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DISTANCE ESTIMATION IN CITIES

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A property of the physical environment of distinct psychological importance is the fact that the environment completely surrounds us. Thus it is not possible for us to experience or perceive all of it at any one instant. We can only turn our attention to discrete aspects of the environment at successive points in time. However, in order for our behaviour to be appropriate, effective, or adequate in relation to the physical environment, it is necessary for it to proceed in a continuous fashion. To explain the way in which this discrete experience can produce continuous interaction it is necessary to postulate some representational process on the part of the individual. This "representation" must amalgamate experience into a form which links discontinuities in perception and allows extrapolations to facilitate preparation for future action.

In the case of an individual coping with a city, it is further necessary to assume that the postulated amalgamation of experiences is somehow summarised. This summary consists of a pattern or structure, the resultant effect of which is to

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organise the "representations" of the experiences of the city and their implications.

Note that the term "representation" is in quotation marks. This is because there is nothing within our description of it to say that it must have any direct relationship to the usual methods of representing cities. Indeed, because our assumption of a representational process derives from the relationships between present experience and continuing behaviour, it seems likely that representations other than visual ones (akin to those used by geographers—"maps") are involved.

These concepts derive from the work of Bartlett (1932) and Lynch (1960). More recently, Stea (1969) and Ittelson (1973) have argued in some detail for crucial differences between the perception of environments and the perception of objects. Stea, in particular, has asked "can urban imagery be quantified?" For the present paper we have moved some way to answering this question. We have examined some aspects of the metric properties of urban "images."

Once it is accepted that internal representation is central to our abilities to cope with cities, then the question of the veracity of this internal process, the properties it handles accurately and those is distorts, becomes paramount. One of the most crucial properties is that of scale, or distance. This is crucial because by its very nature any representation of the city environment cannot be of the same physical size. Yet many of the qualities of any representation relate to its scale (i.e., the ratio between distances on the representation and actual distances). Indeed, for geographic surveys we may consider an inch-to-the-mile map appropriate for dealing with cities but not for countries. Are there any analogous psychologically appropriate metrics for cities?

Research in environmental distance estimation has already revealed a number of consistencies. There is thus the likelihood that such inviting but formerly speculative concepts as a city's image (Lynch, 1960; Appleyard, 1970) now may be examined precisely and numerically by the use of distance estimation. For example, Ekman has carried out a number of studies (summarised by Lundberg et al., 1972). The central aim of these was to show that a square root relationship held between subjective distance and emotional involvement for capitals around the world—a relationship such that intensity of emotional involvement was inversely related to the square root of subjective distance. Such a relationship has been demonstrated in a number of studies (Dornic, 1967; Bratfisch, 1969), but unlike the studies from the same laboratories on subjective temporal distance (Lundberg, forthcoming), no evidence seems to have been published to show that this relationship provides the best or most parsimonious account of the data.

The reasons for the use of "subjective" as opposed to "objective" distance estimations Lundberg ascribes to Ekman's (1961) suggestion that psychophysical relationships should be explored on the "purely psychological level." However, in the case in which comparisons are being made with emotional involvement, it would seem that (in English anyway) both judgements may be really synonymous for the same concept. How subjectively far away a place feels can only mean the degree to which one feels linked with it or concerned with activities which take place within it, in other words, how emotionally involved one is with it. Thus finding a relationship between these two statements only helps to show they do indeed have a similar meaning. It does not tell us much about the relationship between psychological and physical variables. The linear relationship between subjective distance and geographical distance which Lundberg (1972) reports does help to provide some information in this direction. However, in this case attitudes toward the various countries and knowledge of them clearly play a key role. Lundberg's findings possibly contribute more to geopolitics than psychophysics. Evidence in favour of the weaknesses of the Ekman and Lundberg studies is given by Stanley (1968, 1971) who, when using judgements of estimated objective distance, found no evidence for the inverse square root relationship with emotional involvement.

Cadwallader (1973) has tackled the problem more directly by asking people to estimate the distance from their home to each of thirty cities in the Los Angeles basin. To examine the importance of the type of distance estimation he had his subjects use two methods. Using absolute mileage estimations, he obtained the regression $Y = 1.09X + 5$ ($r = 0.96$), whereas using "magnitude estimation" the regression was $Y = 0.59X + 0.46$ ($r = 0.94$), where Y was the mean of the estimated and X the actual distances.

Golledge and Zannaras (1973) also showed that high correlations could be obtained between "perceived" and actual distances. Judgements were made of distances between the university campus and a series of locations along a "major north-south artery." However, they found newcomers less accurate in their distance estimates than established residents. They also report that there was "an underestimation of distance moving away from the down town area." In other words, distances into the town were perceived as relatively longer than distances out of it. Briggs (1972) followed up this finding and found some support for it.

This contrasts markedly with the study by Lee (1970) in which students estimated the walking distance between pairs of points in Dundee. The pairs were so selected that some of the distances were inward and some outward. Lee found that there was an overestimation of outward journeys. It is intriguing that this supports Lee's essentially cognitive orientation. He sees distortions in estimation as brought about by factors such as desirability of the journey destination. Lee argues that the centre of Dundee was more attractive to his students than its periphery. The Golledge and Briggs studies, however, led support to the learning theory stance which they take. They see experience of the journey, with increasing traffic toward the downtown area, as the key determinants of distortions in perception. Yet Lee and Golledge are both dealing with quite different city forms: the grid pattern of northern Columbus contrasting with the contour following plan of Dundee. Indeed, in the latter case there will be a slight tendency for the outward distances to be uphill away from the Firth.

The final environmental study we must refer to is that of Lowrey (1970). He examined in detail the scalar properties of distance estimations to known urban facilities. He came to the conclusion that people were indeed able to estimate distances in a manner akin to ratio scaling.

These studies have covered a wide range of distances, from hundreds of yards to hundreds of miles, and they have also included a range of types of distance estimate. But in particular, there seems to be some confusion in the literature as to whether actual routes are estimated or direct ("crow flight") distances. At the large country or city scale of Lundberg or Cadwallader crow flight distances are seemingly the only meaningful ones to ask subjects to estimate. Route distances would be confused by the range (or lack) of routes available. But at the city scale it would seem that actual route distances would weight the estimate in terms of experiences directly related to following the route itself, details such as time and direction having a considerable impact. Crow flight estimates may be drawn more directly from some abstracted representational process which the person has developed. Admittedly this process may be built upon many experiences, such as travelling about the city, but crow flight estimates should enable us to deal with the general residue of this experience, rather than its particular manifestations. For our studies, then, we have concentrated upon crow flight distance.

However, in dealing with direct distances it is easy to confuse distance estimation with the psychophysical studies of length estimation. Both Ittelson (1973) and Stea (1969) have emphasized the difference between the latter, in which a target object is present for perception, and the former in which the object cannot immediately be perceived. Furthermore, even the longest lengths judged in psychophysical studies, around 700 metres (Kuroda, 1971), were from a seated position along a straight road. More typical are the studies by Kunnapas (1968) with lengths up to four metres being judged under highly controlled and often excessively distorted conditions. In these situations many of the depth cues such as size of the image on the retina or familiarity of the object perceived have been shown to have a marked effect on judgments of their distance from the observer (Kunnapas 1968; Gogel 1969).

In the same vein Stevens has developed the Weber-Fechner functions to show a power relationship between psychological judgements and physical measurements. This power function seems to vary according to the sensory attribute being judged (Stevens, 1957), but there is some discussion as to what its value is for distance. In his 1957 paper Stevens indicates that it might take on a variety of values for estimates of distance under different conditions, being close to one for physical length (Stevens and Galanter, 1957). Others have argued (Kunnapas, 1960; Teghtsoonian, 1971) that the exponent depends upon the range of the stimuli being judged and when this is taken into account an exponent of 0.03 copes with most data. But here again the lengths judged are always immediately available to the senses, often in the region of one to three metres, and thus are qualitatively different from distance estimation in cities. The question is thus raised whether the same relationships will hold for "cognitive" estimates as for "perceptual" ones.

One further value of studying distance estimations is that they are a significant component of our environmental vocabulary. The study is thus especially valuable if the units of estimation are drawn from the commonly available language of yards or miles (and possibly minutes and hours). Whether it be as a basis of signposting or word-of-mouth comment, distances frequently occur as environmental descriptors with implications for behaviour. The fact that there is a publicly available criterion against which to validate these descriptors does not necessarily imply that they are used exactly in accord with that criterion. The study by Cadwallader suggests that they are not.

In summary then, the studies to date have shown that consistent (if consistently inaccurate) estimates of distances between environmental locations can be made. These estimates might well be of a different kind from those normally examined by psychophysicists and they are also likely to be sensitive to aspects of environmental experience. They thus have great potential for contributing to the understanding of the representations of cities which we all develop.

Of the questions requiring future study which emerge from this survey of research the one we have identified as central is: what general statements can we make about the relationship between estimated and actual distance? In other words, is this relationship constant across cities and cultures? A corollary of this question will also be examined: what distortions in estimations can be related to the form of any given city?

METHOD

In all, eleven distinct studies were carried out in seven cities in five different countries. A summary of these studies is presented in Table 1. In all cases the points were selected by a resident to give a reasonable distribution over the city and to relate, in general, to reasonably well-known, identifiable locations. The type of location depended on the city, but they tended to be landmarks and stations. However, some attempt was made to introduce one or two less well-known points for later comparisons. Subjects were presented with the names of points in the form of a matrix: they had one set of names across the top and the other set down the side. For studies 1 to 6 the two sets of names were the same, for studies 7 to 11 they were different.[1] Thus, for the first 6 studies all interpoint distances were obtained but not for the remainder.

For the reasons discussed above it was decided to obtain estimates in a form common in daily speech. Each subject estimated the *direct* (as the crow flies) distance between every pair of places to the nearest half mile (or half kilometre). He was told to guess if he was not sure. He thus completed every

TABLE 1
SUMMARY OF ELEVEN DISTANCE ESTIMATION STUDIES

City	Study Number	Number of Subjects	Number of Points	Number of Distance Estimates	Mean Actual Distance	Standard Deviation Actual	Mean Estimated Distance	Standard Deviation Estimated	Subjects
Glasgow	1	50	5	10	2.67	0.86	3.97	0.76	Pedestrians in Central Glasgow
Glasgow (Inner Distances)	2	38	7	21	1.36	2.33	4.18	2.89	Architecture undergraduates
Glasgow (Outer Distances)	3	38	7	21	6.22	2.58	7.53	2.07	Architecture undergraduates
Edinburgh	4	35	7	21	1.28	0.60	1.92	0.88	Art school undergraduates
Heidelberg	5	24	7	21[a]	2.50	1.21	3.15	1.02	Psychology undergraduates
London	6	25	5	10	3.96	2.24	4.77	1.74	Architecture undergraduates
Sydney[b]	7	23	12	36	13.61	6.53	17.19	7.70	Architecture undergraduates
Tokyo	8	64	11	30[a]	6.89	3.39	10.59	5.00	Architecture undergraduates
Tokyo[c]	9	41	13	30[a]	6.69	2.78	11.77	4.63	Technical college undergraduates
Nagoya[c]	10	18	10	40[a]	5.33	2.36	7.51	3.57	Architecture undergraduates
Nagoya[c]	11	20	12	35[a]	5.16	2.35	6.46	2.80	Technical college undergraduates

a. Estimates in kilometres (all others in miles).
b. We are grateful to Ross Thorne for conducting this study.
c. We are grateful to Dr. Inui and Dr. Miyata for conducting these studies.

cell in the matrix for the latter five studies and one half of the matrix for the former six. After their responses had been collected, it was apparent from subjects' comments that their estimates did not usually come from any clear "mental map." They did, however, frequently express a reasonable confidence in them and did not appear to find the task too onerous.

For the purpose of analysis arithmetic means for each group were calculated for each of the interplace distance estimates.

THE RELATIONSHIPS BETWEEN ESTIMATES AND DISTANCE

Reference to Table 1 shows that all the mean estimates are greater than the actual mean distances: all further comments must be taken against this background of overestimation. In order to answer our central question linear regressions were calculated between all the mean estimates and the actual distances. For instance, with 5 points there are 10 estimates, with 7 there are 21. Correlations for these regressions were also calculated to see if the assumption of linearity was acceptable. To further test the possibility derived from the work of Stevens (1957) that a nonlinear power function is involved, regression of the log mean against the log actual distance and their correlations were calculated. A summary of these results is presented in Table 2.

The results in that table have been arranged in order of regression slope so that the studies can be seen in the sequence from those which give a decrease in overestimation against length (i.e., the A-coefficient is less than 1.00) to those which give a general overestimation of distances. However, before referring to the implications of this sequence two general points emerge from Table 2.

First, in general these subjects, when their responses are averaged, do give answers which correlate highly with the actual distance. Yet because few of the slopes are 1.00, there is a tendency for their estimates to have a consistent bias (or misestimation) in proportion to the actual distance. (The

TABLE 2

REGRESSION OF MEAN ESTIMATES AGAINST ACTUAL DISTANCE

(X = is actual distance)

City	Study Number	Linear Regression (Y = AX + B)	Correlation for Y = AX + B	LogLog Regression (Log Y = ALogX + B)	Correlation for Log Y = ALogX + B
Glasgow	1	0.45 + 2.72	0.45	0.35X + 0.45	0.52
Heidelberg	5	0.70X + 1.41	0.83	0.53X + 0.30	0.87
London	6	0.74X + 1.84	0.95	0.73X + 0.36	0.97
Glasgow	3	0.76X + 2.81	0.95	0.59X + 0.42	0.92
Glasgow	2	1.01X + 1.28	0.93	0.79X + 0.26	0.94
Nagoya	11	1.07X + 0.95	0.90	0.92X + 0.16	0.91
Sydney	7	1.12X + 1.19	0.95	0.89X + 0.03	0.97
Nagoya	10	1.27X + 0.77	0.84	1.04X + 0.13	0.95
Edinburgh	4	1.29X + 0.27	0.88	1.03X + 0.17	0.93
Tokyo	8	1.39X + 1.03	0.94	0.93X + 0.24	0.95
Tokyo	9	1.54X + 1.46	0.93	0.82X + 0.39	0.92

practical implications of this in such areas of decision-making as traffic engineering could be considerable). The one group which stands out in respect of correlations is that of Study 1. This is the only group of "real" people, i.e., nonstudents accosted in the street and asked to answer some questions. They would be expected to come from a background of experience and training very different from the students. Such a discrepancy between their averaged ability to estimate distances and that of the undergraduates poses a very important and potentially fruitful question for future investigation.

The second point emerges from a comparaison of the two regression equations and their correlations. From this comparison, although there is a tendency for the LogLog regression to account for a little more of the common variance, this is certainly not consistent. In the light of this our future discussion will deal only with the linear relationships.

There is one practical value of the high correlations. They do support the assumption that the ratio of estimate to actual distance is a reasonably constant one for any set of distances. Thus we may consider, in general, average misestimation without the fear that these average ratios (say, of actual divided by the estimate or the slope of the regression line) will relate to the actual magnitude, or scale, of the distances involved. Accepting this we may then question the sequence of the studies in Table 2 to see what hypotheses they suggest for such notable differences between cities.

REGRESSIONS AND PREGNANZ

The studies fall into three groups in relation to their linear regressions. The first group covers the Glasgow, Heidelberg, and London studies. In four cases the A-coefficients are less than one and the B-values are greater than one. The general trend for estimating distance, which emerges from these relationships, would seem to be to add a constant distance and then to underestimate the actual distances. This produces overestimation for shorter distances. However, once the actual distance is above six or seven miles, underestimation is the tendency. In the main, these cities appear to have some property which leads the respondents to think of longer distances being, on the average, about three-quarters of what they actually are. The second group contrasts with this. In this group, drawing studies from Nagoya, Edinburgh, and Tokyo, there is a tendency to consider places about a third further away again than is actually the case, as well as adding a small constant. One study from Glasgow and one from Nagoya can be treated with the Sydney study as forming a third group which falls in between the previous two.

An examination of the general form of the seven cities involved was carried out, on discovering these groupings, to see if there were any obviously distinct properties of the cities which might account for the groupings. Lynch's (1960) concept of "imageability" was kept in mind during our search. It is plausible that the more a city possesses what Lynch describes as those "physical qualities which relate to the attributes of identity and structure in the mental image," the more likely are people to be able to relate their judgements to specific, identifiable locations and thus produce accurate estimates. However, we are dealing with estimates taken across the whole city and so only the most general and obvious indicators of imageability are likely to be relevant.

One answer seemed to lie in the fact that the cities are either essentially coastal, with a large bay or sea acting as the most distinct boundary of the city, or they are placed upon a large river which effectively divides the city in half. Glasgow, Heidelberg, and London are divided by rivers; Nagoya, Tokyo, and Edinburgh are bounded by bays or oceans. Sydney forms an intributing combination of the two, being placed on either side of an estuary with the Pacific Ocean as a boundary. The only other distance regression we could locate (Cadwallader, 1973) has been quoted. It will be noted that it falls between our

Sydney and Nagoya regressions. As this study was in the Los Angeles basin it does not go against the general pattern described here. Before considering the implications of this it must be emphasised that there are two studies which rather muddy the water, one from Glasgow, the other from Nagoya. Thus any general hypotheses that are derived from considering them will require considerable modification in relation to specific groups of respondents in specific cities.

The sources adding to the variations in responses should be noted. We are dealing with responses generalized across locations and across respondents. As Cadwallader (1973) has illustrated, there are large differences between people for the correlations between estimated and actual distances. We have comparable data which will be the subject of later reports. Lowrey (1970) has emphasised the differing role of different types of location in the estimation process. We can find less evidence for this in our studies. This is nonetheless a potential cause for variability in our results: it is so difficult to equate location types across cities as varied as Heidelberg, Sydney, and Nagoya. However, from the generalised view adopted in this paper, the type and variety of locations and individual's perceptions of them are crucial components of the "mental image." We therefore argue that there is considerable validity in making cross-city comparisons on the basis of distance estimations.

In general, for the concept of imageability to find some empirical validity from our data it is necessary for it to be modified. We would like to relate it more closely to the Gestalt concept of "Pregnanz." If we accept that people place some structure upon their ideas of a city in order to cope with that city, then it is plausible that a "simple structure" is involved. This would mean that people would place on their concepts some simplifying scheme which would enable them to remember and act on their image the more readily.

For example, in the case of a city with a river running through it, it is possible that the river would act as a reference line. As it takes up geographical space we may expect people to add the psychological attributes of that space as a constant to their judgements. Support for this is found in the comparison of Study 2 with Study 3. In the former, in which distances are across and around the Clyde at its narrow point, the B-value is 1.28. In the latter case, where the wider part of the river toward the estuary is included, the B-value is 2.81. Can the B-values be used as a test of the psychological dominance of major geographical features?

The role of the "reference line" in longer distance estimates, it is hypothesised, may well be to facilitate estimation due to the facilitation of accurate location in the conceptual structure of the estimated points. If we further assume that actual size of this reference line is discounted in the estimation of the distances we would obtain the situation illustrated here: an overall reduction in the error of estimated distances as the actual distance increases. These hypotheses derive, in the main, from the structure of our linear regression equations, a structure which contains two distinct components linked to the A- and B-coefficients. That certain geographical features, such as rivers, may play differing roles in each of these components is one of the major hypotheses requiring future testing to be derived from our studies.

In a city lacking an obvious formal component, like Tokyo, we would expect people to place a simplifying form upon it. Attempting to find a circle, or rectangle, in the jumble of streets or railway lines would be one method of doing this. People need to encompass the city in order to cope with all of it. The lack of a formal component would tend, psychologically, to act in the opposite way to a central river (drawing places away from the centre), thus leading to overestimations. At best this is a very loose formulation! Very few locations were used in each city and Tokyo and Edinburgh, for instance, both have centrally located castles, which might be expected to aid in structuring. Therefore, for further clarification we shall next examine particular studies from each of the three groups.

Even if later evidence discounts this formulation, it is clear that the precision of distance estimation and the regression model does contribute considerably to our definition and understanding of city images. For example, a number of detailed hypotheses may now be put forward which would test our briefly stated formulation. (We would welcome collaboration with anyone wishing to cooperate in these tests.) We would predict, as an illustration, that cities with a clear structure (e.g., Paris, San Francisco, New York, Stockholm?), especially when placed on either side of some dividing topographical feature, would produce slopes of actual to estimate of less than one and B-values greater than one. Whereas cities with a less readily definable simple form would produce overestimates (e.g., St. Louis, Los Angeles, in the United States; Birmingham or Milan in Europe?).

COMPARISONS OF CONFIGURATIONS

In order to explore further the patterns revealed by distance estimations one study from each of our three groups has been selected, a Tokyo study (number 8), the Sydney study, and the Glasgow study (number 3). For each of these sets of data a configuration of the locations in two-dimensional space was required. This was in order to see what types of distortions from the actual geographical configurations were present in the estimated distances. The idea behind the use of distance estimations is, of course, that they must in part be drawn from, or relate to, some conceptual configuration. Thus by working backward, so to speak, and producing a configuration based upon the estimates, it should be possible to highlight important psychological properties of the "conceptual configuration."

The process used to generate the configuration was the nonmetric multidimensional scaling procedure developed by Guttman and Lingoes "SSA-1" (Lingoes, 1973). In essence this is an algorithm which takes as its starting point the rank order of, in our case, the mean distance estimates. It then, by a series of iterations, produced a two-dimensional arrangement of the locations such that the rank order of the distances between them is the same (within specified limits) as the original rank order of the means. However, both because the number of locations is limited and because of the nonmetric nature of the programme, even if the actual distances were used instead of estimates, a geographically accurate arrangement would not necessarily be produced. It is thus essential to compare arrangements based upon estimates with one based upon actual distances, both produced by the same programme.[2]

Figure 1 shows the "actual" and "estimate" configurations for each of the three studies. In interpreting these configurations it must be remembered that only the distance

between locations is used as data. Thus any simple transformation which maintains the relationships between these distances is possible. Two configurations which were, for instance, mirror images of one another, or upside down in relation to each other, would be identical in terms of the statistics on which the programme is based. The crucial differences between actual and estimated configurations are as a consequence not those relating to orientation of the points in space (which is an artifact of the programme) but the relative distances between the points. Furthermore, because the programme has only limited information about the points, it is possible for quite large distortions from geographical accuracy to occur. However, because an identical algorithm is used for each set of data, comparisons are still meaningful even when these distortions are gross (as with the Sydney study). To facilitate the interpretation of the configurations a key geographical feature has been indicated in Figure 1.

Two things may be noted in the results for Glasgow shown in Figure 1. First the estimated locations tend to be distorted in relation to the actual locations by, in general, being closer to the Clyde. This is shown clearly by reference to Guttman-

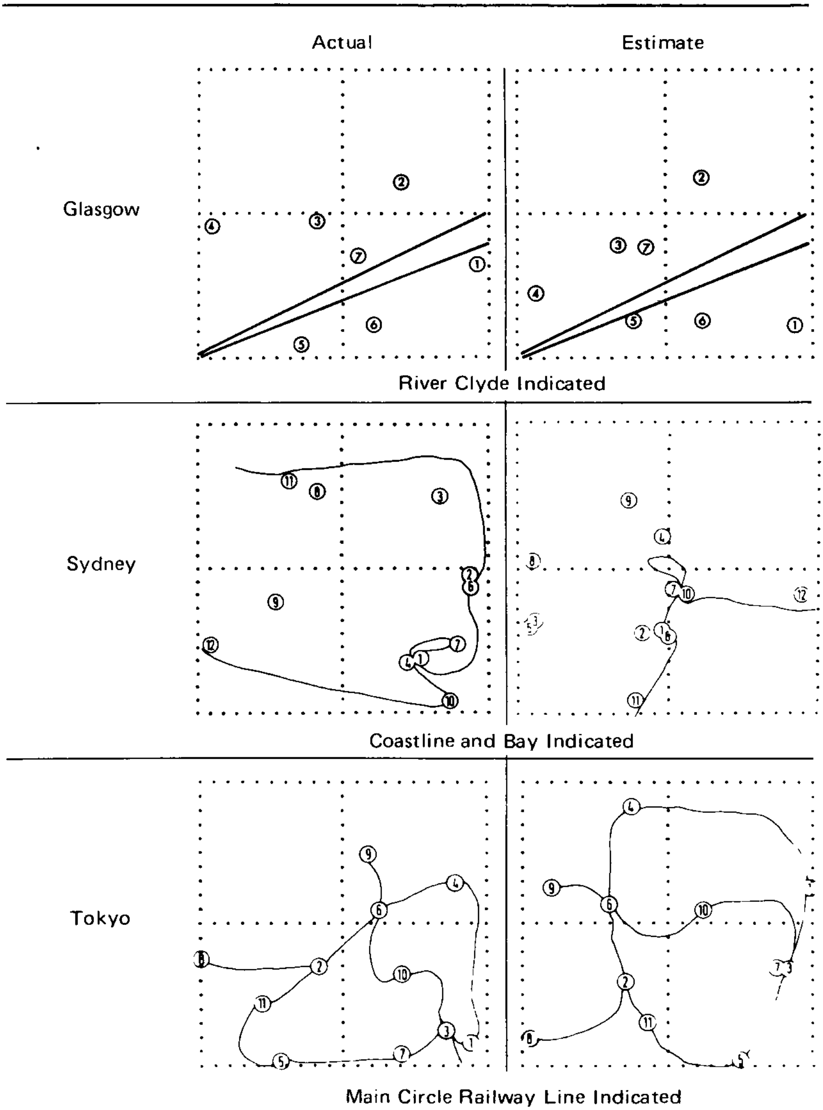

Figure 1: SSA-1 CONFIGURATIONS FOR GLASGOW, SYDNEY, AND TOKYO BASED ON ESTIMATED AND ACTUAL DISTANCES.

Lingoes's derived distance coefficients. For the cross-Clyde distances between points 4 and 5, and 3 and 6, they are 1.15 and 0.89 for the actual configuration, respectively. But they are 0.78 and 0.76 for the estimated configuration. However, for the distances parallel to the Clyde between points 4 and 3, and 5 and 6, they are 0.79 and 0.63 for actual and the scarcely different values of 0.79 and 0.65 for the estimated distances.

The second point to emerge from the Glasgow study is that the points toward the estuary (points 1 and 2 at the right of Figure 1) are much further away from each other in the estimated than the actual (1.27 estimated, 0.83 actual). This goes against the general trend for Glasgow but seems to relate to the bridges available: there are many in the city centre at the left of our configuration. This is a point to which we shall return.

Jumping to the Tokyo study we can see how distances are overestimated there. The railway stations, which form the named locations most readily available in Tokyo, form a configuration approximating a circle when based on estimates, whereas they are actually in a form nearer to an ellipse. This implies that north-south estimates (along the line) are reasonably accurate, but that east-west judgements are overestimated. This relates well to our finding that when ten respondents were asked to draw a map of Tokyo all immediately produced a circle to represent the main railway and elaborated from there. This railway system is represented as a circle in generally available schematic diagrams. A consideration of Tokyo will show that it is such an intricate city that there is no other overall structure to which reference can be made when representing it schematically. The implications of the simplifying circle are thus clearly revealed in the distance estimates.

Sydney's complex form together with the sparse information available in the data leads SSA-1 into some difficulties. It was found necessary to curve the line of points along the coast (12, 10, 1, 6, and 11) in order to fit them into its two-dimensional space. The estimated distances lead to the opposite trend, folding the geographically straight row of points in to bring the extremes closer. The corollary of this seems to be to push the inland locations, which are far from the city centre, much further away from the coast in the estimated situation. Thus 12 and 9, and 11 and 8, whilst very close in the actual configuration are a long way from each other in the estimated. The resultant of these two processes appears to average out overall and give us a regression slope close to unity. It may be noted again that the distances across Sydney harbour (e.g., 7 to 4), where there is a major road/rail crossing, were little distorted from one configuration to the other. But (as in Glasgow) those distances which did not share any main transportation artery were most susceptible to distortion (e.g., 12 to 9, and 11 to 8).

SUMMARY AND CONCLUSIONS

The seminal work of Lynch has produced studies based, in the main, upon data extracted from the maps which people have drawn. These studies have proven time consuming to conduct and their analysis has often erred on the side of illustrative quantity rather than statistical quality. Yet many of the ideas relating to city images do have quantitative implications, especially for perceived or estimated distances. An examination of these implications should lead to a clarification of the basic assumptions. Thus at the large scale, the imageability or "legibility" of a city should relate to the general pattern of distance misestimation. Yet we have seen that whilst a city with a confusing image (like Tokyo) may well lead to general overestimation, a more "legible" city (like Glasgow or Heidelberg) may still produce distortions in the direction of underestimations. The common sense quality of these relationships only serves to hide a profound psychological question as yet unanswered. If you have a clear idea of where places are in relation to each other, do they seem closer together? Why? And is this a part of the conflicting effects of direction of distance in relation to the city centre reported by Lee, Golledge, and others? Our study indicates the critical roles which may be played by road and rail systems, general topography, and major geographical features. This leads to the argument that the contrast between the findings of Golledge et al. and Lee possibly relates to the fact that the former were dealing with estimates along a major road in essentially featureless countryside whilst Lee was not.

Indeed, the role of rivers and roads may help to bridge the theoretical differences between these two groups. Lee's explanation in terms of the valence of the city centre may be replaced from our results with the valence properties of a whole series of places linked in some conceptual structure. This structure, in its turn, may be based upon the types of experiences and learning processes which Golledge and Zannaras emphasise. Furthermore, when dealing with concepts at the scale of cities, it would appear that roads, railways, and rivers rather than acting as "barriers" may act to give the city its coherent structure. Indeed, they may all be more fruitfully construed as different types of conceptual "links."

Finally, then, we can point to the readily available, crow flight distance estimations as a valuable part of the arsenal of techniques available for examining the internal representations of cities. It is hoped that more people will make use of them in the future.

NOTES

1. The slight differences in the number of points in each study can only be explained as a function of time and distances at which the studies were carried out. The most effective procedure, embodied in Studies 1 to 6, emerged during the course of the other studies.

2. Like all other nonmetric multidimensional scaling algorithms, SSA-1 involves the iterative refinement of a starting configuration in terms of the given constraints.

The nature of this configuration can be important. In this example, the default option of the eigen vector starting configurations was used. When a geographical, grid-based starting configuration was substituted, the resulting configuration proved more difficult to interpret.

REFERENCES

APPLEYARD, D. (1970) "Styles and methods of structuring a city." Environment and Behavior 2, 1: 100-116.

BARTLETT, F. C. (1932) Remembering. New York: Cambridge Univ. Press.

BRATFISCH, O. (1969) "A further study of the relation between subjective distance and emotional involvement." Acta Psychologica 29: 244-255.

BRIGGS, R. (1972) "Cognitive distance in urban space." Ph.D. dissertation. Ohio State University.

CADWALLADER, M. T. (1973) "A methodological analysis of cognitive distance," in W.F.E. Preiser (ed.) Environmental Design Research, Volume 2. Stroudsburg, Pa.: Dowden, Hutchinson & Ross.

DORNIC, S. (1967) "Subjective distance and emotional involvement, a verification of the exponent invariance." Psychological Laboratory Report 237. University of Stockholm.

EKMAN, G. (1961) "Some aspects of psychophysical research," pp. 35-47 in W. A. Rosenblith (ed.) Sensory Communication. New York: John Wiley.

GOGEL, W. C. (1969) "The effect of object familiarity on the perception of size and distance." Q. J. of Experimental Psychology 21: 239-247.

GOLLEDGE, R. and G. ZANNARAS (1973) "Cognitive approaches to the analysis of human spatial behaviour," pp. 59-94 in W. H. Ittelson (ed.) Environment and Cognition. New York: Seminar Press.

ITTELSON, W. H. [ed.] (1973) "Environment perception and contemporary perceptual theory," pp. 1-19 in W. H. Ittelson (ed.) Environment and Cognition. New York: Seminar Press.

KUNNAPAS, T. (1970) "Scales for subjective distance." Scandanavian J. of Psychology 1: 187-192.

——— (1968) "Distance perception as a function of available distance cue." J. of Experimental Psychology 77: 523-529.

KURODA, T. (1971) "Distance constancy: functional relationships between apparent distance and physical distance." Psychologische Forschung 34: 199-219.

LEE, T. (1970) "Perceived distance as a function of direction in a city." Environment and Behavior 2, 1: 40-51.

LINGOES, J. (1973) The Guttman-Lingoes Nonmetric Program Series. Ann Arbor: Mathesis.

LOWREY, R. A. (1970) "Distance concepts of urban residents." Environment and Behavior 2, 1: 52-73.

LUNDBERG, V. (forthcoming) "Individual functions of subjective time distance and emotional reaction." Scandanavian J. of Psychology.

———, O. BRATFISCH, and G. EKMAN (1972) "Emotional involvement and subjective distance: a summary of investigations." J. of Social Psychology 87.

LYNCH, K. (1960) The Image of the City. Cambridge, Mass.: MIT Press.

STANLEY, G. (1968) "Emotional involvement and subjective distance." J. of Social Psychology 84: 304-310.

STEA, D. (1969) "The measurement of mental maps: an experimental model for studying conceptual spaces," pp. 228-252 in Studies in Geography No. 17. Northwestern University.

STEVENS, S. S. (1957) "On the psychophysical law." Psych. Rev. 64, 3: 153-181.

——— and E. H. GALLANTER (1957) "Ratio scales and category scales for a dozen perceptual continua." J. of Experimental Psychology 54: 377-411.

TEGHTSOONIAN, R. (1971) "On the exponents in Steven's law and the constant in Ekman's law." Psych. Rev. 78, 1: 71-80.