Heads Up: Using Cognitive Mapping to Develop a Baseline Description for Urban Visualization

Submission #513

ABSTRACT

Mapping interfaces have become increasingly important, particularly with the spread of mobile devices (GPS, cell phones). While a plethora of data is available, there is little quantitative information about how to prioritize the display. Building on the work of geographers, urban designers and cognitive scientists focused on cognitive maps, we propose three elements for urban visualization; segments, landmarks and neighborhoods. We then conducted a user study of 55 students' sketch maps of Chicago that tests the frequency of these three elements, their interrelationship and the effect of gender, age, experience and scale. We conclude that all three types of elements are used, that competent cognitive maps involve relatively small numbers of elements (17 +/- 12), that the number of landmarks and neighborhoods are negatively related to the number of segments, that scale may influence the relative proportion of elements and that gender and age are worth considering in customizing interfaces.

Author Keywords

Cognitive Map, Visualization, Recall, Geography, Urban Design, Cognitive Science

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation: Miscellaneous—*User Interfaces*

INTRODUCTION

Interface designers have increasingly turned their attention to urban mapping applications, relying on the work of geographers, urban designers and cognitive scientists for insights about how to configure interfaces. But there has been very little quantitative analysis of the elements of such interfaces and their interrelationship for the user.

The considerable literature from urbanism, cognitive science and geography establishes criteria and methods for urban legibility. The central concept of such work is the idea of a cognitive map, which proposes that the brain can acquire, code, store, recall, and decode information about the relative locations and attributes of various phenomena in their spatial context. This work has established fundamental elements of cognitive maps and has studied the uses and development of cognitive maps in different settings and by different user groups.

Our objectives in this paper are:

- From the study of existing literature in a wide range of disciplines, extract a simple but complete set of spatial elements (landmarks, segments, neighborhoods) that are essential to constructing cognitive maps;
- By means of a user study, establish the base level for each element for a competent description of a cognitive map;
- Measure and study the relative interdependence of each element in describing an urban environment;
- Discover any differences in the number of elements for users based on age, previous experience and gender.

We begin with a review of previous work that leads to the establishment of three classes of elements (landmarks, segments, and neighborhoods) that serve as the basis for our study. These three elements have several interesting properties, including differing degrees of locational precision. A landmark is seen as one specific point, a segment is a regarded as a line, and a neighborhood is often a loosely defined area.

In order to generate a baseline description of a cognitive map, we conducted a user study of architectural students after a four-day field trip to Chicago, distant from their home university. Specifically, we chose to examine hand-drawn sketch maps as a tool to extract information from participants' cognitive maps of each city. Sketch maps show only limited or schematized information about the environment allowing for the most memorable and relevant information of one's mental representation to surface. Therefore, we asked each student to draw a sketch map of the city they visited, using an open question protocol. The resulting maps were coded to identify spatial characteristics of the city using landmark, segment, and neighborhood elements.

Our subsequent analysis was aimed at establishing a baseline for a competent cognitive map. How many landmarks, segments, and neighborhoods did participants on average feel were necessary to use in order to give a clear depiction of the city? Just as important, we wanted to determine if the

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use of one type of element substitutes for another. If you identify a lot of landmarks, do you in general use fewer segment elements? Does previous knowledge of a city affect your use of elements? Does gender or age?

The result of this study is an understanding of the number, type and interdependence of elements that form a description of an urban setting that can serve as a guide for interface designers.

RELATED WORK

In recent years, several innovative mapping applications have been proposed that used cognitive mapping, although without any quantitative understanding about the elements that constitute such a cognitive map.

LineDrive [1] is an interface that incorporates principles of map distortion to the rendering of routes, adjusting lengths and angles to more closely approximate the kind of simplifications that mimic human users. This approach focuses almost entirely on segment elements, and demonstrates a subtle and effective adjustment to individual users. The shortcoming of this approach is the lack of contextual information, leading to problems with users becoming confused after a single wrong turn.

Copernicus [17] attempts to correct flaws within the LineDrive system by adding context to the interface. Generally, this involves adding segments and neighborhoods (cities and towns) to the segments from LineDrive. This represents an advance in terms of legibility, but leaves unsolved the issue of how much information to display and which types of elements should be used.

Work at Carneige Mellon on the MOVE system has developed mapping software that uses some of the principles from LineDrive in a two dimension interactive network that adjusts as the user moves through the city [11]. This corrects some of the original problems, but does not seek to address directly the issues of cognitive mapping.

Some interfaces have attempted to incorporate landmarks into maps [6], focusing on selection processes for identifying landmarks and geo-referencing them on tourist maps. This represents an advance in sort the data related to landmarks, but it does not address their relationship to the user.

There has also been some effort related to GPS navigation system in cars, notably at SIGCHI 2008. The foci of these studies have been general evaluation of user behavior while in the car [12], performance of a driving simulator to study accuracy rates of proposed systems [7], or an evaluation of quick search versus categorical semantic search systems [10]. But again none of this research has sought to establish guidelines for display visualizations.

Therefore, we identify a need to rely on the research of urban planners, cognitive scientists and geographers who examine the question of urban legibility. More specifically, we are interested in research that identifies a base set of spatial elements that are recognizable in any city. While each field of research focuses on cognitive maps of the city in unique ways, we want to address the most relevant work in relation to our focus on element recognition, setting aside issues of spatial proximity judgments and element recognition sequencing.

We should be clear about our use of the terms cognitive map and sketch map. By cognitive map we mean the internal mental image that enables people to code, store and decode spatial information. By sketch map, we mean an external representation of a cognitive map that is solicited by the need to communicate in daily life (and by researchers).

Cognitive Science

The term cognitive map was first used by psychologist Edward Tolman in “Cognitive Maps in Rats and Men” [15]. He describes a maze previously mastered by rats that is blocked at a critical point and replaced by a series of radially arranged alternatives. His finding is that the rats greatly preferred the route that demonstrated an understanding of the spatial overview of the maze. Partly a reaction against strict behaviorism, his work leads to the development of cognitive psychology.

As Barbara Tversky [16] has noted, within psychology the current interest centers on issues of categorical error rather than on fundamental processes of interaction with the world. We have centered our search on other disciplines that are more focused on active involvement with urban environments.

Urban Design and Planning

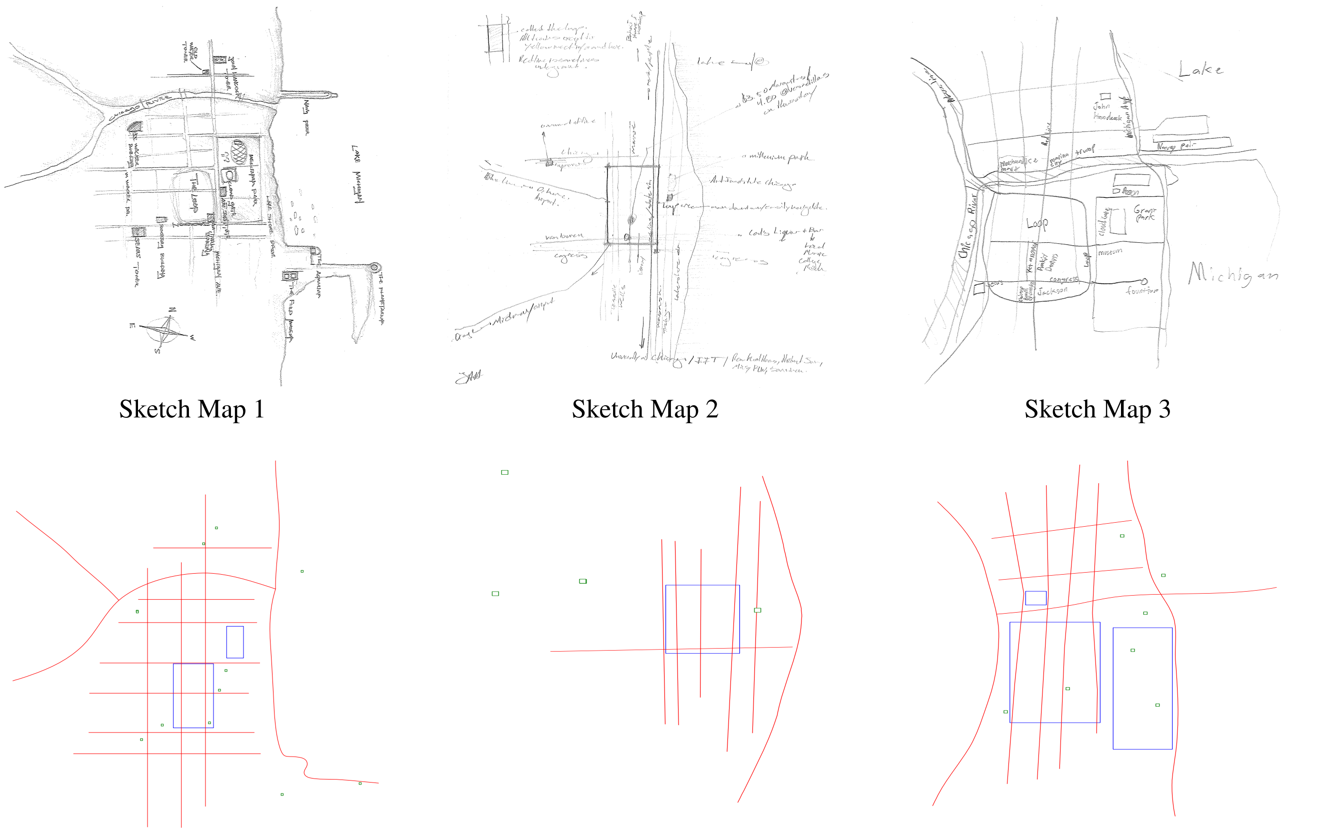
The work of Kevin Lynch [13] is one starting point for our study. He claims that the city’s image is represented in memory through five common elements: path, edge, district, node and landmark. Lynch’s elements are recognizable in most urban settings but some have proven to be more frequently used by subsequent researchers. We use these elements as a baseline set of urban elements from which to work.

Donald Appleyard, a collaborator of Lynch’s, also works in the field of environmental cognition and planning. While most of Appleyard’s work focused on a view of the city from a navigational standpoint, his work in the city of Ciudad Guayana [2] also addresses the image of the environment as a tool to plan for a better community.

Geography

While many of these methods relate to the sequential development of a cognitive map, our objective is to identify a common understanding within the field of the elements necessary for a cognitive map.

Research methods of environmental cognition follow a common set of integrated steps that define the process of recalling the environment [5]. First, a person acquires declarative knowledge of discrete places, things, and events. Next, they develop an understanding of a node and path sequencing of the environment. This provides the subject with a connective structure of transit paths and concentrated locations. Last,



Sketch Map 1 Sketch Map 2 Sketch Map 3

Vector Map 1 Vector Map 2 Vector Map 3

Figure 1. Sample Sketch Maps (top row) and their corresponding Vector Maps (bottom row). In the Vector Maps, segments are drawn as red lines, neighborhoods as blue rectangles, and landmarks as green dots (or rectangles).

a completely integrated spatial representation is developed including characteristics of distance, direction, orientation, proximity, clustering, and hierarchical ordering.

In addition to these fundamental processes that occur in cognitive map development, Evans et al. [3] develop a theory from a study using participant sketch maps drawn over a period of ten months. Their findings suggest that landmarks and relative locations are among the first components that are learned, followed by paths, and then building from the framework of paths the initial relative locations become more precise. As a three step process, this serves as an incremental approach for which to understand the relationships and integration of elements in the environment.

Hintzman et al. [9] reconfirm a sequential development of a cognitive map based on studies of orientation and target domains. They argue that instead of recalling the environment as a holistic cognitive map participants first recall the origin and target in memory, activate the shortest route between them, and then span the route for correct response.

Golledge [4] focuses on the development of cognitive maps starting with specific landmarks to larger general areas. His findings suggest recognition of the environment begins with recall of landmarks, then the paths that connect the landmarks. Finally, a spread effect occurs for the location of regional knowledge of place. He refers to this step as developing concepts of neighborhood and community.

Elements of Cognitive Maps

Our conclusion from this research is that we could establish landmark, segment and neighborhood as three elements of cognitive maps that have been most frequently identified by researchers in different fields as the primary elements that constitute the construction of cognitive maps. Identification of these elements in sketch maps would give us reliable measures to compare individual effort toward a collective competency of mental representation of the city.

We have chosen to use the terms landmarks, segments and neighborhoods rather than more neutral, geometric terms to recognize that semantic meaning usually is comingled with spatial information, although this current paper does not attempt to address this difference directly. There is also a significant difference in the attachment of semantic information to each type of element, with the landmark having one precise semantic label, the segment a set along the line and the neighborhood a loose set of semantic descriptors.

USER EXPERIMENT

This investigation focuses on cognitive representations of the environment using participant sketch maps. While prior

Parameter	Estimate	Standard Error	Chi Square	Probability
Intercept	0.7916	0.8259	0.92	0.338
Age	-0.0100	0.0416	0.06	0.810
Gender	0.1062	0.1659	0.41	0.522
Prior Experience	-0.2274	0.1933	1.38	0.239
Scale	0.6402	0.1558	16.88	0.000

Table 1. Negative Binomial Regression of Neighborhood Counts on Socio-economic and Contextual Variables. Note: For gender, male is coded '1', female is coded '0'. Some prior travel to Chicago is coded '1'; '0' otherwise; A local scale is coded '0', and citywide is coded '1'. The same coding convention is used throughout the paper.

Parameter	Estimate	Standard Error	Chi Square	Probability
Intercept	4.2380	0.9182	21.30	0.0001
Age	-0.1232	0.0464	7.04	0.008
Gender	0.3300	0.1515	4.74	0.029
Prior Experience	-0.2742	0.1764	2.42	0.120
Scale	-0.2093	0.1638	1.63	0.201

Table 2. Negative Binomial Regression of Landmark Counts on Socio-economic and Contextual Variables

studies focus on the order of element recall [3, 5, 4, 9, 14], elements of navigational recall [2], or an overall image of a place one experiences [13], our study aims to quantitatively uncover the baseline elements necessary for a cognitive map of a city.

Participants

Fifty-five college students (22 females and 33 males) participated in the experiment based in the city of Chicago. Participants' ages ranged from 19 to 26. Based on questionnaire responses, 13 of the 55 participants said they had visited Chicago prior to the trip leading to the experiment. Therefore, to ensure the results of the study were consistent, we carefully analyzed the 13 sketch maps by testing for the equality of group means (Student's t-tests) and found no statistically significant difference in any measure of element recognition analyzed in comparison to the participants who never visited Chicago prior to the experiment.

Study Area

Each participant traveled to the city of Chicago for a period of four days as part of a class field trip. Participants were required to travel as a class to a large number of locations widely distributed across the city. For approximately 50% of their time, participants were free to travel the city independently or in small groups.

Procedure

Two days after returning from the trip participants gathered in a study room equipped with a desk (each spaced a distance apart), a questionnaire (see section Experiment Questionnaire), and a writing utensil. To start, participants were given a brief overview of the study for the first time, but were not told about specific elements later used for analysis. Participants were then instructed to complete all questions in a thorough manner and to take as much time as needed. The study was complete after each participant finished and returned the experiment questionnaire.

Experiment Questionnaire

The experiment questionnaire primarily consisted of a recall exercise including the drawing of a sketch map of the city. Other questions included background information about the participant such as gender, age, prior visits, and length of prior visit, if any.

The sketch mapping statement was phrased, "Now that you have traveled to Chicago, think about the environment you experienced. Imagine that you have a friend who has never been there before. Draw them a map to help them to understand and navigate Chicago." We intentionally left the statement fairly open ended to allow the participant to draw freely in order to capture the most influential elements in each person's cognitive map of a place.

Data Extraction

Upon completion of the user study, each map was digitally scanned and converted into a vector file based on the landmark, segment, and neighborhood element classes (see Figure 1). A researcher then performed content analysis by counting the number of landmarks, segments and neighborhoods drawn on each map and recorded the data. The researcher also analyzed each map based on relative scale to determine if it represented a local or citywide view of the city [2] and sorted the sketch maps accordingly. Thus, three sets of data were formed: landmarks, segments, and neighborhoods from local maps; landmarks, segments and neighborhoods from citywide maps; and landmarks, segments and neighborhoods from both local and citywide maps combined.

Data Analysis Procedures

Distribution analysis is the first method used to analyze the data. Here we are interested in comparing the results of the Chicago maps independently using three data sets: local maps, citywide maps, and local and citywide maps combined. In distribution analysis the elements are considered individually. We calculate the mean, median, mode, range and standard deviation of the total count of landmarks, the total count of segments, and the total count of neighborhoods in each data set.

In addition to distribution analysis for each element independently, we pool together the three element types and determine the average number of total elements the subjects used in local, citywide, and local and citywide maps. The standard deviation of this additional dataset is calculated as well. Through this distribution analysis we are looking for trends or inconsistencies regarding the number of each of the three elements used in sketched maps of Chicago, as well as in the total number of elements used in the sketched maps. The standard deviations serve as indicators as to how closely the data cling to the sample mean. A small standard deviation indicates a set of data distributed tightly around the mean, whereas a large standard deviation indicates a wide range of element numbers across the sample of experiment participants.

Next, a series of t tests are applied to test for the invariance of several measures of urban legibility across gender groups, the scale of the map sketched, and according to whether prior visits to Chicago were made. In particular, we look at the total number of elements reported on each sketched map, the proportion of neighborhoods to other elements, the proportion of neighborhoods to all three elements, the proportion of segments to other elements, the proportion of segments to all elements, the proportion of landmarks to other elements, the proportion of landmarks to all elements, and finally the proportions of segments to landmarks, of segments to neighborhoods, and of landmarks to neighborhoods.

Multivariate regression models of the proportion of each map element to the other two elements combined, as well as to each of the other two map elements taken separately, are estimated through ordinary least squares to understand the pattern of covariance among map elements in individual maps and the influence of socio-demographic and experiential factors.

Finally, multivariate regression models of the total count of elements, as well as of the count of each element type are estimated. Given the non-normal distribution of these dependent variables, a negative binomial regression framework is used for this purpose and estimation is conducted through maximum likelihood.

In all cases, statistical significance is evaluated at the 0.05 level and all models are estimated with SAS 9.3.

RESULTS

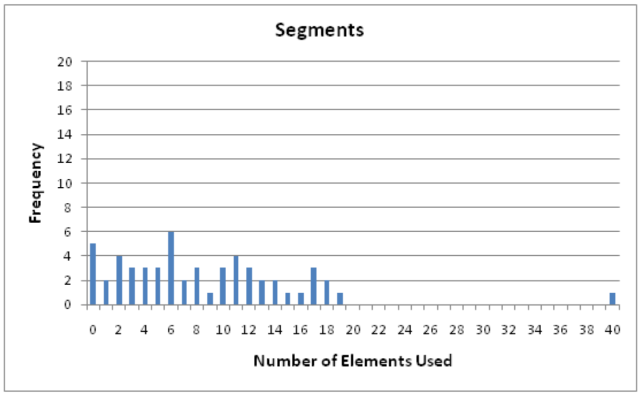
Distribution analysis is performed on the number of landmarks, segments, and neighborhoods in three data sets. In the data set of local maps, the segment counts return a mean of 8.79, a median of 8.5, a mode of 10, a range of 0-19, and a standard deviation of 5.24. The landmark counts returns a mean of 6.89, a median of 7, a mode of 8, a range of 0-20, and a standard deviation of 4.13. The neighborhood counts returns a mean of 1.84, a median of 2, a mode of 2, a range of 0-4, and a standard deviation of 1.08.

In the data set of citywide maps, the segment counts return a mean of 8, a median of 5, a mode of 6, a range of 0-40, and a standard deviation of 10.06. The landmark counts return a mean of 5, a median of 5, a mode of 6, a range of 0-12, and a standard deviation of 2.55. The neighborhood counts return a mean of 3.14, a median of 4, a mode of 4, a range of 0-6, and a standard deviation of 1.87.

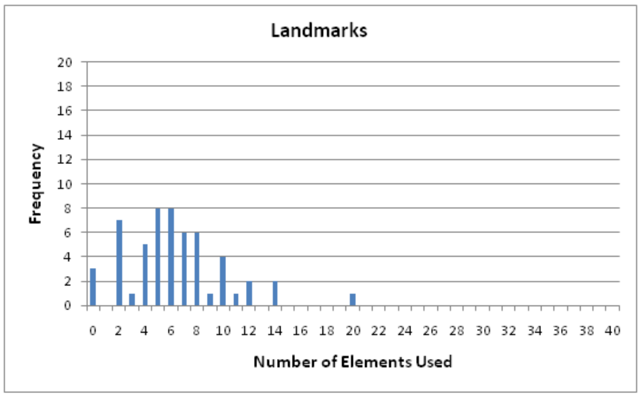
In the data set of combined local and citywide maps, the segment counts return a mean of 8.55, a median of 7, a mode of 6, a range of 0-40, and a standard deviation of 6.99. The landmark counts return a mean of 6.31, a median of 6, a mode of 5, a range of 0-20, and a standard deviation of 3.79. The neighborhood counts return a mean of 2.33, a median of 2, a mode of 2, a range of 0-6, and a standard deviation of 1.54. These three data spreads are represented in Figure 2.

As indicated earlier, a battery of t-tests of equality of group means has not detected any significant effect of having had prior experience of the city of Chicago on the cognitive mapping of the city with constructs of landmarks, segments, and neighborhoods. The scale of the map (local versus citywide) sketched by each participant is found to be a significant discriminating factors of a few measures of element recognition, namely the proportion of neighborhoods to all elements (10.8% on local maps against 23.9% on citywide maps; t value of 3.52), the proportion of landmarks to neighborhoods (4.4 on local maps versus 1.7 on citywide maps; t value of 4.3), and the proportion of neighborhoods to segments and landmarks (12.9% on local maps versus 36.2% on citywide maps; t value of 3.43). Tests involving other measures of urban legality reveal no scale dependence. Finally, tests of means are largely inclusive as to the influence of gender on the mix of urban elements recognized by individuals. Of all the measures tested, only the proportion of landmarks to the combined number of segments and neighborhoods used in a sketch is significantly larger for males (1.1 on average) than for females (0.6 on average) (t value of 2.2).

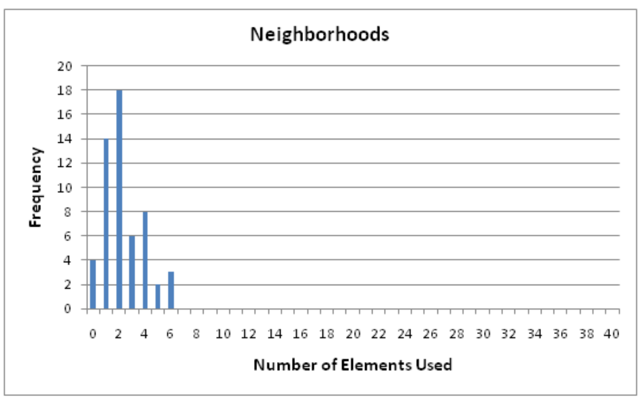
The regression analyses performed on the sketch maps of Chicago returned a number of results informing on how the three element types are used jointly to represent the city, and on the variability of the resulting constructs across socioeconomic groups and other conditions. First, while the total number of elements used is found to be independent of age, gender, prior experience of the city, and representational scale, more subtle patterns emerge when each of the three types of elements is examined in turn. The first negative binomial regression is performed on the neighborhood totals (Table 1) with a deviance of 57.7. While age, gender, and prior experience are not significant factors, scale is. Consistently with expectations, more elements tend to be used as large sections of a city are represented. The number of landmarks is larger among male and young respondents, while scale and prior visits to Chicago has no effect on the number of landmarks (Table 2) (deviance of 64.9). The number of segments cannot be significantly explained by any of the tested factors.



(a) Segments used in sketch maps



(b) Landmarks used in sketch maps



(c) Neighborhoods used in sketch maps

Figure 2. Histograms of landmarks, segments, and neighborhoods

In a second set of negative binomial regressions, the number of elements of each type is regressed against the number of map elements of the other two types. Results are reported in Tables 3a, b, and c. While the number of landmarks used is higher in maps with fewer segments, there is no statistical relationship with the number of neighborhoods incorporated in the sketched map. Also, there is a weak inverse association between the number of segments and the number of neighborhoods (significance level of 6.84%), but not with the number of landmarks. As indicated by Table 3c, neighborhood elements cannot be predicted by the segment and landmark totals. The three-way relationships between the types of elements used in map sketching are depicted graphically in Figure 3.

The third set of regressions focuses on the identification of significant correlates of the mix of map elements used to sketch maps of Chicago. Proportions of each type of elements to other types, either collectively or separately are the dependent variables in each model estimated by ordinary least squares. No correlates of the proportion of segments has been identified (Table 4a), while a significantly higher proportion of neighborhoods is found in citywide maps (Table 4c). Finally, landmarks are found to be relatively more common in maps drawn by male and younger respondents (Table 4b).

DISCUSSION

The main focus of this paper is to establish guidelines for cognitive maps that are recognized as competent by users and to discover any correlations between types of map elements. We have assumed that sketch maps as drawn by users represent in the aggregate a competent representation of the city, and therefore accurately reflect cognitive maps as mental processes.

Based on our study, users tend to use all three types of elements (segments, landmarks, neighborhoods) in constructing cognitive maps.

Cognitive Map Elements

Our first finding is that users employ a relatively small number of total elements, 17.19 (+/-12.32). Although there is no absolute definition for "small", our finding is many less elements than the number in most maps or displays currently in use. This finding may be consistent with research about the limits of human memory for independent variables. More specifically, we find mean values for the use of 8.55 (+/-6.99) segments, 6.31 (+/-3.79) landmarks and 2.33 (+/-1.54) areas.

The tendency to identify segments and landmarks with greater frequency than neighborhoods (about three to four more frequent) is, we believe, due to the more diffuse shape of neighborhoods making them more difficult to place on a map.

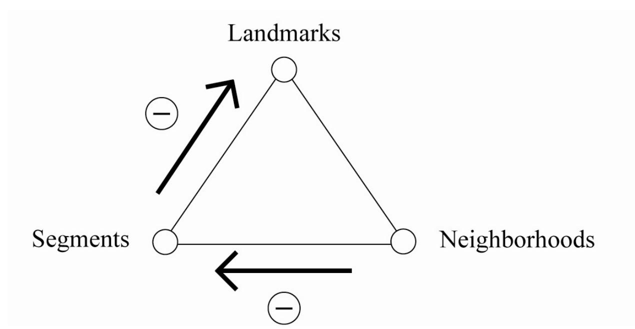


Figure 3. Significant Relationships between Map Elements

(a)Dependent variable = Number of Segments;
Deviance = 65.0; 52 Degrees of Freedom

Parameter	Estimate	Standard Error	Chi Square	Probability
Intercept	2.7294	0.2428	126.33	0.0001
Number of Landmarks	-0.0430	0.0266	2.63	0.105
Number of Neighborhoods	-0.1539	0.0845	3.32	0.068

(b)Dependent variable = Number of Landmarks;
Deviance = 62.1; 52 Degrees of Freedom

Parameter	Estimate	Standard Error	Chi Square	Probability
Intercept	1.9735	0.1996	97.78	0.0001
Number of Landmarks	-0.0326	0.0135	5.79	0.016
Number of Neighborhoods	0.0517	0.0527	0.96	0.326

(c)Dependent variable = Number of Neighborhoods;
Deviance = 58.1; 52 Degrees of Freedom

Parameter	Estimate	Standard Error	Chi Square	Probability
Intercept	0.88130	0.2206	15.96	0.0001
Number of Landmarks	0.0243	0.0223	1.19	0.275
Number of Neighborhoods	-0.0247	0.0147	2.84	0.092

Table 3. Negative Binomial Regression of Segment Counts (a), Landmark Counts (b), and Neighborhood Counts (c)

There is a fairly wide range in the number of each element that users choose to use, which probably reflects some variation in personal style. Our study indicates that the total number of elements in a cognitive map should be restricted to a maximum of 30 total elements, which would be within the standard deviation found in our study.

We found that there is no significant difference in the total number of elements based on the four factors that we studied (age, gender, experience or scale). This leads us to conclude that an interface designer can be confident that the use of this number of total elements is likely to be successful with a wide demographic, and is probably related to the cognitive load that seems tolerable for a wide range of users.

Use of Map Elements

We were also interested in the use of each of the three types of element, and if one type of element could substitute for another in the construction of a cognitive map. If, for example, an interface presented more neighborhoods, is it likely that fewer segments were needed to establish a competent cognitive map?

Our finding is that most of the relationships between elements do not have significant interrelationships. One exception is the relationship between the use of segments and landmarks. It appears that the use of segments leads to a decrease in the number of landmarks, which suggests that they may substitute for each other in constructing a cognitive map, although the reverse relationship does not hold in general (see Figure 4).

We also notice a trend toward a relationship between segments and neighborhoods; again, as neighborhoods decrease, segments increase; yet the reverse is not substantiated by the statistical analysis.

Taken together, this suggests that an there may be a relationship between the number of segments and the number of neighborhoods and landmarks. As our identification of meaningful landmarks and neighborhoods improves, it may affect the number of segments in the cognitive map.

Use of Elements with Age, Gender, Experience or Scale

We were also interested in how age, gender, experience and scale should be taken into consideration when designing map interfaces.

Our results indicate that gender and age have a significant impact on the formation of cognitive maps.

We find that men and younger subjects use significantly more landmarks, both in absolute terms as well as in proportion to segments and neighborhoods. This is corroborated by the finding that the ratio of landmarks to neighborhoods significantly varies by age, with younger subjects using significantly more landmarks. Given the narrow range of ages within the study, it is surprising to find significant differences in the use of landmarks, especially considering that previous experience in the city has no significant impact on the same measure.

This suggests that urban interface designers should consider tailoring their interfaces to gender and age, specifically targeting landmarks as the most likely area to adjust the interface. However, it should be noted that our finding that men tend to generate more landmarks in a sketch map is seemingly incompatible with the common finding in cognitive science that women tend to remember more landmarks than men during route recall and navigation tasks [8]. While this contrast may be attributed to differences between route-driven tasks and the higher-level city mapping task used in our study, it does suggest that we should be cautious in in-

(a)Dependent variable = Proportion of Segments to Landmarks and Neighborhoods; R^2 = 9.37%

Parameter	Estimate	Standard Error	T value	Probability
Intercept	-4.4744	4.6100	-0.97	0.337
Age	0.2566	0.2307	1.11	0.271
Gender	0.2985	0.8259	0.36	0.719
Prior Visits	1.4003	0.9116	1.54	0.131
Scale	0.5589	0.8524	0.66	0.515

(b)Dependent variable = Proportion of Landmarks to Segments and Neighborhoods; R^2 = 14.7%

Parameter	Estimate	Standard Error	Chi Square	Probability
Intercept	3.7719	1.4832	2.54	0.014
Age	-0.1591	0.0747	-2.13	0.038
Gender	0.6237	0.2673	2.33	0.023
Prior Visits	-0.1341	0.3043	-0.44	0.661
Scale	0.0244	0.2814	0.09	0.931

(c)Dependent variable = Proportion of Neighborhoods to Segments and Landmarks; R^2 = 31.49%

Parameter	Estimate	Standard Error	Chi Square	Probability
Intercept	-0.1152	0.2793	-0.41	0.681
Age	0.0136	0.0141	0.97	0.337
Gender	-0.0398	0.0493	-0.81	0.423
Prior Visits	-0.0286	0.0555	-0.52	0.608
Scale	0.2256	0.0517	4.36	0.0001

Table 4. Regression of the Proportions of Segments (a), Landmarks (b), and Neighborhoods (c), to Other Map Elements

terpreting our gender-related findings. Future work would be needed to explain this effect.

We also find significant differences as the scale of the map is increased (see Figure). The proportion of the neighborhoods to the combined of the other two elements is very significantly higher when the scale is higher. Neighborhoods are often specifically named at the larger scale of the city, and we might expect them to be more prominent as we zoom out to this larger scale. But there is nothing natural about the scale at which areas are named. As a process, areas are semantically rich; that is, they can combine many different kinds of information into a single element. Our findings about neighborhoods may imply if we are able to use these labels as an alternative to segments and landmarks, they may be able to bring more information to a map with fewer elements.

Heads Up and Drill Down

The use of cognitive maps in urban visualization impacts at least two types of interfaces.

The most obvious impact is on what we might call "heads up" applications. These types of application are for devices that must convey a maximum amount of information as quickly as possible. Mobile devices of all types, including but not limited to GPS devices, must not distract drivers or users from their immediate task. Cognitive maps can provide interface designers with a quantitative understanding of the most important elements and their relationship, helping to set limits on the numbers and type of elements.

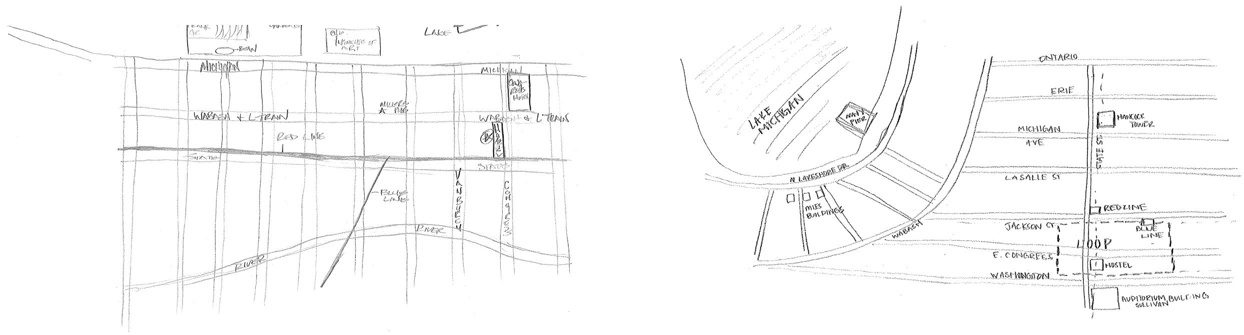
By contrast, urban mapping and visualization may seem unlikely candidates because of the immense amount of data (layer upon layer of information about roads, buildings, flood zones, businesses, etc.) and the heterogeneity of the information. But here too, cognitive maps provide us with insights about the layering of information. Given a complex set of data, an interface designer will need to sift through this wealth of information to foreground the most important and provide a hierarchy of primary, secondary and tertiary information within a densely packed interface. Cognitive maps, because of the difference between the three elements, also guides an understanding of how spatial and semantic information can be engaged at the same time. In this case, cognitive maps provide us with guidance for "drilling down" into information.

CONCLUSION AND FUTURE WORK

We conclude that segments, landmarks and neighborhoods are used in the construction of cognitive maps and that such maps involve relatively small numbers of elements (17 +/- 12).

We also find that the number of landmarks and neighborhoods are negatively related to the number of segments, that scale may influence the relative proportion of elements and that gender and age are worth considering in customizing interfaces.

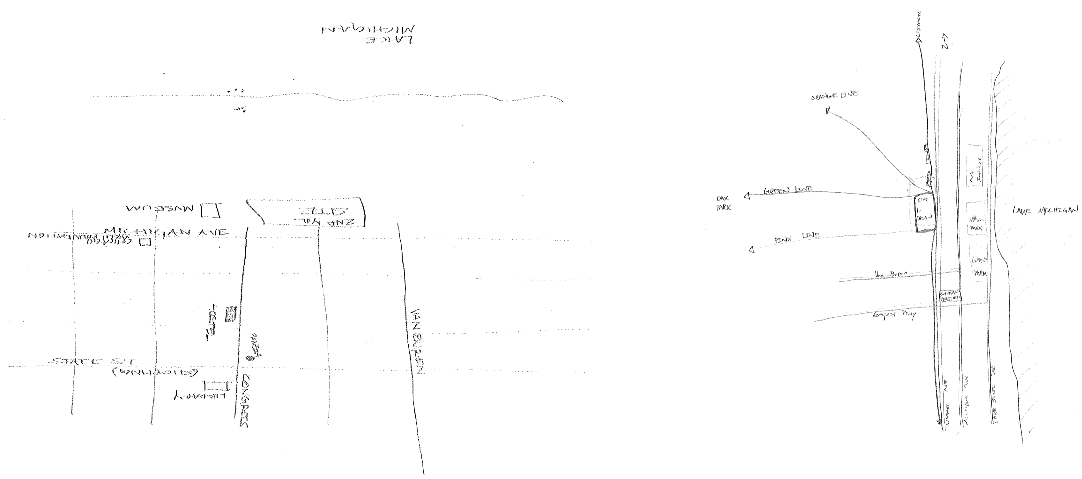
Our research has been limited at this point to Chicago. Extending this to other cities will provide additional informa-



(a) A sketch map demonstrating fewer than average neighborhoods and more than average segments

(b) A sketch map demonstrating fewer than average landmarks and more than average segments

Figure 4. Two sketch maps showing the inverse relationships between (a) segments and landmarks and (b) segments and neighborhoods



(a) A sketch map drawn at the local scale where the area depicted in the map only covers a few blocks of the city

(b) A sketch map drawn at the city scale where the area depicted in the map covers most of the city

Figure 5. Two sketch maps demonstrating the two different scales: (a) local scale and (b) city scale

tion both about the validity of our analysis, and with an understanding of how cities may differ.

We also believe that another study can be designed to study more specifically the relationships between landmarks, segments and neighborhoods.

We are also interested in how the idea of neighborhoods can be understood as an aspect of urban visualization. As the amount of data about cities continues to expand and become available to mobile devices, the ability to generate meaningful clusters of data within a city may become a key aspect of the formation of cognitive maps.

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