form quality, (e) marker salience, and (f) visual salience.

The relationship between referentiality and the semantic scales was assessed by correlating the mean scale value for each location with the referentiality index for that location. Table 6 presents the single scale in each of the six clusters that is most highly correlated with referentiality. Those scales that were significantly related to referentiality were familiarity ($r = .84$, $p < .01$), dominates nearby places ($r = .60$, $p < .05$), near the center of a region ($r = .45$, $p < .05$), and cultural importance ($r = .48$, $p < .05$).

A stepwise multiple regression analysis was then employed to assess the degree to which a combination of the semantic scales could account for variation in referentiality. This analysis was carried out using both the sum of cluster scores and the best predictor scale from each cluster. Since the latter method accounted for the most variance, the results of that analysis are presented in Table 7. The regression analysis indicated that the predictor scales accounted for a significant amount of variance in referentiality, $F(6, 7) = 17.82$, $p < .01$. The specific contribution of each of the semantic scales to the prediction of referentiality can be determined by observing the increase in variance accounted for (r^2) as each scale is added to the prediction equation. The results indicate that referentiality may be predicted by the following scales: familiarity, visibility from a distance, domination of nearby places, and cultural importance.

Table 6
Intercorrelations Between Criterion and Predictor Variables

Criterion	1	2	3	4	5	6	7
1. Referentiality index		.84**	.60*	.29	.48*	.45*	.22
2. Familiarity			.57*	.45	.57*	.42	.16
3. Dominates nearby places				.75**	.47	.11	.53*
4. Visible from a distance					−.01	.04	.26
5. Cultural importance						−.08	.43
6. Near the center of a region							−.38
7. New							

* $p < .05$, one-tailed. ** $p < .01$, one-tailed.

Table 7
Stepwise Multiple Regression of Referentiality on Semantic Description Scales

Step and semantic scale	r^2	r^2 change	p[a]
1. Familiarity	.72	.72	.01
2. Domination of nearby places	.74	.02	.01
3. Visibility from a distance	.81	.07	.01
4. Cultural importance	.91	.10	.05
5. Nearness to the center of a region	.93	.02	*ns*
6. Age	.93	.00	*ns*

[a] Of regression coefficient.

Taken together, these four variables account for 91% of the variance in the referentiality index.

General Discussion

The present research suggests that cognitive representations of large scale spaces contain elements that may be termed *reference points*, and that these points serve as organizing loci for other points in space. Obtained data indicate that the cognitive distance between reference points and nonreference points is asymmetrical; nonreference points were judged nearer to reference points than were reference points to nonreference points. Results of the RT experiments provide additional evidence concerning the function of spatial reference points. The data indicate that from a given position in space, the proximity of adjacent reference points may be more quickly verified than can the proximity of equivalently spaced nonreference points. Further, the data indicate that the orientation of a particular point in space may be more quickly verified when the observer is cognitively located at a reference location than when the observer is cognitively located at a nonreference location. These data suggest that the cognitive location of many points in space are either stored or retrieved in relation to a smaller set of spatial reference points. Spatial reference points appear to provide an organizational structure that facilitates the location of adjacent points in space.

Such reference points should be distinguished from landmarks; the concepts are not entirely synonymous. It seems likely that there exist discriminable features of terrain that are remembered and that could be used to guide navigational decisions but that do not produce the effects observed in the present research. Landmark is a more general term than is reference point.

The results of the present investigations are relevant to questions concerning the degree of isomorphism between cognitive representations of space and cartographic representations of space (Shepard & Chipman, 1970). Because cartographic representations of distance may usually be combined independently of the order in which distances are measured, models of cognitive distance have assumed this property (Golledge & Rushton, 1972). The present data indicate, however, that when the array of stimuli that are modeled contains reference points, it is unreasonable to assume that cognitive distances are either symmetrical or commutative. The data further suggest that multidimensional scaling, or any geometrical model that assumes a Euclidean representation of distance between stimuli, is not an entirely adequate technique for producing a representation of cognitive distance. The conclusion is consistent with the critique of the symmetry assumption in multidimensional scaling developed by Tversky (1977).

The present investigation of spatial reference points was based on assumptions concerning cognitive economy. It was assumed that a system which represented the spatial relationships between a small number of reference locations, and which allowed the computation of the position of other places, would make less demands on storage capacity than would a system that represented the spatial relationships between all known locations. Part of the evidence that was adduced to support cognitive economy assumptions concerned asymmetries in distance cognition. It should be noted, however, that the concept of reference points does not logically require the existence of such asymmetries.

The concept of reference point involves assumptions concerning the way in which spatial information is cognitively organized and represented. It suggests that spatial information is organized into conceptual units, with a number of locations cognitively located in relation to reference points. An important qualification of the present investigation concerns the possibility that the observed pattern of results was caused by the way in which spatial information was retrieved and compared rather than the way in which it was stored. Whether referentiality effects derive from storage or retrieval processes cannot be deduced from the present series of studies.

Because a portion of the present work was simulated by procedures developed by Rosch (1975), spatial reference points bear an obvious resemblance to cognitive reference points (prototypical instances of semantic categories). In both cases there exist asymmetries in linguistic usage in a sentence frame task between reference points and nonreference points. In both cases asymmetries have been demonstrated in a spatial-mapping task, although the task represents semantic similarity in one instance and geographic proximity in the other. Both prototypes and spatial reference points may, in some instances, be related to frequency of presentation or familiarity. The rating scale data gathered in the present research indicate that familiarity is the best predictor of the landmark status of a given location. One important theoretical position on the abstraction of prototypes emphasizes the role of the frequency of features, either individually (Neumann, 1974, 1977) or collectively (Hayes-Roth & Hayes-Roth, 1977).

Despite these similarities, there are obvious differences between cognitive reference points and spatial reference points. Cognitive reference points are defined as the best examples or most prototypical instances of a given category of stimuli (Rosch, 1975). In contrast, spatial reference points need not be semantically related to points around them and do not qualify as prototypical instances of a category. Prototypes represent central positions in geometric models of semantic similarity (Goldman & Homa, 1977), whereas spatial reference points represent the organizational structure of cognitive maps of spatial locations.

In the present series of studies, a given reference point was paired with a nonreference point that was located spatially adjacent to the reference point. This procedure was followed because spatial reference points were defined as locations that other points were seen "in relation to." It seems plausible that asymmetries in cognitive distance between reference points and nonreference points may diminish if locations are chosen that are not spatially proximate. The concept presupposes that spatial information is organized into conceptual units. Crossing such conceptual boundaries may eliminate an asymmetry effect.

Further, the relationship between distance estimates made in the present context and distance estimates made during an actual journey is unknown. Siegel and White (1975) and Ittleson (1973) have reviewed data which indicate that the representation of distance that emerges from a mapping task may not correspond to estimates of distance gathered during a journey. The extent to which asymmetries in distance estimation would occur during actual journeys between reference points and nonreference points remains to be demonstrated.

Finally, the present findings have implications for extant models of spatial cognition. Following the lead of Piaget and Inhelder (1967), a number of theorists have posited a three-stage developmental sequence during which children progress from a "topological" to a "projective" to a Euclidean representation of large scale space. The assumption that adults achieve a metric representation of spatial relationships is widely held and is consonant with current methods of assessing spatial knowledge (Hart & Moore, 1973). The present data indicate, however, that when the group of stimuli being considered contain cognitive reference points, the cognitive distances between points will not be symmetrical and the second distance axiom will not hold. Data from the present study suggest that although Euclidean assumptions may adequately model the subjective spatial relationship between reference points, the spatial location of nonreference points is cognitively represented in terms of topological concepts such as proximity.

Reference Note

1. Levine, E. *Physical vs. nonphysical features as determinants of landmark salience.* Paper presented at the meeting of the American Psychological Association, New York, September 1979.

References

Acredolo, L. P. Developmental changes in the ability to coordinate perspectives of a large-scale space. *Developmental Psychology*, 1977, *13*, 1–8.

Allen, G. L., Siegel, A. W., & Rosinski, R. R. The role of perceptual context in structuring spatial knowledge. *Journal of Experimental Psychology: Human Learning and Memory*, 1978, *4*, 617–630.

Appleyard, D. Why buildings are known. *Environment and Behavior*, 1969, *1*, 131–156.

Downs, R. M., & Stea, D. Cognitive maps and spatial behavior: Process and product. In R. M. Downs & S. Stea (Eds.), *Image and environment*. Chicago, Ill.: Aldine, 1973.

Goldman, D., & Homa, D. Integrative and metric properties of abstracted information as a function of category discriminability, instance variability, and experience. *Journal of Experimental Psychology: Human Learning and Memory*, 1977, *3*, 375–385.

Golledge, R. M., & Rushton, E. *Multidimensional scaling: Review and geographical applications* (Commission on College Geography Tech. Paper No. 10). Washington, D.C.: Association of American Geographers, 1972.

Hart, R. A., & Moore, G. T. The development of spatial cognition: A review. In R. M. Downs & D. Stea (Eds.), *Image and environment*. Chicago, Ill.: Aldine, 1973.

Hayes-Roth, B., & Hayes-Roth, F. Concept learning and the recognition and classification of exemplars. *Journal of Verbal Learning and Verbal Behavior*, 1977, *16*, 312–338.

Howard, I. P., & Templeton, W. B. *Human spatial orientation*. London: Wiley, 1966.

Ittleson, W. H. Environment perception and contemporary perceptual theory. In W. H. Ittleson (Ed.), *Environment and cognition*. New York: Seminar Press, 1973.

Lynch, K. *The image of the city*. Cambridge, Mass.: MIT Press, 1960.

Moore, G. T. Knowing about environmental knowing. *Environment and Behavior*, 1979, *11*, 33–70.

Neumann, P. G. An attribute frequency model for the abstraction of prototypes. *Memory & Cognition*, 1974, *2*, 241–248.

Neumann, P. G. Visual prototype formation with discontinuous representation of dimensions of variability. *Memory & Cognition*, 1977, *5*, 187–197.

Piaget, J., & Inhelder, B. *The child's conception of space*. New York: Norton, 1967.

Rosch, E. Cognitive reference points. *Cognitive Psychology*, 1975, *7*, 532–547.

Sadalla, E. K., & Staplin, L. J. The perception of traversed distance: Intersections. *Environment and Behavior*, 1980, *12*, 167–182.

Shepard, R. N., & Chipman, S. Second order isomorphism of internal representations: Shapes of states. *Cognitive Psychology*, 1970, *1*, 1–17.

Siegel, A. W., & White, S. H. The development of spatial representations of large scale environments. In H. W. Reese (Ed.), *Advances in child development and behavior* (Vol. 10). New York: Academic Press, 1975.

Sokal, R. R., & Sneath, P. H. A. *Numerical taxonomy: The principles and practice of numerical classification*. San Francisco, Calif.: Freeman, 1973.

Stevens, A., & Coupe, P. Distortions in judged spatial relations. *Cognitive Psychology*, 1978, *10*, 422–437.

Tversky, A. Features of similarity. *Psychological Review*, 1977, *84*, 327–352.

Received March 3, 1980 ■