CANADIAN JOURNAL OF PSYCHOLOGY, 1984, 38(3), 440–453

Mental Mapping of a Megastructure*

Joan E. Foley and Annabel J. Cohen
University of Toronto

ABSTRACT The acquisition of spatial information about a large multi-functional complex building was studied by obtaining distance estimations, confidence judgements, and imagery reports. Magnitude estimation functions for particular sets of distances were computed for each subject by the method of iteratively weighted least squares, yielding an exponent and weights for each distance. Improvement in performance on different measures with increasing experience was not uniform; indeed, certain distances were increasingly in error. The data suggest that abstract schemata operate at all levels of exposure but that structural consistency increases. Directional asymmetries in distance judgements which accompanied shifts in imagery are taken as evidence for qualitatively different encodings of the environment: abstract versus scenographic. It is argued that superior performance on the distance estimation task depends on the construction of a dynamic abstract representation or "working map."

RÉSUMÉ Les auteurs étudient l'acquisition d'information spatiale au sujet d'un gros édifice complexe et multi-fonctionnel et ce, au moyen d'évaluations de distance, de jugement de confiance et de comptes-rendus d'imagerie. Des fonctions d'estimation de grandeur pour des ensembles particuliers de distances sont calculées pour chaque sujet par la méthode des moindres carrés pondérés itérativement qui donne un exposant et des poids pour chaque distance. Il n'y a pas d'amélioration uniforme de la performance aux différentes mesures en fonction de l'expérience. En fait, la marge d'erreurs s'accroît plutôt pour certaines distances. Les résultats laissent supposer que des schémas abstraits agissent à tous les niveaux d'exposition, mais que l'uniformité structurale s'accroît. Les asymmétries directionnelles dans les jugements de distance, asymmétries qui accompagnent des changements dans l'imagerie, sont considérées comme des indices de l'existence d'encodages différents de l'environnement: abstrait va scénographique. Les auteurs en déduisent qu'une performance supérieure à la tâche d'estimation de distance dépend de la construction d'une représentation abstraite dynamique ou "carte fonctionnelle."

It is usually proposed that information about the environment is stored not simply as a long list of places, routes, or temporal sequences of events but that there also emerges an encoding which is characterized by simultaneity, structure, and configuration (e.g., Siegel, Kirasic, & Kail, 1978; Siegel & White, 1975).

Hierarchical organizations of environmental knowledge have been proposed by Stevens and Coupe (1978), Wilton (1979), and Lehtiö, Poikonen, and Tuunainen (1980) who all suggest that superordinate information is accessed first. The idea of levels also appears in the work of Kaplan (1976) and of Hardwick, McIntyre, and Pick (1976) for whom the higher level represents general spatial relations and is more abstract; the lower level is closer to sensory experience and is more specific. In their accounts, it seems that information at any level can be accessed directly,

*This study was supported by grants from the National Science and Engineering Research Council of Canada to the first author. Address reprints requests to J.E. Foley, University of Toronto, Scarborough Campus, 1265 Military Trail, Scarborough, Ontario, Canada M1C 1A4.

depending on the cues presented, with a second step being required to access information at another level. Siegel et al. (1978) liken this kind of organization to using a microscope at different powers.

Siegel and White (1975) proposed a model for the development of cognitive maps of large-scale space in which higher order organizational structures develop later. Data consistent with this proposition are reported by Appleyard (1970, 1976), Evans, Marrero, and Butler (1981), Moore (1974), and Siegel and Schadler (1977). However, it seems quite likely that subjects would come to a new environment with expectations about the general configuration; that is, that higher level operations would be involved from the beginning. Where inappropriate, these would have to be discarded and subjects would be likely to converge on a common configuration after some experience.

Extant studies concerned with the effect of amount of experience on environmental spatial knowledge include some which test knowledge after varying numbers of days, weeks, months, and/or years of exposure to an environment with which subjects are in regular contact (e.g., Appleyard, 1970, 1976; Evans et al., 1981; Gärling, Böök, Lindberg, & Nilsson, 1981; Herman, Kail, & Siegel, 1979; Kozlowski & Bryant, 1977; Siegel & Schadler, 1977; Thorndyke & Hayes-Roth, 1982), and others in which the experimeter introduces subjects to the environment under relatively controlled conditions and measures the effect of a limited number of repeated exposures (e.g., Allen, Siegel, & Rosinski, 1978; Gärling et al., 1981; Herman & Siegel, 1978; Kozlowski & Bryant, 1977; Lindberg & Gärling, 1981). The present study examines the mental mapping of one set of locations after both very limited and extended exposure. In addition, an attempt is made to assess the impact of expectations upon the development of the cognitive map by including subjects who have yet to be exposed to most of the enivironment.

Information about whether the sex of the subject is relevant to environmental cognition is surprisingly meagre (see Evans, 1980; Moore, 1979) given the large literature on sex differences in spatial ability (Harris, 1981; McGee, 1979). Although sex differences favouring males have been reported in studies of children (Herman & Siegel, 1978; Keough, 1971; Siegel & Schadler, 1977; Weatherford & Cohen, 1980), effects associated with the sex of adult subjects, when reported, are weak (e.g., Gärling et al., 1981; Pearce, 1977). Possibly, the environmental spatial tasks typically studied in adults have been too easy. Low levels of exposure to a rather complex environment may favour the detection of sex differences, if they exist.

The experiment to be reported here investigated the organization of the mental representation of a very large and irregular built environment in male and female subjects whose exposure to it was (a) brief and incomplete, (b) a comprehensive conducted tour, (c) several months or (d) several years of rather intensive use. This was done by obtaining distance judgements among a sample of widely distributed locations and comparing performance on chosen subsets of distance intervals. To assist in the interpretation of these data, a number of other measures, including imagery reports and confidence ratings, were obtained.

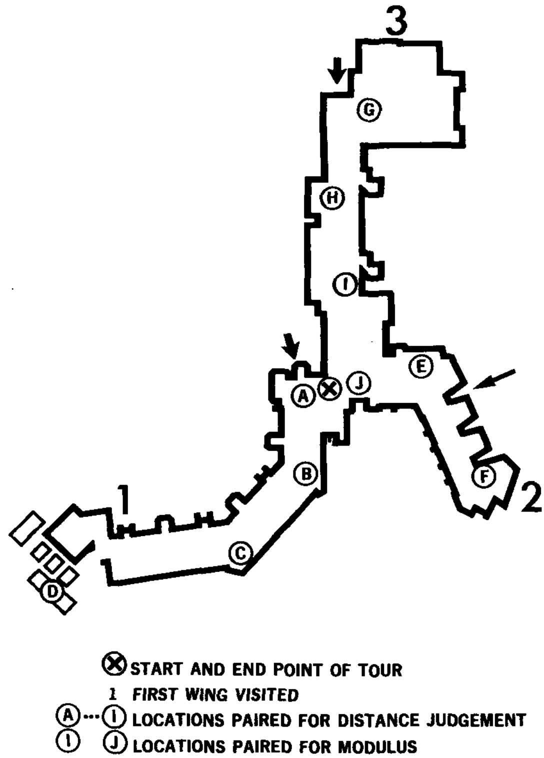

Figure 1. Layout of the building and 10 locations referred to in experiments.

METHOD

Subjects

The subjects were undergraduates and prospective undergraduates of the University of Toronto who varied in their experience with the Scarborough campus. The most experienced were fourth year undergraduates who had made intensive use of the campus for at least 28 of the approximately 40 months elapsing between entry and the time of testing (Year 4). Less experienced were undergraduates in their first year who had been in attendance for between 3 and 6 months immediately prior to testing (Year 1). Prospective undergraduates who were visiting the campus for the first time a few months before entry were tested either immediately before (Pre-tour) or after (Tour) being taken by a guide on a grand tour of the building. Pre-tour subjects had had only uncontrolled limited exposure to the building on their way to the student counselling office, the location of which is marked X in Figure 1. The main points of entry to the building for arrivals from off-campus are shown by arrows in Figure 1. Tour subjects were approached to participate in the study only after the tour was completed.

Subjects ranged in age from 18 to 24 years. The mean age of the fourth year students was 3 years greater than those in the first year, who were in turn approximately 6 months older than the prospective students. It is unlikely that there are age-related changes in environmental spatial cognition in young adults (see Evans, 1980).

The Environment

The environment studied was a very large, unique, multi-functional university building (Scarborough College) constituting a self-contained arts and science campus serving approximately 4,000 users. Often referred to as an example of a megastructure (Banham, 1976; Drexler, 1979), the multi-level building comprises three irregular wings connected at the level of the main pedestrian concourse. Ten locations well-known to students and distributed throughout the building all at the main pedestrian level were employed in the study as shown in Figure 1. These locations were three large classrooms (B, C, F) a cafeteria (E), an information desk (I), a pinball room (H), gymnasium (G), student radio station (J), bookstore (D), and a broad and heavily trafficked stairway (A) which provides the only major change in elevation of the main pedestrian street system.

For subjects at all levels of experience in our study the central area is liable to be more familiar than the periphery. Prior to the tour, subjects had arrived at the counselling office (X) but had not likely had much exposure to the wings; the tour itself left from this point and returned to some part of the central area after the expedition along each of the wings. For regular users, the low mean outdoor temperature during the academic session encourages the use of internal routes through the centre rather than the more direct external ones. The centre also contains an architecturally dominant feature, a large meeting place including location A (broad flight of stairs) and overlooked from vantage points on higher levels. It is surrounded by student services and facilities and is the site of various special events. The "centre" of the building is a psychological rather than a geographic construct and appears to constitute a region rather than a point. A questionnaire administered to 133 upper year students, none of whom participated in the present study, included a request to choose the location nearest to the centre of the building from among a list of 16, including the 10 used in this experiment. Forty-three percent chose location A, 20% chose E, 10% chose J, and B and I also received mentions.

Procedure

All groups were tested in a windowless room in the central area of the building. The testing of Tour subjects began no more than 15 minutes after the completion of the tour.

Subjects worked from a computer print-out which first listed the 10 locations to be used in the experiment. In the case of large areas, quite specific locations were named (e.g., entrance to the gym, cash register in the cafeteria), and in all cases subjects were shown photographs to ensure that there was no confusion about the location intended. All were readily recognized by undergraduate subjects and by those who had completed the tour. Subjects who had not taken the tour were asked to anticipate where these locations would be found. They did not appear to consider the request an unreasonable one (cf. Baird, 1979).

Next followed instructions for magnitude estimation of distance. The distance between locations I and J was chosen as the modulus and subjects were told to assign the value 100 to it. Direct straight-through distances (i.e., "as the crow flies") were to be judged in all cases. Following each judgement, the subject was to indicate the degree of confidence in the judgement by circling the appropriate number on a 5-point scale. The subject then judged each of the 36 distances between all possible pairs of nine locations (J was not included) in turn. The subject was instructed not to look back at or change earlier judgements. The 36 distance intervals were arranged in 3 blocks of 12 each with the constraint that the blocks contained similar proportions of distances within and between the various wings of the building and had approximately the same mean distance. The six possible orders of the three blocks were assigned to the six different subjects of a given sex at a given level of experience. Within each block, a different random order was generated for each subject.

After completion of all distance and confidence judgements, the subject was called upon to indicate on a percentage scale the extent to which the modulus had been used in making the magnitude estimates.

Next, subjects provided ratings on a 5-point scale of the extent to which each of the following had been thought of during the distance estimation task: (a) the exterior appearance of the building, (b) walking through the building; and (c) a map-like image of the building.

Design

At each of the four levels of experience, six male and six female subjects were tested.

For most of the 36 distances it was possible to identify one location as being closer to the centre of the building than the other. In order to examine possible asymmetries of judgement (cf. Sadalla, Burroughs, & Staplin, 1980), three subjects in each group received trials directed away from centre (Away condition), that is, the location closer to the centre was named first. For the other three subjects in each condition, the locations were named in the reverse order (Toward condition). Where the relative proximity of a pair of locations to this region was not obvious, they were ordered arbitrarily.

There were, therefore, 16 groups in $4 \times 2 \times 2$ between-subject design with $N = 3$: 4 levels of experience (Pre-tour, Tour, Year 1, Year 4), 2 sexes, and 2 directions of presentation of distance intervals vis-à-vis the centre of the building (Away and Toward).

RESULTS

The data are satisfactorily fitted by power functions as has generally been found for magnitude estimation of distance in large-scale environments (e.g., Golledge, Briggs, & Demko, 1969; Thorndyke, 1981). When plotted in log-log coordinates the data points approximate a straightline relationship between judged and actual magnitude. The slope of the log-log function (exponent of the power function) is indicative of the subject's sensitivity to variation in distance. A linear system has a slope (exponent) of 1.00.

Magnitude estimation functions were computed for individual subjects using a method of iteratively weighted least squares to obtain n and the weights (w) accorded individual data points in the final iteration (Mosteller & Tukey, 1977, pp. 356-365). This method yields better estimates of the parameters of the line than the more commonly used unweighted method, especially when smaller numbers of data points are available and individual subjects' data are fitted. Data points which are accorded low weights are outliers, that is, atypical in that they do not conform well to the general behaviour of the set of points. Exceptions to the general pattern may provide insight into the structure of the representation.

From the literature it appeared desirable to examine performance with respect to the central area in comparison with performance in more peripheral regions (cf. Byrne, 1979; Golledge et al., 1969; Tversky, 1981). Also, the literature on hierarchical effects (e.g., Stevens & Coupe, 1978; Wilton, 1979) suggested the utility of comparing within-wing distances with those between wings, and distances entirely within either the centre or the periphery with those which cross this boundary. In order, then, to examine the data for evidence of these organizational principles, the 36 distance intervals were categorized as shown in Table 1. For the purpose of this grouping the central region was assumed to be described by a circle with locations B, E, and I on its circumference and containing location A. Four independent sets of distance types were obtained: Type 1 (Central) distances are those entirely within the central region; Type 2 (Within) distances are those outside the centre and between two locations in the

TABLE 1
Categorization of All 36 Distances

		Distance type		
Central	Within	Between	Mixed	
A — B	B — C	F — C	F — B	I — D
A — I	B — D	F — D	I — F	E — D
A — E	C — D	F — H	B — H	A — H
B — I	I — H	F — G	E — H	A — G
B — E	I — G	C — H	B — G	A — F
E — I	H — G	H — D	E — G	A — C
	E — F	C — G	I — C	A — D
		G — D	E — C	

Note. Locations are directed away from the centre of the building (Away condition).

same wing of the building; Type 3 (Between) distances are those between two peripheral locations in different wings; and Type 4 (Mixed) distances are those where a segment of the distance is in the periphery and another segment within the centre.

It should be noted that this categorization was used for purposes of analysis only; all 36 stimuli were presented in random order to each subject. Therefore, in comparing the types, we are not vulnerable to the range effects which might occur if the different types of distances were tested in separate series of trials (cf. Poulton, 1979; Teghtsoonian & Teghtsoonian, 1978). The data may not be free of stimulus spacing biases (cf. Poulton, 1979), but this is a minor concern since we will not be dealing with a main effect of distance type, but rather with the interaction between type and other variables such as experience and test direction. All groups of subjects were exposed to the identical spacings of stimuli; nevertheless, the variables of experience and test direction affect the functions obtained for the different distance types differentially.

Because the variances associated with the Pre-tour condition were high relative to experienced users of the building, that condition was omitted from the analyses of variance; however, means will be reported where appropriate.

Slope

The slopes of individual subjects were subjected to analysis of variance as described above and including the within-subject variable of distance type. The mean slopes averaging across all distance types increased from Pre-tour (.21) to Tour (.74) then to Year 1 (.93) and Year 4 (.92). However, the interaction between distance type and experience approached the .05 level, $F(6, 72) = 2.1, p \simeq .06$. Figure 2 shows the change in slope as a function of experience and distance type. Increases in slopes for central and between initially lag behind within but all approximate 1.00 given sufficient experience, with that for within apparently declining again in Year 4. By contrast, slopes for the mixed type never reach 1.00, but level off at a lower value established after the tour.

The interaction of distance type and direction approached the .05 level of

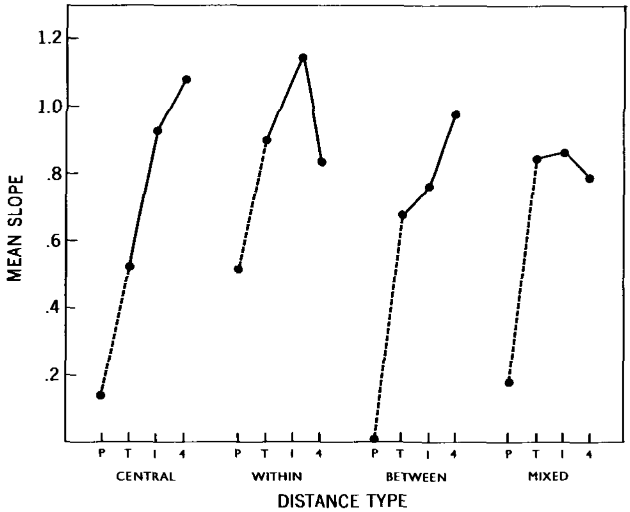

Figure 2. Mean slope as a function of distance type and experience (P = Pre-tour; T = Tour; 1 = Year 1; 4 = Year 4).

significance, $F(3, 72) = 2.5, p \simeq .06$, due to a high slope in the Away direction on within distances (see Figure 3). The direction effect in the within set was significant at the .001 level by a Scheffé test. That is, the direction effect is clear in the one set which is entirely comprised of distances which are quite unambiguous in direction vis-à-vis the centre. Thus, slopes were calculated for a larger set of 15 distances in which radial direction was very clear, viz., all 7 within distances together with the 8 between A and each of the locations B-I. These slopes were analyzed using the same design, but omitting the variable of distance type. The mean slope for the Away direction (.81) was significantly higher than for the Toward direction (.57), $F(1, 32) = 4.04, p < .05$.

Weights

The weights accorded each distance for individual subjects in the final iteration for each distance type (central, within, etc.) were subjected to analysis of variance with the within-subject variable of distance. The purpose of these analyses was to detect any specific distances which were outliers in relation to the pattern of judgements typical for the set (i.e., were accorded consistently low weights). The effect of experience on the pattern of outliers would provide clues to the developing organization of the representation. Significant interactions between the variables of distance and experience were found in the case of both the within and the between sets.

In the within set the weight accorded to B-C increased consistently with experience, whereas the weights accorded to C-D and E-F decreased with experience, $F(18, 192) = 1.7, p < .05$. B and C were classrooms with similar names and the distance between them tended to be underestimated initially both

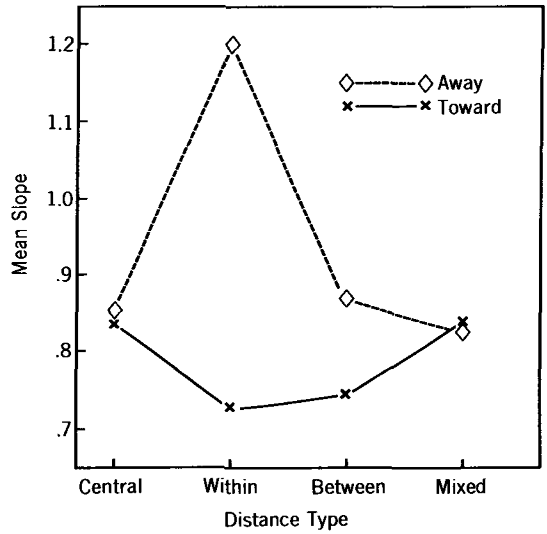

Figure 3. Mean slope as a function of distance type and direction of presentation (Pre-tour condition eliminated).

absolutely and relative to other members of the set. While the amount of relative underestimation decreased with experience, the direction of the deviation persisted. C-D and E-F are the outer segments of wings 1 and 2, respectively. At the highest level of experience, C-D (in the longest wing) was underestimated and E-F (in the shortest wing) was overestimated relative to other members of the set.

In the between set the weight accorded D-F decreased with experience , $F(21, 224) = 2.0, p < .01$. D-F is the distance between the end-points of wings 1 and 2 which was characteristically underestimated, this tendency increasing with experience.

Confidence

Mean Confidence: The mean of all 36 confidence judgements was calculated for each individual subject and the scores subjected to analysis of variance. The main effect of experience was significant, $F(3, 32) = 14.3, p < .0001$. Mean confidence in Year 1 (3.2) and Year 4 (3.2) was higher than in Pre-tour (2.2) and Tour (2.4) conditions.

The main effect of sex was significant, $F(1, 32) = 11.6, p < .005$, with males (3.01) expressing higher confidence than females (2.53). However, the interaction between sex and direction was also significant, $F(1, 32) = 4.5, p < .05$. Low mean confidence for females was obtained only in the Toward (2.29) as compared with the Away (2.76) condition.

Correlation Between Confidence and Judged Distance: Generally, the confidence expressed by subjects decreased as the distance judgement increased. That is, there seems to be some awareness on the part of subjects of additional uncertainty in the mental measurement of larger distances.

TABLE 2
Mean Reported Percentage Use of the Modulus as a Function of Sex and Increasing Experience

	Increasing experience			
Sex	Pre-tour	Tour	Year 1	Year 4
Female	53	42	82	87
Male	45	73	77	83
Mean	49	58	79	85

Individual product moment correlation coefficients were calculated and transformed to Fisher z' values, then subjected to analysis of variance. The main effect of experience was significant, $F(3, 32) = 10.0$, $p < .0005$. The mean correlation coefficients obtained from reconversion of the mean z' values for the Pre-tour ($-.21$) and Tour ($-.07$) conditions were lower than those for Year 1 ($-.49$) and Year 4 ($-.44$). The presence of some negative correlations in the Pre-tour condition reflects the partial knowledge of these subjects and their certainty that S-309 and S-319 would be found together. The main effect of sex was also significant, $F(1, 32) = 7.94$, $p < .01$, with reconverted mean correlations of $-.41$ for males and $-.22$ for females.

Reported Use of Modulus

The percentile ratings obtained from individual subjects were subjected to analysis of variance. The reported use of the modulus increased with experience, $F(3, 32) = 8.6$, $p < .001$, but the interaction of experience and sex approached significance at the .05 level, $F(3,32 = 2.6$, $p \simeq .07)$. As seen in Table 2, this arises from a sex difference in the Tour group where the mean for males is higher than for females.

Reported Use of Imagery

Individual ratings of the use of the three types of imagery were subjected to analysis of variance including the within subject variable of image type. The main effect of image type was significant, $F(2, 64) = 19.2$, $p < .0001$. The mean for "exterior" imagery was 2.15, much lower than for "walking inside" (3.69) and "map-like" imagery (3.23).

A second analysis of variance was performed combining "walking inside" and "exterior" into one category of "scene" imagery for comparison with the more abstract "map-like" image. The interaction of image type and direction was significant, $F(1, 32) = 3.94$, $p < .05$). The amount of map-like imagery increased in the Away condition whereas reports of scene imagery decreased in this condition (see Figure 4).

DISCUSSION

There are indications that naive subjects approach the building with expectations about the spatial layout. The three classrooms (B, C, & F), none of which are

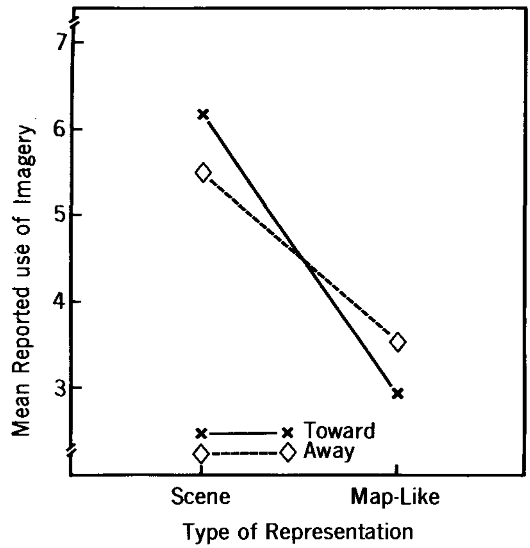

Figure 4. Mean reported "scene" and "map-like" imagery for each direction. Scene comprises walking inside and exterior imagery, maximum value = 10.0, minimum value = 2.0. For map-like imagery, maximum value = 5.0, minimum value = 1.0.

likely to have been encountered prior to the tour, are expected to be in relatively close proximity, an assumption which is incorrect in the case of F. The expectation is particularly strong in the case of B and C, which are similar in name as well as in function. The relative as well as absolute underestimation of B-C is only gradually reduced with experience and remains apparent in the data of the most highly experienced subjects. The type and amount of imagery reported by Pre-tour subjects was quite similar to that of more experienced subjects, suggesting that they have a variety of abstract and specific ideas about the spatial layout.

One comprehensive tour of the building results in a large and significant improvement in distance judgements as reflected in the slopes of the magnitude estimation functions, and further improvement is evident 3 to 6 months later. However, confidence, which we interpret as the subject's estimate of the precision of his/her response, is not notably improved by the tour, but awaits further exposure to the environment. The concurrent increasing negative relation between confidence and judged distance suggests that the relative clarity of the representation of shorter distances increases with experience whereas longer distances remain relatively imprecise. Alternatively, more experienced subjects may be sensitive to variability (uncertainty) associated with each mental application of the measuring unit (the modulus) to the distance being judged and with the operation of counting, consistent with the observation that more experienced subjects report relatively high use of the modulus. Gärling, Böök, and Ergezen (1982) and Stapf (according to Lundberg, 1973) also found that certainty varied inversely with distance.

Our data accord in general with those of others who have noted rapid learning of spatial relations (Allen, et al., 1978; Herman & Siegel, 1978; Siegel et al., 1978). However, our results also suggest that different aspects of performance do not necessarily increase at the same rate. One tour suffices to develop a representation which approximates the actual spatial relations, but considerable uncertainty attaches to the placement of the various locations at this stage. In addition, subjects may have difficulty in using the method of mental measurement called for by the experimenter; that is, they cannot readily manipulate the information which has been stored. Once subjects begin to make continuing active use of the environment, the map is refined in accuracy and subjective precision increases dramatically. The ability of subjects to measure mentally one distance in terms of another also improves at this stage and may continue to do so over several years (reported use of the modulus increases over the whole range of experience studied).

It appears that users first map each of the three wings of the building (rapid increase in within-wing slopes). Subsequently, between-wing and central relations are instated, but partitioning of the centre from the peripheral region persists as indicated by the failure of the slopes for mixed distances to increase over the value of 0.8 established after the tour. Distances between locations in the centre and others outside it are either not well represented or the information can be obtained only indirectly (cf. Allen, 1981).

Consideration of those distances which emerge as outliers, as revealed by the analysis of weights, contributes further insight into the developing organization. Over the entire range of experience examined, the judgements of the outer segment of wings 1 and 2 and of the distance between the endpoints of these wings become increasingly atypical of those of other distances of the same type. The relative lengthening of wing 2, along with relative shortening of wing 1 and shortening of the distance between the two, suggests a higher-order structure which emphasizes symmetry and stability at the expense of veridical representation of the relations among the three wings, viz., a central region with three equally spaced wings of equal size. This effect is most evident in more experienced subjects, consistent with the idea that subjects converge on this particular structure because, in this environment, it proves more useful than others which are tested and discarded.

At all levels of experience it was typical for subjects to report use of more than one kind of imagery, suggesting the availability of more than a single encoding or representation of the building. While others have directed attention to multiple representations of large-scale space (e.g., Hardwick et al., 1976; Kaplan, 1976; Siegel et al., 1978), this study is the first to quantify the use of various types of representations and to show that it is affected by direction of presentation of test trials: reports of map-like imagery were high when the location nearer the centre was named first (Away) and of scene imagery when it was named last (Toward). This effect intimates a propensity to access different encodings in the two test situations. Associated direction effects in the slope data for clearly directed distances suggest that the encodings differ in the quality of spatial information available: that which is accompanied by high frequencies of report of scene imagery (scenographic encoding) is associated with relatively low sensitivity to variation in distance; that which is accompanied by high frequencies of report of map-like imagery (abstract encoding) permits high sensitivity to variation in radial distances.

The information which is considered by the experienced subject during the experimental task includes by no means all that he knows about the environment. We suggest that an active representation is constructed, the contents of which may be influenced by the questions addressed during the series of trials. For example, if the more central locations are named first on test trials, the subject is liable to construct an abstract simultaneous representation or *working map*. This map is likely to include locations named in the experiment, but most likely not many other locations of which he has tacit knowledge (Downs, 1981) and, on specific trials, may not include all experimental locations (see also Wickelgren, 1981, for a discussion of the distinction between active memory and passive/long-term associated memory). An integrated abstract working map of locations widely dispersed in a large environment is achieved by the application of a simplifying higher-order structure: an *aide memoire* (cf. Kolers & Smythe, 1979) which, in the present study, enables many relationships to be represented but at the cost of relatively large errors in a few specific cases. Reversal of the direction of the test trials is less conducive to construction of an abstract working map. In relation to this environment, the subject who is mentally approaching the centre is more likely to think of scenes and/or movements which provide a relatively poor basis for direct distance judgement.

Our distinction between abstract and scenographic representations echoes dichotomies in the literature such as simultaneous versus sequential, or survey map/configuration versus route/procedural knowledge. However, our data do not support the frequent contention that sequential, route encoding of the environment is developmentally prior to simultaneous, survey mapping when adults encounter a new environment (Siegel & White, 1975; Thorndyke & Hayes-Roth, 1982). At all levels of exposure, both abstract and scenographic imagery are reported by our subjects. We emphasize the qualitative difference between these separate subsystems which yield remarkably different sensitivity to variations in distances in the environment. To liken moving from one of these representations to the other to a change in power of a microscope (Siegel, et al., 1978) is not apt, nor are they hierarchically linked as implied by Hardwick et al., (1976), Kaplan (1976), and others. Our findings are compatible with the proposal of Lindberg and Gärling (1982) that dual representation is functionally justified, in that it provides a back-up system for the solution of spatial problems. They describe the acquisition of information about the locomotion path as relatively automatic, whereas acquiring information about relative locations requires central processing; nevertheless, the two systems may be developed concurrently. The disadvantage of path information is that the location of a reference point is not then available directly, but requires time-consuming retrieval and combination of the stored information, with much potential for error (see also Thorndyke & Hayes-Roth, 1982).

It was hypothesized that this large, complex, and hence difficult environment might lend itself to the detection of sex differences, if they exist, particularly in the early phases of exposure. None appeared in the distance estimations themselves, suggesting that males and females are quite comparable with respect to the formation of an abstract mental map of this highly irregular and very large environment. Differences favouring males were noted in the case of mean confidence, the correlation between confidence and judged distance, and the reported use of the modulus. These data may reflect differences in the mental manipulation of spatial information demanded by our distance judgement task, or arise from conservatism on the part of females in self-report of cognitive abilities.

REFERENCES

Allen, G.L. (1981). A developing perspective on the effects of "subdividing" macrospatial experience. *Journal of Experimental Psychology: Human Learning and Memory*, **7**, 120-132.

Allen, G.L., Siegel, A.W., & Rosinski, R.R. (1978). The role of perceptual context in structuring spatial knowledge. *Journal of Experimental Psychology: Human Learning and Memory*, **4**, 617-630.

Appleyard, D. (1970). Style and methods of structuring a city. *Environment and Behavior*, **2**, 100-118.

Appleyard, D. (1976). *Planning a pluralistic city*. Cambridge, MA: M.I.T. Press.

Baird, J.C. (1979). Studies of the cognitive representation of spatial relations I. Overview. *Journal of Experimental Psychology: General*, **108**, 90-91.

Banham, R. (1976). *Megastructure: Urban features of the recent past*. London: Thames.

Byrne, R. (1979). Memory for urban geography. *Quarterly Journal of Experimental Psychology*, **31**, 147-154.

Downs, R.M. (1981). Maps and mappings as metaphors for spatial representation. In L. Liben, A.H. Patterson, & N. Newcombe (Eds), *Spatial representation and behavior across the life span* (pp. 143-146). New York: Academic Press.

Drexler, A. (1979). *Transformations in modern architecture*. New York: Museum of Modern Art.

Evans, G.W. (1980). Environmental cognition. *Psychological Bulletin*, **88**, 259-287.

Evans, G.W., Marrero, D., & Butler, P. (1981). Environmental learning and cognitive mapping. *Environment and Behavior*, **13**, 83-104.

Gärling, T., Böök, A., & Ergezen, N. (1982). Memory for the spatial layout of the everyday physical environment. *Scandinavian Journal of Psychology*, **23**, 23-25.

Gärling, T., Böök, A., Lindberg, E., & Nilsson, T. (1981). Memory for the spatial layout of the everyday physical environment: Factors affecting rate of acquisition. *Journal of Environmental Psychology*, **1**, 263-277.

Golledge, R.G., Briggs, R., & Demko, D. (1969). The configuration of distance in intraurban space. *Proceedings of the Association of American Geographers*, **1**, 60-65.

Hardwick, D.A., McIntyre, C.W., & Pick, H.L. (1976). The content and manipulation of cognitive maps in children and adults. *Monographs for the Society for Research in Child Development*, **41**, No. 166.

Harris, L. J. (1981). Sex related variations in spatial skill. In L. Liben, A.H. Patterson, & N. Newcombe (Eds.), *Spatial representation and behavior across the life span* (pp. 83-117). New York: Academic Press.

Herman, J., Kail, R., & Siegel, A. (1979). Cognitive maps of a college campus: A new look at freshman orientation. *Bulletin of the Psychonomic Society*, **13**, 183-186.

Herman, J., & Siegel, A. (1978). The development of spatial representation of large-scale environments. *Journal of Experimental Child Psychology*, **26**, 389-406.

Kaplan, S. (1976). Adaptation, structure and knowledge. In G.T. Moore & R.G. Gollege (Eds.), *Environmental knowing*. Stroudsburg, PA: Dowden, Hutchinson, & Ross.

Keough, B.K. (1971). Pattern copying under three conditions of an expanded spatial field. *Developmental Psychology*, **4**, 25-41.

Kolers, P.A., & Smythe, W.E. (1979). Images, symbols and skills. *Canadian Journal of Psychology*, **33**, 158-184.

Kozlowski, L.J., & Bryant, K.J. (1977). Sense of direction, spatial orientation and cognitive maps. *Journal of Experimental Psychology: Human Perception and Performance*, **3**, 590-598.

Lehtiö, P., Poikonen, L., & Tuunainen, K. (1980). Retrieval of information from a mental map. In R.S. Nickerson (Ed.), *Attention and Performance 8*. Hillsdale, NJ: Erlbaum.

Lindberg, E., & Gärling, T. (1981). Acquisition of locational information about reference points during locomotion with and without a concurrent task. *Scandinavian Journal of Psychology*, **22**, 109-115.

Lindberg, E., & Gärling, T. (1982). Acquisition of locational information about reference points during locomotion: The role of central information processing. *Scandinavian Journal of Psychology*, **23**, 207-218.

Lundberg, U. (1973). Emotional and geographical phenomena in psychophysical research. In R.M. Downs & D. Stea (Eds.), *Image and environment* (pp. 322-337). Chicago: Aldine.

McGee, M.G. (1979). Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences. *Psychological Bulletin*, **86**, 889-918.

Moore, G.T. (1974). Developmental variations between and within individuals in the cognitive representation of large-scale spatial environments. *Man-Environmental Systems*, **4**, 55-57.

Moore, G.T. (1979). Knowing about environmental knowing: The current state of theory and research on environmental cognition. *Environment and Behavior*, **11**, 33-70.

Mosteller, F., & Tukey, J. (1977). *Data analysis and regression*. Don Mills, Ontario: Addison-Wesley.

Pearce, P.L. (1977). Mental souvenirs: A study of tourists and their city maps. *Australian Journal of Psychology*, **29**, 203-210.

Poulton, E.G. (1979). Models for biases in judging sensory magnitude. *Psychological Bulletin*, **86**, 777-803.

Sadalla, E.K., Burroughs, W.J., & Staplin, L.J. (1980). Reference points in spatial cognition. *Journal of Experimental Psychology: Human Learning and Memory*, **6**, 516-528.

Siegel, A.W., Kirasic, K.C., & Kail, R.V. (1978). Stalking the elusive cognitive map: The development of children's representation of geographic space. In J.F. Wohlwill & I. Altman (Eds.), *Human behavior and environment (Vol. 3)*. New York: Plenum.

Siegel, A.W., & Schadler, M. (1977). Young children's cognitive maps of their classroom. *Child Development*, **48**, 388-394.

Siegel, A.W., & White, S.H. (1975). The development of spatial representations of large-scale environments. In H.W. Reese (Ed.), *Advances in child development and behavior* (10). New York: Academic.

Stevens, A., & Coupe, P. (1978). Distortions in judged spatial relations. *Cognitive Psychology*, **10**, 422-437.

Teghtsoonian, R., & Teghtsoonian, M. (1978). Range and regression effects in magnitude scaling. *Perception and Psychophysics*, **24**, 305-314.

Thorndyke, P.W. (1981). Distance estimation from cognitive maps. *Cognitive Psychology*, **13**, 526-550.

Thorndyke, P.W., & Hayes-Roth, B. (1982). Differences in spatial knowledge acquired from maps and navigation. *Cognitive Psychology*, **14**, 560-589.

Tversky, B. (1981). Distortions in memory for maps. *Cognitive Psychology*, **13**, 407-433.

Weatherford, D.L., & Cohen, R. (1980). Influence of prior activity on perspective taking. *Developmental Psychology*, **16**, 239-240.

Wickelgren, W.A. (1981). Human learning and memory. *Annual Review of Psychology*, **32**, 21-52.

Wilton, R.N. (1979). Knowledge of spatial relations: The specification of the information used in making inferences. *Quarterly Journal of Experimental Psychology*, **31**, 133-146.

Received 8 August 1983
Revision received 15 December 1983
Accepted 27 March 1984