EFFECT OF STREET TREES ON SPATIAL COGNITION IN RESIDENTIAL AREAS: AN INVESTIGATION BASED ON DEVELOPMENT PERSPECTIVE

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Vegetating a non-vegetated setting changes the visual form of space. A change to the visual form, along with the strong psychological impacts of vegetation, could in turn affect how people understand and represent spatial relationships. This paper attempts to evaluate how the presence of linear vegetation in residential streets affects human spatial representation. Based on the gradual spatial knowledge development perspective, effect of vegetation was studied for landmark knowledge, route knowledge and survey knowledge. Vegetation negatively affected the memory of elements in the background by affecting place identification capabilities. But configurational understanding and way finding capabilities remained unaffected. Observation related distance cognition revealed an experience dependent behavior of vegetation effect, which may have important implications for the effect of physical features on cognitive systems.

Key Words: *Street Trees, Spatial Cognition, Landmark Knowledge, Route Knowledge, Survey Knowledge*

1. INTRODUCTION

(1) Vegetation and preference

Orienting oneself within the environment or finding one's way is important for all human beings. Absence of such capabilities could result in negative consequences, starting from minor frustrations or extended travel times, ranging up to survival threats. Even in the presence of external sources of information, such as maps, human navigational decisions are often based on internally formed spatial representation, termed as spatial cognition. Such spatial representation could be influenced by the variation of spatial and geometric characteristics of space and the presence or absence of different elements. Vegetation, being an important element in street environment, may also change the way people perceive space, especially through visual and psychological impacts. Although the role of vegetation has been studied in relation to a range of impacts, such as economical or environmental impacts, comprehensive knowledge related to the effects of the presence of vegetation on human spatial representation is still inadequate. This paper presents an experimental study based on the hypothesis that vegetation presence can change how people perceive and cognize spatial relations.

(2) Evidence for spatial effects of vegetation

The effect of vegetation on human spatial representation as suggested above could be supported by observing the visual effects of street vegetation in reality. According to Arnold[1)] trees can organize the space both horizontally and vertically. Horizontally, this is achieved by visually enclosing, completing or defining an area of open space. Vertically, space is defined by the ceiling of the canopy. Thus the space, when reorganized by trees, could be cognized in a manner different to its non-vegetated status. Zube[2], giving specific reference to the tree lined streets of Paris, suggested the ability of street trees to reduce the city scale down to a level comprehensible to humans. Trees are frequently used for a range of screening purposes. For a moving observer, trees break up continuous building facades allowing the delineation of space, shrubs anchors structures to the ground and grass or ground cover creates an edge to the pavement[3]. Ogi, et al. [4] found that feeling of openness of pedestrians, is influenced by vegetation form. They also found that such influence could influence pedestrian's virtual territory. Highlighting visual effects of trees Appleyard[5], stated that "Trees blur the distinctiveness of urban form; they mask and confuse the messages."

(3) Hypothesized effects of vegetation on spatial representation

As discussed above, the psychological and visual effects of vegetation could affect human spatial representation. The effect could operate on metric relations, cognition of elements of the space or on the understanding of the area as a whole. Visual effects created by changing the form of space could significantly influence cognition of elements. Trees, if attractively placed, could be well remembered and subsequently utilized as a landmark to recall the location. Also, well-landscaped areas may increase the landmark potential of the surrounding elements[6]. Yet, in the case of a densely vegetated setting, the visibility of elements in the background could be blocked, imposing difficulties on identification or recall of such elements.

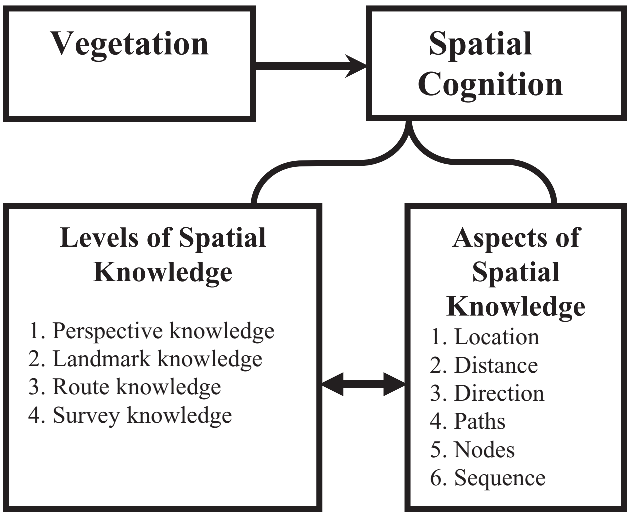

Fig. 1 Experimental framework

Trees may influence the metric understanding through their influence on cognitive distance and cognitive direction. At a relatively micro scale, individual trees can act as features of segmentation, affecting distance judgment. On the other hand densely spaced line of trees could operate as a wall. This will influence the segmenting function by the background features, influencing distance cognized. As a result people may judge the distance in a manner different from a non-vegetated setting[7]. Also one mechanism of cognizing the directional understanding is to judge the angles based on the distance relations. Thus any influence in cognitive distance could be extended to cognitive direction.

The need to study the effect of landscaped elements on human spatial representation systems has been highlighted on several occasions, particularly considering the visual and psychological effects they bring about[8]. Evidence from spatial cognitive studies, has shown that variations in spatial form, such as changes to spatial and geometric characteristics of the space and various elements therein, could affect spatial representation. Vegetation, while being an element with strong evolutionary meaning, changes the spatial form due to its presence in bulk. Thus, considering the effect that vegetation creates on spatial form, there is a possibility of spatial cognition being affected by the presence of vegetation. Spatial cognition refers to the knowledge and beliefs about the spatial properties of objects and events in the world[9]. The attainment of such knowledge results from a gradual learning process through multiple exposures. Thus, in studying the effect of vegetation on spatial cognition, consideration was given to the process of spatial knowledge development, in terms of different aspects of spatial knowledge.

(4) Evaluating human spatial representation

a) Research frame work & Scope of work

The work presented here is part of an investigation that aims to clarify the effect of vegetation on human spatial representation, using the framework shown in Fig. 1. Accordingly, possible effects of vegetation were studied for relevant aspects of knowledge belonging to the four spatial knowledge levels.

b) Aspects investigated by previous work

In relation to spatial cognition at perspective knowledge level, previous work has presented positive evidence on distance cognition[10, 11] and on cognition of space in general[12]. Evans and Smith[6] found that areas with landscaped elements were well represented in cognitive maps, showing the effect of vegetation for landmark knowledge formation. In terms of vegetation effect on distance cognition related to route knowledge, the authors' previous work[10] showed the absence of an effect.

c) Hypothesized vegetation influences investigated in present study

While vegetation could reduce the visibility of landmarks and thereby create a negative influence, increase of attractiveness could have a positive influence on landmarkability. Thus in relation to knowledge of landmarks, effects of vegetation presence on the cognition about landmark presence were investigated..

Cognition at route knowledge level is related to the memorizing of the sequence of elements which is a cognitive function. Such function may be independent of form variation and thus vegetation may not impose significant influence at this stage. At route knowledge level, vegetation influence was investigated by assessing knowledge on the sequential occurrence of landmarks, accuracy of turns and ability to recall scenes along the routes.

Variations to visual form could influence the understanding of spatial form and thus the cognitive map. Reduction of visibility of the background could negatively influence the cognition of elements. Also authors' previous work suggested that vegetation influence on distance cognition could become ineffective when the respondents are allowed to have more exposure to the setting.Thus effects on the survey knowledge level was evaluated by evaluating the accuracy of cognitive map, distance and direction cognition, memory of elements and the ability of find the way. If vegetation can influence the spatial understanding, then the way finding decision taken based on such understanding would also be influenced. Effect of vegetation presence on the way finding capabilities was investigated through set of way finding decisions.

For each of the spatial knowledge parameter the experimental hypothesis that a setting vegetated with trees would induce a spatial cognition (in relation to the specific spatial knowledge parameter) that is different from the spatial cognition (in relation to the specific spatial knowledge parameter) induced by a non-vegetated setting was checked. This was done by comparing the spatial knowledge of two groups of subjects who were exposed to an experimental setting either in its vegetated form or non-vegetated form. Since finding both vegetated and non-vegetated areas in a single setting was impossible, a virtually simulated environment was used as a stimulus. To facilitate an inter-group comparison, respondents from both groups were subjected to a similar experiment using a virtual simulation of a hypothetical environment. Performance of the two groups in this task showed no statistically significant difference proving the absence of any initial differences between groups.

2. MATERIALS & METHODS

(1) Materials & Methods

a) Subjects

32 Saitama University students belonging to the Faculty of Engineering and Graduate school of Science & Engineering voluntarily participated in the experiment. The subjects were randomly divided in to two groups to be exposed to one of the two types of stimuli, either vegetated or non-vegetated.

b) Case study area & Simulation using CG

Shiki Newtown, a suburban residential area located within Saitama Prefecture, was selected as the case study area to be simulated through CG. None of the subjects had previous exposure to the real site. Initially the experiment was conducted in the real site as a pilot study. The last stage of the pilot study was a questionnaire, in which the respondents identified the elements utilized in the experimental tasks. In addition a site survey was conducted to identify additional elements that could influence spatial judgment. From the identified elements home vegetation and low height bushes in sidewalks were excluded as such could influence experimental aims. The other elements namely residential buildings, garbage collection areas within residential areas, buildings of common usage, recreational spaces, street furniture, and signage were represented in the simulation (Fig. 2). An average 4m floor height was used in simulating buildings while real values were used for plan dimensions. Buildings were rendered with windows and doors and painted with colors depicting real colors of the respective buildings. Street trees were simulated using simulation software. Trees were placed considering their spacing in the real site while the height and canopy sizes were extracted from standard charts.

c) Presentation of stimuli

Subjects were introduced to the test environment through guided tours in the form of animations, passing a set of named landmarks. Upon completion, they were tested with a set of tasks, evaluating their knowledge comprehensively. Thus the guided tours were laid along Route 1 & Route 2 (Fig. 3) which ensured sufficient exposure to the site. Yet the routes did not include segments CH and IF which were used for spatial knowledge testing tasks. The guided tours were presented as animations though CG simulated environments as shown in Fig. 4. Each of the vegetated and non-vegetated forms consisted of four

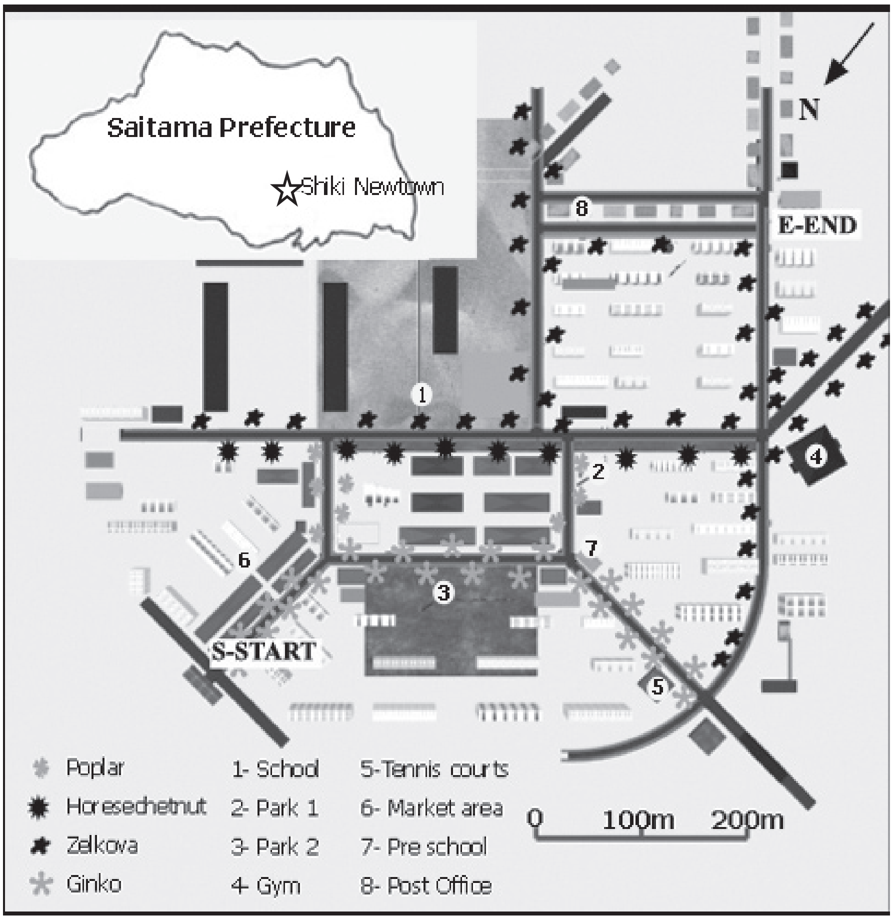

Fig. 2 Location of the site & Plan of virtual environment showing simulated elements

animations (Route 1 forward, Route 1 backward, Route 2 forward and Route 2 backward). In order to increase the level of exposure to the test environment, routes were repeated through backward movement in addition to the forward movement. Forward animations: Route 1 forward and Route 2 forward, showed the movement from Start(S) to End(E) while the backward animations: Route 1 backward and Route 2 backwards, showed movement from E to S. All animations depicted a pedestrian's viewpoint from the sidewalk. Each of the subjects was tested individually in the laboratory. The animations were projected to the main screen of size 2m*1.5m while the subject was seated 3.2m away from the screen. The experimenter played the animation, while respondents had the option of requesting a change of playing speed at any time during the experiment.

At each major intersection or where they turned, the subjects were provided with information about that point. This was done through four photos showing views forward, backward, left and right, with respect to the original direction of movement. These photos were displayed on a separate computer screen (52cm*32.5cm) placed by the side of the subject. Just before the intersection was reached, animation was stopped and the four photos appeared within one screen. The respondents viewed the photos with no time limitations and informed the experimenter when they had finished, after which the animation on main display was continued.

d) Tasks

Fig. 5 depicts the flow of experimental tasks. After viewing all animations, the main screen views were changed to show a static view from S along the direction SA. Respondents used this view for the distance and direction task. By taking line SA as the reference line, the subjects were instructed to mark the points End(E) and the position of park 2(L4), on a paper which had line SA already drawn. Subsequent tasks did not use any display images.

In the next task, respondents were first instructed to classify a set of 12 photographs in to three groups (those belonging to Route 1, Route 2 and dummies). Upon completion, the experimenter classified the photos into correct groups and instructed the subjects to arrange photos of Route 1 and Route 2 in their sequence of occurrence in forward moving direction.

In the task for navigation narration, the respondents were asked to propose possible paths of movement between three named sets of origin-destinations. First narration task was to propose any route from point L3 to L2. The second narration task named as

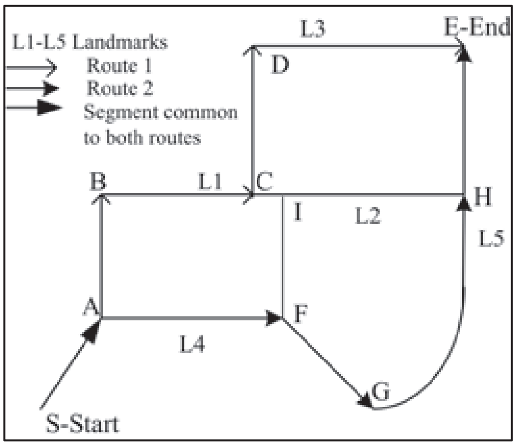

Fig.3 Layout of the setting showing routes & Landmarks

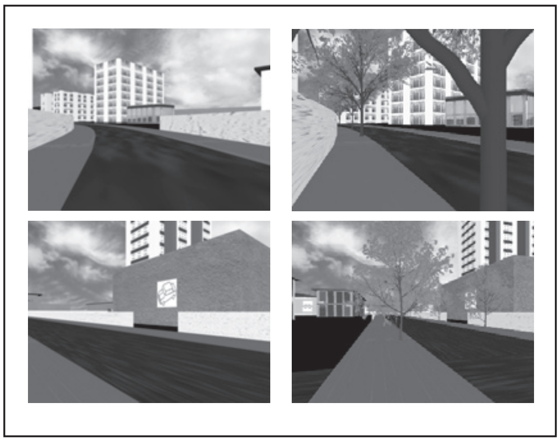

Fig.4 Experimental stimuli - Views of point G(top) & A(bottom) in non-vegetated(left) & Vegetated(right) forms

alternative route task was to propose route of movement from L5 to L1. For task they were instructed to use segments untraversed during guided tours. Last narration task was to propose the shortest route from L2 to L4.

This was followed by sketch map task. Three colored pencils, reflecting three confidence levels were used here. Using three colors, respondents differentiated their confidence levels in drawing path segments and in marking memorized elements (orange – highest; blue – medium; green – least). In the map, respondents were instructed to sketch Route 1, Route 2, mark 5 landmarks and all other elements they could recall including sketched intersections and all other road segments. In addition they were given instructions to name out those elements of which the exact locations were not remembered. Thereafter, they were asked to mark positions of photos of Route 1 & Route 2 (used in Task 2) on the sketch map.

(2) Data analysis

For each of the evolution parameters shown in Table 1, individual parameter values were calculated and group mean values were calculated for each of the vegetated and non-vegetated groups. Experimental hypotheses were checked by comparing the means of the two groups.

3. RESULTS

(1) Route confidence score

a) Measurement aim

Confidence about our own spatial capability could be a reflection of the actual level of spatial knowledge possessed[13, 14]. Therefore, in this study, in addition to the actual knowledge parameters, the subjects' confidence about spatial knowledge was assessed though the route confidence scores. The Route confidence score was evaluated using the confidence of path segments sketched.

In evaluating performance of different tasks in spatial cognition experiments, previous researchers[15, 16] have adopted the approach of defining performance categories and assigning suitable scores which reflect the level of performance. Although such measures do not form accurate psychometric scales, these are utilized as evaluation parameters in comparing different experimental conditions through statistical testing. Thus a similar approach was used in evaluating the performance related to Route confidence as well as Navigation capability and Inter route connectivity.

b) Results

The results showed a higher level of confidence within the non-vegetated group than the vegetated group, though this was not statistically significant. Detailed investigation analyzing the individual path segments also revealed a similar tendency at individual node level.

c) Interpretation

This implies that the presence of vegetation does not affect the subjects' confidence about the spatial knowledge they possess.

(2)Distance error

a) Measurement aim

The distance error reflected the deviation of subjective distance ratio (evaluated distance/ reference distance) from the relevant objective distance ratio

b) Results

Better performance of the non-vegetated group than the vegetated was observed, though this was not statistically significant. Thus cognitive distance was not affected by the presence of vegetation.

c) Interpretation

Comparing this with the results of previous work[10], this result strengthens evidence for the insensitivity of cognitive distance to vegetation presence (as shown for route knowledge), differing from the results for perspective distance. In the case of perspective distance, vegetation introduction led to a significant overestimation (with respect to non-vegetated status), which could have resulted from route length being segmented by trees. As discussed in relation to route knowledge[10], usage of features such as turns by both groups, to cognize spatial relationship between objects could have led to the non-significant differences. Distance cognition is one aspect of spatial knowledge that is formed in the early stages of spatial knowledge development. Any differences of judgments as found in perspective level could be limited to the initial stages of spatial knowledge development. Thus, once formed, it could be maintained without experiencing prominent changes upon further processing[17].

(3)Direction error

a) Measurement aim

The direction error expressed the difference between the subjective angle and the related objective angle.

b) Results

The error ranges did not differ much across the two cases of E and L4, with no significant differences between the two groups for each case.

c)Interpretation

In expressing the directional relationships most respondents were likely to use the distance proportions. As discussed above, the distance judgments were not affected by vegetation presence.The absence of an effect on direction cognition could have been due to the same influence as in direction judgment.

Task 0 - View the stimuli: View four animations in the order, Route 1 forward, Route 1 backward, Route 2 forward and Route 2 backward along with images of intersections.They are introduced with five landmarks while viewing animations.

↓

Task 1 - Distance and Direction task: Marking points End (E) and Park 2 (L4) by referring to line SA on the marking sheet

↓

Task 2 - Photo tasks

(1) Group photos in to three 3 groups; Route 1, Route and Dummy

(2) Experimenter accurately assigns the images in to the three groups and the subjects are asked to arrange the photos of Route 1, Route 2 in the sequence of forward direction of each route

↓

Task 3 - Navigation narration task – giving verbal way finding directions

(1) *Simple task*– Propose the any route from Post office (L3) to the Park 1(L2)

(2) *Alternative task* – Propose a route from Gym (L5) to the Elementary School (L1) utilizing un-traversed segments during the guided tours

(3) *Shortcut task* – Propose the shortest route from L4 to the L1 using shortest paths

↓

Task 4 - Sketch map task

(1) Sketching Route 1and Route 2

(2) Mark positions of 5 landmarks, any other elements remembered, intersections, roads; Name any other elements remembered

(3) Mark the positions of photos of Route 1 and Route 2 (used inTask 3(2))

Fig. 5 Flow of the Experimental tasks

Table 1 Description of analysis parameters

	Knowledge type	Parameters	Method of calculations
1	Confidence about spatial capability	Route confidence score	Each path segment was assigned with a confidence value based on level of confidence (Highest = 0.5; Medium = 0.3333; Least = 0.1667). Route confidence score was obtained by averaging the individual segment scores over the whole route (segments *a* to *i*).
2	Distance cognition	Distance error-End, Distance error-L4	*Distance error = absolute value of the difference between objective & drawn ratio scaled distance with respect to the reference distance SA*
3	Direction cognition	Direction error-End, Direction error-L4	*Direction error = absolute value of the difference between objective & drawn angle of deviation from line SA.*
4	Place identification	Photo selection score, Photo sequence score, Photo placement score	*Photo selection score = Number of total correctly selected photos* *Photo sequencing score =Number of photos placed in the same position as in reality* *Photo placement score = Number of photos correctly placed (placement within the correct path segment of route map)*
5	Navigational capability	Simple navigation task score, Alternative navigation task score, Short cut task navigation score, Cumulative navigation task score	*Simple task: Did they find any route from L3 to L2? If Yes – simple task score = 2; If No– Simple navigation task score = 0* *Alternative task: Did they find any correct route from L5 to L1 using only traversed paths? If Yes – score (a) =1; If No – Score (a) = 0* *Did they find the correct route L5 to L1 including un-traversed paths? If Yes – score (b) =1; If No – Score (b) = 0* *Alternative navigation task score = Score (a) + Score (b)* *Shortcut task:* *Did they find any correct route L2 to L4? If Yes – score (a) =1; If No – Score (a) = 0* *Did they find the correct shortcut L2 to L4? If Yes – score (b) =1; If No – Score (b) = 0* *Short cut navigation task score = Score (a) + Score (b)* *Cumulative navigation task score = (Simple task + Alternative task score + Short cut task score)*
6	Cognition of turns	Route turn accuracy score	*Route turn accuracy score:* At each of the turning points of Route 1 (A, B, C, D) & Route 2 (A, F, G, H) by checking the accuracy of turning direction as clockwise or anticlockwise, Accuracy scores of 1or 0 were assigned correct and incorrect answers respectively. Route turn accuracy score was obtained by taking the sum across all points.
7	Landmark knowledge	Landmark sequence score and Landmark presence score	*Landmark sequencing score = Number of landmarks placed in the same position (within the correct road segment) as in reality* *Landmark presence score =Number of landmarks remembered*
8	Knowledge of elements	Item Count- All with locations known, Item Count- All with locations known/unknown	*Item Count- All with locations known = Total number of items coupled with locational information marked in sketch map or expressed verbally* *Item Count- All with locations known/unknown = Total number of items with or without locational information marked/written in sketch map or expressed verbally.*
9	Knowledge of road segments	External roads score, Internal roads score, All roads score	*External roads score= Number of external roads drawn* *Internal roads score = Number of internal roads drawn* *All roads score = Number of external roads & internal roads drawn*
10	Map configuration	Map completeness score	Sketch maps assigned with a score on a 0 to 5 scale based on overall accuracy
11	Inter-route connectivity	Connection path score	(I) Connecting route from H: *No such connection route; Score = 0, Presence of a route starting from H; Score = 1, Presence of a route starting at H that connects to C; Score = 2, Presence of a route starting at H that connects to C, which is a straight line; Score = 3, Presence of a route starting at H that connects to C, which is the straight extension of BC; Score = 4* (II) Connecting route from F: *No such connection route; Score = 0, Presence of a route starting at F; Score = 1, Presence of a route starting at F that connects to road BC; Score = 2, Presence of a route starting at F that connects to BC at a poison in between B & H OR Presence of a route starting at F that connects to BC perpendicularly; Score = 3, Presence of a route starting at F that connects to BC perpendicularly, at a position between B & H; Score = 4* *Connection path score = score for (I) + Score for (II)*

Table 2 Results of statistical testing

	Parameter Name	Max. Value	Non-vegetated		Vegetated		Stat. Result	
			Mean	SEM	Mean	SEM	P value	SIG.
1.	Distance error: End		0.9375	0.1970	0.9375	0.2135	0.5992	N
2.	Distance error: L4		0.5197	0.1197	0.3829	0.0694	0.3252	N
3.	Direction error: End		20.4400	3.4400	26.530	7.6340	0.4736	N
4.	Direction error: L4		23.0600	4.7640	19.320	3.4450	0.5288	N
5.	Route confidence score	0.5	0.3993	0.0179	0.3530	0.0303	0.1983	N
6.	Photo selection score	12	8.9380	0.4422	7.2500	0.6423	0.0385	S
7.	Photo sequence score	8	5.9380	0.5879	3.3130	0.7113	0.0079	S
8.	Photo placement score	8	6.3130	0.5379	4.8750	0.7296	0.1232	N
9.	Simple navigation task score	2	1.1250	0.2562	1.1250	0.2562	1.0000	N
10.	Alternative navigation task score	2	0.8750	0.2394	0.5000	0.1826	0.2225	N
11.	Short cut navigation task score	2	0.5625	0.2230	0.4375	0.2035	0.6818	N
12.	Cumulative navigation task score	6	2.5630	0.6122	2.0630	0.5437	0.5460	N
13.	Route turn accuracy score	8	6.6880	0.3733	6.5000	0.5083	0.7683	N
14.	Landmark presence score	5	4.7500	0.1118	4.8130	0.1360	0.7250	N
15.	Landmark sequence score	5	4.2500	0.3354	4.4380	0.3158	0.6869	N
16.	All roads score		31.3800	2.0020	24.130	1.8860	0.0132	S
17.	External roads score		5.0000	0.5083	3.0630	0.6980	0.0324	S
18.	Internal roads score		26.3800	1.8880	21.130	1.2970	0.0291	S
19.	Item Count-with locations known		11.9400	0.6799	8.3130	0.4977	0.0002	S
20.	Item Count- with locations known/ unknown		12.0000	0.6646	8.4380	0.4913	0.0002	S
21.	Map completeness score	5	2.5000	0.3416	3.1880	0.4105	0.2078	N
22.	Connection path score	8	4.0000	0.6770	2.5630	0.7526	0.0624	N
Max. : Maximum value of the parameter where applicable; SEM: Standard Error of the Mean; Stat. Result: Results of the unpaired t-test; SIG.: Significant or not; S: Significant; N: Non-Significant								

(4) Photo tasks

a) Measurement aim

The photo tasks evaluated the subjects' ability to recall the scenes from the environment to which they were exposed. The selection task evaluated their ability to distinguish scenes between Route 1 and Route 2. The sequence task evaluated their sequential understanding of each of the respective routes. The photo placement task evaluated their ability to recall the scenes, along with locational information using their cognitive map.

b) Results

The non-vegetated group performed significantly better than the vegetated group in photo selection and sequence tasks. The photo placement task had a similar trend, although the difference was not significant.

c) Interpretation

According to Abu-Obeid[18], environmental representation is composed of two image types, namely, abstract imagery and scenographic imagery. The first is related to the spatial layout of the environment in the form of the topographical geometric system. When represented externally, this can take the form of a cartographic map. Scenographic imagery represented as system of pictorial information is related to the figural quality of the environment. Abu-Obeid[18] further suggested that the distinction between abstract imagery and scenographic images could be parallel to the distinction between survey knowledge and sequential knowledge. Accordingly, when spatial knowledge develops gradually more scenographic images are related to sequential understanding, while abstract images are related to the survey knowledge.

The selection and sequence tasks were performed just after the environmental exposure phase, but the placement was done after plotting the sketch map which represents the survey knowledge. The selection and sequence tasks are related to memory of the two routes and involve identification of scenes without place information. This reflects the utilization of their scenographic knowledge. While the photo placement task could have also benefited from good scenographic knowledge, additionally it required locational information of the stimuli. The presence of well-developed survey knowledge or abstract imagery in the post-sketching stage would have benefited the performance of this task. Thus, performance differences for selection and sequential tasks, along with similar performance in placement tasks, suggest that vegetation affects scenographic image but not the abstract image.

Reduced visual access[19, 20] to background elements, lack of differentiation[20, 21] could reduce the distinguishability of the environment. The mere presence of linear vegetation in bulk can generate a monotonous appearance while blocking the visibility of elements in the background. As found in selection and sequence tasks, the subjects' capability to distinguish the places along the route has negatively been affected by the presence of trees.

These results do not support the findings of Evans and Smith[6]. While this study found vegetation negatively affected the place memory, they found vegetation improving the memory of buildings. Such disparity could be explained in terms of vegetation arrangement, with respect to the features memorized. The linear street trees in this study reduced the visibility of background features. On the other hand, vegetation in landscaped form, in the Evans and Smith[6] study, increased attractiveness of the area and thus lead to better recall. Nevertheless, this imposes some limitations to the general applicability of data, unless attention is paid to the particular arrangement of vegetation.

(5) Navigation tasks

a) Measurement aim

The navigation task evaluated whether the vegetation effect on spatial cognition could influence a navigation decision taken utilizing spatial knowledge. The tasks consisted of three exercises to narrate the directions of movement between predefined landmarks of the setting.

b) Results

Data revealed more accurate performance by the non-vegetated group, though the differences were not significant. Among the three tasks, performance of the simple task was best. The start and end of this task fell within Route 1 backward direction, enabling high performance by the subjects'. Alternative route task evaluated the subjects' ability to find alternative paths between two points, a typical utilization of survey knowledge. The capability was relatively lower and most of the subjects opted to move along the known routes, walked in the guided tour, until they met and switched to the other route. This showed that they used route knowledge for this task.

The third task evaluated the capability to cognize shortcuts within the setting, another typical application of survey knowledge[22]. The performance here was also poorer than for the simple task, showing a low level of survey knowledge.

c) Interpretation

According to Passini[23], even if survey and topographical representations can induce metric and topographical distortions, these are not necessarily detrimental to way finding. Cubukcu and Nasar[15] found that the effect of urban form differentiation was reflected in human spatial representations. But at the stage of utilizing such knowledge for navigational decisions, form differentiation could not impose significant impact. Thus, while studying the vegetation effects on spatial representation, the authors investigated whether such effects would influence navigational decisions. Most of the route and survey knowledge parameters showed no significant effect of vegetation. Thus, at the utilization stage of knowledge vegetation did not have a significant effect.

(6) Route turn accuracy score

a) Measurement aim

The route turn accuracy score reflected the accuracy of changing direction at each of the intersections (intersections A to H), which is fundamental to route knowledge.

b) Results

No significant effect was revealed, which could be due to the non-sensitivity of a basic knowledge aspect to a visual feature, such as vegetation.

c) Interpretation

In a post-experiment questionnaire, the subjects were asked about the method of identifying the turning point. Usage of landmarks was relatively low among the vegetated group. They compensated for this by using the intersection configuration (whether a T junction or where the road ends) or sequential understanding of the intersections.

The absence of the effect of vegetation for route turn is mostly explained by the usage of landmarks for decision point identification and a strict turning direction memorization, with respect to an egocentric framework. Trees could have reduced the overall visibility, thereby reducing utalizability of background visual cues for identification purposes. Although such effect had the potential to affect cognitive understanding, this may be compensated for by the adoption of different cognitive mechanisms as discussed above.

(7) Landmark sequence and presence scores

a) Measurement aim

These scores reflect the memory of the presence and sequence of named landmarks.

b) Results

Both groups had high performance across all landmarks showing that memory was not affected by the presence of vegetation.

c) Interpretation

With the knowledge of landmarks remaining as basic knowledge aspect, effects due to form variations have not been able to impose a significant influence.

(8) All roads, external roads and internal roads

a) Measurement aim

The all roads score reflected the total of external and internal roads. All three parameters were evaluated as separate parameters from the raw data of the sketch maps.

b) Results

For all three parameters, the non-vegetated group's performance was significantly better than that of the vegetated group.

c) Interpretation

This significantly better performance could have resulted from the visibility effect. The ability to view roadside elements could have been negatively affected by vegetation presence. This trend is consistent with the other observations of item count scores.

(9) Item count scores

a) Measurement aim

Item count scores reflected the memory of elements, as recorded in the sketch map or narrated verbally. Memory of an element could either be limited to its presence or the presence may further be coupled with locational information. The parameter "Item count score with/without locational information" refers to the former and the parameter, "Item count score with locational information" reflected the latter.

b) Results

For both parameters non-vegetated group had a significantly better performance,

c) Interpretation

As with the road scores, reduced visibility has reduced the performance.

(10) Map completeness score

a) Measurement aim

This score reflected the overall configurational accuracy of the sketch map measured as a cumulative parameter, incorporating the effects of some other parameters. Each map was assigned with a subjective score, based on the accuracy of each of the two traversed Routes, commonality of end point, connecting route accuracy and accuracy of overall orientation.

b) Results

Better performance by vegetated group was revealed, but the difference was not statistically significant.

c) Interpretation

This provides evidence that vegetation introduction does not harm the overall configurational understanding of the setting.

(11) Connection path score

a) Measurement aim

Connection path score describes the ability to comprehend two paths each connecting the two routes at different points.

b) Results

Performance of the non-vegetated group was better, though the difference was not statistically significant.

c) Interpretation

Inferring connecting paths could have been executed mainly by visual observations or through the usage of distance and directional relationships. Post-experiment discussions revealed that both groups adopted similar mechanisms for judging connecting routes, by using of distance or directional relationships.

4. DISCUSSION

(1) Influence of vegetation on spatial cogntion : Outcomes of the present study

In investigating the effect due to the introduction of street trees on spatial cognition, as hypothesized, the authors found evidence for probable visual and psychological effects of vegetation on human spatial representation. At landmark knowledge level, the cognition of the landmark presence was not influenced by street trees. In relation to route knowledge, neither the understanding of the sequential occurrence of the landmarks along the route nor the cognition of turns was affected. Yet the ability to recall other scenes along the route was negatively affected by the introduction of trees. At the survey knowledge level, cognition of distance and directions, understanding of the configuration of the setting and the ability ones way within the setting was unaffected by vegetation presence. Yet the memory of elements was adversely affected by vegetation presence.

(2) Influence of street trees on a development perspective

By considering the outcomes of this investigation and previous work, the effects can be categorized in to four types. First is the type of effect that is strong and continues to be effective. Effect on the memory of roads and elements fall within this category, where the effect was present even at later stages. The next type is related to those aspects, where the effect, which was present at earlier stages, gradually diminished with exposure. For example, vegetation effect on distance found to be significant in perspective knowledge level[10] was not observed in cognitive distance at route knowledge level[10] or survey knowledge level here. Repeated exposure could sharpen the attention and thereby allow cognition of new information that was blurred out by the presence of trees earlier. Also, with the allowance of time, the existing information would be processed to make new inferences, which would sharpen and rectify errors in the understanding. The third is the type where the vegetation could impose some kind of effect, but the respondents were not affected because they used alternative methods of spatial judgment. As discussed in results, vegetation effect on route turn accuracy and cognition of connecting paths could have been dampened out by the use of alternative methods of spatial judgment. Fourth is where the vegetation has no significant effect. Navigational capabilities, landmark presence and sequence scores investigated in this study belong to this category.

(3) Street trees and memory of elements

The results suggested that, with a linear arrangement, street trees would neither become landmarks nor would they increase the landmarkability of other elements. However, the presence of vegetation negatively affected the memory of elements in general. Visibility blocking could have affected the acquisition of knowledge of items in the background. This blocking, along with the monotonous appearance brought about by vegetation, could have lead the subjects to create a weak image or to encode the setting in a manner different to its non-vegetated form as found by Sheets & Manzer[12]. Poorer performance in photo tasks by the vegetated group gives evidence to this.

This outcome is in line with objection by shopkeepers against the presence of vegetation in shopping streets, giving less flexibility for vegetation design in such settings. As was pointed out in verbal comments, the fact vegetation presence was remembered proves the potential success in using vegetation to screen off negative visual elements of the streetscape. This, along with the unaffected navigational capabilities, shows that designers can confidently ignore the possibility of any negative impact on spatial capability upon introducing vegetation to a non-vegetated setting.

In relation to landmark knowledge, vegetation could have affected the memory of elements by becoming a landmark itself or by improving the landmark potential of any other object, through highlighting it. According to answers of the question on methods of spatial judgment, vegetation was not used as a landmark. Also, the analysis of those elements, which were used as landmarks, revealed that all had their own landmark potential and did not show any relation to the presence or absence of vegetation.

At the next stages of spatial knowledge, vegetation effect could be seen in terms of its effect on non-landmark items. At this stage, vegetation can become a memorized element, with either its presence cognized or with both presence and locational information cognized. This is supported by the fact that some subjects accurately sketched distribution of street trees in their sketch maps, showing the presence of a vegetation map.

(4) Limitations of the study

Since the creation utilization of a single setting both in vegetated and non-vegetated form imposed practical constraints, this experiment was conducted using a virtually simulated stimulus. In order to test the validity of results and to identify possible deviations within results, the study was repeated in a corresponding real life setting, which was in vegetated form. Except for a few parameters, the results proved Virtual Environment could be utilized as a good simulator for an experiment of this nature. Due to practical and economical constraints, many psychological researches are conducted using students as subjects, as in this study. This can impose problems in applying the results to other age groups. Evidence from preference researches have shown that demographic factors impose little effect, with students` responses having a strong correlation to non-students[24]. Although this demonstrates the possibility of similar behavior in relation to spatial cognition, future work investigating how representative of the population as a whole the student sample was, is required.

As discussed earlier, memory for non-landmark elements was negatively affected by vegetation presence, whereas Evans and Smith[6] found otherwise. This disparity highlights the need to exercise care in applying these findings to other arrangements of vegetation. However, it also shows the flexibility offered to the designer in selecting a suitable vegetation arrangement based on design targets related to legibility. This highlights the importance of future work to clarify probable effects of varied designs of vegetation on spatial cognition.

5. CONCLUSION

In an investigation to evaluate the effect of vegetation presence on multiple aspects of spatial cognition, it was found that street trees negatively affected the place identification capabilities and memory of elements. The ability to distinguish different places within the setting was significantly reduced by the introduction of a line of trees to the sidewalk. Accordingly, if the design aim of the place is to create a uniform image of the setting, success could be achieved by planting street trees. But if the aim is to distinguish the identity across different places within the setting, additional work is needed such as the introduction of elements which are visually distinguishable. While the street trees reduced the identification of elements in the background, they did not exert any influence on identification of main landmarks. Further, people could create an accurate cartographic representation of the setting while their distance and directional understanding was not influenced. Also they could their way finding capabilities did not differ due to vegetation presence. Much previous work has studied the effect of physical features at specific stages of spatial knowledge. Through studying the vegetation effects at multiple levels of spatial cognition, this work attempted to study the effect using a development perspective. In combining this result with authors' previous work, influence of vegetation which was significant on distance cognition at perspective level became insignificant at higher knowledge levels. This development dependent behavior of vegetation influence suggested the possibility that the effect of physical features on spatial cognitive systems could decline with exposure. How a person understands the spatial relations during his first visit may be influenced by physical features such as vegetation. Yet with repeated exposure such influence of physical features on his judgment could decline significantly. More focused investigations are needed to identify the features and different aspects of spatial knowledge which could be subjected to such transformation process.

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