

# **COGNITIVE MAPPING, TRAVEL BEHAVIOR, AND ACCESS TO OPPORTUNITY**

Paper submitted for presentation at  
the 85th Annual Meeting of the Transportation Research Board

August 1, 2005

(6,714 words, 3 tables/figures)

by

Andrew Mondschein  
Institute of Transportation Studies  
UCLA School of Public Affairs  
3250 Public Policy Building  
Los Angeles, CA 90095-1656  
Phone: (310) 927-1563  
Fax: (310) 206-5566  
Email: mond@ucla.edu

Evelyn Blumenberg  
Institute of Transportation Studies  
UCLA School of Public Affairs  
3250 Public Policy Building  
Los Angeles, CA 90095-1656  
Phone: (310) 903-3305  
Fax: (310) 206-5566  
Email: eblumenb@ucla.edu

Brian D. Taylor  
Institute of Transportation Studies  
UCLA School of Public Affairs  
3250 Public Policy Building  
Los Angeles, CA 90095-1656  
Phone: (310) 903-3278  
Fax: (310) 206-5566  
Email: btaylor@ucla.edu

## **ABSTRACT**

In this paper we combine theoretical and empirical research on cognitive mapping with our own initial research on the topic to suggest how cognitive mapping might be employed to help us better understand and predict travel behavior, emphasizing how spatial cognition shapes access to opportunity. We argue that the path-based, cumulative process of spatial learning, during which the cognitive map develops primarily through wayfinding and travel experience, affects accessibility by determining whether and how destinations are encoded into a person's cognitive map. Variations in cognitive mapping, spatial knowledge, and resultant travel behavior can vary between individuals or among groups in systematic ways. Some of these differences are related directly to previous travel experience, including experience with various travel modes. Such variations in spatial knowledge can result in different levels of functional accessibility, despite ostensibly similar locations, demographics, and other factors commonly thought to influence travel behavior.

Our initial survey of residents in three Los Angeles neighborhoods suggests that cognitive mapping is indeed influenced by neighborhood and travel mode experience, in addition to demographic characteristics. Such modally constructed cognitive maps, which are likely to vary systematically by both location and socio-economic status, may affect perceptions of activity opportunities in ways that travel behavior researchers are only beginning to understand. To a carless job seeker, job opportunities not easily reached by transit are effectively out of reach and even transparent. Modally constructed cognitive maps, in other words, are key to understanding both travel behavior and accessibility in cities.

## 1. INTRODUCTION

Coined in 1948 by Edward C. Tolman (1), the term cognitive map refers to the internal mental representation of environmental information. Both a process and a product of the mind, cognitive mapping is essential for spatial behavior and decision-making – whether rummaging in a refrigerator, traveling across a continent, or traversing a metropolitan area. The primary purpose of cognitive mapping is to enable individuals to make choices related to the spatial environment. Some transportation researchers have begun to engage with cognitive mapping to a limited degree, acknowledging that travel and transportation systems are influenced by and themselves influence spatial cognition (2, 3).

So far, much of the focus in transportation research has been placed on how cognitive mapping influences path selection, the routes chosen by travelers. However, the relationship between travel and spatial cognition extends beyond route choice. Cognitive mapping encompasses individuals' knowledge not only of potential travel routes but also of destinations themselves, as well as their proximity, purpose, desirability, and familiarity. As such, spatial cognition shapes each person's access to opportunities in the urban environment. Variation in cognitive maps between individuals and groups can therefore result in variation in access to opportunities. A better understanding of the complex relationships between spatial cognition, travel, and other factors such as socio-economic status, culture, and individual abilities can help guide transportation policymakers seeking to improve accessibility to important resources such as jobs, healthcare, recreation, and other amenities.

In this paper we combine theoretical and empirical research on cognitive mapping with our own initial research on the topic to suggest how cognitive mapping might be employed to help us better understand and predict travel behavior by emphasizing how spatial cognition shapes access to opportunity. We argue that the path-based, cumulative process of spatial learning, during which the cognitive map develops primarily through wayfinding and travel experience, importantly affects accessibility by determining whether and how destinations are encoded into a person's cognitive map. We suggest that variations in cognitive mapping, spatial knowledge, and resultant travel behavior can vary between individuals or among groups in systematic ways. Some of these differences are related directly to previous travel experience, including experience with various travel modes. Such variations in spatial knowledge can result in wildly different levels of what we term functional accessibility, despite ostensibly similar locations, demographics, and other factors commonly thought to influence travel behavior.

This paper is divided into five sections. Following this first introductory section, we define in the second section cognitive mapping and examine the role of cognitive mapping in spatial learning and decision-making. The third section applies this literature to the relationship between cognitive mapping and transportation decision-making. In the fourth section, we examine data and findings from a first phase of surveys examining the relationship between residential location and spatial cognition in three very different Los Angeles neighborhoods. We also briefly discuss methodological issues associated with this type of research. Finally, the fifth section of the paper explores the potential implications of this research with respect to transportation planning and policymaking. We conclude by suggesting that differences between modally constructed cognitive maps, learned variously through pedestrian, transit, automobile, and other travel modes, are key to understanding both travel behavior and accessibility in cities.

## 2. WHAT IS COGNITIVE MAPPING?

In *Image and Environment: Cognitive Mapping and Spatial Behavior*, Roger Downs and David Stea define cognitive mapping:

“Cognitive mapping is a construct which encompasses those cognitive processes which enable people to acquire, code, store, recall, and manipulate information about the nature of their spatial environment. This information refers to the attributes and relative locations of people and objects in the environment, and is an essential component in the adaptive process of spatial decision making” (4).

Cognitive mapping relates perceptions and preferences within a spatial matrix. This mixture of qualitative and spatial information in the cognitive map allows individuals to make decisions in a spatial context (5).

A cognitive map includes spatial information about the environment, including places’ and routes’ identity, location, distance, direction (6). Both person-to-object relationships and object-to-object relationships are contained within the cognitive map (7). Thus, the cognitive map is the end product of a cognitive mapping process. The space within a cognitive map has been termed “psychological space.” It is:

“Any space which is attributed to the mind...and which would not exist if minds did not exist... In contrast, physical space is any space attributed to the external world independent of minds” (8).

Cognitive maps embody the space actually experienced by individuals. Its features are mental representations of the physical, external environment. Because cognitive mapping internalizes geography, the temptation to interpret a cognitive map as a mental version of a cartographic map is strong. “In western cultures, however, much emphasis is placed on interpreting and using space represented as a Euclidean metric” (9). However, there is no simple, one-to-one relationship between cognitive mapping and a cartographic representation of space. Instead, the cognitive map should be taken as a metaphor for a cognitive construct that is much less literal than a cartographic map (10, 11).

As a mental construct, the cognitive map is not a flawless or photographic representation of physical space:

“So it can be expected that spatial representations in humans are incomplete and error prone, providing the distortions or fragmentations frequently mentioned by research on human spatial representation” (7).

The incomplete and error-prone nature of cognitive mapping causes variability between the cognitive maps of individuals and serves to explain the “bounded rationality” of spatial behavior (7). Individuals may choose seemingly irrational routes or destinations that, within the framework of their cognitive map, are completely logical.

Error and incompleteness are not completely random in individuals’ cognitive maps. Rather, the variations between individuals are in part due to external factors such as experience, social processes, and demographic factors.

### 2.1 Components of the Cognitive Map

Notwithstanding the caveats that cognitive mapping is metaphorical and error prone, it is generally accepted that cognitive maps are composed of basic geometric features such as points, lines, areas, and surfaces (9). In a cognitive map, these geometric features represent aspects of the physical environment. “Landmarks” are the major point feature of cognitive mapping and can be any notable, relatively stationary point feature. Landmarks are associated with

information such as identity, location, dominance in the hierarchy of all landmarks. Landmarks are also used in the cognitive map as navigation aids: They are travel decision points (e.g. turn here, go a little further) in addition to being origins or destinations.

Lines also play a major role in cognitive mapping, both as boundaries/edges and as routes (9). As potential routes, lines possess multiple features including length, connecting nodes, directionality from landmarks, linearity or curvature, and assemblages into networks and hierarchies. Areas are used as two dimensional spatial classification devices. They include regions, neighborhoods, communities, urban places, and other arbitrary/political districts. As cognitive constructs, areas are containers of layouts of landmarks and routes and help establish hierarchies of scale. Finally, surfaces are areas with gradient information. Surfaces can simply represent physical topography such as changes in slope or elevation, or they can represent more social, qualitative features such as gradients of perceived crowding, accessibility, or safety.

## 2.2 Spatial Learning

Like other mental processes, cognitive mapping develops over time. Developmental psychologist Jean Piaget found that environmental perception and cognition are different in children than in adults:

“The cognitive processes are not constant but undergo change with age (or development) and use (or learning). Similarly, a cognitive map is an abstraction which refers to a cross-section, at one point in time, of the environment as people believe it to be” (4).

Influenced not only by age but experience, cognitive mapping is an interactive process, learned mainly “on the fly” through experience and much less through reflection (6). Variations in spatial experience result in variations in cognitive mapping. While visual information is the primary spatial sense, cognitive mapping has no particular sensory modality but instead spans all of the senses (7). For example, the sense of distance in a cognitive map may draw upon multiple sensory and cognitive inputs, including motor response timing, the sensation time and velocity, the utilization of patterns in the structure of the physical environment, and interpretation of symbolic representations, such as maps and road signs (6).

In general, spatial learning occurs in a progression from “landmark” to “route” to “survey” knowledge (12). After learning of a landmark, isolated landmarks are linked in routes, but individual routes in the cognitive map remain largely unrelated. However, with greater experience and spatial facility, more systematic knowledge of the environment can be learned, often called survey or configurational knowledge (9). This type of knowledge incorporates isolated routes into a system:

“Sectoral or local regional knowledge may accrue in the vicinity of a route. Initially, therefore, knowledge of an area may develop as a series of strips or corridors surrounding specific routes. This facilitates knowledge integration if the routes are known and are overlapping. Evidence exists that integration of information learned from different routes is not automatic, and may be achieved only partially” (9).

As linkages are made between individual routes and locations, increased functionality is added to the cognitive map, such as the ability to devise shortcuts between destinations and create complex trip chains.

### 2.3 Individual and Group Difference

Not all individuals reach the same level of development in their cognitive maps. As suggested above, different individuals will have varying abilities in wayfinding and cognitive mapping (13). Differences in individual spatial abilities explain some differences in the development of cognitive mapping, such as the ability to think geometrically, image complex spatial relations, recognize spatial patterns, perceive three-dimensional structures in two dimensions, and understand network structures (7). Similar personal characteristics that influence the spatial learning process include spatial-sequential memory, topological knowledge, motor capabilities, spatial perception, and general information-processing capabilities. Such capabilities are partly innate in individuals, but researchers have also found that they can be developed and extended through training and use (7).

Researchers who have investigated cognitive maps have also seen social and economic difference as a potential sources of difference between groups and individuals. Factors include social and cultural characteristics, education, and income (14, 15). In *Beyond the Neighborhood Unit: Residential Environments and Public Policy*, Tridib Banerjee and William Baer found that characteristics of an individual's cognitive map are related to their socioeconomic characteristics (16). Specifically, they observed that different groups tended to draw different size neighborhood maps. For example, while upper-income white residents often drew broad ranging maps that encompassed large areas of many square miles, many lower income residents (of varied ethnic/racial groups) drew maps that were focused on smaller areas, sometimes just an intersection or apartment complex. Significantly, Banerjee and Baer found that such variations in neighborhood map size reflected not only different spatial locations in the city but the varied level of mobility and access associated with different communities (16). Social grouping can affect the scope of cognitive maps to the extent that rival groups may not "see" the territory of their rivals in their cognitive maps. The conceptual structuring varies also across cultures (17, 18). For example, different cultures may emphasize different features of the physical environment such as buildings versus signage resulting in cognitive maps with different building blocks (19).

## 3. COGNITIVE MAPPING AND TRAVEL

While the literature on theories and measurement of cognitive maps is well-established, the links between cognitive maps and travel behavior is less well-developed. Specifically, research on cognitive mapping and travel has tended to focus primarily, in fact almost exclusively, on the fourth and final part of the traditional travel demand analysis process: route choice. In contrast, the first three steps – trip generation (how many trips?), trip distribution (where to go?), and, in particular, mode choice (by what means of travel?) have been given far less attention by cognitive mapping researchers. So it is to the potential role of cognitive mapping in trip generation, trip distribution, and mode split we now turn.

### 3.1 Path-Based Spatial Learning

Cognitive maps are acquired, primarily, through travel and interaction with existing transportation systems, whether it be streets and highways, sidewalks, bike paths, or bus and subway routes; these cognitive maps, in turn, influence travel (2). Golledge and Stimson state:

“A transactionally-based hypothesis concerning our knowledge of urban environments would be that one obtains knowledge about the city according to the type of interactions that one has with it. Thus, urban knowledge accumulates as a

result of the various trips undertaken as part of the everyday process of living. Whereas other conceptualizations focus more on the node and landmark structure or areal pattern of urban knowledge, the conceptualization is path based” (7).

This path-based theory of spatial learning gives travel and navigation a primary role (14). The cognitive process of wayfinding allows humans to expand their cognitive maps:

“Wayfinding is taken more generally to involve the process of finding a path (not necessarily previously traveled) in an actual environment between an origin and a destination that has previously not necessarily been visited. Wayfinding can thus be identified with concepts such as search, exploration, and with incremental path segment selection during travel. Wayfinders can also use technical assistance (e.g., compass, global positioning system, network map) but, more often, use cognitive maps” (3).

Each of these activities—search, exploration, path selection—allows individuals to learn about their environment (6). As the product of the wayfinding process, route-based knowledge is considered the most basic type of spatial knowledge (9). Landmarks and routes between places and/or people are usually the first things learned when traveling through a new environment.

Both route knowledge and landmark knowledge of potential opportunities/destinations are developed through the wayfinding process. Navigation through the environment occurs through a systematic process of movement along vectors defined at their beginnings and ends by, what cognitive mapping scholars call, “choice points.” Choice points are the locations where individuals make some necessary decision in navigation, such as a change in direction. According to Golledge and Stimson, “Environmental cues or other features of the environment have the highest probability of being perceived and recognized if they are in the immediate vicinity of choice points” (7). Therefore, individuals are most likely to learn about opportunities in the environment if those opportunities are near choice points. Hence, nodal points in the transportation network are important locations in the landscape of daily life. Some have proposed defining spatial behavior in terms of “activity spaces” which are defined by the dispersion and frequency trips taken on a daily basis, with home at center of each activity space (7).

### **3.2 Transportation Mode and Spatial Learning**

While cognitive mapping researchers have recognized the connection between travel and spatial learning, little is known yet about how the existing transportation infrastructure itself shapes cognitive maps and, in turn, affects route selection as well as other aspects of travel including trip frequency, trip purpose and destinations, and mode choice (3). However, the limited available research suggests that transportation infrastructure and, in particular, wayfinding on overlapping, yet distinct, modal networks – sidewalks, bike lanes, transit routes, local streets and roads, and freeway networks – affects the development of cognitive maps and, in turn, travel behavior.

The hierarchical nature of both transportation networks and land use systems in an urban environment can affect the cognitive mapping process. In general, the more significant a particular pathway or landmark is to an individual’s navigation, the more it will dominate the cognitive map (7). The hierarchies of pathways in a region, such as highway and freeway segments dominating arterial and main roads, which in turn dominate local community and neighborhood street systems, contribute to the hierarchical organization of cognitive maps. In fact, individuals will recognize elements in the environment more quickly if “primed” by a cue

from the same portion of their regional hierarchy. Zannaras also found that the layout of a city significantly explained variations in the accuracy of wayfinding and location tasks (20). Sectorally-organized cities proved the more effective for remembering locations, while concentrically-organized cities made wayfinding and location tasks more difficult. Likewise, familiarity, or “route learning,” is clearly an important part of both route selection and mode choice because familiarity is dependent on repeated experience. Stern and Portugali highlight two aspects of route familiarity: [1] specific experience of a given locality and [2] general familiarity with city structures, the hierarchy of roads, traffic and signage (21). Those who use different modes will clearly develop different degrees of familiarity with each transport system. Such research suggests that those who use different travel networks, such as auto and transit users, will understand the same urban environment in very different ways.

Much of the scholarship on cognitive mapping has focused on drivers and the street and highway network (22). This emphasis is likely due to the dominant role of automobiles as well as the route flexibility associated with using the street network. Yet preliminary evidence suggests that cognitive maps are differentially shaped by alternate transportation modes. For example, we know that individuals who rely on public transit or walking, on average, travel shorter distances and travel less frequently than those who travel by motor vehicle. Therefore, one can hypothesize that the scope of their spatial knowledge would be more limited and differently configured (by, for example, the network of transit routes) than those who rely on automobiles and can travel longer distances at greater flexibility and speed.

The quality and detail of spatial maps also may differ by mode. In a study of children traveling to school, “active” modes of travel, such as walking and biking, appear to contribute more to the development of spatial knowledge than passive modes of travel, such as being chauffeured by an adult or riding in a school bus. Specifically, walking and cycling to school have been found to increase knowledge of the environment in comparison to children who are bused (23). These results suggest that variation in transportation mode may result in very different levels of functional accessibility for individuals from otherwise similar socioeconomic or cultural backgrounds.

Finally, research also suggests that travel behavior is influenced by perceptions of distance which affect “the decision to stay or go...the decision of where to go...[and] the decision of which route to take” (24). Cognition of environmental distance is influenced by pathway features, travel time, and travel effort which are substantially different depending on travel mode (25). The characteristics of travel by transit, which include indeterminate waiting at transfer points and walking trips between services, may add to cognitive distance in a way that auto travel does not.

Drawing on a path-based theory of spatial learning, differences in cognitive maps between socioeconomic groups may also be explained at least in part by the different travel patterns of those groups. Certainly, adults in higher income households are more likely to have reliable access to automobiles. In contrast, over one quarter of low-income households do not have automobiles and are transit dependent (26). But transit use is also high among adults in low-income households with automobiles since oftentimes there are too few vehicles to accommodate the number of household drivers.

In addition to the well documented role that cognitive maps play in explaining wayfinding and route choice, we hypothesize that travel by different modes in more or less transit- and pedestrian-friendly areas systematically manifests in individuals’ cognitive maps structured more by transit networks (i.e. transit lines, stations, and stops) than by the arterials,

collectors, and local streets that make up urban street networks. In other words, a modally specific wayfinding experience significantly and systematically influences the formation of cognitive maps. And these maps, in turn, influence trip generation, trip distribution, and mode choice.

#### 4. RESIDENTIAL LOCATION AND SPATIAL COGNITION: THREE LOS ANGELES NEIGHBORHOODS

We hypothesize that residential location in more or less transit- and pedestrian-friendly areas systematically manifests in individuals' cognitive maps. While there are many ways to measure how individuals translate transportation network experience and information into cognitive maps, one simple test of street network familiarity is the ability to identify cross-streets near familiar nodes – in this case common travel destinations. So for the first phase of what will be a multi-year study of cognitive mapping and travel, we tested our hypothesis regarding the influence of neighborhood location and transportation mode on spatial cognition in a random telephone survey of 34 households in three very different Los Angeles neighborhoods (see Figure 1). The first, Pico Union, is a high-density, low-income neighborhood located just west of the downtown Los Angeles central business district. Neighborhood residents are largely Hispanic immigrants and the neighborhood is well served by public transit. The second neighborhood, Pacoima, is located in the San Fernando Valley, a lower-density, low-income suburb approximately 20 miles north west of downtown Los Angeles. Here too, the residents are predominantly Hispanic, although fewer are recent immigrants compared to Pico Union. However, while transit service is available in Pacoima, relatively dispersed origins and destinations and longer headways make transit travel convenient than in Pico Union. Finally, we surveyed residents living in Westwood, a high-density, higher-income neighborhood near the UCLA campus about 15 miles west of downtown.

Westwood has numerous employment opportunities and is well served by public transit with connections to various parts of the region. Data were collected in a telephone survey conducted during early evening on weekdays over a week in April 2005. The sample of households called was selected randomly from the set of all residential phone numbers within a particular neighborhood. The response rate for this telephone survey, at sixteen percent, was low but not unusual for cold-call telephone surveys. In the Pacoima neighborhood, the number of responses was improved by surveying in both English and Spanish. The ten to fifteen minute survey included questions on various types of trips made by respondents (to the grocery store, to work, to visit friends), the mode taken, and their perceptions of location, travel time, and distance for those trips. Respondents were also asked demographic information such as year born, country of origin, education level, and auto ownership. This first phase

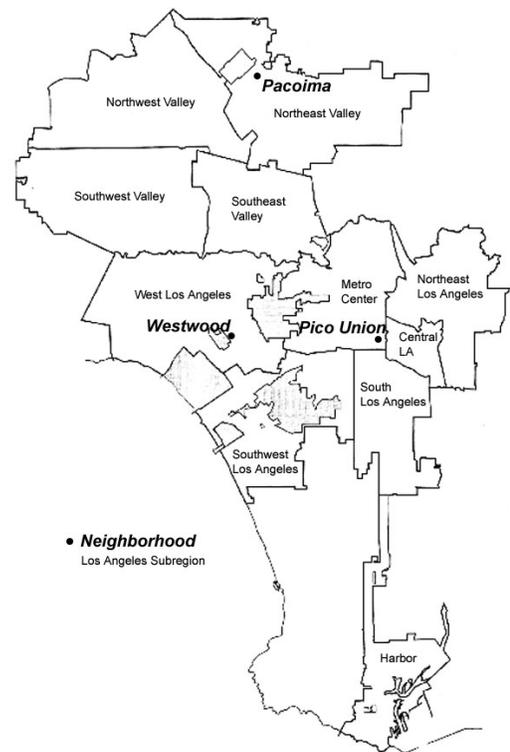


FIGURE 1 Neighborhood Context

survey produced thirty-four completed, valid responses. The results of this initial phase of the research project serve two purposes: [1] to illuminate general trends and develop hypotheses of for further investigation and [2] refine the survey instrument and research design.

An immense variety of methodologies have been developed or proposed for extracting empirically analyzable spatial products from cognitive mapping (7, 14). The myriad spatial products generated by these methods draw upon the wide range of geometries, orientations, perceived quantities, and qualitative characteristics contained within a cognitive map. The wide variety and overlapping purposes of many methodologies make it difficult to choose a methodology to address a particular research question. Some methods are particularly attractive because of the breadth of information that they provide for analysis. For example, sketch maps can provide analyzable data such as the number of total features, a mix of point, line, and area features, indications of dominant functions as perceived by the sketcher, information such as sequences along routes, and the overall regularity or irregularity of features. Other methods, such as verbal questions about distance or location may provide fewer types of data but be more desirable because of low skill requirements, cross-subject comparability, and ease of execution. For this phase of research, we chose to employ verbal methods exclusively, asking individuals questions about their spatial knowledge over the telephone. Utilizing verbal methods both allowed us investigate neighborhoods across a broad geographical area and provided results that were relative easy to compare across subjects.

The survey data show substantial variation in spatial knowledge as demonstrated by the ability to name locations for various activities with exact cross streets. While the ability to verbalize precise locations may not encompass every aspect of spatial knowledge, it likely reflects the degree of refinement in an individual's cognitive map. We first compared the ability to name cross-streets across residents in the three neighborhoods and then examined the characteristics of the neighborhood in relation to this spatial ability. These data are presented in Table 1.

	<b>Pacoima</b>	<b>Pico Union</b>	<b>Westwood</b>
Able to name cross-streets	38%	47%	83%
Reported travel times to given destination	16.7	18.5	15
Grade level	8.8	11	16.2
Born in U.S.	24%	43%	60%
Years in Los Angeles	20.3	26.3	10.8
Years in neighborhood	15.1	11.1	3.8
Know how to drive	76%	100%	100%

The ability to name cross streets (aggregated by neighborhood) appears to be positively correlated with grade level, nativity, and, in part, knowing how to drive. Grade level can serve as a proxy for income since educational level and income are highly and positively correlated. Thus, we can infer that higher income residents, on average, are better able to identify cross streets than lower income residents. Given that income levels have long been shown to be highly correlated with both private vehicle access, trip making, and average travel distances (26-28), such a finding is not surprising.

More surprising, perhaps, are data showing that both years spent in their current neighborhood and years living in Los Angeles are both *inversely* correlated with the ability to identify cross streets. Specifically, the few transit-dependent respondents living in dense, transit-rich Pico Union data who, because of age, income, disability, or immigration status, are not able to drive, were substantially less likely to be able to identify cross-streets near common destinations. This suggests that, while such regular transit users may have well-developed transit-network-based cognitive maps, their knowledge of the larger LA street system is less-developed. We intend to further explore this question in considerable detail in a subsequent phase of this research.

Survey respondents were asked to identify the cross-streets near their most recent trip to [1] the grocery store, [2] visit friends, and [3] paid employment. The results of these queries are summarized in Table 2, which shows that, for all neighborhoods combined, respondents' ability to identify nearby cross-streets varies significantly across the three trip types; better than two-thirds of respondents identified cross-streets near grocery stores, just over half could identify cross-streets near work, but just over a third of respondents could identify cross-streets near a more recent trips to visit friends. We speculate that the relative infrequency of visiting friends might explain the surprisingly low ability to name cross-streets for that activity. Trip frequency, however, cannot explain why respondents found it easier to name cross-streets for the grocery store than employment. Notably, the ability to name cross-streets appears to be inversely correlated with perceived travel times, at least when aggregated by activity type. In other words, the longer the perceived travel time, the less likely the respondent was to identify the exact cross street of the destination. This finding seems to support the theory described earlier that spatial knowledge is concentrated around anchor points. If the home is the primary anchor point in a persons' cognitive map, then locations further out, even employment locations, will be less well-defined in their cognitive maps (9).

	Able to Name Cross-Streets	Reported Travel Times
Grocery Store	71%	11.3
Visiting Friends and Family	37%	21.3
Employment	55%	18.7

Perhaps not surprisingly, respondents across all neighborhoods were able to provide perceived distances much less reliably than perceived travel times. (This refers not to the accuracy of the estimates, but to the ability to offer trip time and trip distance estimates at all.) However, the ability to report estimated travel distances tracks closely with an individual's ability to identify cross-streets near common destinations. In our sample, respondents living in more affluent Westwood and those traveling to the grocery store from any neighborhood were most likely to offer trip time and distance estimates. Finally, the ability to identify one's neighborhood by name (any name) and give it cross-street-defined center was far higher in more-affluent, less-immigrant-based Westwood, than in either Pacoima or Pico Union.

This initial analysis of the cognitive ability of the residents of three Los Angeles neighborhoods with varying travel mode and income characteristics suggests that cognitive ability does vary with socioeconomic factors such as education, nativity, and ability to drive. Such variation can be attributed at least in part to variations in the transportation modes available

and typically used by individuals in each neighborhood. In further stages of this research, we will focus more specifically on the spatial learning process and differences in how the cognitive maps of individuals utilizing different modes develop. In addition, we will explore other methodologies for collecting a diverse range of information from individuals' cognitive maps.

## 5. COGNITIVE MAPS, TRANSPORTATION PLANNING, AND ACCESS

A few scholars have suggested the importance of including cognitive mapping in travel choice models (2, 3). For example, Golledge and Gärling state:

“Current opinion appears to indicate that, because factors such as cognitive-mapping ability, cognitive map knowledge of feasible alternatives, navigation and wayfinding strategies, and preferences for path selection criteria all are presumed to have a substantial impact on travel choices, there is a growing need to include spatial cognition explicitly in models” (3).

Much of this literature has focused on the role of spatial cognition in predicting travel paths or route choice. As a result, cognitive mapping and travel behavior research has centered on how “information on what is known about the location, possible destinations, and feasible alternatives for any choice” affects “what is known about the network [and] over which travel must take place;” this link between cognitive mapping and travel choices, argue Golledge and Gärling, calls for developing a “means for spatializing attribute information by attaching values and belief or preference ratings or measures to specific geocoded places” into travel choice models (3).

We have argued in this paper that the links between cognitive maps and travel choices are central to understanding travel behavior. But is cognitive mapping too abstract, too hard to measure, too academic to be of any relevance to transportation planning practice? Perhaps not. The literature on household activity modeling as a more conceptually sound and robust way to predict travel behavior than traditional travel demand modeling is large and growing (29-34). Activity modeling could be enhanced significantly with better information on how modal experience shapes individuals' cognitive maps. In other words, the cognitive maps of [1] people who mostly walk and use public transit may vary systematically from [2] those who are mostly chauffeured in private vehicles, and from [3] those who usually drive. Past modal experience, in other words, may substantially affect future trip generation and trip distribution *ceteris paribus*.

This line of reasoning is consistent with research on job search behavior among low-wage workers. Those with regular access to private vehicles tend not only to search larger geographic areas for work, but tend to perceive job opportunities in less spatially constrained ways (35, 36). In order to remedy such cognitive barriers to job opportunities experienced by those without regular access to autos, “compensatory” solutions such as trip planning services, guaranteed ride home services, and overall improvements to transit service could be implemented. Another means of compensating for limitations in individuals' cognitive maps could be the dissemination of Intelligent Transportation Systems (ITS). Such systems reduce individuals' overall reliance on their own cognitive maps potentially increasing access to known destinations. However, ITS would not necessarily influence how prior spatial knowledge informs the initial portions of the travel behavior sequence, trip generation and trip distribution. Individuals would still rely on their cognitive maps when choosing to make a trip and selecting a particular destination for that trip.

Public transit planning could potentially benefit from cognitive mapping research in at least two other ways. First, the well-documented body of research showing that different people tend to construct and interpret cognitive maps in systematically different ways such as isolated

route knowledge as compared to broader configurational knowledge of a region suggests that the representation of transit networks, routes, transfer points, and schedules might best be consistently represented in redundant ways to be user-friendly to different types of spatial learners. For example, regional transit information pamphlets could include on one side complex maps of transit routes integrated with the local street network for those with advanced configurational knowledge, while on the backside each route could be illustrated in isolation with landmarks and major destinations iconically listed along the route in order to assist those who feel more comfortable dealing with a single route at a time.

Second, if street and transit networks, though overlapping in space, tend to be constructed entirely separately in the minds of most travelers, this may explain why large shares of private vehicle drivers never use, or even consider using, public transit. While drivers may prefer private vehicle travel over transit, they may never consider using transit – even if a particular transit trip may be competitive in time and cost with an auto trip – if the transit network is, for all intents and purposes, transparent. But if marketing programs are successful in encouraging drivers to use transit once or twice, awareness of transit may cause drivers to amend their cognitive maps to include transit as a possibility for some trips. Given that 86.4 percent of all trips in 2001 were made in private vehicles (28), efforts to encourage drivers to occasionally use transit (such as when their car is in the shop) could bear substantial fruit for transit systems anxious to attract more riders.

## **6. CONCLUSION**

We have argued in this paper that cognitive mapping research has the potential to address the enduring focus on accessibility in transportation research. While accessibility has traditionally been conceived as proximity of (or cost of travel between) one location and others, cognitive mapping research shows that physical distances are only one factor shaping how individuals make choices in a spatial context (37). Individual differences, including prior modal travel experiences, cultural preferences, and spatial abilities, shape the cognitive map and, thereby, the cognitive proximity and accessibility of potential destinations in a region. As a result, travelers do not necessarily follow the “rational” path selection routines of standard travel models (38).

Our initial survey of residents in three Los Angeles neighborhoods suggests that cognitive mapping is indeed influenced by neighborhood and travel mode experience, in addition to demographic characteristics. Such modally constructed cognitive maps, which are likely to vary systematically by both location and socio-economic status, may affect perceptions of activity opportunities in ways that travel behavior researchers are only beginning to understand. To a carless job seeker, area job opportunities not easily reached by transit are effectively out of reach, and even transparent, regardless of Euclidian distance. Modally constructed cognitive maps, in other words, are key to understanding both travel behavior and accessibility in cities.

## ACKNOWLEDGEMENTS

This research was conducted with generous funding from the University of California Transportation Center (UCTC), and the authors are grateful for this support. Any errors or omissions are the responsibility of the authors and not the UCTC. Thanks also to Stephen Crosley, Marisa Espinosa, Candice Fukusaki, Kristen Lauckhart, Keri Tyler, and Kendra Vernon for conducting the initial survey. Finally, we thank the survey respondents for their participation.

## REFERENCES

1. Tolman, E.C. Cognitive Maps in Rats and Men. *Psychological Review*, Vol. 55, No. 4, 1948, pp. 198-208.
2. Weston, L. and S. Handy, *Mental Maps*, in *Handbook of Transport Geography and Spatial Systems*, D.A. Hensher, et al., Editors. Elsevier, Amsterdam, 2004.
3. Golledge, R.G. and T. Gärling, *Cognitive Maps and Urban Travel*, in *Handbook of Transport Geography and Spatial Systems*, D.A. Hensher, et al., Editors. Elsevier, Amsterdam, 2004.
4. Downs, R.M. and D. Stea, eds. *Image and Environment: Cognitive Mapping and Spatial Behavior*. Aldine Publishing Co., Chicago, 1973.
5. Suttles, G.D., *The Social Construction of Communities*. The University of Chicago Press, Chicago, 1972.
6. Downs, R.M. and D. Stea, *Maps in Minds: Reflections on Cognitive Mapping*. Harper & Row, Publishers, New York, 1977.
7. Golledge, R.G. and R.J. Stimson, *Spatial Behavior: A Geographic Perspective*. The Guilford Press, New York, 1997.
8. Liben, L.S., A.H. Patterson, and N. Newcombe, eds. *Spatial Representation and Behavior Across the Life Span: Theory and Application*. Academic Press, Inc., New York, 1981.
9. Golledge, R.G., *Human Wayfinding and Cognitive Maps*, in *Wayfinding Behavior: Cognitive Mapping and Other Spatial Processes*, R.G. Golledge, Editor. Johns Hopkins University Press, Baltimore, MD, 1999.
10. Downs, R.M., *Maps and Mappings as Metaphors for Spatial Representation*, in *Spatial Representation and Behavior Across the Life Span: Theory and Application*, L.S. Liben, A.H. Patterson, and N. Newcombe, Editors. Academic Press, Inc., New York, 1981.
11. Gattis, M., *Thinking through Maps*, in *Spatial Schemas and Abstract Thought*, M. Gattis, Editor. The MIT Press, Cambridge, MA, 2001.
12. Shemyakin, F.N. *General problems of orientation in space and space representations*. Office of Technical Services, Washington DC, 1962.
13. Allen, G.L., *Spatial Abilities*, in *Wayfinding Behavior: Cognitive Mapping and Other Spatial Processes*, R.G. Golledge, Editor. Johns Hopkins University Press, Baltimore, MD, 1999.
14. Kitchin, R.M. and M. Blades, *The Cognition of Geographic Space*. I. B. Tauris, London, 2002.
15. Orleans, P., *Differential Cognition of Urban Residents: Effects of Social Scale on Mapping*, in *Image and Environment: Cognitive Mapping and Spatial Behavior*, R.M. Downs and D. Stea, Editors. Aldine Publishing Co, Chicago, 1973.

16. Banerjee, T. and W.C. Baer, *Beyond the Neighborhood Unit: Residential Environments and Public Policy*. Plenum Press, New York, 1984.
17. Loukaitou-Sideris, A. and L. Gilbert. Shades of Duality: Perceptions and Images of Downtown Workers in Los Angeles. *Journal of Architectural and Planning Research*, Vol. 17, No. 1, 2000, pp. 16-33.
18. Kita, S., E. Danziger, and C. Stolz, *Cultural Specificity of Spatial Schemas, as Manifested in Spontaneous Gestures*, in *Spatial Schemas and Abstract Thought*, M. Gattis, Editor. The MIT Press, Cambridge, MA, 2001.
19. Ramadier, T. and G. Moser. Social legibility, the cognitive map, and urban behavior. *Journal of Environmental Psychology*, Vol. 18, 1998, pp. 307-319.
20. Zannaras, G. *The cognitive structure of urban areas*. Presented at EDRA IV. Stroudsburg, PA, Dowden, Hutchinson, and Ross, 1973.
21. Stern, E. and J. Portugali, *Environmental Cognition and Decision Making*, in *Wayfinding Behavior: Cognitive Mapping and Other Spatial Processes*, R.G. Golledge, Editor. Johns Hopkins University Press, Baltimore, MD, 1999.
22. Golledge, R.G. and T. Gärling. *Spatial Behavior in Transportation Modeling And Planning*, in *University of California Transportation Center Working Papers*: Berkeley, CA, 2001.
23. Hart, R.A., *Children's Spatial Representation of the Landscape*, in *Spatial Representation and Behavior Across the Life Span: Theory and Application*, L.S. Liben, A.H. Patterson, and N. Newcombe, Editors. Academic Press, Inc., New York, 1981.
24. Cadawaller, M.T., *Cognitive distance in intraurban space*, in *Environmental Knowing*, G.T. Moore and R.G. Golledge, Editors. Dowden, Hutchinson, & Ross, Stroudsburg, PA, 1976.
25. Montello, D.R., *The perception and cognition of environmental distance: direct sources of information.*, in *Spatial Information Theory: A Theoretical Basis for GIS*, S.C. Hirtle and A.U. Frank, Editors. Springer-Verlag, Berlin, 1997.
26. Pucher, J. and J.L. Renne. Socioeconomics of Urban Travel: Evidence from the 2001 NHTS. *Transportation Quarterly*, Vol. 57, No. 3, 2003, pp. 49-77.
27. Blumenberg, E. and M. Waller. *The long journey to work: A federal transportation policy for urban families*. Brookings Institution, Washington, DC, 2003.
28. Hu, P.S. and T.R. Reuscher. *Summary of Travel Trends: 2001 National Household Travel Survey*. US Department of Transportation, Federal Highway Administration, Washington, DC, 2004.
29. Meyer, M.D. and E.J. Miller, *Urban Transportation Planning, 2nd edition*. McGraw Hill, Boston, 2001.
30. Lee-Gosselin, M.E.H. and E.I. Pas, *The implications of emerging contexts for travel-behaviour research*, in *Understanding Travel Behaviour in an Era of Change*, P.R. Stopher and M.E.H. Lee-Gosselin, Editors. Elsevier, Amsterdam, 1997.
31. Mahmassani, H.S., *Dynamics of Commuter Behaviour: Recent Research and Continuing Challenges*, in *Understanding Travel Behaviour in an Era of Change*, P.R. Stopher and M.E.H. Lee-Gosselin, Editors. Elsevier, Amsterdam, 1997.
32. Pas, E.I. and A.S. Harvey, *Time Use Research and Travel Demand Analysis and Modeling*, in *Understanding Travel Behaviour in an Era of Change*, P.R. Stopher and M.E.H. Lee-Gosselin, Editors. Elsevier, Amsterdam, 1997.

33. Kitamura, R. and J. Supernak, *Temporal Utility Profiles of Activities and Travel: Some Empirical Evidence*, in *Understanding Travel Behaviour in an Era of Change*, P.R. Stopher and M.E.H. Lee-Gosselin, Editors. Elsevier, Amsterdam, 1997.
34. Stopher, P.R., *Measurement, Models, and Methods: Recent Applications*, in *Understanding Travel Behaviour in an Era of Change*, P.R. Stopher and M.E.H. Lee-Gosselin, Editors. Elsevier, Amsterdam, 1997.
35. Stoll, M.A. Spatial job search, spatial mismatch, and the employment and wages of racial and ethnic groups in Los Angeles. *Journal of Urban Economics*, Vol. 46, No. 1, 1999, pp. 129-155.
36. Holzer, H.J. and J. Reaser. Black applicants, black employees, and urban labor market policy. *Journal of Urban Economics*, Vol. 48, No. 3, 2000, pp. 365-387.
37. Kwan, M.-P. and J. Weber. Individual accessibility revisited: implications for geographical analysis in the 21st century. *Geographical Analysis*, Vol. 35, No. 4, 2003, pp. 341-353.
38. Golledge, R.G. *Path Selection and Route Preference in Human Navigation: A Progress Report*, in *University of California Transportation Center Working Papers*: Berkeley, CA, 1995.