UNPACKING THE IMAGE OF THE WATER CITY WITH THE THEORY OF IMAGEABILITY

RISING, HOPE HUI
Washington State University, hope.rising@wsu.edu

1 ABSTRACT

This study investigated how to design imageable cities with water using Lynch's (1960) theory of imageability. It examined the contributions of imageability elements (landmarks, paths, nodes, edges, and districts) and components (structure, identity, and meaning) to the image of the water city. The author sampled 55 sketch maps from 60 participants in eight water cities and colored water elements blue to generate 55 colored maps. To measure uncolored map identifiability (UMI) and colored map identifiability (CMI) as dependent variables, raters 1 and 2 were asked to identify the city associated with each uncolored sketch map, and raters 3 and 4 were asked to identify the city associated with each colored sketch map. To assess the contribution of water (CW) to CMI, raters 3 and 4 were asked to indicate the extent to which the map's blue features helped the raters identify the city on a three-point Likert scale. The contribution of water (CW) was used to weight CMI to generate the dependent variable of water-based colored map identifiability (WMI). The author used cognitive mapping, photovoice, and nonvisual protocols to measure waterscape attributes using imageabilty components, waterscape mappability, identifiability, and attachment as potential explanatory variables for UMI, CMI, and WMI. Regression analyses suggest that only canal mappability (the structure of water-based paths) significantly contributed to all measures for the image of the water city (UMI, CMI, and WMI) while controlling for the potential effects of gender, environmental exposure, age, income, education, and aquaphilia sensitivity baseline, which measured people's attachment to water.

1.1 Keywords

Imageability, identifiability, sketch map, water cities, spatial anchor

2 INTRODUCTION

2.1 Water cities as imageable and resilient environments

In *The Image of the City*, Lynch (1960) speculated that Venice and Dutch polder cities were often highly imageable environments; specifically, he pointed out that Dutch urban designers created polder cities as “a total scene” that made it easy for residents and visitors to “identify its parts” and “structure the whole” (p. 13). Although Lynch foregrounded the aesthetic intention underlying these imageable water cities, Hooimeijer (2011) considered this urban design tradition a way to keep urban developments dry in a watery territory below sea level.

2.2 An emerging water-coherent approach to green infrastructure

Such systemic integration of man-made water bodies with public realm design has been regaining momentum among coastal cities seeking urban design interventions as mitigation and adaptation strategies for the impacts of climate change and rise in sea level (Backhaus & Fryd, 2012; Jacob, 2014; Ross, 2014; Ruggeri, 2015; Waggonner & Ball, 2013). This blue thrust in the green infrastructure movement has been considered the critical path through which biophilic urbanism contributes to livability and climate change adaptation (Beatley & Newman, 2013). However, the emergence of blue-green infrastructure has largely been driven by technocratic discourse. Hydrologic conditions have been discussed as the predominant generator of urban forms (Backhaus & Fryd, 2012). The systemic potential of water in enhancing the image of the city has been largely unexplored as a design theory by academics and as a siting strategy by practicing urban designers.

2.3. Contributions of structure, identity, and meaning to imageability

Lynch’s (1960) theory of imageability provides a point of departure for investigating how water-based aesthetics may contribute to the image of resilient cities. Lynch (1960) alluded to imageabilty as a pattern of high continuity with distinctive yet interconnected parts. This definition seems to suggest that imageability could be attributed to the combination of structure and identity provided by uninterrupted paths and landmarks. Although Lynch (1960) pointed out three components of imageability (structure, identity, and meaning), The Image of the City focused primarily on the contributions of structure and identity.

2.4 Waterscapes as spatial anchors

In an imageability study conducted with visitors and residents in three Dutch water cities, De Jonge (1962) observed greater detail in sketch maps drawn at closer proximity to water bodies. These results indicate the high likelihood that water-based elements may be higher-order spatial anchors, which the anchor-point theory defines as organizers of spatial information (Golledge, 1992). Jodelet and Milgram (1976) and De Jonge (1962) discovered that waterscapes seem to emerge first in sketch maps regardless of their cognitive forms, or, in Lynch’s (1960) terms, elements of imageability. It is likely that water-based elements surface early during spatial memory recalls because all other spatial information must be organized around them.

2.5. Influences of waterscapes’ elements of imageability on the image of the city

Lynch (1960) described the Charles River as an edge in Bostonians’ cognitive maps. Jodelet and Milgram (1976) found that the Seine River showed up first in participants’ sketch maps of Paris. The salience of the Seine River in the cognitive maps for Paris may be attributed to its cognitive form as an edge and/or to its simple presence as water. Though rivers pass through many cities, most of them would not have been described by Lynch as imageable cities like Venice and the Dutch Polder cities, which are often characterized by the presence of well-integrated water bodies within their urban fabrics. It is possible that canals or water-based paths, which have narrower linear water surfaces, may be more salient water-based spatial anchors than rivers or water-based edges.

2.6 Study objective and research question

This study intended to investigate possible ways to design imageable cities through a water-coherent approach to designing green infrastructure at the city level. To this end, the investigation sought to better understand Lynch’s theory of imageability in the context of water cities, particularly those that are similar to Venice or Dutch polder cities. Specifically, the proposed research design strove to answer the question of how the image of the water city could be attributed to waterscapes' imageability components (structure, identity, and meaning) and imageability elements (landmark, path, node, edge, and district).

3. METHODS

3.1 Sketch map identifiability as a measure of environmental imageability

In observing the ways the Dutch polder cities were designed, Lynch (1960) pointed out that an identifiable environment could potentially contribute to the imageability of these water-centric cities. However, Lynch's sketch map studies were conducted in three land-based cities with rivers rather than water-centric cities with water bodies integrated within their urban fabrics. De Jonge's (1962) study of visitors' and residents' sketch maps from three Dutch water-centric cities suggests that an identifiable sketch map is possibly a reflection of an identifiable environment. According to Lynch (1960), imageability also encompasses environmental affordance for spatial comprehension. Kim and Penn (2004) found that certain parts of sketch maps were more identifiable because their corresponding environmental configuration was more conducive to wayfinding (Kim & Penn, 2004). To assess spatial abilities, Beck and Wood (1976) and Evans (1980) used sketch maps to study the extent of spatial knowledge required to form a cognitive map of a physical environment. These empirical sketch map studies indicate that sketch map identifiability is a promising measure of environmental imageability. To better understand imageability, this study utilized sketch maps as a data source. Participants were asked to draw sketch maps only once because Blades (1990) found that sketch maps had sufficient test-retest reliability for evaluating spatial knowledge.

3.2 Deriving imageability-based dependent variables from sketch map identifiability

To assess the influences of waterscapes' imageability elements and components on the image of the city, the study developed three regression models using three sketch map identifiability measures as dependent variables. To account for the impact of blue color typically used for water bodies on cartographic maps, their water elements were colored blue. Then, to generate scores for uncolored map identifiability (UMI) and colored map identifiability (CMI), independent raters assessed the identifiability of the cities represented by uncolored and colored sketch maps, respectively. UMI and CMI were used as dependent variables for the first two regression models. In addition, the CW was also assessed and used as multiplier for CMI to derive the value for water-based map identifiability (WMI), the dependent variable for a third regression model. Each regression model included a final set of nine explanatory variables composed of three explanatory variables selected from 15 waterscape attributes (Section 3.3) and six confounding variables (Sections 3.4, 3.5, 3.6) selected from literature review.

3.3 Waterscape structure, identity, and meaning as potential explanatory variables

To explore the interrelationships of various imageability concepts in the context of water-centric cities, the investigator conducted stepwise regression analyses to examine how imageability related to any of the 15 waterscape attributes generated from the combinations of five waterscape types (water landmarks, canals, lakes, rivers, and harbors), as water-based counterparts of five imageability elements and three imageability components (structure, identity, and meaning). A water landmark is an iconic feature or salient scene along and/or across a body of water. Both additive and subtractive regression analyses were used to identify a final set of explanatory variables that resulted in a significant change in the regression model's F value (Burkholder & Lieber, 1996). To measure waterscapes' structure, identity, and meaning, to the extent to which they are mappable, identifiable, and memorable, the investigator employed the top-down, eye-level, and emotional perspectives for probing the participants' spatial memory recall sequence through interview instructions and questions (Section 4.3).

3.4 Aquaphilia sensitivity baseline as confounding variable

Coss (1990) attributed people's preferences for water scenes and the optical properties of water, especially glossiness, to the evolutionary advantage of being able to identify clean drinking water. These observations suggest a possible association between the CW to imageability and aquaphilia. This study defines aquaphilia as an innate emotional bond with safe, clean water or water-centric environments. Aquaphilia sensitivity baseline is likely to have an impact on the image of the city because emotion has been found to affect spatial cognition (Tucker, Hartry-Speiser, McDougal, Luu, 1999). The association between emotional bonding and proximity seeking (Scannell & Gifford, 2010) suggests that the aquaphilia sensitivity baseline can be measured through participants' desire to live close to water.

3.5 Socioeconomic variables accounting for group differences in spatial cognition

Montello, Lovelace, Golledge, and Self (1999) and Lawton (1994) discovered gender differences in environmental spatial abilities and wayfinding strategies. Levine, Vasilyeva, Lourenco, Newcombe, and Huttenlocher (2005) revealed that income level mediated the gender difference in spatial skill. Age has been found to be a significant factor influencing environmental learning and wayfinding behaviors (Kirasic, 2000). Ishikawa and Montello (2006) discovered that some participants' spatial knowledge developed with increasing environmental exposure while others either demonstrated accurate metric spatial knowledge from the first navigation session or never developed this survey knowledge, even after several navigation sessions. These previous studies suggest that gender, income, age, and environmental exposure are potential confounding variables.

3.6 Education as a proxy for the influence of exposure to map and information

Despite little evidence, Olkun (2003) suggested that specific training materials, such as engineering drawing activities, could potentially improve spatial abilities. However, more education could potentially be associated with a greater exposure to maps and secondary information sources. Previous studies that investigated the influence of map exposure on sketch maps and spatial comprehension were inconclusive. Some found no correlation between map exposure frequency and sketch-map accuracy (Devlin, 1976), while others noted spatial performance improvement due to map exposure (Devlin & Bernstein, 1995). Kreimer (1973) discovered that specific elements in environmental cognition were emphasized, possibly due to the extensive use of secondary information sources, such as television, newspapers, and radio, as opposed to direct environmental exposure. In order to better examine the influence of direct environmental experience, the author proposed education as a rough proxy for controlling the potentially confounding effect of map and information exposure.

4. DATA COLLECTION

4.1 Selection of water cities

A Google search indicated that 12 cities have been referred to as "Venice of the North" because of their water-based appeal to visitors and residents. Wikipedia provides a list of 10 such cities: Amsterdam, Bruges, Copenhagen, Giethoorn, Hamburg, Henningsvær, Manchester, 's-Hertogenbosch, Saint Petersburg, and Stockholm. Berlin (MacLean, 2011) and Ghent (Raplee, 2010) have also been compared to Venice. Among this shortlist of alluring water cities, the author chose six as study sites based on precipitation pattern similarity and geographical proximity for cost of sampling as selection criteria. These first six cities selected were Amsterdam and Giethoorn in the Netherlands, Ghent and Bruges in Belgium, and Berlin and Hamburg in Germany. Only Amsterdam and Hamburg are coastal cities with harbors in proximity; the other four are inland water cities. Rotterdam and Almere, the two fastest-growing polder cities in the Netherlands, were also appealing water cities with easily accessible harbors. (Kwadijk, Haasnoot, Mulder, Hoogvliet, Jeuken, van der Krogt, & van Waveren, 2010; Tao & Zhengnan, 2013). These two coastal polder cities were thus added to the selection of study sites, for a total of eight cities.

4.2 Recruitment of field participants

A simple and obvious sampling frame for residents and tourists in these eight cities does not exist, because tourists enter and exit the cities constantly; these tourists typically do not have permanent addresses. Sampling sites were thus randomly sequenced to recruit participants in order to create an approximation of a random sample derived from a theoretical sampling frame, which assumes it is possible to include all residents and tourists in all eight cities during the sampling time frame. The investigator used a randomized order to sequence the eight cities. Each city's nine sampling sites always included major entry points (such as airports, intercity train stations, and bus stations), city halls, and tourist bureaus, as well as various hotels, cafés, ethnic stores, and universities. The author chose these sites to sample a representative mix of residents and visitors, high- and low-income populations, environmental design experts and non-experts, and immigrants and visitors from various countries of origin. Each sampling site was sampled for 5 hours, for a total of 45 hours for each water city.

4.3 Field interviews

The author recruited 60 semistructured interview participants from sampling sites in all eight cities. As shown in Table 1, during each interview, the investigator conducted cognitive mapping (item 1), photovoice (item 3), and nonvisual protocols (item 4) to prompt the participant to recall the city as the first five features to emerge from a two-dimensional, top-down cognitive map, the first five photograph-like eye-level cognitive images to surface from spatial memory, and the five elements that would be most missed if the participant had to leave the city the next day.

Table 1. Interview items and coding for environmental factor variables.

Variables	Interview items for field participants
sketch map identifiability[c]	2. Sketch map protocol: Please draw a map of your city on the next page. Include as many features as you can recall. Number the features directly on the map to indicate the sequence in which they emerged from your memory.
waterscape identifiability[ab]	3. Photovoice protocol: If you were to take 5 pictures of the city to describe it to someone who has never been there, what would you take pictures of?
waterscape attachment[ab]	4. Non-visual protocol: What are the 5 things you would miss about the physical environment if you had to leave the city tomorrow?

a. Code each answer 1 or 0 based on whether it contains a target waterscape, assign a weight from 5 to 1 to account for the sequence of recall, and use a weighted average to create variable measures.
b. A targeted waterscape can be a canal, river, lake, harbor, or a water landmark (a landmark along and/or across a body of water).
c. The sketch map was used to three generate sketch map identifiability measures (Section 2.7).

The author used these three recall protocols to assess the mappability, identifiability, and attachment of the five waterscape types as measures for their imageability components (structure, identity, and meaning). The targeted waterscape types included canal, river, lake, harbor, and water landmarks. Immediately after the cognitive mapping protocol, the investigator conducted the sketch-map protocol (item 2) to instruct each participant to draw a map of the city while keeping track of the sequence in which each feature appeared in his or her memory. Some 60 interviews resulted in 55 sketch maps because five participants could not draw their cognitive maps from recall, although they confirmed their ability to draw maps before the interviews. Table 2 illustrates other interview questions for measuring the following six confounding variables: aquaphilia sensitivity baseline, gender, income, age, length of stay, and education or implied map and informational exposure.

Table 2. Interview items and coding for individual factor variables.

Variables	Interview items for field participants (coding)
age	5. In what year were you born? (convert to age)
aquaphilia sensitivity baseline[a]	6. If you could live anywhere, would you choose to live? □ Right on the water (5) □ With easy access to water (4)□ With visual access to water (3) □ Far away from water (2) □ As far away from water as possible (1)
education[a]	7. What is the highest level of education you have completed? □ Graduate degree (5) □ Higher education (Bachelor's degree) (4) □ Some college (3) □ Secondary school (2) □ Elementary school (1)
gender	8. Which sex or gender do you identify with? □ Female (0) □ Male (1)
income[a]	9. Approximately what was your total household income for 2012? Please include all income sources for every member in your household. □ Less than €15,000 (4) □ €15,000–€30,000 (3) □ €30,000–€45,000 (2) □ More than €45,000 (1)
environmental exposure	How many years/days have you lived in this city (altogether)? (convert to days)

a. Assume response categories as equally spaced points along a Likert scale to generate scores as shown above in parentheses.

5. DATA ANALYSIS

5.1 Coding for field data

For items 1, 3, and 4 in Table 1, the investigator assigned a base score of 1 or 0 to each response depending on whether it contained one of the five targeted waterscapes. The basis for classifying these waterscapes was on the literal use of the waterscape terms or the names of actual water bodies in participants' responses. When a waterscape type was unclear in a response, the investigator asked the participant to clarify before ending the interview. The author applied a weight of 5 to the base score for the first answer, 4 for the second, and so forth, to account for the significance of each waterscape type's recall sequence. As shown in the following formula, the investigator took a weighted average from the sum of all five weighted base scores:

Weighted average = (5 * *first answer base sco*re + 4 * *second answer base score* + 3 * *third answer base score* + 2 * *fourth answer base score* + 1 * *fifth answer base score*) / 5

This formula was used to derive the mappability, identifiability, and attachment measures, respectively, for canal, harbor, lake, river, and water landmarks from the results of the cognitive mapping, photovoice, and non-visual recall protocols in Table 1.

As shown in Table 2, the investigator used a five-point Likert scale to ordinate the score for aquaphilia baseline (item 6) and education (item 7) and a four-point scale for income (item 9). For gender (item 8), female and male were coded 0 and 1, respectively. Each participant's birth year was subtracted from 2016 to calculate age (item 5). Environmental exposure was converted to days.

5.2 Sketch map evaluation protocol

Several studies utilized two independent raters to analyze sketch maps to establish inter-rater reliability for measures that could be influenced by subjective judgments (Ferguson & Hegarty, 1994; Maguire, Burke, Phillips, & Staunton, 1996; Quaiser-Pohl, Lehmann, & Eid, 2004). Independent raters without previous exposure to either the study or the eight cities were recruited for evaluating the identifiability of 55 sketch maps. These 55 sketch maps were presented in a randomized sequence in Qualtrics, an online survey platform, for comparison with eight city maps.

During the first sketch map survey, raters 1 and 2 were guided by written instructions to glance at the eight city maps for no longer than 10 seconds to determine whether they could recognize the city represented in each sketch map by answering item 1 in Table 3. The author assigned a code of 1 or 0 to this item when each sketch map was identified successfully or not, respectively, to generate the measure of uncolored map identifiability (UMI).

The author colored the water elements in the same 55 sketch maps in blue for evaluation by raters 3 and 4, who also had no previous exposure to the study or the eight cities. They were asked to scan eight city maps for no longer than 10 seconds to identify the city associated with each colored sketch map using item 1 in Table 3. The author then assigned a code of 1 for correct and 0 for incorrect and unsure identification of each sketch map to generate the measure for the variable of CMI.

Raters 3 and 4 were also asked to assess the extent to which blue features contributed to the identifiability of each map by answering item 2 in Table 3. The item assumed its three response categories as equally spaced points along a three-point Likert scale to generate scores for CW. The measure for WMI was generated by multiplying CMI with the CW.

5.3 Inter-rater reliability tests

The investigator calculated the intraclass correlation coefficients (ICCs) of all map identifiability measures in Table 3 in SPSS 24, using a two-way mixed model and an absolute agreement definition, as suggested by McGraw and Wong (1996), to assess how reliable these map identifiability measures were between raters. Along with the Cronbach's alpha as a commonly used inter-rater reliability indicator, SPSS provided the ICC average measure to assess the proportion of a variance attributable to judges for the average ratings of two independent raters.

ICC values between 0.60 and 0.74 are commonly cited as cutoffs for good inter-rater reliability (Cicchetti, 1994; Hallgren, 2012). Several studies used 0.6 as an acceptable ICC threshold (Baumgartner & Chung, 2001) and as an acceptable threshold for determining internal consistency reliability with Cronbach's alpha (Hume, Ball, & Salmon, 2006). As the lower bound of a reliability coefficient, Cronbach's alpha does not require measures of precision, such as confidence intervals (Cronbach, 1951). This study used 0.6 as the cut-off value for both ICC and Cronbach's alpha to qualify reliability between raters.

Table 3. Survey questions and coding schemes for map identifiability measures.

Descriptive Name	Variable	Colored sketch map survey items and coding schemes
uncolored/colored map identifiability	UMI[ac]/ CMI[bc]	1. This is a map of what city? □ Almere □ Amsterdam □ Berlin □ Bruges □ Ghent □ Giethoorn □ Hamburg □ Rotterdam □ Not Sure
contribution of water	CW[d]	2. To what extent do the map's blue features help you identify the city? □ Very much (3) □ Somewhat (2) □ Not (1)
water-based colored map identifiability	WMI	3. The contribution of water to correct colored map identification. Colored map identifiability (CMI) * contribution of water (CW)

a. For raters 1 and 2 during the first sketch map survey using uncolored sketch maps.
b. For raters 3 and 4 during the second sketch map survey using colored sketch maps.
c. Code 1 for correct or 0 for incorrect/unsure responses.
d. Assume response categories as equally spaced points along a Likert scale to generate scores as shown above in parentheses.

5.4 Generating final scores for UMI, CMI, and WMI

As there was sufficient inter-rater reliability, the UMI, CMI, and WMI scores were averaged between raters to generate the final scores for UMI, CMI, and WMI. Five participants confirmed that they were capable of drawing maps before the interviews. However, during the interview, they could not recall enough spatial information to draw sketch maps. As UMI, CMI, and WMI attempted to measure the extent to which a city was imageable to a participant, for these five participants, 0 was used as the final scores for these three sketch map identifiability variables.

5.5 Data reduction

This study used stepwise (both additive and subtractive) regression analyses to identify the final set of explanatory variables from the 15 waterscape attributes. The data reduction process tested all possible sequences in which the candidate variables could be added to or omitted from the regression models. A candidate variable was selected when its elimination from or addition to each model resulted in a significant change in models' F-values (Seber & Lee, 2012). This smaller pool of candidate variables was used for another round of stepwise (both additive and subtractive) regression analyses to test the model fit. The variables used for the best-fitting models were included in the final three regression models, along with six confounding variables.

5.6 Data preparation

To normalize the different scales used for age, length of stay, income, education or assumed map and informational exposure, and aquaphilia sensitivity baseline, their means were subtracted from the original values, and then the remaining values were divided with their means. For waterscape mappability, mappability, and attachment variables, the original values were used because they were derived from the same cognitive map recall protocol and coded with a consistent weighting method based on the sequence in which they were called.

5.7 Power analysis and sample size

Each of the regression models had a total of nine independent variables: the three waterscape attributes derived from the data reduction process and the six confounding variables identified by the literature review. A power analysis conducted in G*Power 3.1.9.2 suggested that the sample size (N = 60) provided sufficient power and a medium effect size (Cohen, 1992 [$d = 0.805 > .08$, $\alpha = 0.05$, $f2 = 0.31$]) for regression models with one dependent variable and nine independent variables.

6. RESULTS

6.1 Inter-rater reliability of sketch map identifiability measures

Both uncolored map identifiability (UMI) and colored map identifiability (CMI), were reliable ($\alpha_{UMI} = .7 > .6$, $ICC_{UMI} = .7 > .6$, $p_{UMI} < .001$; $\alpha_{CMI} = .7 > .6$, $ICC_{CMI} = .7 > .6$, $p_{CMI} < .001$). Acceptable inter-rater reliability was also observed for WMI (α_{WMI} = .7>.6, ICC_{WMI} = .7 > .6, p_{WMI} < .001). The results suggest that the ratings for UMI, CMI, and WMI did not significantly differ between the raters.

6.2 Final independent variables

Among the 15 waterscape attributes, the first set of stepwise regression analyses identified the following 10 potential explanatory variables that significantly contributed to the model fit: canal mappability, water landmark mappability, river mappability, lake mappability, harbor mappability, canal identifiability, water landmark identifiability, river identifiability, and harbor identifiability, and canal attachment. A second set of stepwise regression analyses were conducted using these 10 variables. The results indicated that the models with canal mappability, harbor mappability, and harbor identifiability had the highest fit. These three waterscape attributes were included with the six confounding variables as the independent variables in each of the three regression models with UMI, CMI, and WMI as dependent variables.

6.3 Descriptive statistics

Table 4 and Figure 1 show that most participants were between 20 and 33 years old; the average age was 35.5 years old (M = 35.5) with a standard deviation of about 15 years (SD = 14.92).

Table 4. Descriptive statistics of confounding variables.

Independent Variables	N	Minimum	Maximum	Mean (*M*)	Std. Deviation (*SD*)
Age	60	18	80	35.500	14.916
Gender	60	0	1	.650	.481
Income	60	1	4	2.480	1.186
Education	60	2	5	3.900	.969
Environmental exposure (day)	60	0	17885	2643.750	4273.905
Aquaphilia sensitivity baseline	60	3	5	4.150	.732

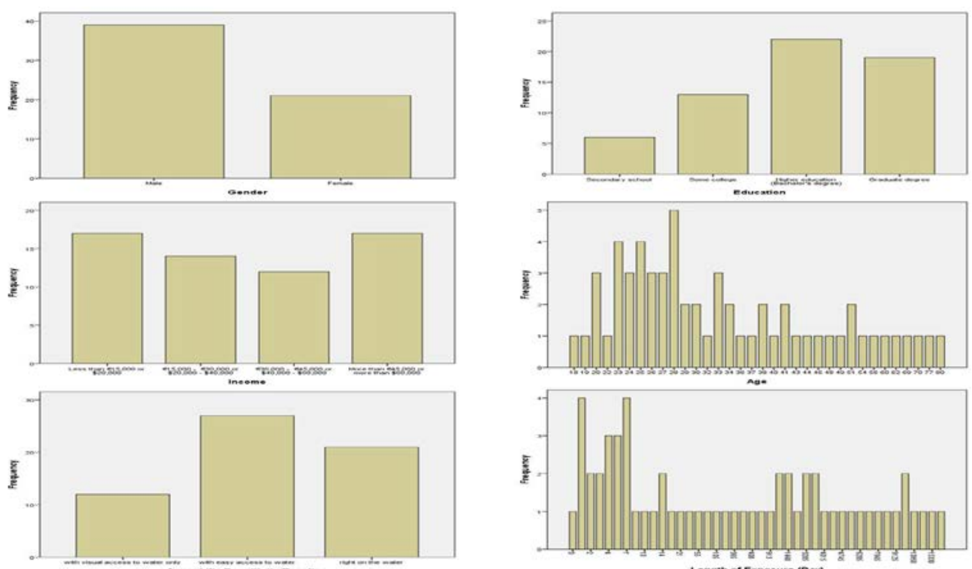

Figure 1. Frequency charts for confounding variables.

There were nearly twice as many male as female participants. The mean income for the sample is somewhere between €15,000–€30,000 and €30,000–€45,000. The participants' average level of education was slightly below higher education (bachelor's degree [M = 3.9, SD = .969]). Their average environmental exposure was 2,644 days with a standard deviation of 4,274 days. There is a cluster of participants with fewer than seven days of exposure. The other participants were rather evenly distributed across a wide range of environmental exposure, from seven to 17,885 days. On average, participants would like to live somewhere with easy access to water with a slightly upward trend toward living right on the water as opposed to having only visual access to water (*M* = 4.15; *SD* = .732).

6.4 Comparisons of regression analyses

WMI regression model had the highest model fit ($R_{WMI}^2 = .52$, $F_{WMI}[9, 50] = 6.05$, $p_{WMI} < .001$), followed by UMI ($R_{UMI}^2 = .47$, $F_{UMI}[9, 50] = 4.86$, $p_{UMI} < .001$) and CMI ($R_{CMI}^2 = .42$, $F_{CMI}[9, 50] = 3.93$, $p_{CMI} < .001$). Table 5 shows that canal mappability had the most significant positive influence on WMI ($\beta_{WMI} = .55$, $t_{WMI}[50] = 5.15$, $p_{WMI} < .001$), much less on UMI ($\beta_{UMI} = .47$, $t_{UMI}[51] = 4.21$, $p_{UMI} < .001$), and the least on CWI ($\beta_{CMI} = .45$, $t_{CMI}[51] = 3.86$, $p_{CMI} < .001$).

Table 5. Results of regression analyses.

	Unstandardized coefficients		Standardized coefficients			Collinearity statistics	
	B	std. error	β	*t*	*sig.*	tolerance	*VIF*
dependent variable: uncolored map identifiability (UMI)							
(constant)	.205	.162		1.266	.211		
gender	.017	.100	.019	.172	.864	.871	1.148
age	-.397	.134	-.385	-2.967	.005	.634	1.578
Income[a]	.129	.114	.142	1.134	.262	.680	1.471
Education[a]	.180	.208	.103	.866	.391	.752	1.329
aquaphilia sensitivity baseline[a]	-.609	.281	-.248	-2.164	.035	.812	1.231
environmental exposure[a]	-.002	.030	-.008	-.073	.942	.858	1.165
canal mappability	.076	.018	.473	4.209	.000	.844	1.185
harbor mappability	.038	.025	.207	1.481	.145	.547	1.828
harbor identifiability	-.058	.038	-.215	-1.525	.133	.535	1.869
.040							
- .076							
- .517							
.608							
.535							
1.869							
dependent variable: colored map identifiability (CMI)							
(constant)	.253	.171		1.483	.144		
gender	-.003	.105	-.004	-.031	.976	.871	1.148
Age[a]	-.029	.141	-.028	-.207	.837	.634	1.578
Income[a]	-.006	.120	-.007	-.051	.959	.680	1.471
Education[a]	.378	.219	.215	1.725	.091	.752	1.329
aquaphilia sensitivity baseline[a]	-.906	.297	-.366	-3.052	.004	.812	1.231
environmental exposure[a]	-.034	.032	-.127	-1.085	.283	.858	1.165
canal mappability	.073	.019	.454	3.859	.000	.844	1.185
harbor mappability	.023	.027	.123	.839	.405	.547	1.828

harbor identifiability	-.021	.040	-.076	-.517	.608	.535	1.869
.040							
- .076							
- .517							
.608							
.535							
1.869							
dependent variable: water-based map identifiability (WMI)							
(constant)	1.132	.337		3.359	.002		
gender	-.060	.237	-.027	-.254	.801	.871	1.148
age	-.191	.318	-.074	-.601	.551	.634	1.578
Income[a]	.045	.270	.020	.166	.869	.680	1.471
Education[a]	.783	.494	.179	1.586	.119	.752	1.329
aquaphilia sensitivity baseline[a]	-2.393	.669	-.388	-3.576	.001	.812	1.231
environmental exposure[a]	-.071	.071	-.106	-1.002	.321	.858	1.165
canal mappability	.221	.043	.549	5.152	.000	.844	1.185
harbor mappability	.085	.061	.186	1.408	.165	.547	1.828
harbor identifiability	-.048	.090	-.071	-.530	.599	.535	1.869
.040							
- .076							
- .517							
.608							
.535							
1.869							

a. Normalized by subtracting means from original values and then dividing the results with means.

Among the six confounding variables, aquaphilia sensitivity baseline had the most significantly negative contribution to WMI ($\beta_{WMI} = -.39$, $t_{WMI}[50] = -3.58$, $p_{WMI} < .001$), closely followed by CMI ($\beta_{CMI} = -.37$, $t_{CMI}[50] = -3.05$, $p_{CMI} < .01$), and much less for UMI ($\beta_{UMI} = -.25$, $t_{UMI}[50] = -2.16$, $p_{UMI} < .05$). Age had a significant negative effect on UMI ($\beta_{UMI} = -.39$, $t_{UMI}[50] = -2.97$, $p_{UMI} < .01$). Education or implied map and informational exposure had a marginally significant positive influence on CMI ($\beta_{CMI} = .22$, $t_{CMI}[50] = 1.73$, $p_{CMI} < .1$).

6.5 Regression Diagnostics

The models did not have serious multicollinearity problems because Table 5 shows that all tolerances were greater than 0.2, and all variance inflation factor (VIF) values were less than 5 (O'brien, 2007). Figure 2 indicates that the models did not violate the normality assumption for multiple regressions. Specifically, the regression standardized residuals followed a fairly normal distribution in the histograms and stayed fairly close to the reference line in the normal P-P plots. However, the scatterplots for all three models had a negative linear trend. The linear trend suggests that the models could have been improved with additional variables with a significantly negative influence on the map identifiability measures. Among all three models, the one using WMI as the dependent variable had best model fit, the least pronounced linear trend, and the most random scatterplot pattern. This suggests that accounting for the extent to which water contributed to map identification helped improve the model.

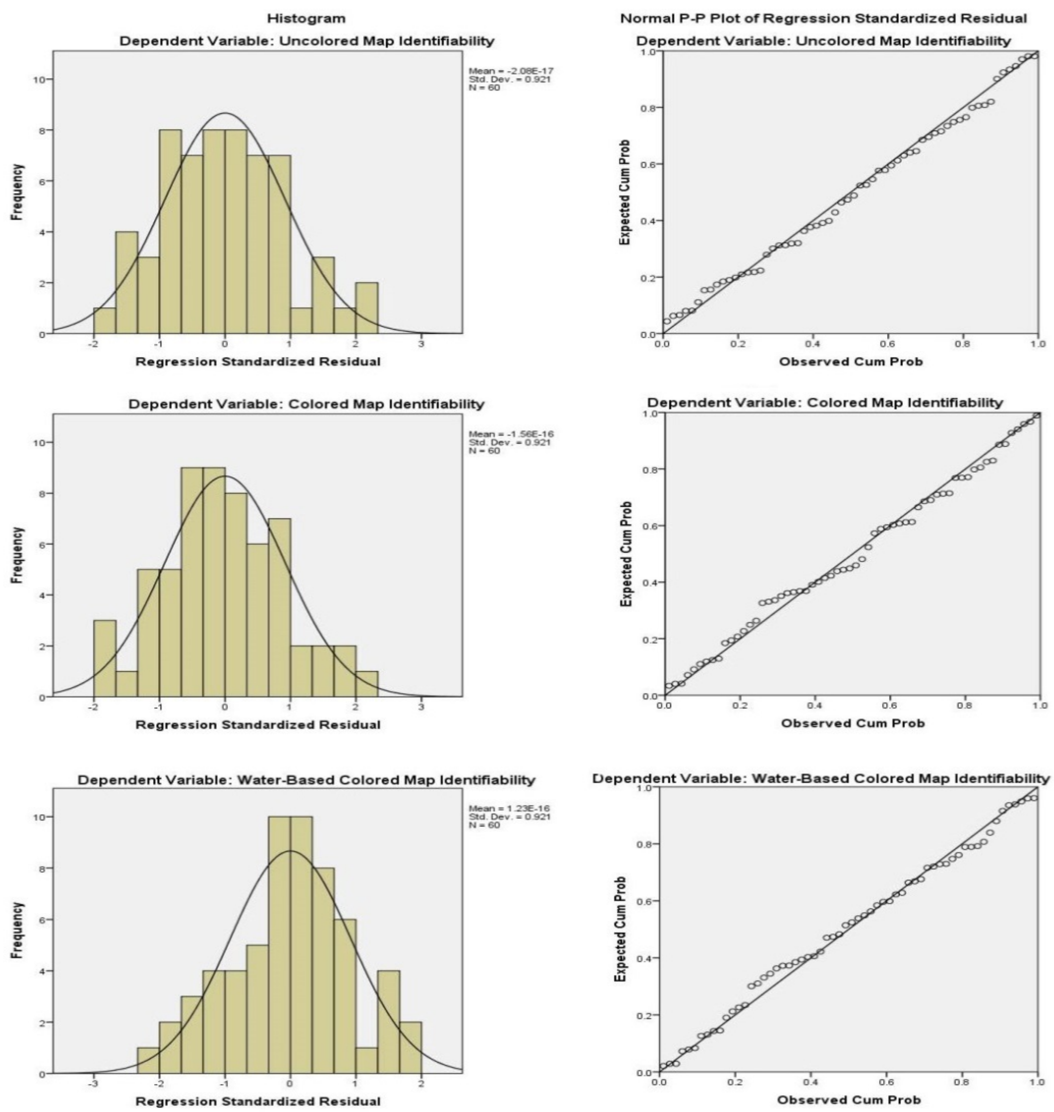

Figure 2. Histograms and P-P Plots for UMI, CMI, and WMI as dependent variables.

7 DISCUSSION

7.1 Differentiating aquaphilia from aquaphobia

A water city was more imageable to participants with less desire to be close to water. Several participants who preferred to have only visual access to water, as opposed to living right on the water or with physical access to water, mentioned they could not swim or were afraid of water. The findings suggest that fear of water might have contributed to the saliency of water elements in participants' cognitive maps. A more clear distinction between aquaphilia and aquaphobia may be necessary in future studies.

7.2 Including psychophysiological baselines in spatial cognition studies

Participants who sought a greater proximity to water might have relied on water to a greater extent for different reasons, such as stress reduction or emotional regulation. As both arousal and emotion have been found to affect spatial abilities (Brunyé, Mahoney, Augustyn, & Taylor, 2009), future studies may investigate whether participants' familiarity with water or less arousal-resilient psychophysiological baseline might have been potential explanatory variables for their less legible sketch maps.

7.3 Studying the interactions between imageability elements and water

A more direct investigation of the relationships between cognitive forms and aquaphilia will be important for confirming whether water-based imageability is entirely independent of or does interact with the five conventional imageability elements. If such interactions do exist, the extent to which water contributes to the saliency of the five imageability elements in cognitive maps will require further investigation. This investigation may involve studying aquaphilia as the extent to which water helps with stress reduction or emotional regulation on smaller sites, such as plazas and parks, possibly through recording environmental experience, eye-tracking data, and psychophysiological measurements. In addition to measuring participants' psychophysiological baselines, researchers should obtain pre- and postexperience behavioral measures using the same cognitive mapping, photovoice, and emotional recall measures for triangulation. By simultaneously recording participants' psychophysiological measurements and eye-tracking data, researchers can better differentiate changes in psychophysiological measurements due to visual fixations on water-based versus non-water-based environmental features. By triangulating this data with cognitive mapping, photovoice, and emotional recall measures, it may be possible to better understand the relative contributions of water and cognitive forms to the recall sequences of environmental features.

7.4 Designing a wayfinding-enabling city for a pluralistic society through water

Consistent with Kirasic's (2000) finding, older participants had significantly fewer identifiable sketch maps when they were not colored. After the sketch maps were colored, better-educated participants, with a marginal statistical significance, had more identifiable colored sketch maps. Education was used as a proxy for measuring participants' exposure to maps and other informational sources about the city. It is possible that participants' greater exposure to colored maps or other informational sources might have a marginally significant correlation with their ability to draw identifiable sketch maps using water elements that were colored blue on colored maps. However, when the CW to map identifiability was factored into water-based colored map identifiability as a weight, none of the confounding variables had significant effects on water-based map identifiability. The findings suggest that water elements might be more cognitively powerful than the conventional elements of imageability. Specifically, water elements could potentially mediate differences in spatial comprehension among different populations, which are, for this particular sample, age groups and groups with different levels of exposure to maps and other informational sources. Future studies may consider the use of mediation analyses to see if salient canal structure mediates the differences in sketch map identifiability among various groups to enable spatially challenged populations to obtain the same level of spatial comprehension.

7.5 Designing for waterscape visibility

Figure 3 shows that the sketch maps from Amsterdam participants were more homogeneous than those from Berlin participants. Tourists with only days of exposure to Amsterdam developed an image of Amsterdam that was rather comparable to mental images from residents who had lived in the city for years. Even residents with years of exposure to Berlin did not have consistent images of Berlin. Both cities have attractive canals frequented by tourists and residents. However, the canals in Amsterdam are highly visible from the street because they are mostly within the right-of-ways, with little freeboard. In contrast, the canals in Berlin tend to be bordered by parks or the backs of public facilities. When they are located within the right-of-ways, they are rarely visible from the street due to their much lower elevation than the street level. The locations of canals and the extent of their freeboard may be critical factors to consider for examining how to make canals more salient eye-level scenes.

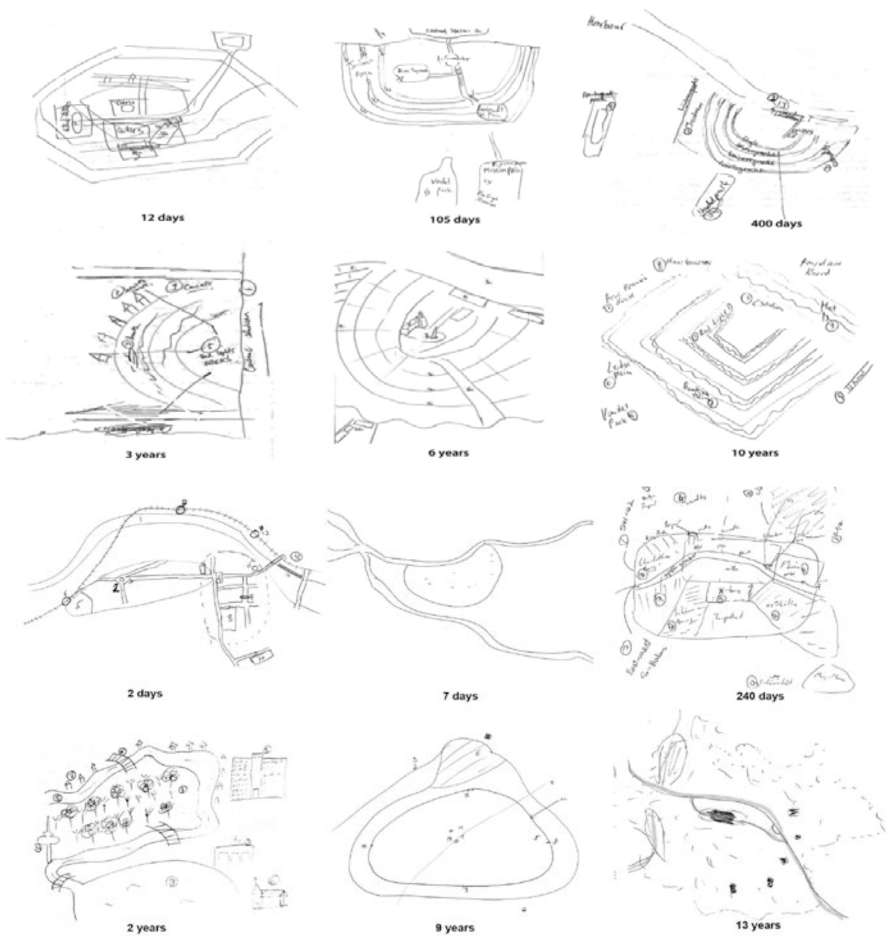

Figure 3. Sketch maps from participants sampled in Amsterdam (top 6) and Berlin (bottom 6).

7.6 Creating imageable cities with salient canal structures

All three models revealed that the earlier and the more frequently canal structures emerged in participants' sketch maps, the easier it was to identify the cities represented by these sketch maps. In the case of cities similar to Venice and Dutch polder cities, structure and path were the imageability component and element with significant positive influences on the participants' mental image of the city. The findings suggest that introducing waterscapes as linear paths that form a salient structure in cognitive maps can significantly improve residents' and visitors' mental image of the city.

7.7 Aligning the city resilient movement with the city beautiful movement

Urban waterways, including daylit streams and canals, have been proposed for many coastal cities, such as Copenhagen, Oslo, Boston, New York, and New Orleans, as mitigation and adaptation strategies for the impacts of climate change and sea level rise (Backhaus & Fryd, 2012; Jacob, 2014; Ross, 2014; Ruggeri, 2015; Waggonner & Ball, 2013). This emerging city resilient movement in coastal cities could potentially be a renaissance of the city beautiful movement to engender more alluring water cities like Venice and the Dutch polder cities. This potential synergy requires engineers and designers to engage in a dialogue on how to maximize these waterways' hydrological and aesthetic performances through the use of an intentional citywide structure to organize these waterways. This study has demonstrated that cognitive mapping could be a helpful tool for identifying salient canal structures as inspiration for cities in the process of reintroducing water into their urban fabrics to better address the impacts of climate change and rise in sea level.

7.8 Mainstreaming the city resilient movement through the city beautiful movement

Compared to downstream, upstream water retention is more cost-effective for mitigating flood risks downstream (Hartmann, 2009). However, upstream cities are not as motivated to participate in water retention if flooding is not an immanent issue. As all reservoir sites have been put to use (Sahagian, 2000), water-based imageability may help encourage upstream water retention within the public realm through a revival of the city beautiful movement. For example, the Riverwalk in San Antonio, the Bricktown Canal in Oklahoma City, and the Canal Walk in Indianapolis are extremely successful downtown revitalization projects. However, they are rather limited in their geographic extents and hydrological performances. These canal projects could potentially be expanded into citywide networks and retrofitted with smart water systems. The smart water systems can be wirelessly connected with weather stations to discharge water from the canals before large storm events to maximize their water retention capacities. They can also help dispatch water within the networks to facilitate coordination between various decentralized water reuse projects. Creating imageable inland cities through citywide water networks could help these cities become better prepared in the face of more intense rainfalls and more sustained droughts as impacts of climate change. Furthermore, this approach promotes a growing trend in upstream water retention within urban fabrics to help reduce downstream flood risks for coastal cities, which are the most vulnerable to the impacts of climate change and rise in sea level.

8 CONCLUSION

The study can be poetically concluded in Dreiseitl's words in the preface for *Recent Waterscape* (Dreiseitl, 2009):

> Coping with ever greater amounts of stormwater run-off from increased urbanization and fierce heavy downpours does not mean endlessly multiplying the number and capacity of technical facilities. . . . Rather, the networking of the city structure as an interactive infrastructure, publicly visible and also aesthetically attractive, is needed. The next generation of networked city infrastructures is habitat, urban and recreational space all in one while at the same time fulling a structural function. (p. 9)

Lynch's (1960) definition of imageability, a pattern of high continuity with distinctive yet interconnected parts, has parallels in many fields, including the notion of mosaics composed of continuous corridors with interconnected patches in landscape ecology (Dramstad, Olson, & Forman, 1996) and the use of smart grid to network decentralized infrastructures at the district level (Sood, Fischer, Eklund, & Brown, 2009). The greenway literature utilizes connectivity as a similar system-based concept that helps enhance the well-being of humans and wildlife (Searns, 1995; Shafer, Scott, & Mixon, 2000). Waterways have also been proven to help stimulate economy, encourage tourism, and promote compact developments (Wagner, 2007). In addition to being conducive to compact developments and connectivity, such imageable water-based structure has also been regarded as the most resilient urban form for responding to the impacts of climate change (Hamin & Gurran, 2009). An imageable citywide network of blue parkways has tremendous potential to enhance a city's infrastructural, aesthetic, recreational, ecological, and economic performance in an age of climate change and rise in sea level.

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