DISTANCE COGNITION AFFECTED BY URBAN VEGETATION: INVESTIGATION AT PERSPECTIVE AND ROUTE KNOWLEDGE LEVEL

Ganga N. SAMARASEKARA[1], Kiyotaka FUKAHORI[2] and Yoichi KUBOTA[3]

[1]Graduate student, Dept. of Environmental Science and Technology, Saitama University
(255,Shimo-ookubo, Sakura-ku, Saitama-shi, Saitama-ken 338-8570, Japan)
E-mail:ganganlk@yahoo.com
[2]Member of JSCE, Asso. Professor, Division of Environmental Science and Infrastructure Eng., Saitama University
(255,Shimo-ookubo, Sakura-ku, Saitama-shi, Saitama-ken 338-8570, Japan)
E-mail: fukahori@post.saitama-u.ac.jp
[3] Member of JSCE, Professor, Division of Environmental Science and Infrastructure Eng., Saitama University
(255,Shimo-ookubo, Sakura-ku, Saitama-shi, Saitama-ken 338-8570, Japan)
E-mail: y1kubota@env.gse.saitama-u.ac.jp

Greenery in the urban space brings about a range of positive impacts such as economical, environmental or psychological. Human health implications related to urban greenery include the restorative benefits or the creation of spaces for physical activities such as walkable communities. Yet vegetating a non-vegetated setting can bring about changes to the urban form, which in turn could affect our spatial cognitive systems. The work presented here attempts to evaluate how the presence of linear vegetation in urban streets affects human distance cognition at perspective knowledge level and at route knowledge level. The results showed that presence of vegetation affected the perspective distance, while the distance cognition at route knowledge level was not affected. Further in relation to perspective distance increased spacing of trees lead to increase of perspective distance while the changes to tree species, growth stage or canopy status variation in between summer and winter status did not yield any such difference.

Key Words: *Cognitive Distance, Perspective Distance, Urban Vegetation, Route Knowledge, Spatial Cognition*

1. INTRODUCTION

(1)Psychological effects of urban vegetation

Vegetation presence in urban space could change the way people perceive the space. Such a change could in turn affect human behavior on urban space and spatial usage. Thus studying how the presence of vegetation in the urban space affects the human cognitive systems could be important in predicting human behavior as well as the usage in urban space.

The ways in which human's cognize vegetation presence could differ from one cognitive system to another. As an example, the presence of bushes in certain settings may not affect sense of safety while negatively affecting preference. Human behavioral decisions results from a series of complex information processing that take place within multiple cognitive systems. Although the relative dominance of each cognitive system on ultimate behavioral decisions could be case dependent, knowledge about effects on each cognitive system could be important in understanding the final outcome. Previous work has extensively studied about vegetation impacts on other cognitive systems. Need to study the effect of greenery on human spatial representation systems has been suggested in several occasions[1)], though work are still few. Work of Sheets & Manzer[2)]and Evans et al.[3)] are some of the few. This work is a part of a detail study that investigates effects of urban vegetation on spatial cognition.

Mere presence of vegetation on urban space changes the urban form, thereby affecting spatial understanding. For designers, vegetation is a tool to improve aesthetical appearance and to alter spatial relations of urban space. According to Arnold[4)] urban trees organize the space through visual suggestion and illusion. In viewing space from ground the feeling of enclosure could be created by the trees that intercept the cone of vision. Among the skyscrapers of urban space, tree canopies act as virtual ceilings to bring the city scale down to a comprehensible level.

(2)Research framework: Spatial knowledge on a developmental perspective

a)Landmark, Route and Survey Knowledge

According to Hart and Moore[5] human environment knowledge on a developmental perspective consists of three knowledge levels, namely landmark knowledge, route knowledge and survey knowledge. In the first level people acquire information about landmarks, which are discrete features of the environment. Landmarks act as reference points for the subsequent processes of spatial knowledge acquisition, storage, processing and retrieval. With increased exposure to the environment route knowledge starts to form, where the landmarks previously learnt are connected sequentially through the paths traversed. Though the initial stages of route knowledge formation is mostly confined to the sequence of landmarks or information about those points at which important navigational decisions are taken during a route traversing exercise[6], the knowledge on spatial relations among landmarks could be formed at higher levels of route knowledge. On the next level, survey knowledge is formed through the accumulation of route knowledge. At this level an understanding of the environment configuration along with metric relations is possessed[6]. Navigational tasks such as finding a short cut or an alternative route are generally executed utilizing survey knowledge.

b)Perspective Knowledge: Direct knowledge acquisition

Among various sources of spatial knowledge acquisition, direct environmental experience stands first. While a range of information cues provides input for such knowledge acquisition, information on a perspective view accounts for the majority of input. Allen at el.[7] in their framework describing the relationship between perceptual context and development of spatial representations, discussed the importance of visual context for the development of landmark and route knowledge. Accordingly, acquisition of spatial knowledge begins by perceiving landmarks and repeated visual experience permits a refined calibration of temporal-spatial relations among features and thereby improving the accuracy of cognitive representation. While their work was mainly focused on post processing of accumulated perceptual information to attain spatial knowledge, a perspective view itself can become a source for direct spatial knowledge acquisition based on prevailing circumstances. Judging distance to, or orientation of a newly encountered intersection while standing a few hundred meters away could be an example in this respect.

In relation to the distance and direction cognition some authors distinguish the knowledge in between its cognitive and perspective components. Such distinction is done based on the two factors, inter-point visibility and whether the observer moves in between the two points or not[8]. In this context, cognitive distance refers to the people's belief about distances between places in large-scale space, places which are far apart and obscured so as not to be visible from each other[9]. The perspective distance on the other hand refers to the people's idea about distances between places, which are visible from each other and are in sight during the estimation procedure[7]. Thus in considering the spatial knowledge on a developmental perspective in addition to considering the cognized component in terms of landmark, route and survey knowledge, the authors identify the need to treat the non-cognized direct perspective component separately.

(3)Research scope and related work

The work presented here is a part of an investigation that aims to clarify the effect of vegetation on spatial cognition due to its presence and design parameter variation. The whole study is based on the framework of spatial knowledge development as described above. Evans et al.[3] found that areas with landscaped elements were well represented in cognitive maps, showing the effect of vegetation for the formation of landmark knowledge. How the presence of trees could affect spatial knowledge at other levels of spatial knowledge is yet unclear. Addressing such a gap, this work intends to investigate how the introduction of vegetation in urban streets can affect the human spatial cognition at perspective knowledge level and route knowledge level. In relation to the type of cognitive representation, the present work is confined to distance cognition. People use of distance cognition for a range of navigational decisions on destination, travel mode or even in deciding whether to go or not.

While the effect of vegetation on human cognitive systems has been researched extensively, the effect of vegetation design characteristics such as tree species[10], canopy status[11], tree density[12], leaf texture[13] have also been studied specially with relation to different cognitive processes. Thus it could be important to clarify the possible impacts of variation of vegetation design parameters on spatial representation. Therefore in addition to studying the effect of introducing vegetation, the effect of vegetation design parameter variation was also considered at perspective knowledge level.

In investigating the above, the authors carried out two experiments to check the effect of vegetation on distance cognition at perspective knowledge level and at route knowledge level. In each of the experiment the subjective distance evaluations related to set of distances of a simulated urban street network was obtained both at vegetated and non-vegetated status. Further, in Experiment I vegetation design parameters were systematically varied. This facilitated the investigation, on how the variation of the tree spacing, growth stage, tree species and the canopy status could ultimately affect the distance cognition. To simulate characteristics that corresponded to perspective knowledge level, a photo simulation method was employed, where the exposure had to be limited to one static view. Route knowledge evaluation on the other hand employed two guided tours along a preset path of a virtually simulated street network. This allowed a dynamic but limited exposure to the environment that could represent a suitable route knowledge development.

(4)Usage of Computer Graphics(CG)

The usage of CG is for researches increasing gradually[13) &14)]. This is mainly due to the flexibility offered by such to attain experimental conditions that are difficult in real conditions, as faced in this research. Such simulations often use two-dimensional displays to present experimental stimuli. Both simulation of complex conditions of the real environment using computer graphics and the substitution of three-dimensional reality by a two dimensional display introduces errors to the outcomes, the severity of which would vary based on particular experiment. Careful experimental design offers some flexibility to overcome such errors to certain extent. Experimental design of this study was done in such a way to obtain the results from a paired comparison in between vegetated and non-vegetated condition, where by bias related to simulation equally operated on both conditions.

2. EXPERIMENT I

(1)Experimental Hypotheses

Hypothesis I: Introduction of trees to street network would change the perspective distance judgment in comparison to the non-vegetated condition.

Hypothesis II: Perspective distance judgment would differ with the variations in design parameters governing the tree design. Variation of the design parameters tree spacing, tree species, growth stage and canopy status (summer canopy Vs winter canopy) were considered in this relation.

(2)Materials and Methods

Subjects: Nineteen students (14 males & 5 females) of Saitama University voluntarily participated in the experiment (Average age 26 years).

Stimuli: In order to evaluate perspective distance judgment, where the stimuli had to facilitate the visibility of both evaluation points simultaneously without walking in between the points, photo simulated stimuli were used. The experiment was carried out using 72 photo simulated street images belonging to 9 different streets, each showing a 200m long typical Japanese residential street. The factors Growth Stage and Spacing were simulated in three levels. Species Ginko, Zelkova and Sakura (in their summer canopy status) represented three levels of species factor along with a bare canopied status of Zelkova tree representing the winter status (**Fig. 1** & **Table 1**). Information from real site observations, design guidelines, details of the nursery owners and street tree maintainers were used in deciding the tree heights and canopy sizes. The resultant 36 vegetation arrangements were used to derive the vegetated conditions. For each of such vegetated street, a corresponding non-vegetated condition was obtained by removing the vegetation while maintaining the other conditions same, thus making up 72 photos. For each condition the first photo showed non-vegetated condition (reference photo) while the second one showed the vegetated (judgment photo) condition of the same street. Tree images were generated using a tree simulating software while the street images were generated using visualization software. With the use of a photo retouch software, the foresaid images of trees and streets were merged to produce the final stimuli depicting a viewpoint from the middle of the road.

Method: The experiment consisted of two phases. In the first phase the non-vegetated picture condition was shown first for 10 seconds within which the participants were asked to judge the distance to a sign shown in the photo. Thereafter the judgment photo was shown for 30 seconds within which the respondents judged distances to each of the two signs in that photo and mark those distances in the evaluation sheet. The two signs represented distances belonging two objective distance ranges (range A=20m-35m; range B=50m-65m). The evaluation sheet consisted of two straight lines depicting the reference and judgment road conditions. Respondents marked judgment distances by referring to the first condition (no meter scale was provided).

Second phase was conducted to evaluate the respondents` subjective idea of distance for a given objective distance. In this phase, subjects were presented only with those pictures showing the non-vegetated condition (the same pictures as used in the phase one) of each of the 9 streets for 15 seconds. Within the given time the participants judged the distance to the sign marked on the photo in terms of meters and marked it on the evaluation sheet. In each of the phases the photos were presented in a random order. Images were projected on to a screen and viewing distance from the screen was adjusted so as to ensure a 60° view angle at the ideal seating position. Since the subjects were tested in pairs, their seating position was slightly shifted from the ideal position interms of distance parallel to the screen. They were instructed to use their intuitive judgements in judging the distances and to avoid the usage of road geometry to calculate distance. The post experiment questionnaire revealed the adherence to such instructions. Exposure time was decided allowing sufficient, yet not too long time for distance judgment and marking. Also in both phases, participants were allowed to do several trials at the beginning, until they were confident about marking.

(3)Data Analysis

Data

Mj_i- Distance judgment of i^{th} judgment street as marked in paper averaged over 19 subjects

MJ_i- Objective distance of of i^{th} judgment street (as used in the visualization software)

Mr_i- Distance judgment of i^{th} reference street as marked on the paper averaged over 19 subjects

Mr_{is}- Distance judgment of i^{th} reference street in meters averaged over 19 subjects

MR_i- Objective distance of i^{th} Reference Street

Analysis for Hypothesis I: Subjective distance judgment of vegetated condition (Mj_i) was plotted against the Subjective distance Judgment of non-vegetated condition (Mr_i*MJ_i/MR_i) (in terms of lengths marked on paper). Least square regression line for data was plotted. Research hypothesis was tested by statistically testing the coincidence of least square regression line with line $Y = X$.

Analysis for Hypothesis II: The data analysis was done by relating a particular subjective distance judgment to the corresponding objective distance

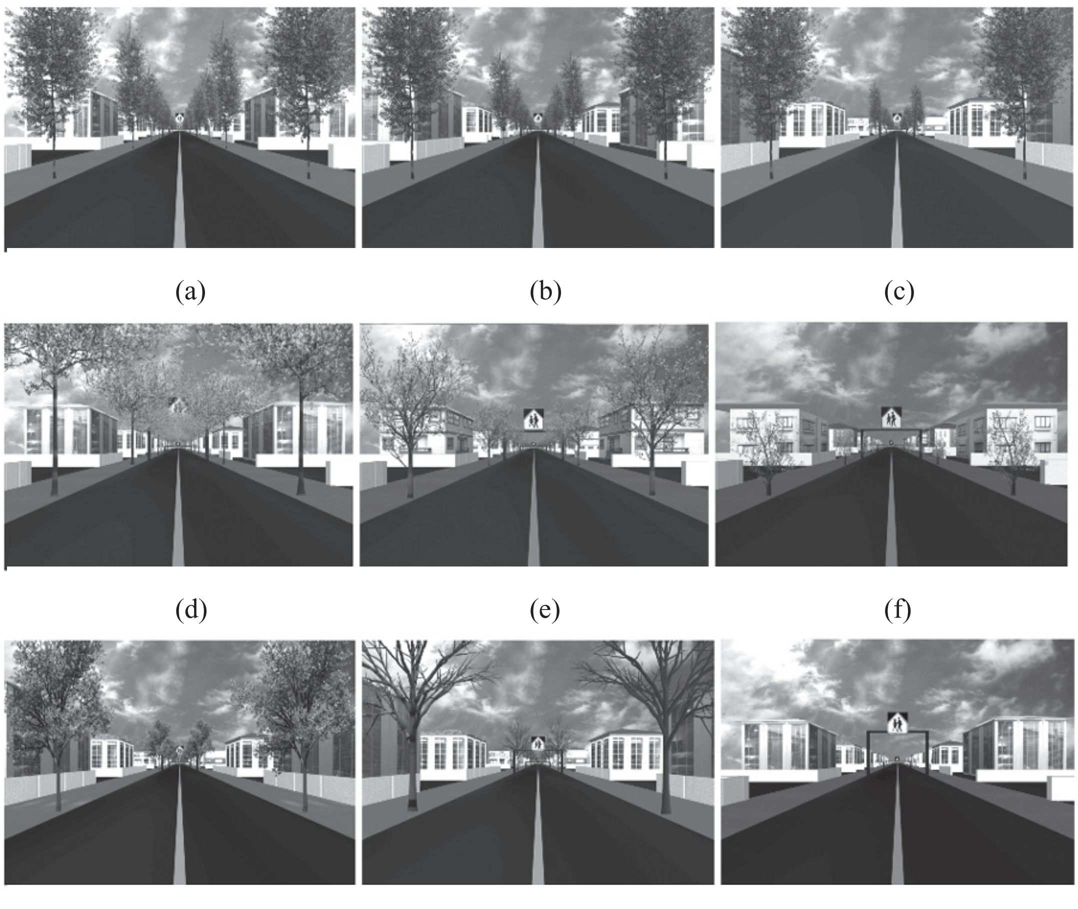


Fig. 1 Stimuli used (a) G, G1, S1; (b) G, G1, S2; (c) G, G1, S3; (d) S, G1, S3; (e) S, G2, S3; (f) S, G3, S3; (g) Z, G1, S3; (h) W, G1, S3; (i) Reference photo (non-vegetated) condition; (G-Ginko, Z-Zelkova, W-Winter Canopy, S-Sakura; G1-Fully Grown, G2-Middle Grown, G3-Young 3; S1-10m Spacing, S2-15m Spacing, S3-30m Spacing)

Table 2. Summary of Regression analysis, Runs Test and Test for one Unified Model for Experiment I & II

		Experiment I												Experiment II	
		Growth Stage			Spacing			Species				Canopy Status		Non-vegetated	Vegetated
		G1	G2	G3	S1	S2	S3	G	Z	W	S	S´(Summer)	W´(Winter)		
Regression Analysis															
Coefficient of determination(r2)	*Linear*	0.881	0.956	0.959	0.962	0.983	0.976	0.898	0.888	0.972	0.959	0.888	0.972	0.945	0.792
	Power	0.892	0.962	0.953	0.967	0.983	0.976	0.919	0.918	0.981	0.961	0.918	0.981	0.926	0.814
Standard error of estimate	*Linear*	9.409	5.678	5.497	4.750	3.562	4.385	3.339	4.258	1.955	2.245	4.258	1.955	0.114	0.095
	Power	9.505	5.888	5.592	12.077	3.726	4.809	3.146	4.071	1.756	2.073	4.071	1.756	0.117	0.092
Regression Intercept(a)	*Linear*	11.179	10.133	8.883	8.349	10.821	11.025	12.853	10.306	10.246	9.211	10.306	10.246	0.156	0.348
	Power	3.582	3.503	3.136	2.856	3.574	3.854	3.740	3.423	3.936	3.966	3.423	3.936	0.959	1.058
Regression Coefficient(b)	*Linear*	1.598	1.644	1.667	1.498	1.678	1.733	1.067	1.153	1.144	1.135	1.153	1.144	0.797	0.699
	Power	0.826	0.836	0.864	0.862	0.838	0.826	0.734	0.760	0.717	0.703	0.760	0.717	0.854	0.677
Standard Error of Regression Coefficient	*Linear*	0.125	0.076	0.073	0.063	0.047	0.058	0.077	0.102	0.049	0.058	0.102	0.049	0.090	0.147
	Power	0.127	0.078	0.074	0.161	0.050	0.064	0.072	0.098	0.031	0.037	0.098	0.031	0.093	0.142
t Value	*Linear*	12.755	21.738	22.765	23.680	35.360	29.678	13.901	11.250	23.522	19.698	11.250	23.522	8.805	4.758
	Power	6.594	11.058	11.806	13.632	17.667	14.147	9.560	7.415	14.733	12.203	7.415	14.733	9.434	4.609
p value (signinficance level)	*Linear*	6.E-12	8.E-17	3.E-17	1.E-17	1.E-21	8.E-20	1.E-12	3.E-09	2.E-14	4.E-13	3.E-09	2.E-14	5.E-05	2.E-03
	Power	1.E-06	1.E-10	3.E-11	2.E-12	7.E-15	8.E-13	2.E-09	1.E-06	4.E-11	8.E-10	1.E-06	4.E-11	3.E-05	2.E-03
Runs Test															
Number of runs	*Linear*	16	16	15	16	15	14	7	6	6	8	6	6	6	3
	Power	16	15	15	15	15	14	6	8	8	8	8	8	6	3
p value	*Linear*	0.952	0.952	0.850	0.936	0.860	0.784	0.109	0.048	0.048	0.251	0.048	0.048	0.9286	0.1429
	Power	0.952	0.889	0.850	0.889	0.860	0.784	0.060	0.238	0.251	0.251	0.238	0.251	0.8857	0.2857
Deviation from the straight line	*Linear*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	S.	S.	N.S.	S.	S.	N.S.	N.S.
	Power	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Test for One Unified Model															
P value	*Linear*	0.977			p<0.0001			0.670				0.9695		0.2331	
	Power	0.978			p<0.0001			0.701				0.9122		0.1914	
Fvalue	*Linear*	0.1338(4,66)			29.54(4,66)			0.6757(4,64)				0.0314(2,32)		1.648(2,12)	
	Power	0.1117(4,66)			27.83(4,66)			0.6358(4,64)				0.09216(2,32)		1.904(2,12)	
Rejection of Ho		D.N.R Ho			Reject Ho			D.N.R Ho				D.N.R Ho		D.N.R Ho	

N.S.-Not Significant　*S-Significant*　*D.N.R Ho- Do Not Reject Ho* judgment. The relationship between a particular cognitive distance and the corresponding objective distance was investigated in terms of two commonly used functions. In addition to the linear function, Stevens's [15] power function that has a wide acceptance to describe the above relationship has been used in this relation (Briggs[16]).

Linear Function

$$Y = a + bX \quad (1)$$

Power Function

$$Y = aX^b \quad (2)$$

Where Y = Subjective Distance, X = Objective distance, and a & b are constants

Spacing, Subjective distance (Mj_i*Mr_{is}/Mr_i) was for the analysis of the factors Growth Stage and plotted against Objective distance (MJ_i) (in terms of lengths in the real environment). For the analysis of Species factor, Subjective distance (Mj_i) was plotted against Objective distance (MJ_i*Mr_i/Mr_{is}) (in terms of lengths marked on the paper). The least square regression lines were plotted for both linear and power functions. Using the regression analysis, the values of constants *a* and *b* were established.

The goodness of fit was checked through coefficient of determination (r^2) and by testing the regression coefficient *(b)* for being significantly different from zero *($t = b/\sqrt{(s^2/\Sigma(u-\bar{u})^2)}$); s= standard error of the estimate, u= objective distance, ū = Mean of objective distance)* for both functions (**Table 2**). In addition Runs Test was done to examine whether such regression lines systematically deviate from the data. The effect due to variation of each design parameter was tested considering the applicability of one unified least square regression model against the usage of multiple models for data belonging to each levels of the a particular design parameter.

(4)Results

Hypothesis I: The null hypothesis that the introduction of vegetation would not change the subjective distance judgment of the respondents was tested. Accordingly the data of the plot Subjective distance (vegetated) versus Subjective distance (non-vegetated) should have yielded a $Y = X$ relationship.(**Fig. 2**) The linear regression model yielded $Y = 8.721 + 0.8511X$. The null hypothesis was rejected significantly ($p < 0.001$). Thus the results suggest that the introduction of vegetation has changed the subjective distance judgment significantly. In order to investigate whether such introduction would lead to overestimation or underestimation, the authors conducted a simple test by considering the number of data points below and above the $Y = X$ line. Out of 72 data points 61 points (84.72%) were above the line $Y = X$ and while 11 points (15.28%) were below the line $Y = X$. These results suggest that the vegetation introduction has lead to an overestimation of subjective distance.

Hypothesis IIa – Effect of Growth Stage: *The goodness of fit of regression lines:* Both linear and power functions well described the data of all 3-growth stages (**Table 2**). Both r^2 value and statistical test on regression coefficients *b* revealed the existence of highly significant correlation for both functions for all growth stages. The Runs Test indicated that the deviation of data from the regression models were not significant.

Effect of growth stage on cognitive distance: The null hypothesis that data belonging to all three growth stages could be explained by one regression curve was tested against alternative hypothesis of usage of different curves to describe data. For both power and linear functions, the data did not reject the null hypothesis implying that three data sets did not support different curves. Thus results suggest that the different growth stages would not induce different cognitive distances.

Hypothesis IIb– Effect of Spacing of trees: *The goodness of fit of regression lines:* Both linear and power functions well described the data of all 3 tree spacing (**Table 2**). Both r^2 value and statistical test on regression coefficients *b* revealed the existence of highly significant correlation for both functions for all three spacing. Runs Test indicated that the deviation of data from the regression models were not significant.

Effect of spacing on cognitive distance: The null hypothesis that data belonging to all three levels of tree spacing could be explained by one regression curve was tested against alternative hypothesis of usage of different curves to describe data. For both power and linear functions, the data rejected the null hypothesis implying that three data sets supported different curves ($p<0.0001$). Thus results suggest that for a given objective distance different tree spacing would induce different cognitive distances. The magnitude to regression coefficient *b* increased with the increase in spacing. This implies that for a given objective distance the trees when spaced far apart would induces longer cognitive distance values than when they are spaced relatively closer.

Hypothesis IIc – Effect of tree species: *The goodness of fit of regression lines: Both* linear and power functions well described the data of all 4 types (**Table 2**). Both r^2 value and statistical test on regression coefficients *b* revealed the existence of highly significant correlation for both functions for all 4 types. The Runs Test indicated that the deviations of data from the regression models were not significant for tree species Ginko and Sakura for both linear and power functions. The two canopy forms of the Zelkova species (summer canopy and winter canopy) showed significant deviation from the linear model while the deviations from the power model were not significant.

Effect of tree species on cognitive distance: The null hypothesis that data belonging to four species types could be explained by one regression curve was tested against alternative hypothesis of usage of different curves to describe data. For both power and linear functions, the data did not reject the null hypothesis implying that four data sets did not support different curves. Thus it is suggested that different tree species would not induce different cognitive distances.

Hypothesis IId – Effect of canopy status: *The goodness of fit of regression lines:* Both linear and power functions well described the data of both summer and winter canopy status (**Table 2**). Both r^2 value and statistical test on regression coefficients b revealed the existence of highly significant correlation for both functions of the two canopy status. The Runs Test indicated that the deviation of data from the regression models were not significant for power model but significant for linear model.

Effect of canopy status on cognitive distance: The null hypothesis that data belonging to both canopy statuses could be explained by one regression curve was tested against alternative hypothesis of usage of different curves to describe data. For both power and linear functions data did not reject the null hypothesis implying that three data sets did not support different curves. Thus different canopy status would not induce different cognitive distances.

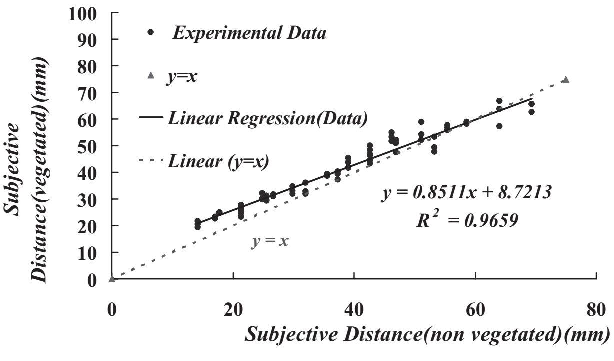


Fig. 2 Subjective Distance (vegetated) (Mj_i) Vs Subjective Distance (Mr_i*MJ_i/MR_i) (non vegetated)

3. EXPERIMENT II

(1)Experimental Hypothesis

Introduction of trees to the street network would change the cognitive distance judgment at route knowledge level.

(2)Materials & Methods

Participants: Thirty students (21 males and 9 females) of Saitama University voluntarily participated in the experiment (average age 27).

Table 1. Tree height (h) and canopy diameter (d) used in the experiment

	Ginko	Zelkova	Sakura	Winter
FG - h	18.6	17.9	15.1	17.3
FG - d	6.7	16.5	12.4	15
Mid - h	9.8	10.8	6.1	10.3
Mid - d	4.8	8.5	5.6	7.6
Young - h	6.0	5.9	3.8	5.9
Young - d	2.7	6.1	3.9	6.1
FG : Fully Grown, Mid : Middle grown ; h: tree height(m), d : Canopy diameter(m)				

Materials: The experimental set up consisted of a virtually simulated street network in a residential neighborhood. In this environment six landmark objects were placed along the road network. A circular travel path traversed passing all six-landmark objects, was defined. Along this the participants were taken in a guided tour showing the view of a pedestrian walking on sidewalk. Changing the vegetation condition as vegetated status and non-vegetated status derived two different cases of this environment representation. The vegetated condition had medium grown Zelkova trees placed on the sidewalk at an average spacing of 10m. While both environments used the same route they differed from each other by the starting point and end point while the direction of movement was maintained same. In order to reduce the level of comprehension difficulties each of the above environments was then divided in two phases. Thus the respondents experienced four environments (**Fig. 3,4**).

Participants rated virtually simulated environment for its ability to represent the real environment for distance judgment tasks as (a) A very good representation of the real environment (0%), (b) A sufficient representation of the real environment (47%), (c) An average representation of the real environment (47%), (d) Not a good representation of the real environment (6%), (e) An inadequate representation of the real environment-not good at all (0%). Since only 6% rated the environment below the average level it could be assumed that the environment created was a representative simulation of the real environment for the given task.

Tasks: The experiment consisted of a training phase and the experimental phase. Training phase included a scale introduction phase for distance marking in a non-vegetated environment. Subjects were presented with an animation showing the movement between two points, the distance between which was defined as the reference distance. Thereafter they judged the reference distance in terms of meters. For all subsequent evaluations the reference distance was used as a scale to express distance judgments. Distance expressions were obtained through a marking task, where the subjects marked the judgment distance on a straight line drawn on the paper by referring to the marking for the reference distance already marked on the line. The trial environment of the following phase having three landmark objects, facilitated subjects to familiarize themselves with the environment and tasks. In the experimental phase subjects viewed an animation showing the movement along the street network of the particular environment passing four landmarks. After viewing the animation twice they were instructed to imagine themselves standing on first landmark point of the route and probed about direct distance to second landmark point along the route. Upon completion, they were taken to next landmark point and probed about the following point and same procedure was repeated for third point. At fourth landmark point they were probed on starting point.

The participants marked the distance on the paper using the scale defined at the training phase. Where they desired they were allowed to sketch the traversed route using their memory and then use it for the judging and marking.

(3)Data Analysis

Data

Dr_{sk}- Subjective distance judgment for the reference distance of subject k

d_{ip} - Distance judgment of for Reference Street as marked in paper

L_{io}- Objective distance for the distance for distance i (as used in the visualization software)

l_{ip}- Distance judgment of the distance for distance i as marked in paper

L_{isk}- Subjective distance judgment for distance i of subject k $(Dr_{sk} \times l_{ip} / d_{ip})$

NDL_{isk}- Non dimensional subjective distance judgment for distance i of subject k (L_{isk} / Dr_{sk})

NDL_{is}- Non dimensional subjective distance judgment for distance i averaged over subjects

NDL_{io}- Non dimensional objective distance for the distance for distance i $(L_{io} / \Sigma L_{io})$

The analysis was conducted by relating the inter landmark cognitive distances to the corresponding objective distances in terms linear and power functional as in Experiment I.

Testing of Error of traversing order: Based on the level of difficulty on the experimental set up there was a possibility that judgments related to the points experienced later on the route to be relatively difficult and thus be erroneous. The error of judgment in terms of deviations of the subjective distance judgment from the corresponding objective distance judgment $((NDL_{is} - NDL_{io})/ NDL_{io})$ was analyzed against the traversing order.

***Testing of Hypothesis*:** The validity of the hypothesis was checked using the plot Subjective Distance (NDL_{is}) versus Objective distance (NDL_{io}) using a similar analysis to Experiment I.

(4)Results

Testing of Error of Traversing Order: The plot Error of judgment Vs Traversing order (**Fig. 5**) revealed a random distribution of data points. Had the latter points of the path been difficult to judge the error of judgment should have been relatively higher. As the data reveals no such inconsistencies in between data it is possible to analyze the data without considering such error.

Testing of Hypothesis: *The goodness of fit of regression lines:* Both linear and power functions well described the data of both vegetated and non-vegetated condition (**Table 2**). Both r^2 value and statistical test on regression coefficients b revealed the existence of highly significant correlation for both functions for both cases. The Runs Test indicated that the deviation of data from the regression models were not significant.

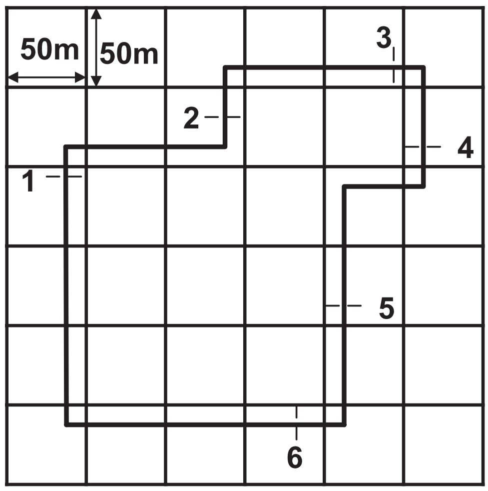
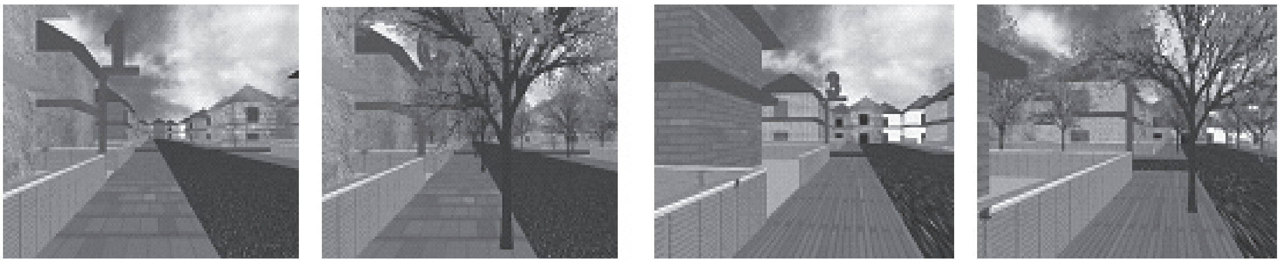


Fig 3. Layout of the experimental setup

Effect of vegetation on cognitive distance: The null hypothesis that data belonging to the non-vegetated and vegetated could be explained by one regression curve was tested against alternative hypothesis of usage of different curves to describe data. For both power and linear functions, the data did not reject the null hypothesis implying that two data sets did not support different curves. Thus results suggest that the vegetation introduction would not induce cognitive distances that are different from non-vegetated status.



(a) (b) (c) (d)

Fig 4. Stimuli used: Views of the Landmarks (LM) (a) LM “1”; (b) LM “C”; (c) LM” 3”; (d) LM” E”

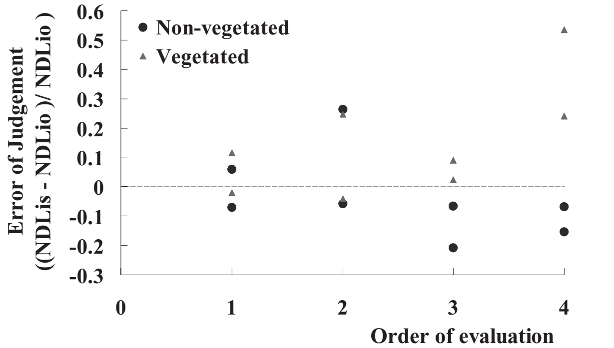


Fig 5. Error of Judgment ((NDL_{is} - NDL_{io}) / NDL_{io}) Vs Order of evaluation

4. DISCUSSION

(1)Presence of vegetation and perspective distance

According to the outcomes of Experiment I, introduction of vegetation has affected the subjective distance judgment at perspective level. Those distances related to the vegetated setting were overestimated in comparison to those non-vegetated setting. Further, trees belonging to different growth stages or different species did not induce different subjective distance judgments. Trees in full canopy state did not induce cognitive distances that were different from bare canopy state. Variation of tree spacing has affected the perspective distance judgment. Those trees placed far apart from each other had induced longer perspective distances in comparison to those placed closer.

An overestimation effect as found here could be brought about either due to the increase in volume of greenery or due to the segmentation of route by trees. Had the former argument been true, the results of Hypothesis II too should have provided consistent evidence. Neither the growth stage variation, where the overall green volume increases for fully-grown trees nor variation of canopy condition, where the leaf quantity was varied yielded significant variations in subjective distance judgments. The evidence from the variation of spacing of trees is in contradiction to this argument. The latter argument based on Route segmentation hypothesis stipulates that routes segmented by features will be felt subjectively longer than unsegmented routes. Accordingly, if the trees were treated as features that segment the routes, the vegetated setting should correspond to longer perspective distance representation in comparison to non-vegetated setting. The data relating to Hypothesis I showed evidence consistent with this argument. In depth observation of **Fig. 2** reveals that this effect was more prominent for shorter distances, which has diminished in relation to longer distances. This could have resulted by closer appearance of trees leading to a reduction of segmentation effect ultimately reducing the overestimation effect. Thus while the results in general suggested an overestimation of cognized distance up on vegetation introduction, such effect gradually reduces for longer distances.

Yet the results relating to the tree spacing contradicts the Feature Accumulation Hypothesis[14)&17)], which relates the cognized distance to the number of features present. Feature Accumulation Hypothesis indicates that increased number of pathway features would lead to increased distance estimates. Accordingly, the subjective distance judgments of far spaced (where the number of trees were lesser) setting should have corresponded to relatively lower subjective distances though the data suggested vice versa. Montello[17)], after observing some different tendencies within his own work, doubted the validity of this assumption. By quoting some similar outcomes and concepts related to travel time studies, he suggested that increased number of features might actually lead to a decrease in distance judgment. Such an effect may take place when too many elements decrease the effect of segmentation due to unification and integration. Though the observations supporting evidence for his suggestion, is mostly from travel time studies, the phenomenon needs further clarification through experimental work in relation to distance cognition.

In relation to the variation of design parameters, only tree spacing showed to have an impact on distance cognition. While the variations of other factors could have brought about significant visual changes, such may not have had significant impacts on distance judgment producing, results different from studies on other cognitive systems.

In comparing the outcomes of this investigation with that of Serpa and Andreas[13], the two studies have produced results that do not agree with each other. While they found the tree size (growth stage factor in this study) and texture (species factor in this study) to be affective on the distance judgment, the results reported here showed neither growth stage nor tree species to be affective on distance judgment. Although mode of stimuli, photographs was same, the studies differ in terms of level of focus to the trees, which could have caused contradiction. The subjects of their study evaluated the distance from them to the tree, which was the single prominent object in the stimuli without any other prominent visual objects. On the other hand the stimulus in this study was a scene of a typical residential street, where a combination of street elements was present with non-being prominent. Also the task in this study did not specifically target trees, where the subjects had to evaluate the distance to a sign on the road. Also the authors of that study interpreted their results in terms of the level of familiarity and size distance invariance hypothesis and not based on any tree characteristics. As the investigation on design parameter variation was limited to perspective distance only, the effect on route knowledge has to be confirmed through further studies.

(2)Presence of vegetation and cognitive distance judgment at route knowledge level

The results of second experiment revealed that, the introduction of vegetation to the street would not affect the distance cognition at route knowledge level. According to our hypothesis, and as found for perspective distance we expected the trees to act as segmenting features and thereby to increase the cognized distance in comparison to non-vegetated condition. The rejection of the hypothesis suggests that either the trees had not acted as segmenting features or some other prominent features could have acted as the segmenting feature.

As proved by some other researchers, features such as turns and intersections can segment a route[14]. Considering the importance of such features in a walking experience against a visual feature such as trees, the segmentation brought about by such being similar on either condition could have produced result of no difference.

Further, it is important to consider the possible differences in terms of mental processes involved in spatial knowledge acquisition and making a judgment. The distance judgment from a perspective view is an instant judgement with no opportunity for post processing of information. Such distance judgment would have been based on visual information in the perspective view. On the other hand, memorizing the spatial relationship between the landmarks after a walking experience, involves a prolonged information acquisition process. In such an exposure, higher level of attention is paid to features like turns, at which points navigational decisions are involved. In early stages of spatial knowledge acquisition where only few relations are cognized, the high level of attention paid to such features can make the variations to the other features to be left unnoticed. In addition impact of visual features such as trees could be relatively less in such an instance. Those information acquired after a prolonged exposure would then be amalgamated and subjected to a processing at a post acquiring stage, which did not take place at perspective level.

In comparison to the type of exposure of the former experiment, which was limited to a static view, the latter experiment allowed walking in the street network passing trees being the segmentation feature. Such increased exposure could have provided an opportunity to rectify those errors of segmentation that existed on a perspective view.

With the use of information on a perspective view of a vegetative setting, people make distance judgments that are different from a similar non-vegetated setting. Yet increased exposure to the environment in terms of repeated movements, would ultimately rectify such differences in spatial understanding up on reaching the route knowledge level. Future work should clarify how the spatial understanding at survey knowledge is affected where more comprehensive and complete knowledge is possessed. Although the route knowledge level reflected a rectification of errors taken place at perspective knowledge level, the results at survey knowledge level may further differ. This is possible since, the level of attention paid to visual features could again be increased with longer exposure.

(3)Distance cognition and human behavior

In navigating a new neighborhood, one may stop by an intersection and judge the distance to elements located along the streets leading from the intersection, which correspond to a perspective distance judgment. Cognitive distance at route knowledge on the other hand would be one's idea of the distance separation in between two points that encountered along a regular route he traverses, within an environment to which he is relatively new. Thus any change to such an understanding would again be reflected in the navigational decisions taken based on such spatial understanding. Thus findings of this study could be used to understand how distance based human navigational decisions could differ in the presence and the absence of vegetation.

People use distance knowledge in deciding destinations, travel mode or even in deciding to go or not to go. The outcomes of the first experiment suggested that, vegetated settings induce subjective distances that are longer than the subjective distances in a non-vegetated setting. Considering the fact that human desire to decide up on options that requires least effort, it could be argued that those felt to be relatively far would be less attractive thus less walkable. Such choices would have negative impact on usage of the space leading to less usage or abundance. This result provides further evidence for the opposition of the shopkeepers to plant trees in such spaces. In the case of those pedestrians who engage in walking as one mode of their journey, if they feel that their destination to be far, they may consider a shift of travel mode. Such outcome may show negative implications for sustainability.

While the cognitive distance has navigational implications as a part of spatial cognitive systems it may also has implications for other cognitive systems such as sense of safety. Interms of refuge value, sense of safety is negatively correlated to the distance to the nearest hiding place. In relating our research findings to the above it becomes clear that the presence of vegetation would make the nearest hiding place to be felt far. Thus such a vegetated setting would negatively affect the sense of safety interms of refuge value. Previous work related to vegetation has proved that increasing linear density of trees could increase the sense of safety in certain settings which agrees with the out come of the second hypothesis. In summing up the above, while introducing vegetation to a setting may decrease the sense of safety, the severity of such could be reduced by increasing the linear density of the vegetation.

Design aims related to new urbanism or neo-traditional planning places a high emphasis on the creation of walkable communities. Kim and Kaplan[18] found that among physical features that increased pedestrianism (community designed for walking and fostering street side activities) nearby natural environment and street landscape including street trees were among the highly rated items constantly across different neighborhoods. They suggested that the ample presence of natural features and their design features could increase walkability.

In an attempt establish the micro-scale environmental variables that are objectively measured Lee and Moudon[19] identified distance, density, destination and route as core constructs to quantify the neighborhood walkability. As most of the users are not equipped with objective distance data, how they cognize the objective data is likely to affect the subjective decisions. In relating the outcomes of the first investigations to this interms distance cognition vegetation has negative impact for walkability. Yet as found by Kim and Kaplan[18] vegetation has positive implications for walkability. In considering the decision to walk as an outcome from information processing in multiple cognitive systems, it seems that the negative effect in terms of distance cognition has been dampened out. Yet this suggests possible positive design implications to improve walkability. Within a vegetated setting, increasing tree linear density would reduce distance cognized and in turn it could increase walkability.

The outcomes related to perspective knowledge level reveal some negative consequences of introducing vegetation. Should this realization lead to a promotion of non-vegetated urban space? Human choices generally result from a series of complex cognitive processes where decisions are based on a number of factors such as preference, sense of safety. As proven in many studies people use urban green space due to the social, health, environmental and economical benefits it offers, showing that greening should be promoted. But it is the duty of the designers to understand how each individual cognitive process and the decisions taken based on those would be affected by the design of the vegetated space. In terms of distance cognition the authors found out that increased linear density lead to relatively lower cognized distances. Thus increase of linear density, could reduce the negative impacts of vegetation introduction in terms of its effect on distance cognition and thus on walkability. Provision of objective distance data to be used in navigational decisions, could be important to reduce negative impacts of vegetation introduction.

According to the outcomes of the study those misunderstanding occurred at the perspective knowledge level are rectified at the route knowledge level. While a correction of the misunderstanding could always be positive, such a change may lead to frustration when one finds that the perspective view was an illusion. Thus it is important for the designer to have a qualitative and quantitative understanding about such illusions that could arise in the designed space. The outcomes of studies of this nature could enlighten designers regarding possible misunderstandings. Such a realization would not necessarily mean that the design should strictly convey the objective measurements. But where such illusions could lead to serious misunderstandings, knowledge about such misunderstandings could be utilized in designing measures of rectification. Displaying additional distance data on maps would be an example of such a measure of rectification.

5. CONCLUSION

In investigating the effect of vegetation on distance cognition, the authors found that the introduction of vegetation to be affective on perceptual distance. But no such effect was observed in relation to cognitive distance at route knowledge level. While the focus of this study was limited to distance cognition, future work would address possible vegetation effects of on other aspects of spatial cognition such as cognitive angle or configurational knowledge. Although outcomes suggest the negative implications on usage of space in terms of cognitive distance, effect of other cognitive processes, along with careful designing may help to overcome such.

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