SPATIAL ORIENTATION AND THE ANGULARITY OF URBAN ROUTES
A Field Study

DANIEL R. MONTELLO *received his doctorate in environmental psychology at Arizona State University. He is currently a Lecturer and Research Associate at the Institute of Child Development, University of Minnesota. His research interests are spatial perception, cognition, and behavior in contexts of both the physical and social environment.*

ABSTRACT: The influence of route angularity on the spatial orientation of pedestrians navigating in an urban field setting was examined. Sixty pedestrians were stopped at one of three locations in the same neighborhood, one on a street orthogonal to the local grid pattern and two on streets oblique to the local grid pattern. They were asked to point to several nonvisible targets, both local features and cardinal directions. Pointing error on four of the five targets was greater on both oblique streets than on the orthogonal street, especially for the cardinal directions; response time was greater only on the second oblique street, a secondary street that is connected to the local grid system via the first oblique street. Length of residency was related to both accuracy and response speed. Results demonstrate that environmental orientation depends in part on the angularity of route structure, the disorienting effect of oblique routes being due to memory distortion or imprecision associated with oblique routes.

Spatial orientation typically depends on perception of the structure of the environment, on knowledge stored in memory, and on processes used to access that knowledge. The structure of the environment must influence the structure of perception and memory; otherwise, stored knowledge would be of little use for locomotion and other forms of orientational behavior. Con-

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versely, memory will influence attention to and perception of various aspects of environmental structure. Both memory and environmental structure thus influence the ease and accuracy with which people acquire new spatial knowledge. The research reported below is a field study of the influence of one aspect of environmental structure, the angularity of routes, on the orientation of urban pedestrians.

Although the structure of knowledge reflects the angular structure of the environment, it does so imperfectly. At least as long ago as 1948, Griffin proposed that people will simplify routes in their cognitive representations by "smoothing curves into straight lines and tending to show most turns as right angles" (p. 381). In his seminal book, Lynch (1960) found that respondents often drew the obtuse corners of the Boston Commons as being more like right angles (also see Byrne, 1979; Milgram, 1976). In a study by Tversky (1981), subjects drew local maps of the Palo Alto area in which streets were distorted towards parallelity or orthogonality with local reference frames or cardinal directions. Moar and Bower (1983) had subjects imagine standing at one street intersection facing a second intersection and draw a line from memory in the direction of a third intersection. On the average, all directions were distorted toward right angles.

These studies have provided some evidence that memory for route intersections tends to be distorted toward right angles, at least in the Western cultures studied. But most of them have used map-drawing methodologies to investigate angular route distortions, a methodology that may introduce drawing biases (e.g., Freeman & Cox, 1985). In addition, they have not provided evidence of distortions and errors based on controlled exposure to routes varying in angularity.

Such evidence was provided by Sadalla and Montello (1989). In their experiment, subjects walked several laboratory pathways containing single turns varying in angularity while wearing a vision-restricting hood. Turn recall, measured with a circular pointer, was least accurate for the most oblique turns (45° and 135°) and was increasingly accurate as turns neared orthogonality (0°, 90°, and 180°). This was true for both left and right turns. There was also a general tendency to recall nearly all turns as being more like right angles than they actually were.

Although Sadalla and Montello (1989) provided quantitative data on angular route distortions under controlled conditions, and without a drawing methodology, their modest-sized laboratory setup was somewhat artificial in that visibility was greatly restricted and little or no landmark information was available. In a naturalistic study conducted in a large-scale space, Herman, Blomquist, and Klein (1987) failed to find any disorienting effects of oblique routes with subjects who were actually moving about suburban route systems. Children and college students pointed to nonvisible target objects from a central testing location in one of two areas, each about five or six blocks in size. One area was described by the authors as a "regular" grid, consisting of several straight streets intersecting at nearly right angles and nearly aligned with the cardinal directions. The second area was an "irregular" grid—its streets were curved and did not intersect at right angles. Subjects were told to pay attention to the relative positions of the target objects as they were driven around one of the areas. Pointing accuracy actually did not differ significantly for the two grids. In particular, the groups of college students at the two grids differed by no more than 1° or 2°. The authors concluded that their irregular grid was actually quite regular; in fact, the streets comprising this grid were parallel for the most part.

Thus the one field study that directly addressed the effects of route angularity on the orientation of people who were actually locomoting through a naturalistic environment did not find evidence of disorientation due to route structure. Furthermore, these studies have not contrasted the severity of such effects on different elements of environmental knowledge (distant landmarks, cardinal directions, and so on). The external geographical knowledge important to the urban navigator may be grouped into two basic categories: local features (routes, nodes, landmarks, and so on), and global reference frames (cardinal directions). Strictly speaking, no information other than that specifying the ground and the sky is necessary for restricted navigational behavior such as simple forward motion. But experienced urban travelers usually know a great deal about a variety of local features as well as the orientation of the cardinal directions, information that can be used to give directions, find shortcuts, and cope with detours.

It is difficult to state unconditionally that knowledge of local features is more important than knowledge of cardinal directions or vice versa. People probably differ greatly in their use of cardinal directions (Ward, Newcombe, & Overton, 1986). Also, environmental knowledge based on maps may involve cardinal directions to a greater extent than that based only on direct experience (Griffin, 1948). Theories of the development of environmental knowledge (Hart & Moore, 1973; Siegel & White, 1975) have suggested that knowledge of local features develops prior to knowledge of abstract or global frames, both ontogenically and microgenically. This hypothesis is still tentative, especially microgenically; it is plausible that a newcomer might know which direction is west very accurately without knowing much about directions to local features. The converse is certainly true as well; many long-time residents probably navigate quite efficiently and effectively without knowledge of cardinal directions. In fact, there has been very little systematic research on the tendency to use the cardinal axes for navigation or giving directions (see Ward et al., 1986). In some cases, global survey-map representations may be accessed to make local navigational decisions. Alternatively, knowledge of cardinal directions may be tied to the orientations of specific local features. In either case, one would not see a differential effect of angular routes on errors in local and global knowledge.

In the research described below, pedestrians were stopped at one of three locations in an urban area and asked to point in the directions of several targets, both local features and cardinal directions. The locations at which testing took place are close to each other in the same neighborhood but on streets that differ in their angularity with respect to the dominant local grid pattern and the cardinal directions. One of the testing locations was on a straight street that is coincident with the local grid, running east-west. The other two testing locations were on streets that are diagonal with respect to the local grid pattern, running northwest and northeast respectively. In addition to the fact that the use of two oblique streets would provide a larger base of comparison, these two streets were chosen because they differ in their connectedness to the local grid pattern; one is directly connected to major streets of the local grid and the other is secondarily connected to the local grid via the first oblique street (the first is a much more important thoroughfare).

Both pointing speed and direction were measured to establish the possible disorienting effects of oblique routes in a field setting. Direction, of course, is a direct measure of the accuracy of spatial behavior (and to some degree, it is assumed, spatial knowledge). Pointing speed was included as a response measure because it might help explicate the nature of differential pointing accuracy, and because it might tell us something interesting in its own right about the psychological effects of route angularity. Response time reflects the *accessibility* of stored information, including the strength of its encoding in long-term memory and the occurrence of any working-memory processes that must be brought to bear on the information to produce a behavioral response. If greater directional error at oblique locations is not associated with greater response time, for example, then we cannot explain accuracy differences as stemming merely from oblique routes being less strongly encoded in memory or from some necessity to access orthogonal route information while responding from oblique routes.

Unlike previous research, this methodology involves subjects who are actually navigating in a naturalistic environment rather than in a laboratory, and it tests their extant knowledge of several local features and cardinal directions. It employs a direct pointing measure of orientation rather than more indirect methods such as map drawing. The use of response time as a measure of spatial knowledge further allows a contrast between the effects of route angularity on knowledge accuracy and its effects on knowledge accessibility. Finally, the use of different types of features (landmark, node, and so on) as targets will allow some comparison of the differential effects of route angularity and familiarity on different elements of spatial knowledge.

METHOD

SUBJECTS

Subjects were 62 pedestrians stopped on the sidewalk at one of the three testing locations. The assistance of all pedestrians who walked by the testing location during data collection was solicited unless someone was being tested at the time. They were told that we were conducting a study on people's knowledge of the city layout and asked if they could spare a couple of minutes to answer some questions. A larger group of about 75 pedestrians was actually stopped, but several refused to participate, largely because they did not have the time to spare. Also, two of the participants were excluded from the analyses because they were not familiar with all the targets asked about.

Of the 60 subjects whose data were analyzed, 18 were female and 42 were male, distributed nearly equally across testing locations. They ranged in age from 17 to 50 years but most were between 19 and 26 years of age. Fifty were staff, students, or faculty at the university.

MATERIALS

Twenty of the final 60 subjects were stopped at each of three testing locations, labeled *Lemon*, *Terrace*, and *Orange* on the map in Figure 1 (locations *orthogonal*, *oblique 1*, and *oblique 2*, respectively). All three locations were within 140 m of each other, close together relative to distances to the local targets. All three locations were within a homogeneous area of off-campus university housing, primarily two-story apartment complexes. None of the three streets are major thoroughfares, although observation indicated that Terrace is the most heavily traveled.

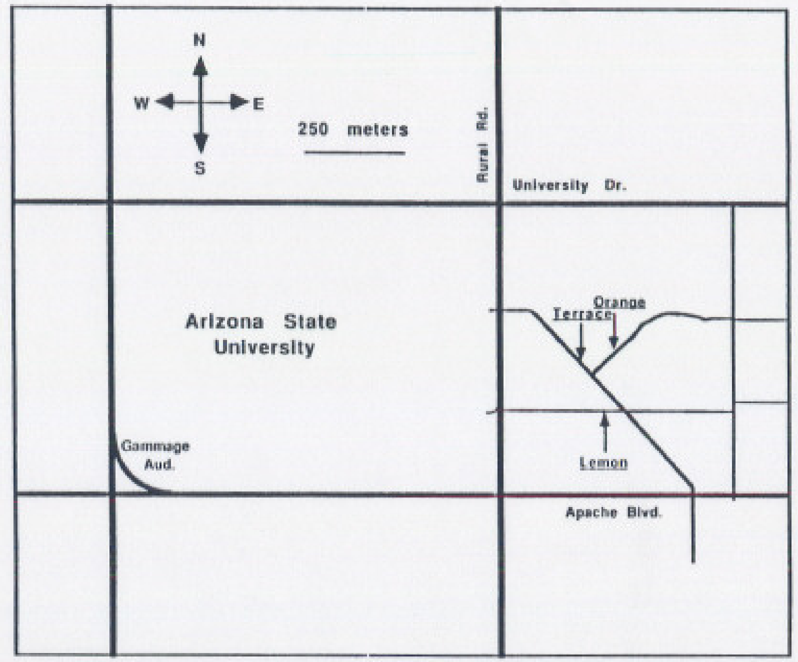

Figure 1: Map of the Testing Area, Including Targets

The local terrain is uniformly flat. Because of trees and buildings surrounding each location, none of the targets asked about nor any other distant landmark cues were visible from the testing locations.

The orthogonal location was on Lemon Street, which runs east-west and coincident with the local grid pattern of streets. One oblique location was on Terrace Road, which runs along a northwest-southeast diagonal at the point of testing. Terrace has some oblique turns in it, most notably the turns near the intersections with Rural Road and Apache Boulevard, major thoroughfares in the local grid system of streets. The second oblique location was on Orange Street, which runs along a northeast-southwest diagonal at the point of testing and has a large number of bends for streets in the area. Also important for this study is the fact that Orange is typically accessed from Terrace or used to access Terrace (in the direction of the university). Thus the second oblique route at which testing took place is connected to the major thoroughfares that follow the local grid system through the first oblique route, Terrace.

Subjects pointed in response to requests about the directions to five targets (see Figure 1): (a) Gammage Auditorium, (b) the corner of Rural Road and University Drive, (c) parallel to Apache Boulevard, (d) south, and (e) northeast. These targets were chosen primarily because they represent a variety of types of features and are familiar to most people. They include local features such as landmarks (Target a), nodes (Target b), and routes (Target c), as well as the global frame established by the cardinal directions (Targets d and e).

Pointing responses were collected with a cardboard matte circle 28 cm in diameter placed on a circular stool 65 cm high. The side visible to subjects was plain white with only a black radius line drawn on it and a rotatable wire attached at the center. Degree gradations marked on the other side allowed the experimenter to quantify subjects' estimates of direction. Response times were collected manually with a stopwatch.

PROCEDURE

Data were collected before 1:00 in the afternoon on 12 days within a 3-month period. The testing location was randomly varied from day to day. After arriving at the testing location, the experimenter set the stool and pointer on the sidewalk running along the north side of the street. All subjects at each location were tested standing with the stool in front of them, half facing directly towards the street and half facing directly away from the street. Before each directional request, the pointer was set up with the wire and drawn radius pointing toward the subject.

Approximately equal numbers of subjects at each location were stopped while walking in either direction along the sidewalk. After agreeing to participate, they were told they would be asked to point in the direction of certain targets. If they did not know the target, subjects were instructed to say so. The pointer was demonstrated, and subjects were told to use it to point in the requested direction without spending too much time thinking about it. The experimenter then verbally presented the five requests in a completely random order for each subject. The stopwatch was started when the target was named and stopped when subjects took their hands off the pointer. Response times were recorded to the nearest second. After each answer, the direction was recorded from the back of the pointer, and the pointing wire was returned to the start position.

After subjects pointed to all five targets, the experimenter asked three questions in a fixed order designed to assess subjects' familiarities with the area around the testing locations. On a 7-point scale, they rated how familiar they were with the street layout within a half mile of the testing location, ranging from *not at all familiar* to *perfectly familiar*. They then estimated how many times they walked by the testing location in an average week. Finally, they stated how long they had lived in the Tempe area, the area containing the targets and testing locations (all subjects were Tempe residents). Finally, the experimenter recorded whether subjects were university students or employees. Data collection required approximately 5 minutes per subject.

RESULTS

Subjects at the three testing locations were very similar in their responses to the three familiarity questions. Mean responses at Lemon, Terrace, and Orange to the question about how well they knew the street layout within a half mile were 4.4, 4.6, and 4.3 on the 7-point scale, respectively. The mean numbers of times they walked by the testing location at Lemon, Terrace, and Orange in an average week were 12.8, 15.0, and 19.4, respectively. The mean numbers of months subjects at Lemon, Terrace, and Orange reported having lived in the Tempe area were 44.5, 25.8, and 37.1, respectively. Mean responses to the three questions were not significantly different across testing locations (all *F*s < 1.0), strongly indicating that subjects were comparable at the three locations.

POINTING ACCURACY

Errors in pointing were compared to test differential accuracy at the three locations. Absolute values of errors from the correct directions were analyzed with a multivariate approach to repeated measures in a mixed design; the five *targets* served as a within-subjects factor, and *testing location* (3 levels) and *side* subjects faced during testing (2 levels) served as between-subjects factors. In an initial analysis, errors did not significantly differ as a main effect of the direction subjects were walking when stopped, nor did direction of walking significantly interact with any of the other independent variables. Mean absolute errors for each target at each location are graphed in Figure 2.[1]

As is apparent in the figure, accuracy was not equivalent at the three testing locations, but in different ways for the various targets. The 3-way interaction between target, location, and side was significant at the .05 level, $F(8, 104) = 2.15$. This interaction was decomposed into simple 2-way interactions of location and side for each target, the analysis of which is described below. These analyses indicated that, with one exception, accuracy was poorer at the oblique locations than at the orthogonal location; the two oblique locations did not differ from each other.

Gammage. Accuracy differed significantly in pointing to this local landmark as a function of location, $F(2, 54) = 4.81, p < .05$. Neither the simple interaction of location and side, $F(2, 54) = 0.54$, nor the simple effect of side, $F(1, 54) = 1.41$, were significant. Contrasts indicated that pointing at the orthogonal location was more accurate than at either of the oblique locations, $F(1, 54) = 9.59, p < .01$. Pointing at the latter two did not differ in accuracy, $F(1, 54) = .03$.

Corner of Rural and University. Of the five targets, only pointing to this local node did not vary systematically with any of the factors examined. Accuracy did not differ as a function of

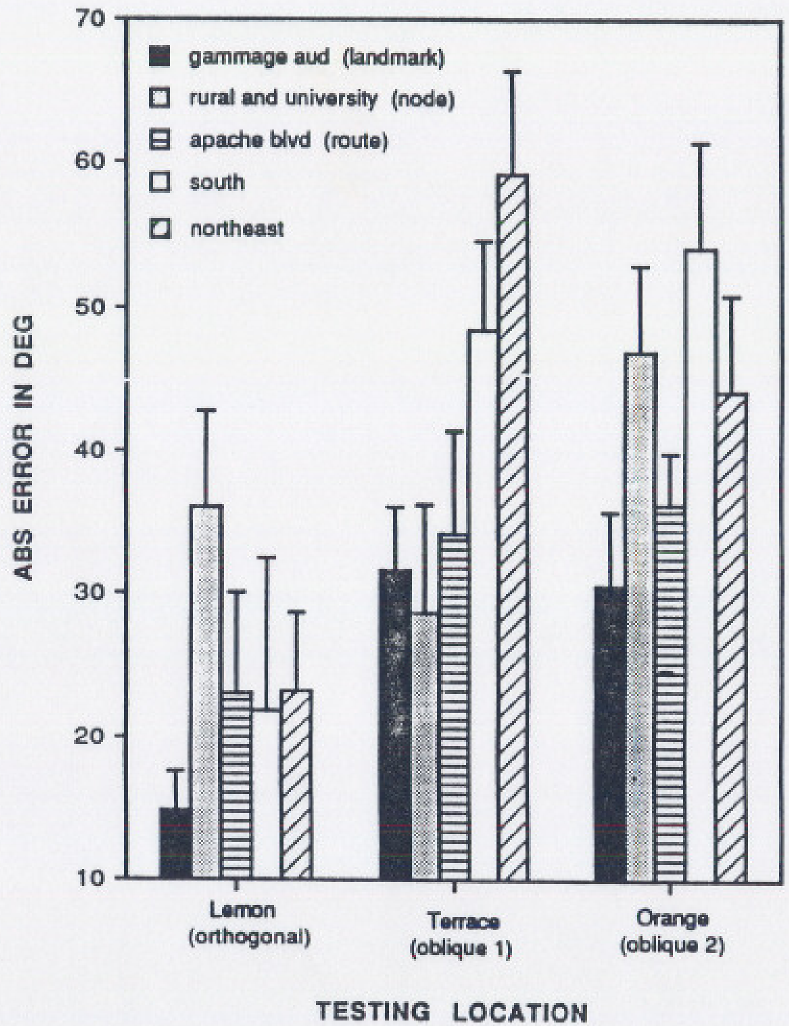

Figure 2: Mean Absolute Pointing Errors and 95% Confidence Intervals for Each Target at the Three Testing Locations

the simple interaction of location and side, $F(2, 54) = 0.04$, the simple effect of side, $F(1, 54) = 2.15$, or the simple effect of location, $F(2, 54) = 1.78$.

Apache. Accuracy in pointing parallel to this local street was greater at the orthogonal location, but unlike the other targets, only for subjects facing away from the street. The simple interaction of location and side for Apache, $F(2, 54) = 5.46, p < .01$, accounts for the overall 3-way interaction reported above. The interaction is due to the subjects at Terrace, the first oblique location: Those facing toward the street (10.8°) were more accurate than those facing away from the street (57.5°), $F(1, 54) = 18.59, p < .0001$. An examination of Figure 1 suggests that subjects at Terrace who responded while facing toward the street (facing southwest) could see the intersections with Lemon and Apache to their left, dramatically improving their accuracy.

Still, except for subjects facing toward the street at Terrace, pointing was less accurate at the two oblique locations. Variation in accuracy across the three locations was significant both for those facing toward and for those facing away from the street, $F(2, 54) = 3.40$ and 3.76 respectively, $p < .05$. For subjects facing away from the street, accuracy was marginally less at the two oblique locations than at Lemon, $F(1, 54) = 3.09, p < .08$, and it was less at Terrace than at Orange, $F(1, 54) = 4.43, p < .05$. Subjects at Terrace facing toward the street pointed just as accurately as did subjects at Lemon, the orthogonal location, both of which were more accurate than subjects facing toward the street at Orange, $F(1, 54) = 6.52, p < .05$.

South. Subjects were differentially accurate in pointing south as a function of location, $F(2, 54) = 4.36, p < .05$. Contrasts again showed that pointing at the orthogonal location was more accurate than at either oblique location, $F(1, 54) = 8.49, p < .01$, and that it did not differ at the latter two, $F(1, 54) = .24$. Neither the simple interaction of location and side, $F(2, 54) = 1.55$, nor the simple effect of side were significant, $F(1, 54) = 0.02$.

Northeast. Just as with pointing to Gammage and pointing south, accuracy in pointing northeast depended on the simple effect of testing location, $F(2, 54) = 7.41, p < .001$. And like these two targets, contrasts indicated that pointing at the orthogonal location was more accurate than at either oblique location, $F(1, 54) = 12.24, p < .001$, and that pointing at the latter two did not differ in accuracy, $F(1, 54) = 2.58$. Accuracy again did not depend on the simple interaction of location and side, $F(2, 54) = 0.88$, nor on the simple effect of side, $F(1, 54) = 0.04$.

Error distributions. As an additional way to examine pointing accuracy, Figure 3 presents distributions of absolute pointing errors for the four targets that varied significantly as a function of testing location, grouped into 20° intervals. Existing naturalistic spatial research does not provide error distributions that might provide increased insight into the nature of spatial disorientation, specifically oblique effects. Relatively severe disorientation at the two oblique locations is evidenced by the modal errors for the four targets. The majority response at the orthogonal location, Lemon, is an error of less than 20° for all four targets. The mode at the first oblique location, Terrace, is 20° to 40° for Gammage and south, 40° to 60° for northeast, and less than 20° only for Apache. The mode at the second oblique location, Orange, is 20° to 40° for Gammage, south, and Apache; there is a mode of 40° to 60° in addition to one of 20° to 40° for northeast. At least half of the subjects pointed with greater than 20° error at Terrace and Orange for each of the four targets.

RESPONSE TIME

In addition to response accuracy at the three testing locations, response times (RT) were compared. Four outlying RTs (1.3% of the data), two each at Lemon and Terrace, were replaced with the next largest RTs at those locations. The RTs were analyzed in the same type of multivariate mixed-model ANOVA as the pointing errors had been. As in the case of accuracy, RTs did not significantly differ as a main effect of the direction subjects were walking when stopped, nor did direction of walking significantly interact with any of the other independent variables. Mean RTs for each target at each location are graphed in Figure 4.

Subjects clearly differed in their response speed at the three locations, $F(2, 54) = 6.86, p < .01$. For all targets, response time was 1 to 3 seconds greater at Orange, the second oblique location, than at Lemon or Terrace, $F(1, 54) = 13.72, p < 001$.

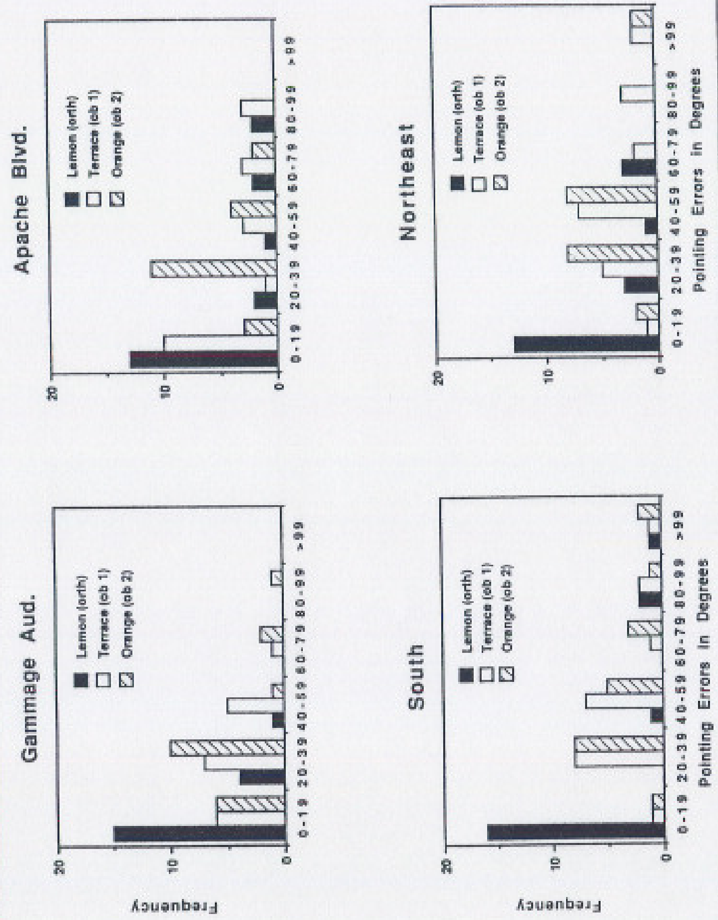

Figure 3: Frequency Distributions of Absolute Pointing Errors at the Three Testing Locations for Targets that Significantly Differed as a Function of Location

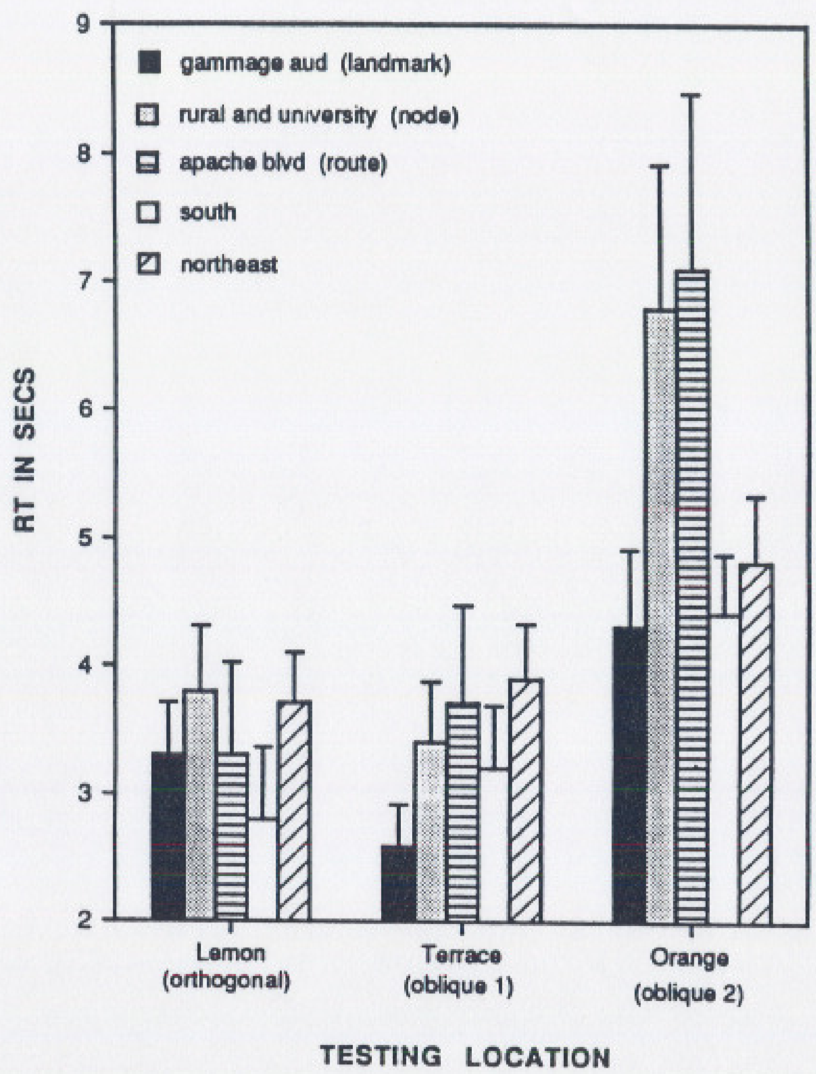

Figure 4: Mean Pointing Times and 95% Confidence Intervals for Each Target at the Three Testing Locations

RT did not differ at the latter two, $F(1, 54) = .00$. Unlike accuracy, the pattern of RTs at the three locations did not significantly vary

TABLE 1
Intercorrelations of Response Time, Pointing Error, and Familiarity Questions

	Response Time	*Error*	*Know*[a]	*Times/Week*[b]	*Lived*[c]
Response Time	—	.18	–.26*	.05	–.26*
Error		—	–.12	–.08	–.38**
Know			—	.07	.12
Times/week				—	.06
Lived					—

NOTE: N = 60.
a. "How well do you know the area within 1/2 mile?" (1-7; 7 is *extremely well*).
b. "How many times in an average week do you come by here?"
c. "How long have you lived in the Tempe area?"
*$p < .05$; **$p < .01$.

as a function of interactions with target, $F(8, 104) = 1.52$, with side, $F(2, 54) = 2.31$, or with target by side, $F(8, 104) = 0.53$. Response times did differ for the five targets, $F(4, 51) = 4.65$, $p < .01$, but not for the two sides subjects faced, $F(1, 54) = 1.63$, nor for the interaction of target and side, $F(4, 51) = 1.36$.

FAMILIARITY AND POINTING PERFORMANCE

Subjects' responses to two of the three familiarity questions, particularly to the question about how long they had lived in the area, were moderately related to speed and accuracy in pointing to the targets (see Table 1). Subjects who had lived in the area for a longer period of time pointed with greater accuracy and speed. In the case of response speed, this relationship was equally strong for all five targets. In the case of accuracy, the relationship was equally strong for all targets except for the corner of Rural and University. For this target, the relationship was weak and not significantly different than 0. Also, subjects who said they knew the immediate area better also pointed more quickly (similarly for the five targets), though not with significantly greater accuracy. The number of times subjects said they walked past the testing location in an average week was unrelated to performance.

Table 1 also shows that responses to the three familiarity questions were not significantly related to each other. It is interesting that subjects who had lived in the area for a longer period of time did not significantly report knowing the immediate area better, in spite of the fact that their pointing accuracy indicated that they did know it better. Finally, Table 1 shows that error and RT were weakly and nonsignificantly correlated, evidence against either a speed-accuracy tradeoff or covariation in these data.

DISCUSSION

As hypothesized, subjects generally pointed with greater accuracy when standing on the orthogonal street (Lemon) than when standing on either oblique street (Terrace and Orange). For the most part, accuracy did not differ on the two oblique streets. Apparently, the roughly 40° deviations of the two oblique streets from the local grid and/or the cardinal directions, or the oblique turns making up these streets, were difficult to compensate for, as evidenced especially by the distributions of pointing errors. Responses were equally fast by subjects standing on the orthogonal street (Lemon) and the first oblique street (Terrace), however, and faster than by subjects standing on the second oblique street (Orange). Structural obliqueness per se apparently did not affect response speed. Rather, the evident need to access spatial knowledge from Orange via Terrace (or some other anchoring route or landmark) increased response time, although it typically did not increase response error. And almost without exception, the speed and accuracy differences did not depend on whether subjects faced toward or away from the street at which they were stopped. Thus the speed and accuracy differences did not depend on whether subjects pointed in front or behind their bodies, and so on, a finding that differs from Sholl's (1987) results (at least to the degree that subjects learned the local targets in the present study via direct experience).

Error distributions (Figure 3) indicated clearly that significantly reduced accuracy at the two oblique locations was not due to a preponderance of very large or random errors at these locations. Rather, subjects compensated poorly but systematically for the oblique displacements of these two routes, Terrace (about 47° north of due west) and Orange (about 42° north of due east). This conclusion is supported by the fact that subjects at these two locations made many errors of between 20° and 60° but only a small number greater than 60°. The disorientation at the oblique locations was not complete; total disorientation (random orientation) would have resulted in nearly equal number of errors less than and greater than 90°.

For the most part, speed and accuracy differences were found without regard to which target subjects were to point. However, the pattern of angular errors depicted in Figure 2 suggests greater disorientation for questions about the global frame-of-reference (cardinal directions) than for questions about local features. This is consistent with the notion that knowledge of cardinal directions may be more strongly tied to knowledge of the local street system than is knowledge of local features when a dominant rectalinear grid is designed to coincide with the cardinal directions, especially in the absence of any highly salient landmarks. Or it may simply indicate that oblique routes will be most disorienting for less well-known features of spatial knowledge. Although impossible to test with the present data, knowledge of cardinal directions is logically less useful for restricted, local navigation in built environments than are less global forms of spatial knowledge. Examination of the RTs in Figure 4 suggests no such local-global difference in response speed, however.

Why is orientation less accurate when navigating along oblique routes? Tversky (1981) provided insight into some of the ways that the angularity of routes can influence performance in spatial estimation tasks. She suggested that spatial memory is subject to heuristics that will bias spatial representations in the direction of reference axes determined by major routes, landmarks, other local features, or cardinal directions. One problem in evaluating this model is that it is often difficult to state a priori what features will induce observable distortions; thus the direction of distortions may be difficult to predict in a principled way. Also, the model predicts constant biases in people's spatial knowledge. There was very little evidence of constant biases in subjects' directional estimates in the present data (see note 1).

Another possibility is that when traveling along oblique routes, it's harder to keep the orthogonal, body-centered axes used to organize surrounding spatial knowledge (see Sadalla & Montello, 1989) coordinated or synchronized with orthogonal axes determined by local features or global frames. The oblique relationship between these two frames will be less accurately represented in memory on the average, just as oblique patterns are generally perceived and remembered less accurately at many levels of processing (e.g., Appelle, 1972). This reduces the accuracy of one's sense of orientation to the surroundings during navigation (spatial updating) and may further decrease the accuracy of memory representations built up from navigational experiences. Previous work (Moar & Bower, 1983; Tversky, 1981) has stressed distortion in the representation of obliques but has not had much to say about on-line orientation processes while actually navigating.

At least three aspects of route angularity may prove disorienting for the urban navigator. First, routes with oblique turns or intersections may lead to disorientation, more so as the number of such turns increases. Second, routes that deviate from dominant local route patterns may tend to be oriented to less accurately. Finally, apart from any local pattern, the obliqueness of routes relative to the cardinal directions should lead to disorientation. This would be true at least with respect to knowledge about cardinal directions, or knowledge about landmarks or districts coded in terms of the cardinal directions. Unfortunately, the streets used in the present research confound these alternative aspects of route angularity. In any case, the availability of highly visible and salient landmark features would counteract disorientation due to route obliqueness.

An important question is whether these oblique effects derive from bias or imprecision in mental representations of geographical space, or instead, from bias or imprecision in the structure of the response itself. According to the first explanation, an oblique bias would show up independent of the method of measurement or of subjects' particular body orientations at the time of pointing (the internal representation is distorted in all cases). According to the second, angular distortions like those reported in this research may be a function of differential error when pointing in different directions from one's body, irrespective of properties of the world or of spatial representations (e.g., pointing straight ahead will generally be less errorful than pointing 30° left of straight ahead). In their laboratory study of memory for angular pathways, Sadalla and Montello (1989) found evidence favoring a response bias explanation. One of their measures required subjects to point straight back to the start location of the pathway. If oblique effects derived from the representation of the pathway, subjects would have pointed most accurately to start after 90° turns (or those near 0° or 180°). In fact, subjects were most accurate after a turn of 135°, a turn which resulted in a direction to start nearest to 90° of any of the turns. Such a pattern suggests a response effect rather than a representation effect.

In the present study, response angularity and street angularity were unconfounded in the case of three of the targets (orthogonal response directions were correct at oblique street locations, and so on). The angularity of correct responses when pointing to Gammage was not in fact very different at the three locations, though pointing accuracy was significantly greatest at the orthogonal location. The angularity of correct responses when pointing to the corner of Rural and University was more nearly orthogonal at the two oblique locations than at the orthogonal location, but accuracy for this target did not significantly differ at the three locations. The strongest contrast is provided by responses when pointing northeast, however. The correct answer is nearly perfectly orthogonal to subjects' bodies at the two oblique locations. Subjects at the orthogonal location

needed to point northeast in a perfect diagonal, 135° or 45°, relative to their bodies. Yet accuracy in pointing northeast was considerably greater at the orthogonal location than at either oblique location. Taken together, therefore, the results of the present study are more readily explained in terms of bias or imprecision in the memory representation, not with bias or imprecision in the response itself.

Results of this study indicated that subjects who claimed to know the area better responded faster, and that subjects who had lived in the area for a longer period of time responded both faster and more accurately. The latter finding replicates a relationship between length of residency and metric accuracy of environmental knowledge found by several investigators (Evans, Marrero, & Butler, 1981; Gärling, Böök, & Ergezen, 1982; Herman, Kail, & Siegel, 1979; Kirasic, Allen, & Siegel, 1984[2]), and it adds to the existing literature a relationship between long-term residency and the speed with which environmental knowledge is accessed. The relationships between performance in pointing to the targets and length of residency were in the same direction and did not significantly differ in strength for the five targets (except for accuracy in pointing to the corner of Rural and University, the one target that was not pointed to less accurately at the oblique locations). Even though developmental theories (e.g., Siegel & White, 1975) would predict a different time course for the changing relationship between familiarity and the accuracy of knowledge for local and global information, such a differential relationship was not observed in these data. This cannot easily be explained by either a restricted range of familiarity or an excessive range beyond that leading to knowledge increases, given that response speed and accuracy increased over a span of from one month to several years. As discussed in the introduction, however, people may store information about local features in representations that are organized around the cardinal directions, or they may organize their knowledge of cardinal directions around their knowledge of local features. If either is true, one would not expect to observe a differential relationship between familiarity and the speed or accuracy of accessing local versus global knowledge.

There are both advantages and disadvantages of the methodology used in this research. The data were collected in a large-scale, naturalistic field setting, from subjects who were actually navigating through that setting just prior to data collection. Because of this, on-line spatial knowledge could be tested instead of knowledge based purely on memory and imagination. Also, the use of a direct pointing measure avoids the ambiguity of using measures involving drawing. But as a field study, the present methodology may suffer from threats to internal validity incurred by the nonrandom assignment of subjects to testing locations and the use of an existing "laboratory" environment with a variety of possible characteristics other than those of interest (the confounding of multiple aspects of angularity, and so on). Also, the number of targets sampled was somewhat limited. In order to reduce the seriousness of these threats to validity, a homogeneous residential area was selected for study, with three testing locations close together but out of sight of one another. Subjects answered questions about their length of residence and familiarity with the area, neither of which were very different at the three locations. An interesting problem for future research is to disentangle the effects of various aspects of route angularity on spatial orientation with the use of similar high-quality field methodologies.

NOTES

1. Signed errors, or mean directions of responses, are not presented in the results because they are not directly relevant to the theoretical framework of this research. The model investigated predicts greater disorientation on oblique routes but doesn't unambiguously predict the direction of any constant bias, especially when dealing with a route that is perfectly diagonal with respect to a local grid pattern. In fact, analysis by circular statistics (Batschelet, 1981) indicated that subjects at the three locations generally did not significantly differ in mean estimated directions to the five targets as a function of whether they faced north versus south, and their mean estimated directions generally did not significantly differ from the correct direction.

2. Unlike the present study, however, Kirasic et al. (1984) found a relationship between familiarity and accuracy of configurational knowledge only when the task was performed as a perspective-taking task in the laboratory, not when it was performed on location.

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