ACCESSIBILITY AND COGNITION: THE EFFECT OF TRANSPORTATION MODE ON SPATIAL KNOWLEDGE

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ABSTRACT

Spatial behavior and decision-making require knowledge of the urban environment, including opportunities available and the means to reach them. Thus, variations in spatial knowledge can result in radically different levels of effective accessibility, despite similar locations, demographics and other factors commonly thought to influence travel behavior. Cognitive maps, which develop primarily through wayfinding and travel experience, are individuals' repositories of spatial knowledge. This paper examines whether differences in cognitive maps can be explained, in part, by variations in travel mode. Adults were surveyed in two Los Angeles neighbourhoods with relatively low auto use and high transit use. The data show that spatial knowledge does indeed vary with previous experience with travel modes.

Keywords: cognitive mapping, accessibility, travel mode

1. INTRODUCTION

Regional transport networks provide *access* to opportunities in the urban environment. A location's accessibility is dependent on the particular configuration of land uses and transport linkages around that location (Levinson and Krizek 2005). However, accessibility can be defined not only in terms of location, but also the individual (Kwan and Weber 2003). In this conceptualization, individual accessibility can be thought of much like an individual's "spatial reach," the constrained set of places and activity that an individual may choose from (Dijst and Vidakovic 2000). Microeconomic theory contributes the important stipulation that an individual's access to opportunities is constrained by the cost of travel, measured in time and money (Boarnet and Crane 2001). Cost, however, is not the only modifier of individual access. Information, specifically knowledge about the urban environment, is essential for spatial behavior and decisionmaking. Psychological and urban research posits that such knowledge resides in cognitive maps (Tolman 1948; Downs and Stea 1973). Cognitive maps encompass individuals' knowledge not only of potential travel routes but also of destinations themselves, as well as their proximity, purpose, desirability, and familiarity. Without knowing of them, potential destinations or routes cannot be utilized and are rendered inaccessible.

Cognitive maps develop primarily through wayfinding and travel experience (Golledge and Gärling 2004). Systematic differences in cognitive maps – and hence accessibility – may be explained, in part, by variations in the experience of travel by different modes. In other words, we hypothesize that one's image of the city, perceptions of activity locations, and the paths linking opportunities are profoundly shaped by whether one typically navigates the city by foot, bus, or train, as an auto passenger or behind the wheel of a car. For example, walking and bicycling typically involve more intimate and slower speed interactions with places than traveling by train or private vehicle. Likewise, walking, bicycling, and driving all require the traveler to actively make wayfinding decisions throughout a trip, while bus, train, and auto passengers are more passively chauffeured by others for significant parts of their journeys. Variation in modal experience is at times stark, and may create significantly different perceptions of cities and the access to opportunities in them among different travelers.

To test our hypothesis, we surveyed adults in a low-income Los Angeles neighborhood and at the University of California, Los Angeles, locations where auto use is relatively low and the variety of travel modes used is large. Our data show that variations in cognitive mapping and spatial knowledge do indeed vary between individuals and among groups in systematic ways. Some of these differences are related directly to previous travel experience, including experience with travel modes. Hence, we conclude that variations in spatial knowledge can result in radically different levels of effective accessibility, despite similar locations, demographics, and other factors commonly thought to influence travel behavior.
This paper is divided into four sections. Following this introduction, the second section examines cognitive mapping, its role in spatial learning and decision-making, and the relationship between cognitive mapping and travel. The third section describes our research, survey data, and findings. In the final section, we explore the potential implications of this research, both for how we conceptualize accessibility and how we plan for cities and their residents. We argue that differences among modally-constructed cognitive maps, learned through varying travel modes, are key to understanding both travel behavior and accessibility in cities. A better understanding of the complex relationships among spatial cognition, travel, and other factors, such as socio-economic status, culture, and individual abilities, can help improve accessibility to employment, services, recreation, and other important destinations.

2. COGNITIVE MAPPING, SPATIAL LEARNING, AND TRAVEL BEHAVIOR

The concept of the "cognitive map" originates in psychology, particularly the work of E.C. Tolman (Tolman 1948; Montello 2001). Early on, cognitive mapping was taken up as a tool for urban research by planners and geographers (Lynch 1960; Downs and Stea 1973; Banerjee and Baer 1984). Since this initial interest amongst planners, however, much of the theorization and empirical research on the topic has been outside the planning field, but continued within psychology and geography.

2.1 Components of the Cognitive Map

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

> …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 (1973, xiv).

Cognitive mapping relates perceptions and preferences within a spatial matrix. This mixture of qualitative and spatial information allows individuals to make decisions in a spatial context (Suttles 1972).

A cognitive map includes spatial information about the environment, including place and route identity, location, distance, and direction (Downs and Stea 1977). Cognitive maps include both person-to-object relationships and object-to-object relationships (Golledge and Stimson 1997). Thus, the cognitive map is the end product of a cognitive mapping process. The space within a cognitive map has been termed "psychological space," because it is space as actually experienced by individuals (Liben, Patterson et al. 1981). Because cognitive mapping internalizes geography, the temptation to interpret a cognitive map as a mental version of a cartographic map is strong (Golledge 1999). However, there is no simple, one-to-one relationship between cognitive mapping and a cartographic representation of space. Instead, the cognitive map is more aptly a cognitive construct for which a cartographic map is only a metaphor (Downs 1981; Gattis 2001). Still, the map metaphor can be quite useful, as with Kevin Lynch's decomposition of cognitive maps into paths, edges, nodes, districts, and landmarks (1960) or Golledge's categories of landmark, route, and survey knowledge (1999). 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 (Golledge and Stimson 1997). Individuals may choose seemingly irrational routes or destinations that, within the framework of their cognitive maps, are completely logical. Error and incompleteness are not completely random in individuals' cognitive maps. Rather, variations across individuals are due to experience, social processes, demographic differences, and other factors (Kitchin and Blades 2002).

2.2 Spatial Learning

An individual's cognitive map develops over time, evolving with age and experience (Downs and Stea 1973). This process of spatial learning occurs primarily through the experience of travel, although other sources of information, such as maps and conversations, can also contribute (Downs and Stea 1977). Variations in spatial experience result in variations in cognitive mapping. Generally, spatial learning occurs in a progression from "landmark" to "route" to "survey" knowledge (Shemyakin 1962). After learning of a landmark, isolated landmarks are linked into routes, but these individual routes in the cognitive map remain largely unrelated. With greater experience and spatial facility, however, more systematic knowledge of the environment can be learned, to construct survey, or configurational, knowledge (Golledge 1999). 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 (Golledge 1999, 11).

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.

Regardless of wayfinding experience, not all individuals reach the same level of cognitive map development (Allen 1999). Differences in individuals' 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, and understand network structures. Other personal characteristics influence spatial learning as well, including spatial-sequential memory, topological knowledge, motor capabilities, spatial perception, and general information-processing capabilities. Such capabilities are partly innate, but researchers have also found that they can be developed and extended through training and use (Golledge and Stimson 1997).

Researchers investigating cognitive maps also find that social and economic differences are potential causes of variation across groups and individuals. Such factors include social and cultural characteristics, education, and income (Orleans 1973; Kitchin and Blades 2002). Banerjee and Baer found that characteristics of an individual's cognitive map are related to their socioeconomic attributes (1984). For example, they observed that members of different groups tended to draw neighborhood maps of different extents. While upper-income white residents often drew broad ranging neighborhood maps that encompassed large areas, many lower income residents of varied ethnic/racial groups tended to draw maps that were focused on smaller areas, sometimes just an intersection or apartment complex. Banerjee and Baer found that such variations in neighborhood map size reflected not only differences in spatial location but average levels of mobility associated with different communities . Conceptual structuring varies also across cultures (Loukaitou-Sideris and Gilbert 2000; Kita, Danziger et al. 2001). For example, people may systematically emphasize different features of the physical environment, such as buildings versus signage, resulting in cognitive maps with different building blocks (Ramadier and Moser 1998).

2.3 Cognitive Mapping and Transportation

The links between cognitive maps and travel behavior are less explored. Research on cognitive mapping and travel has focused primarily on route choice, the fourth and final part of the traditional travel demand analysis process. In contrast, cognitive mapping researchers have given far less attention to the first three steps – trip generation (how many trips?), trip distribution (where to go?), and, in particular, mode choice (by what means of travel?).

Cognitive maps are acquired, primarily, through travel and interaction with transportation systems, whether streets, sidewalks, bike paths, or bus and subway routes. These cognitive maps, in turn, influence travel (Weston and Handy 2004). 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 (1997, 251).

This path-based theory of spatial learning gives travel and navigation a primary role (Kitchin and Blades 2002). The cognitive process of way finding allows humans to expand their cognitive maps through search, exploration, and incremental path selection (Golledge and Gärling 2004). Each of these activities allows individuals to learn about their environment (Downs and Stea 1977).

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 decisions in navigation, such as direction changes. 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” (1997). 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.

Little is known about how different parts of the transportation system shape cognitive maps and, in turn, affect route selection, trip frequency, trip purpose, trip destination, and mode choice (Golledge and Gärling 2004). However, the limited research to date suggests that transportation infrastructure and way finding on overlapping, distinct modal networks – sidewalks, bike lanes, transit routes, local streets and roads, and freeway networks – affect the development of cognitive maps and, in turn, travel behavior. In general, the more significant a particular pathway or landmark is to an individual's navigation, the more it will dominate the cognitive map (Golledge and Stimson 1997). The functional hierarchies of pathways in a region, from highways and freeways to collector roads to 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 (1973) also found that the layout of a city significantly explained variations in the accuracy of way finding and location tasks. Sectorally-organized cities proved the more effective for remembering locations, while concentrically-organized cities made way finding 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 (1999) 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. 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 different ways.

Much of the scholarship on cognitive mapping has focused on drivers and the street and highway network (Golledge and Gärling 2001). This emphasis is likely due to the dominant role of automobiles in cities, particularly in the United States, as well as the route flexibility associated with street networks. Nevertheless, fragmentary evidence suggests that cognitive maps are shaped differentially by alternate modes. For example, we know that individuals who rely extensively on public transit or walking, on average, travel shorter distances and travel less frequently than those who travel by motor vehicle (Boarnet and Crane 2001; Pisarski 2006). Therefore, one can hypothesize that the scope of their spatial knowledge would be differently scaled and configured (by, for example, the network of transit routes) than those who rely on automobiles and travel longer distances at greater speed and route flexibility.

The quality and detail of spatial maps also may differ by mode. In a study of children traveling to and from school, "active" modes of travel, such as walking and biking, appear to contribute more to the development of spatial knowledge among children than passive modes of travel, such as being chauffeured by an adult or riding in a school bus (Hart 1981). These results suggest that variation in transportation mode may result in different levels of functional accessibility for individuals from otherwise similar backgrounds. 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" (Cadawaller 1976). Cognition of environmental distance is influenced by pathway features, travel time, and travel effort which are substantially different depending on travel mode (Montello 1997). The characteristics of travel by transit, which include indeterminate waiting at transfer points and walking trips between services, may add to cognitive distance in ways that auto travel does not (Iseki and Taylor Forthcoming). Reliance on various modes of travel may also influence the logical structure of travel decisions, with different modes availing individuals with different sets of choices and preferences (Hannes, Janssens et al. 2008).

3. RESEARCH

Building on the findings described in the literature review, our research explores how travel behavior affects cognitive processes and, by extension, accessibility. We hypothesize that the experience of travel mode shapes the cognitive map and, hence, effective accessibility. To test this hypothesis, we collected survey data from respondents in South Los Angeles and on the UCLA campus, areas with relatively high levels of non-single-occupant vehicle travel, through very different in many other respects. We compare the responses of individuals across measures such as auto availability, predominant travel mode, and predominant cognitive travel “style” (which we characterize as active,passive, or mixed), to questions designed to extract spatial knowledge from their cognitive maps. Across multiple measures of spatial knowledge, we find that travel mode affects how individuals think about their environment and, specifically, that variation in cognitive mapping influences how individuals perceive the accessibility of destinations in their environment. In this section, we describe our methodology and discuss the results of our analysis.

3.1 Methodology and Sample Characteristics

We designed a survey to extract from respondents information both on travel behavior and spatial knowledge. The in-person survey was conducted in South Los Angeles at the Kenneth Hahn Shopping Center, a commercial center serving the local area directly adjacent to the Rosa Parks Transit Center. Two light rail lines (the north-south Blue Line links downtown Los Angeles and downtown Long Beach, and the east-west Green Line links LAX with the working-class suburb of Norwalk) and nine local and express bus lines converge at the transit center, supplying the shopping center with a relatively high proportion of transit users compared to Los Angeles overall. In addition to the abundance of transit users, the South Los Angeles location is particularly appropriate to study because its population is relatively poor and minority, groups for whom accessibility is a frequent concern. The survey was also conducted at the central transit hub of the UCLA campus, another location with a relative abundance of transit users. Figure 1 locates the survey sites in their regional context, including other locales called out in the surveys.

The survey was conducted during repeated two to three hour sessions between April and July 2007, during afternoon and early evening commute periods. In South Los Angeles, the survey was administered in both English and Spanish, and at UCLA it was administered only in English. At both survey locations, unless already assisting a respondent with a survey, surveyors[i] approached all potential respondents passing them in high-traffic locations at the shopping center and transit hub, respectively. The surveys asked about a wide variety of travel and spatial cognition factors, described below, and took approximately 10 minutes to complete. Participation was encouraged with a ten-dollar gift card to Starbucks, a vendor in the Hahn Shopping Center and near the UCLA campus. In South Los Angeles, approximately one third of those approached participated in the survey. At UCLA, the participation rate was somewhat lower, about one fifth of those approached.[ii] In total, one hundred ninety-six responses were collected in South Los Angeles and one hundred ninety-nine at UCLA.

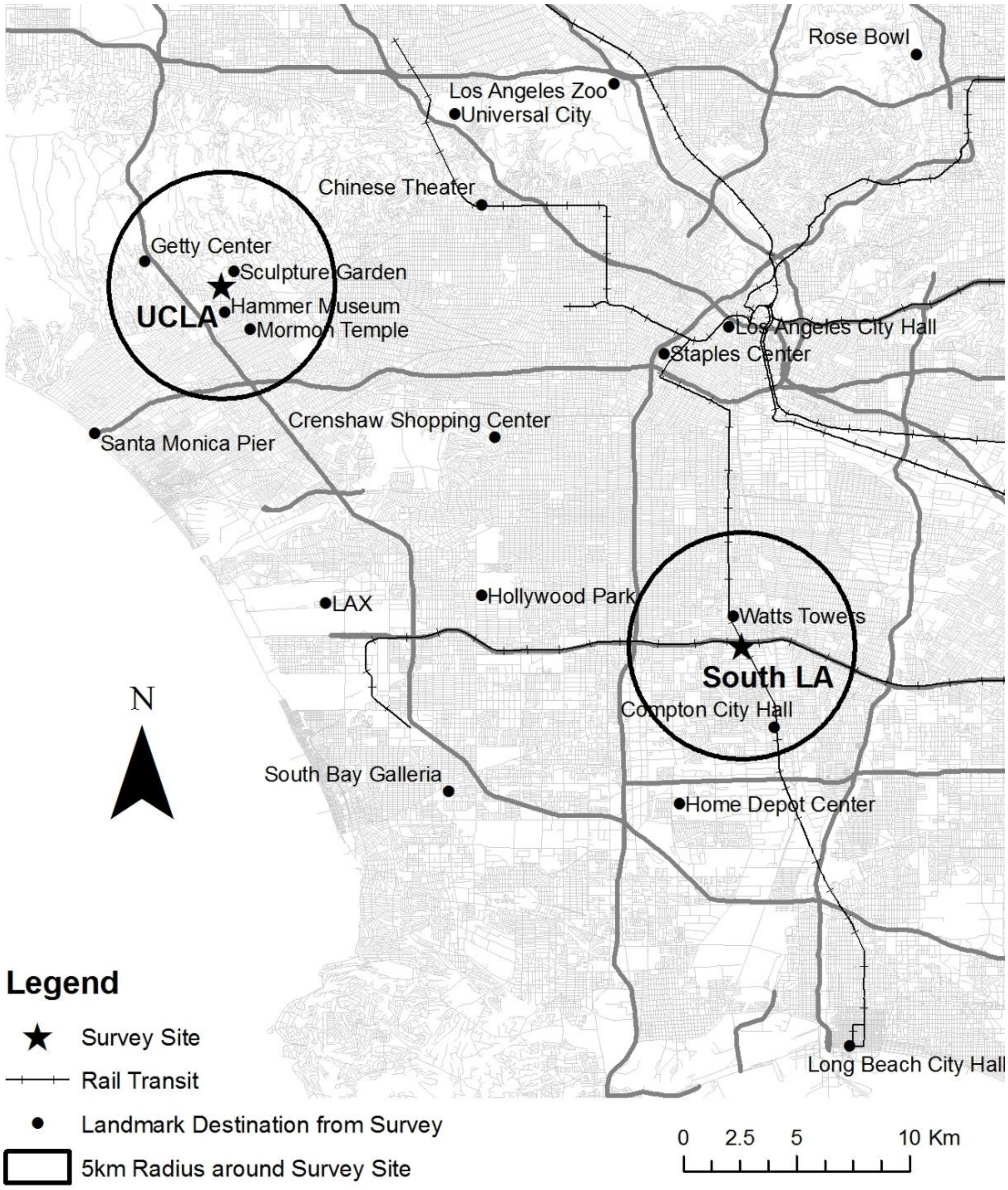

Figure 1 – Regional Context

Cognitive Data Extraction

Numerous methodologies have been developed to extract empirically analyzable spatial products from cognitive maps (Golledge and Stimson 1997; Kitchin and Blades 2002), none of them simple or easy.[iii] Cognitive maps are, by definition, abstract phenomena, and consistently representing these maps across respondents is an epistemological challenge. The spatial products generated by available methods draw upon the complex geometries, orientations, perceived quantities, and qualitative characteristics contained within a cognitive map. The variety and overlapping purposes of many methodologies suggest that employing a diverse set of techniques to extract cognitive information is preferred (Kitchin 1996). Some methods are particularly attractive because of the breadth of information they provide. For example, sketch maps can provide data on the number of total features, a mix of point, line, and area features, indications of dominant functions perceived by the sketcher, sequences along routes, and the overall regularity or irregularity of features. Such maps, however, can be a challenge to analyze in the aggregate because common map elements such as scale, extent, symbolization, and orthogonality may not be consistent from sketch map to sketch map (Golledge and Stimson 1997). Other methods, like factual and perceptional questions about distance and location, provide more limited data but are desirable because of low skill requirements, cross-subject comparability, and ease of execution.

We asked respondents several questions about both our independent variable of interest, travel mode, and primary dependent variable, cognitive mapping, in order to mitigate the risk that the particulars of survey design influence the results more than the constructs we seek to investigate. To extract cognitive information in a public setting in a relatively timely manner, we emphasized verbal data collection techniques, including questions about the location of destinations and the distance to generic and specific destinations by both absolute and relative measures. In order to understand how travel mode dominates an individuals' cognitive mapping over their lifespan, we asked questions about mode traveled that day, mode to employment, mode to hypothetical destinations, and the availability of autos. We also included questions about length of time residing in one's neighborhood and various personal characteristics including age, education, nativity, race/ethnicity, and sex.

Composite Measures of Modal Experience

At the conceptual level, we explore differences between groups broadly defined by travel mode experience. To operationalize this concept empirically, we developed several composite measures to characterize modal experience, based on the questions in the survey:

- *Auto availability* – The first measure is auto availability, which is based on how often individuals reported having access to cars (possible responses: "always," "usually," "sometimes," or "never"). Respondents' reported level of auto availability is hypothesized to relate to their propensity to travel by a particular mode or set of modes, but does not directly measure modal experience. We focus on the extremes of the measure ("always" and "never" responses), a sample size of 269 (out of 395 total respondents).

- *Travel mode* – The second measure is "travel mode," which is the mode respondents named when asked about (1) their mode when traveling to the survey site, (2) their typical mode to work/school, and (3) their hypothetical mode to a landmark destination. This measure directly tests the basis of our hypothesis. Many individuals responded differently to various modal questions, but we categorize travel mode by those who *consistently* answered that they did or would travel by a particular mode, resulting in a smaller sample size of 140 clearly contrastable respondents.
- *Cognitive travel style* – The third measure, cognitive travel style, extends the travel mode measure by categorizing respondents by the hypothesized cognitive burden of various modes, rather than by the modes themselves. This categorization is consistent with the literature on cognition and travel described earlier (Hart 1981; Montello 1997). Specifically, driving an auto and walking are considered to be "active" modes, because travelers must actively wayfind during their journey, while public transit and being an auto passenger are defined as "passive" modes, because travelers need not engage in the same level of cognitively challenging wayfinding. Selecting route itineraries, walking to and from stops and stations, and transferring between vehicles on public transit does require some degree of wayfinding, particularly relative to being a auto passenger.[iv] However, we posit that public transit requires neither the unstructured nor ongoing wayfinding that driving an auto or walking require, as fewer choice points are encountered along the journey. As such, we have categorized transit as a relatively "passive" mode. As with the travel mode measure, the "passive" and "active" categories include only respondents who *consistently* selected either driving and walking or using transit and being a passenger. However, we also report the results of respondents belonging to the "mixed" category, comprised of those who responded to the mode questions with both passive and active modal choices. The categorization of respondents into active, mixed, and passive allows the inclusion of all 395 respondents from both survey sites.

Respondent Characteristics

Table 1 shows the distribution of respondents by the modal measures described above. The diverse set of modes utilized by respondents allows us to investigate our hypotheses regarding the relationships between cognition and mode. Table 1 also describes key socio-economic characteristics of the respondents by modal category. For the South Los Angeles respondents, key characteristics that may explain variations in cognitive mapping and spatial knowledge are relatively equally represented across modal groups. Respondents in all of the groups have lived in their current neighborhood on average for nearly 10 years. Average age is similar, as is percent female and average grade in school completed. Respondents in the modal categories in the UCLA sample were more heterogeneous. For example, those having no access to cars tend to be younger, less educated, and more likely students, while those who consistently use transit or drive are older, more educated, and more likely staff or faculty.

Table 1. Characteristics of Respondents by Auto Availability, Travel Mode, and Cognitive Travel Style

Modal Categor-ization	*N*	*Years in Neighborhood*		*Age*		*Years of Education*		*% Female*	*% African-American*
		Mean	*25th – 75th pct.*	*Mean*	*25th – 75th pct.*	*Mean*	*25th – 75th pct.*		
South Los Angeles									
Auto Availability									
Never	40	9.7	1-12	34.1	25-41	11.6	11-12	77%	65%
Always	91	14.0	3-25	38.0	28-48	12.8	12-14	69%	69%
Travel Mode									
Public Transit	49	10.6	1-15	33.2	22-39	12.1	12-13	68%	69%
Auto Driver	45	13.4	3-25	35.1	26-42	13.3	12-14	68%	76%
Cognitive Travel Style									
Passive	68	11.5	1-19	34.0	22-44	12.0	12-13	74%	72%
Mixed	78	11.6	2-19	37.7	28-48	12.3	12-13	72%	69%
Active	50	13.8	3-25	34.3	26-42	13.2	12-14	67%	74%
UCLA									
Auto Availability									
Never	39	2.2	1-2	21.7	19-22	14.3	13-15	79%	2.6%
Always	97	5.4	1-7	29.0	22-31	16.3	15-17	59%	11%
Travel Mode									
Public Transit	16	7.1	1-4	32.0	23-33	16.8	15-18	63%	19%
Auto Driver	29	7.0	2-11	30.9	23-33	16.9	16-18	53%	10%
Cognitive Travel Style									
Passive	24	5.9	0.7-4	29.3	22-32	16.0	15-18	62%	17%
Mixed	116	3.5	0.6-3	25.5	20-25	15.1	13-16	68%	8.5%
Active	57	4.5	0.8-3	26.7	22-28	16.2	15-17	58%	6.0%

In addition to the demographic characteristics described in Table 1, respondents were also asked to indicate their current residential neighborhood with the question, "What neighborhood do you live in?" While relatively open-ended, the question allowed respondents to provide a range of answers that were spatially specific and identifiable, whether responding with traditional neighborhood names, small city names, or situationally meaningful terms such as "the dorms." For both survey sites, respondents tended to live relatively close by (in a regional context), with only 12% reporting a neighborhood beyond 10km for UCLA and merely 2% reporting a neighborhood beyond 10km for South Los Angeles (not a surprising result as this survey was conducted at a local-serving shopping center). While the specific spatial contours of each individual's activity patterns can be expected to shape their knowledge of the environment, for the questions about regional landmarks employed in this survey, the residential proximity of respondents to their survey site suggests that most will have roughly similar spatial contexts from which to answer the region-scaled cognitive questions posed in the survey.

3.2 Results

Our analysis explores the relationships among spatial knowledge, travel mode, and accessibility revealed by our survey of adults in South Los Angeles and at UCLA. We find that, indeed, the experiences encoded within individuals' cognitive maps produce differences in how individuals think about their environment. We find evidence that travel mode affects how individuals perceive the built environment, both in how they estimate distance and in the relative refinement of their cognitive maps. In this paper, we specifically explore how cognitive measures in our survey vary across modally-defined groups. We employ relatively straightforward statistical approaches, highlighting the robustness of evident trends across different versions of the independent and dependent variables.

Distance Estimation by Mode

Distance estimation is a common technique employed to extract information from individuals' cognitive maps. In this survey, all respondents were asked to estimate the distance from their respective survey site to a major, well-known landmark – Los Angeles City Hall for South Los Angeles respondents and Santa Monica Pier for UCLA respondents (refer to Fig. 1). This measure provides information both about the accuracy of cognitive mapping with regards to distance and the prominence of a particular location in the cognitive map. We asked respondents an open-ended ("About how far away would you say…") distance question, allowing them to respond in the spatial terms that made the most sense to them, whether Euclidean or network distance (not necessarily distinguishable in a cognitive map).[v] Respondents were not asked about travel time. Asking a distance question from common points (the survey sites) to well-known landmarks serves to minimize route unfamiliarity and increase comparability across respondents. The survey sites, City Hall and Santa Monica Pier, are located at major transit nodes, so relatively direct travel is possible by both public transit and private vehicle and actual travel distances (if not travel times) are quite similar regardless of mode. For South Los Angeles, the Metropolitan Transportation Authority's (Metro) transit router calculates a distance of 10.5 miles to Los Angeles City Hall, and MapQuest returns an auto trip distance of 9.6 miles. For UCLA, Metro's transit router calculates a distance of 6.2 miles, and MapQuest returns an auto trip distance of 5.8 miles.

Table 2. Distance Estimated to "Landmark" Destination, Grouped by Measures of Modal Experience

Survey Population	South Los Angeles (10 miles[1])			UCLA (6 miles[2])		
Statistic	Median[3]	SD	N	Median[3]	SD	N
Auto Available						
Never	10	30.6	30	8	6.5	33
Always	10	9.0	80	7	6.8	90
Relative Difference	0%	-70.6%*		-14.3%	4.6%	
Travel Mode						
Public Transit	13	11.4	39	6.5	5.5	16
Auto Driver	12	8.0	40	7	2.5	27
Relative Difference	-8.3%	-29.8%*		7.1%	-54.6%*	
Cognitive Travel Style						
Passive	13	23.4	55	7	8.2	24
Mixed	10	11.8	65	8	7.3	105
Active	13	7.8	45	7	2.9	54
Relative Difference (Passive vs. Active)	0%	-66.7%*		0%	-64.6%*	
All Respondents	10	16.1	165	7	6.5	183

1 – Actual approx. distance by auto or transit from survey site (Kenneth Hahn Shopping Center) to LA City Hall.
2 – Actual approx. distance by auto or transit from survey site (Transit Center at UCLA) to Santa Monica Pier.
3 – Median used as central tendency as responses are right-skewed and mean not representative.
* - Denotes significantly different standard deviation at the 0.05 significance level.

Table 2 shows that, while tied to geographic distance, respondents' estimates of the distance to the landmarks vary significantly by modal experience. Two patterns in respondents' estimates are evident, consistent between the South Los Angeles and UCLA samples and between the measures of modal experience, whether characterized by auto availability, travel mode, or cognitive travel style. First, median distance estimates for each group by each modal measure, as well as the samples in their entireties, are not significantly different but tend toward the actual geographic distance.[vi] This suggests that the distance estimates are not arbitrary but relate to urban geography. Second, while each group estimate tends toward the "real" median distance, the variability among the passive, transit-oriented respondents' estimates is generally much higher than the variability in the responses of the active, more auto-oriented respondents. This indicates that those who usually travel by less active modes are, as a group, more uncertain about the distance to major landmarks.

The differences between groups are somewhat more pronounced for the South Los Angeles sample. The difference between standard deviations by the various modal measures is almost always statistically significant, using a F-test of the null hypothesis that the variances of the two groups are equal. The high variability in the estimates of passive travel respondents suggests that while most individuals in those groupings did provide a distance estimate, it was more of a guess than the responses provided by the active travel respondents. This greater uncertainty supports our conceptualization of passive versus active travel.

The variability of the distance estimates appears to be significantly different between modal groups whether defined in terms of auto availability, travel mode, or cognitive travel style. However, do these differences persist when controlling for other respondent characteristics? Table 3 provides the results of a linear regression model addressing this question for the South Los Angeles population.[vii] We examine how the accuracy of respondents' distance estimates to the landmark of Los Angeles City Hall varies with regards to a variety of demographic and experiential. The dependent variable here is the difference between a respondent's estimate and the true distance to the landmark, so a larger number would imply greater *inaccuracy.* Thus, for interpreting the coefficients, negative values imply greater accuracy associated with a particular variable and positive values imply greater inaccuracy. We use the cognitive travel style (rather than strict travel mode or auto availability) as our primary independent variable.

Both an expansive and parsimonious version of the model are provided. The set of independent variables found to significantly influence distance estimation are cognitive style of travel, time spent in the neighborhood, being employed or a student, gender, and African-American ethnicity. Consistently travelling by active modes significantly reduces the inaccuracy of the distance estimate relative to passive travelers, while those traveling by mixed modes also show greater accuracy than passive travelers. The other characteristic observed to improve accuracy is length of time spent in the neighborhood. As discussed in the literature review, spatial learning is a process, so it is not surprising that it takes time to learn about the urban environment.

Table 3. Inaccuracy of Distance-to-Landmark Estimate, Regression Model

Dependent Variable	Inaccuracy of landmark distance estimate[1] (For coefficients, positive values are associated with more inaccurate estimates and negative values with more accurate estimates)	
Sampled Population	South Los Angeles	
Model Number	1	2
Independent Variables	*Coef.*	*Coef.*
Active Travel Style (versus Passive)	-0.533***	-0.532***
Mixed Travel Style (versus Passive)	-0.355**	-0.381**
Knows How to Drive	-0.174	
Number of Cars in Household	-0.058	
Years in Neighborhood	-0.008	-0.010*
Employed	0.361**	0.384**
Student	0.398**	0.457**
Years of Education	0.028	
Female	0.539***	0.593****
Age	-0.010	
African-American	0.352**	0.329*
Constant	-0.224	-0.525**
Number of obs.	155	155
F	4.16****	6.05****
R-squared	0.242	0.224

1 – Inaccuracy of the estimate formulated as: Ln absolute difference between estimated distance to landmark and measured network distance. For South LA, measured network distance between survey site and Los Angeles City Hall is 10 miles, the mean of the 9.6 mile MapQuest driving distance and 10.5 mile Metro transit distance.
* - 0.10 level of significance
** - 0.05 level of significance
*** - 0.01 level of significance
**** - 0.001 level of significance

Other variables significantly increased inaccuracy. Both those who described themselves as employed and those who described themselves as students showed significantly greater inaccuracy. While the result for students is consistent with the expectation that students are typically younger and less experiences (although age itself was not found significant), the result for employed persons is harder to explain; although, perhaps working in a fixed locale limits the ability to explore. Female respondents showed significantly greater inaccuracy in their estimates, controlling for other factors. This finding is consistent with extensive literature on gender differences in spatial abilities (Voyer, Voyer et al. 1995; Dabbs, Chang et al. 1998). Some degree of inaccuracy was also associated with African-American respondents relative to those of other race/ethnicities. Overall, the model was highly statistically significant, explaining about twenty-two percent of the variation in estimate accuracy

Pair Estimates

In addition to the distance estimation exercise, respondents were asked to pick the closer of two widely known local or regional destinations (relative to the survey site). For each destination pair, respondents could (1) select one or the other as closer, (2) designate them equidistant, or (3) report they did not know which was closer. The pair exercises facilitate exploration of the overall accuracy and clarity of respondents' cognitive maps, as well as the relative distribution of destinations in respondents' maps, giving some dimensionality to those maps that can be compared across modal groups. These measures allow us to extend our analysis of spatial knowledge beyond a single destination (regardless of that destination's importance in the region) to a broad set of opportunities distributed throughout the Los Angeles region. The pairs were selected to test knowledge at various scales (local, subregional, regional) and of various types of destinations (employment, shopping, cultural, etc.).

Table 4. Overall Accuracy and Clarity in Responses to Distance Pairs, Grouped by Cognitive Travel Style

	South Los Angeles[1]		UCLA[1]	
	Mean	N	Mean	N
Correct Responses (Accuracy)				
Passive	52.2%	67	48.5%	24
Mixed	53.6%	78	53.0%	116
Active	60.4%	50	53.2%	59
Relative Difference (Passive vs. Active)	15.7%*		9.6%	
Correct Responses for those Living in Neighborhood <5 Years				
Passive	44.8%	25	45.8%	20
Mixed	54.8%	38	51.2%	97
Active	57.6%	17	53.7%	45
Relative Difference (Passive vs. Active)	28.6%*		17.1%	
Don't Know Responses (Clarity)				
Passive	5.8%	68	9.7%	24
Mixed	7.2%	78	9.2%	116
Active	4.8%	50	5.5%	59
Relative Difference (Passive vs. Active)	-17.2%		-43.1%	
Don't Know Responses for those Living in Neighborhood <5 Years				
Passive	11.2%	25	10.8%	20
Mixed	10.6%	38	9.2%	97
Active	9.4%	17	5.5%	45
Relative Difference (Passive vs. Active)	-19.2%		-49.2%	

1 – Note: Five pairs total for South Los Angeles, six pairs for UCLA.
* - 0.05 level of significance

First, we explored the basic accuracy and clarity of individuals' cognitive maps, grouped by passive and active cognitive travel styles. Accuracy is defined by the total number of correct responses to the pair questions, and clarity is defined by the number of "don't know" responses to the pair questions. Table 4 summarizes the responses of the South Los

Angeles and UCLA samples. The active travelers chose correctly more often than the passive travelers, and the passive travelers tended to be unable to select a destination more often than the active travelers. Much like the landmark distance estimation task, those living in their neighborhood for less than five years tended overall to be less able to choose correctly and more likely to answer "don't know." Furthermore, the relative difference between active and passive groups was consistently wider in terms of both accuracy and clarity for those having spent less time in the neighborhood.

While measurement of overall accuracy and clarity of the cognitive map and differences between modal groups is consistent with our hypothesis, the pair estimation measures also allow us to look more closely at the spatial variation in cognitive knowledge by modal experience. Tables 5 and 6 break down the differences between those who stated they would take public transit or drive themselves to the hypothetical pair questions posed to them in the survey. Because these measures are specific to particular destinations and attendant transportation networks and hierarchies, they provide an opportunity to explore how mode alters individuals' cognitive geographies (see Fig.1 for landmark locations). As this exploration of the results highlights, the effect of mode on the cognitive map varies substantially between pairs, with marked effects in some instances and little relevance in others, including pairs where both transit users and drivers "misperceive" the relative proximity of a landmark.

Table 5. Destination Pair Choices by Stated Mode Choice for South Los Angeles Respondents

Pair A	Watts Towers*	Compton City Hall	Equidistant	Don't Know	N
Public Transit	72.7%	18.0%	6.0%	3.4%	117
Auto Driver	76.6%	10.9%	7.8%	4.7%	64
Pair B	Home Depot Center*	Hollywood Park	Equidistant	Don't Know	N
Public Transit	59.8%	29.1%	2.6%	8.6%	117
Auto Driver	79.7%	12.5%	1.6%	6.4%	64
Pair C	Crenshaw Shopping Ctr.	South Bay Galleria*	Equidistant	Don't Know	N
Public Transit	59.5%	28.5%	4.3%	7.8%	116
Auto Driver	53.1%	32.8%	6.3%	7.8%	64
Pair D	Los Angeles City Hall*	Long Beach City Hall	Equidistant	Don't Know	N
Public Transit	48.7%	39.3%	7.7%	4.3%	117
Auto Driver	61.0%	31.3%	3.1%	4.7%	64
Pair E	Los Angeles Zoo*	Santa Monica Pier	Equidistant	Don't Know	N
Public Transit	50.4%	41.0%	3.4%	5.1%	117
Auto Driver	50.0%	46.9%	3.1%	0.0%	64

* - Denotes closer destination. Actual pair distances, according to MapQuest shortest network distance analysis:

A	Watts Towers: 1.10 mi	Compton City Hall: 2.45 mi
B	Home Depot Center: 5.79 mi	Hollywood Park: 8.10 mi
C	Crenshaw Shopping Center: 11.37 mi	South Bay Galleria: 9.05 mi
D	LA City Hall: 9.63 mi	LB City Hall: 12.89 mi
E	LA Zoo: 18.74 mi	Santa Monica Pier: 20.21 mi

Table 5 contains the destination pairs for the South Los Angeles survey. For Pair A, public transit users were substantially more likely to incorrectly choose Compton City Hall as the closer destination, despite the large relative difference in the two destinations' distances from the survey site. However, Compton City Hall is located on an MTA Blue Line light rail stop, while Watts Towers is located on a side street, a ten to fifteen minute walk from the Watts Blue Line station. Similarly, transit users were much more likely to incorrectly select Hollywood Park Race Track as closer to the survey site than the Home Depot Center sports stadium, potentially because Hollywood Park is only about a mile from the MTA Green Line, while the Home Depot Center is both newer and does not have as direct mass transit access. The other pair with a notable difference between modal groupings was the comparison of Los Angeles and Long Beach City Halls. While both are relatively accessible by transit, the Long Beach City Hall is directly adjacent to the Blue Line terminus, while the Los Angeles City Hall requires a transfer. As a result, transit users appear to "collapse" the greater distance to Long Beach City Hall somewhat; thirty-seven percent more public transit users designate Long Beach City Hall as closer to or equidistant from the survey site than auto drivers.

Table 6. Destination Pair Choices by Stated Mode Choice for UCLA Respondents

Pair A	Hammer Museum	UCLA Sculpture Garden*	Equidistant	Don't Know	N
Public Transit	24.1%	63.2%	7.0%	5.8%	87
Auto Driver	12.0%	77.1%	4.4%	6.5%	92
Pair B	Getty Center	Mormon Temple*	Equidistant	Don't Know	N
Public Transit	42.5%	42.5%	1.2%	13.8%	87
Auto Driver	47.8%	43.5%	2.2%	6.5%	92
Pair C	Chinese Theater	Santa Monica Pier*	Equidistant	Don't Know	N
Public Transit	18.4%	75.9%	1.2%	4.6%	87
Auto Driver	13.0%	79.3%	4.4%	3.3%	92
Pair D	Downtown Los Angeles	LAX Airport*	Equidistant	Don't Know	N
Public Transit	33.3%	52.9%	12.6%	1.2%	87
Auto Driver	27.2%	63.0%	8.7%	1.1%	92
Pair E	Universal City Walk*	Staples Center	Equidistant	Don't Know	N
Public Transit	37.9%	46.0%	2.3%	13.8%	87
Auto Driver	35.9%	55.4%	4.4%	4.4%	92
Pair F	Home Depot Center	Rose Bowl*	Equidistant	Don't Know	N
Public Transit	54.0%	25.3%	3.5%	17.2%	87
Auto Driver	45.7%	34.8%	5.4%	14.1%	92

* - Denotes closer destination. Actual pair distances, according to MapQuest shortest network distance analysis:

A	Hammer Museum: 1.23 miles	Sculpture Garden: 0.60 miles
B	Getty Center: 2.93 miles	Mormon Temple: 1.92 miles
C	Chinese Theater: 7.69 miles	Santa Monica Pier: 5.79 miles
D	Downtown LA: 11.83 miles	LAX: 10.51 miles
E	Universal City Walk: 10.53 miles	Staples Center: 11.63 miles
F	Home Depot Center: 22.25 miles	Rose Bowl: 20.48 miles

Table 6 contains the results from the six pairs tested at UCLA, differentiated by public transit and auto drivers. Unlike the South Los Angeles survey site, UCLA is not accessible by rail transit, but it is well served by many bus routes and all 50,000 students, staff, and faculty pay just 25¢ to use most transit services. Pair A demonstrates the possible effect of the distribution of those bus routes around the UCLA campus. Public transit users were two times more likely to incorrectly select the Hammer Museum, south of the campus in Westwood Village, as closer to the survey site than the UCLA Sculpture Garden located at the northeastern corner of UCLA's campus. Despite the fact that the Hammer Museum is two times as far from the survey site as the sculpture garden, most of the bus routes serving the campus pass right by the museum, while relatively little transit serves the northern end of campus. Both Pairs C and D are examples where transit users are more likely to incorrectly select destinations in the more densely developed areas east of UCLA as being closer than destinations to the south or west of campus.

Cognitive Map Components

The third aspect of spatial knowledge explored in this analysis employs neither absolute nor relative distance, but seeks to understand the elements comprising respondents' cognitive maps, and whether these elements vary by modal experience. As discussed in the literature review, cognitive maps are comprised of geometric elements that represent components of the built environment. Furthermore, individuals' cognitive maps vary in their degree of refinement, in a continuum from landmark to route to survey knowledge. We already have seen that mode has a significant relationship to the accuracy and certainty of individuals' cognitive maps, and that the distribution of elements within one's cognitive geography may vary by modal experience. However, can we observe any differences in how travelers of different modes fundamentally assemble their cognitive maps? In an attempt to do so, we compare the elements respondents use to construct their cognitive maps by mode (transit versus auto driver) and cognitive travel style (active, passive, and mixed).

Table 7 compares the types of elements used by respondents in South Los Angeles[viii] to describe the location of their home.[ix] Regardless of travel mode or travel style, four-fifths of respondents named the street on which they lived, and about half named the nearest cross street as well. The primary difference between the two modal groups was in the propensity to use landmarks to describe where they lived. In this case, public transit or passive travelers were about 2.5 times as likely to use landmarks to describe the location of their homes compared to drivers or active travelers.

Table 7. Elements Used to Describe Home Location, Grouped by Travel Mode to Work

	Street	Cross Street	Landmark	N
Travel Mode				
Public Transit	80.0%	48.9%	22.2%	49
Auto Driver	83.7%	46.5%	9.3%	45
Travel Style				
Passive	82.0%	45.9%	21.3%	68
Mixed	84.6%	47.4%	10.3%	78
Active	85.1%	46.8%	8.5%	50

Table 8 compares the types of elements used by respondents in South Los Angeles to describe the location of their workplace. Notably, the respondents overall (regardless of mode) were less able to name streets or cross-streets and relied on landmarks to greater extent. In fact, the use of landmarks was relatively equal between modal experience groups, and higher than for the description of home location. The difference between groups remained within the street and cross-street measures, where auto drivers/active travelers were approximately 25% more likely to name either a street or a cross-street to describe the location of their workplace. Drawing upon our conceptual framework, these results suggest that, overall, travelers may be more likely to describe a location in terms of landmarks if they are less familiar with that location (home being more familiar than work location). For less familiar destinations, passive travelers may shift to using streets and cross streets relatively more slowly, retaining landmarks as the centerpiece of their cognitive maps for a longer period than active travelers.

Table 8. Elements Used to Describe Work Location, Grouped by Travel Mode to Work

	Street	Cross Street	Landmark	N
Travel Mode				
Public Transit	62.2%	35.6%	28.9%	49
Auto Driver	76.7%	44.2%	27.9%	45
Travel Style				
Passive	62.3%	32.8%	27.9%	68
Mixed	62.8%	34.6%	28.2%	78
Active	78.7%	42.6%	27.7%	50

4. DISCUSSION AND CONCLUSION

4.1 Current Findings and Future Research

With respect to cognitive mapping, this research underscores that differences in spatial knowledge due to the spatial learning process are not only the result of *where* we travel, but *how* we travel. Differences between active and passive travel and their effects on learning are realized in the everyday travel modes of individuals in the city. Travel modes, even when providing relatively equivalent mobility to a given destination, can differentially shape awareness of that destination and intervening opportunities. These effects persist even when controlling for other factors already known to shape spatial knowledge including length of experience (time spent in the neighborhood) and gender.

The findings in this analysis bring a relatively unexplored area of urban research into sharper focus. However, the observed differences between modal groups raise questions for further exploration. Topics for future research include:

- *Alternative Metrics* – How much of the observed differences between groups may be the result of different cognitive metrics for distance? For example, would transit users perform better when asked about time than distance? Conventional wisdom would suggest “yes” (MacEachren 1980; Witlox 2007), though our analysis suggests that variability is accentuated among those with passive travel styles, so while transit users may be better at estimating time than distance, these (relatively) passive travelers may still be less accurate in estimating travel time than those who primarily walk, bike, or drive.

- *Comparative Analysis* – While the central Los Angeles neighborhoods studied in this research are more dense and well-served by transit than popular perception may suppose, investigation of a broader, a global cross-section of urban regions with a wide range of transport policies and systems, as well as a variety of urban forms, would assist with the generalization of these findings to other urban environments and populations.
- *Technology-Guided Travel* – A new "travel mode" appears to be rapidly taking shape in urban regions. To ever increasing levels, auto drivers are using devices such as in-car GPS and internet-based mapping which guide both route and destination choices. In a sense, this new form of guided yet self-directed travel is a hybrid between the active and passive modes investigated here. Would the effects of technology-guided travel on spatial learning be similar to the effects identified in more passive modes in this analysis?

4.2 Cognition, Accessibility, and Experience of Travel

We have argued that cognitive mapping research has potential to meaningfully address the enduring focus on accessibility in transportation research. While accessibility has traditionally been conceived as proximity of (or impedance/cost of travel between) locations, cognitive mapping research shows that physical distances are only one factor shaping how individuals make spatial choices (Kwan and Weber 2003; Golledge and Gärling 2004; Weston and Handy 2004). The expanding body of literature on individual accessibility includes multiple factors found to shape accessibility including personal time constraints, activity duration, activity scheduling and time-of-day effects, as well as social and familial constraints, such as gender roles (Kwan 1999; Dijst and Vidakovic 2000). Kwan and Hong (1998), in fact, establish a specifically cognitive framework for incorporating individual constraints into a network-based accessibility measure.

To this stream of individual accessibility research, this analysis adds the experience of travel, differentiating that experience by travel mode. Utilizing multiple measures of spatial knowledge, we find that differences in prior modal travel experience are associated with differences in the content and construction of individuals' cognitive maps. These differences in the experience of travel, as well as spatial location, and social, cultural, and economic characteristics, shape the cognitive map and, thereby, the cognitive proximity and accessibility of potential destinations in a region. Using the terminology of Kwan and Hong, modal experience would play a role in shaping the "cognitive feasible opportunity set" when measuring individual accessibility. A potential transformation of a spatial set of opportunities that would reflect the findings in this research could be to add an attractiveness penalty to all potential destinations for passive travelers, to reflect their lack of spatial knowledge generally, but to alleviate that penalty near modal choice points, such as transit stops for public transit users.

Cognitive-mapping-focused travel behavior research to date 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 (2004, 6), 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.We have argued in this paper that the links between cognitive maps and travel choices extend well beyond route choice and are in fact central to understanding all aspects of travel behavior. The literature on household activity modeling as a more conceptually sound and robust way to predict travel behavior than traditional zonal-based trip generation travel demand modeling is large and growing (Kitamura and Supernak 1997; Lee-Gosselin and Pas 1997; Mahmassani 1997; Pas and Harvery 1997; Stopher 1997; Meyer and Miller 2001). Activity-based modeling could be enhanced significantly with better information on how modal experience shapes individuals' cognitive maps, creating fundamentally different activity-opportunity matrices. Specifically, we have shown in this sample that the cognitive maps of people who mostly walk and use public transit tend to vary systematically from those who are mostly chauffeured in private vehicles, and from those who usually drive. Past modal experience may substantially affect trip rates, destination choices, and mode selection, as well as routes taken, *ceteris paribus*. As land use and household activity patterns are further disaggregated in new activity-based models, cognitive mapping can inform how individuals incorporate and value places and pathways in a regional system, modifying typical utility maximization problems of both residential location and travel behavior.

These findings on travel mode have implications not only for accessibility measures and travel behavior analysis, but for directly improving access for disadvantaged populations. The findings of this analysis are 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 also tend to perceive job opportunities in less spatially constrained ways (Stoll 1999; Holzer and Reaser 2000). To remedy such cognitive barriers to job opportunities experienced by those without regular access to autos, "compensatory" solutions such as trip-planning services, car-share programs, guaranteed ride home services at large worksites, and better integration of transit networks could be implemented. A different approach would be services to help people overcome limited, incomplete, or inaccurate cognitive maps. For example, boarder dissemination of intelligent transportation systems (ITS) could reduce individuals' overall reliance on their own cognitive maps, thereby increasing access to previously unknown destinations in the short term, if also possibly slowing or reducing the rate of spatial learning over the long term.

Our survey findings suggest that cognitive mapping is indeed influenced by travel mode experience. Such modally-constructed cognitive maps likely reflect perceptions of opportunities, and, hence, effective accessibility in ways that travel behavior researchers are only beginning to understand. To a car-less job seeker, job opportunities not easily reached by transit are effectively out of reach, and even transparent, regardless of Euclidian distance. Modally-constructed cognitive maps, therefore, are key to understanding both travel behavior and accessibility in cities.

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[i] Surveyors were undergraduate students at UCLA. Five total surveyors worked in groups varying from three to five during survey outings. Surveyors practiced administering the survey at least ten times upon each other and other UCLA students.

[ii] We expect that response rates were lower at UCLA because a relatively higher value of time for the UCLA population reduced the attractiveness of the incentive.
[iii] We particularly recommend Kitchin (1996) as an excellent summary of spatial cognitive research methods.
[iv] We assume that for the type of everyday, local or regional trips asked about in the survey, those reporting the mode of "auto passenger" are not co-pilots, navigating the journey from the passenger seat, but being chauffeured.
[v] The way that respondents report distance – network versus Euclidian distance, for example – could affect individual distance estimates. However, we do not expect the types of distance measures used by respondents to vary systematically across our modal categories of analysis.
[vi] We report results in miles rather than kilometers because, as a cognitive exercise, the survey questions themselves were framed in the units familiar to the population being investigated – in this case, Americans primarily accustomed to imperial units of measure.
[vii] We explored the same model for UCLA and found the model was significant in terms of the primary variable of interest, active versus passive travel, but insignificant and unrevealing in terms other variables in the model. The remarkable heterogeneity of the UCLA population in terms of occupation, immigrant status, time spent in the area, and familiarity with the area diminishes the likelihood of the demographic variables available in the survey being able to explain variations in spatial knowledge.
[viii] We explored the same measures for UCLA. However, because so many of the UCLA respondents lived and worked (or attended school) on the UCLA campus, respondents' descriptions of the locations of home and work were idiosyncratic to a campus setting (i.e. "DeNeve Hall"). Accordingly, we focus only on the South Los Angeles part of the sample for this portion of the analysis.
[ix] We asked respondents the question, "If you were telling someone where you lived what kinds of features would you use to describe your location? For privacy reasons we don't need your address; but could you give us your zip code, street, cross street, or another landmark or feature that identifies the location of your neighborhood?"