PERCEIVED DISTANCE IN THE CITY AS A FUNCTION OF TIME

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ABSTRACT: Estimates of walking distances up to 2 miles along a busy road were correlated with the length of time, between 2 and 26 months, that participants had been acquainted with the route in question. It was discovered that perceived distances increased the longer participants had known them. A mile was estimated, on average, to be 1.24 miles by a 1st-year student, 1.33 miles by a 2nd-year student, and 1.45 miles by a 3rd-year student. It is argued that this increase supports the feature-accumulation hypothesis of distance perception as opposed to the route-segmentation hypothesis. This result is used to explain Lee's anomaly that distances into a city are seen as shorter than equal outward journeys. A case is made for investigating distance perception in real rather than reduced-cue environments.

Keywords: *distance perception; urban environment; feature accumulation*

Are perceived distances and complexity related? Our natural judgment of space allows us to estimate distances, orientate ourselves, to navigate and to make efficient decisions about journeys. Just how we perform these day-to-day tasks ought to be of interest to urban designers because there is evidence that places of equal measured dimensions are not always judged to be equal in size. There are discrepancies between mappings of physical space and what people actually see, the differences coming about, in part, because complex things and places appear larger than simple ones. Experimental evidence that this is so can be found, for example, in Verillo and Graeff (1970), who noticed that complicated patterns seem larger than simple ones.

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Coeterier (1994), investigating perception of space using photographs of empty fields into which occasional trees or pylons were introduced, concluded that the more relationships there were to be discovered in a landscape, the bigger it will seem. Domestic interiors may seem larger and more complex to children than adults (Crompton, 2001). Besides influencing perception of space in general, complexity also disturbs our judgment of walking distances; Sadalla and Staplin (1980a) found that an urban journey with two intersections was felt to be shorter than an equal one with six intersections, confirming what they found earlier with participants walking along taped paths indoors. Sadalla and Staplin (1980b) also showed that routes with easily memorable attributes were estimated as longer; this supports the feature-accumulation hypothesis that cognitive representation of distance is related to the quantity of information stored about the route.

Most distance perception experiments use reduced-cue environments over short ranges. The link to real-world environments is made by supposing that we apprehend environmental distances in streets, parks, neighborhoods, and so forth by integrating data during extended periods (Montello, 1997). The few experiments done in real urban environments are not so different in their results from those done in the laboratory to lead us to doubt this approach. Be this as it may, an article by Yang and Purves (2003) on distance perception from a fixed position to fixed objects reversed this approach in a way that may have implications for environmental distance perception. They made laser surveys of natural scenes, in woodland and on campus, and measured the probability that objects in the field of view were a particular distance from the observer. A log–log graph of the probability distribution versus distance to objects gave a straight line indicating that the environments they had studied were scale invariant; that is, they were fractal. They used this to explain five illusions of distance experienced in reduced-cue experiments such as the specific distance tendency. They hypothesized that we have evolved to take advantage of such a statistical structure in generating perceptions of physical space; the expectations this produces can lead us to make errors when presented with isolated objects in the absence of other distance cues. Their reversed approach explains the anomalies of simpler experiments by accepting that our untutored cognition is adapted to complex environments.

From this point of view, illusions revealed by reduced-cue experiments may in fact play no part in everyday perception. It might, therefore, be more profitable to make a direct investigation of distance perception in complicated urban areas rather than trying to explain our perception by integrating from experiments done in simplified environments. If we are predisposed to expect our surroundings to be scaling fractals, we might expect unusual

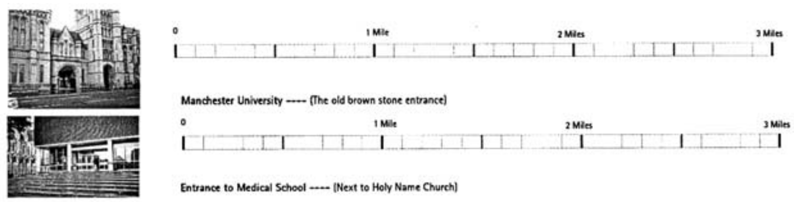

Figure 1: Part of the Form Used for Distance Estimation

results in areas which are not fractal—that is, in areas in which particular scales predominate. Perhaps types of places that seem large or small for their size could be identified. It was with these thoughts in mind that a series of tests was begun that asked students to estimate walking distances in picturesque, urban, and rural environments. During the course of one of these tests, the results of which will be published separately, it was observed that 1st- and 2nd-year students gave significantly different estimates of distances around their own campus, so suggesting the hypothesis that distance estimates increase over time. This has a certain plausibility because perceived complexity might increase as time passes and we observe more about our surroundings. The experiment described below was therefore designed to test this hypothesis and to see if cities really do get bigger the longer we know them.

EXPERIMENTAL METHOD

The participants of the experiment were undergraduate architecture students who filled in a questionnaire asking them to estimate the walking distances from a single starting point to 22 familiar destinations between 0.1 and 1.8 miles distant in the university district of Manchester. The destinations were a mixture of well-known places of entertainment, halls of residence, public buildings, and so forth, chosen so that 11 lay toward the city center and 11 away from it. In this matter, the experiment followed Lee's Dundee experiment of 1970, whose results this experiment took the opportunity to check. The task given to the students was to estimate the walking distance from the steps of their Students Union to the destinations by marking a horizontal scale about 150mm long at the considered point. The scales were marked with graduations at mile and tenth of a mile intervals up to 3 miles at the end of the scale, each destination was accompanied by a little photograph and description. Figure 1 shows a part of the form.

All the destinations lay along Oxford Road, a straight, level road going from the center of the city through the university. This busy route has many changes of scene and places of interest to students who travel it on foot and by bus in their daily lives. The written and spoken instructions advised participants to mark their judgments tentatively and adjust them if needed after they had established a feel for the distances involved. The exact end point of each walk was either the main entrance to a building or, failing that, another point described on the form. The direction of each journey, in and out of town, was alternated to reduce any undue influence from the preceding judgment, and two versions of the questionnaire were used with the destinations in a different order. Students were asked to omit any destinations not known to them rather than to attempt a guess. In total, 140 students who completed the form with three or fewer missing estimates were used in the analysis: They comprised

40 first-year students who had been in Manchester 2 months and were tested in October, 2003,
55 second-year students who had been in Manchester 14 months and were tested in November, 2002,
45 third-year students who had been in Manchester 26 months and were tested in November, 2003.

Also, 19 students belonged to both the 2nd- and 3rd-year groups, so providing a within-group check. Older students were more often able to fill in the form completely; 45 1st-year forms were discarded because they had more than three entries missing, whereas only two 3rd-year forms needed to be set aside. Did anything significant change on Oxford Road during the year that elapsed between the first and last tests? I believe not; in any case, there were differences between 1st- and 3rd-year students tested at the same time that would tell against an explanation of the results based on a change in the character of the site. The choice of Oxford Road avoided the influence of corners and slope on distance. Uphill and downhill journeys both seem longer than journeys on the flat; Okabe, Aoki, and Hamanoto (1986) established this by means of an experiment in Tokyo botanical gardens where he measured overestimation factors of about 1.15 for journeys on a slope. It is also known that corners and turns increase the perceived length of a journey (Sadalla & Magel, 1980). None of these factors ought to play a part here. The number of intersections can influence distance (Sadalla & Staplin, 1980a). Although Oxford Road is not exactly regular, the number of intersections (eight in the 1st mile) was the same both into and out of town from the starting point; this balance ought to mitigate the effects of this factor when comparing inward

TABLE 1
Table of Overestimation Factors for Students in Different Years

	Months	*Inwards*	*Outwards*	*p Value*
1st year	2	1.27	1.56	<0.0003
2nd year	14	1.35	1.58	<0.0007
3rd year	26	1.66	1.84	<0.0350

and outward journeys. The direction of destinations was noted because Lee had found that direction affected distance judgment, and in consequence, destinations into or out of town were treated separately in the analysis.

RESULTS

The results indicated that distance estimates increase over time. The experiment also found that journey estimates are almost always overestimates and that journeys into town are perceived as shorter than equal journeys away from the center, so repeating Lee's findings of 1970. Averaged over all participants, journeys into town were overestimated by an average factor of 1.42, those out of town by a factor of 1.71. The significance of these figures was assessed by calculating the average fractional error for outward and inward journeys for each participant. A paired t test indicated that the difference between these averages was significant for all 3 years. This was a one-tailed test, looking for differences in the direction predicted by Lee; however, a two-tailed test would still be significant for the 1st and 2nd year. The table above shows the probability of this happening by chance along with the length of time since the students arrived at university and the overestimation factors averaged for each year.

A regression analysis showed that as the distance to be estimated got longer, so the overestimation factor decreased. This effect was significant and more pronounced for outward than inward journeys (inward $F = 5.75$, $df = 10$, $p < 0.03$; outward $F = 23$, $df = 10$, $p < 0.0009$). It had not been possible to exactly match the length of inward and outward journeys, and it happened that outward ones were slightly longer; correcting for this would reinforce the difference found between inward and outward journeys. The figures above must be adjusted slightly before they can be fairly compared with what Lee reported in 1970. His overestimation factors for inward and outward journeys were 1.14 and 1.35 over distances of between 0.17 and 0.82 miles, a shorter range of distances than used here. For comparison, over the same range of distances, 1st-year students had overestimation factors inwards and outwards of 1.25 and 1.52, rising to 1.59 and 1.84 in the 3rd year. Lee did not specify the ages of the elementary psychology students used in his survey, but results for 1st-year students are reassuringly similar to his values.

Figure 2 shows an error bar graph for two typical destinations, year by year; the bars contain 95% of the estimates. The year-on-year rise in means may be observed, yet the overlap of the bars and the spread of the estimates shows what a slight effect is being expressed here. Nonetheless, the increase in average estimate seems to be real; it is illustrated more clearly in the upper part of Figure 3, which shows average estimates for the 22 destinations by students in different years. The ordering of the points in lines one above the other demonstrates that estimates increase the longer students have been in the university. A Manchester mile is estimated, on average, to be 1.24 miles by a 1st-year student, 1.33 miles by a 2nd-year student, and 1.45 miles by one from the 3rd-year. As can be seen from Figure 2, for 3 of the 22 journeys, the 1st-year estimate was larger than the 2nd year, although only by a tiny amount. For all the rest, the order (third > second > first > actual distance) was preserved. That the increase in estimate over time is significant must be judged from the graphs themselves, the probability that they would fall by chance into such an ordered array is clearly very small. The lower part of Figure 2 shows the estimates of 19 students who took part in the experiment as both 2nd- and 3rd-year students. The graph shows that the average length of all the journeys was judged greater by these students when they were in their 3rd year than when in their 2nd year. *t* tests showed no significant difference between these 19 and other participants from the 2nd and 3rd year, suggesting that the increase between the 2nd and 3rd year was not because of any differences between groups but indeed because of estimates increasing over time.

LEE'S ANOMALY: INWARD AND OUTWARD JOURNEYS

Lee (1970) established that perceived distances are a function of direction by asking students to estimate walking distances between landmarks in Dundee. He showed that distances were overestimated and that, other things being equal, distances toward the center were seen as shorter than those out of town. In addition, he found that women judged some distances into town to be less than men, a fact he attributed to women being more interested in shopping. Of the many factors that might be involved in these effects, he

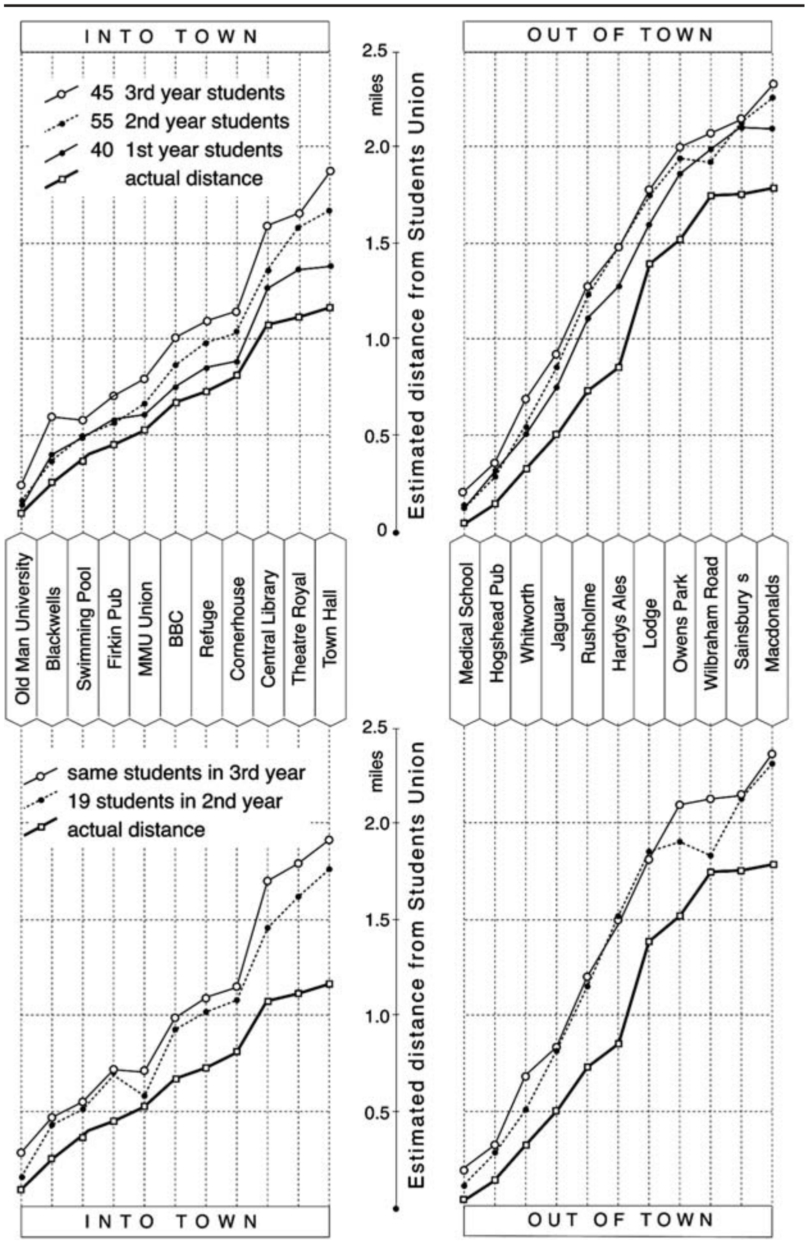

Figure 2: Error Bar Graph for Two Typical Destinations

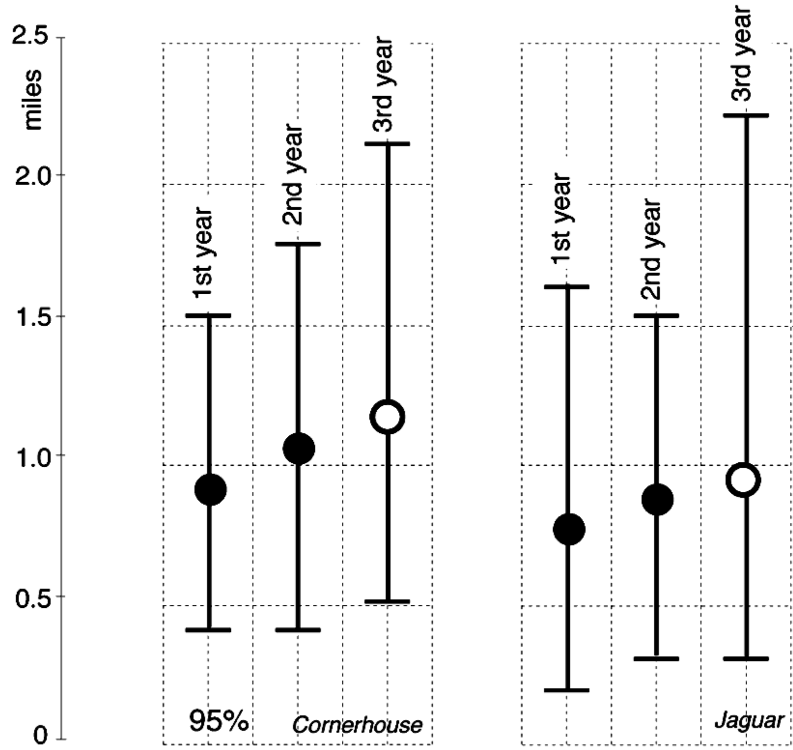

Figure 3: Upper Part: Distances Estimates by 1st-, 2nd-, and 3rd-Year Students; Lower Part: Estimates by the Same 19 Students in Their 2nd and 3rd Year

considered the most important to be that journeys to the center seemed shorter because they were more rewarding, citing experimental evidence that if objects are viewed with favor, they are seen as closer. He added that the complexity of a journey might lead to shorter time estimates by analogy with the perception of filled and unfilled temporal intervals—that is, eventful journeys seem shorter. This is, of course, the opposite of the hypothesis above, and it was, in part, to get to the bottom of whether distances seem bigger or smaller in complex environments that the form of the experiment was arranged to check his results. Lee's landmarks were distributed about Dundee, and he found it necessary to look for a correlation between the angle of direction of travel to the center and perceived distance as well as having to remind his participants to consider walking distances not the flight of crows.

Dundee, it ought also to be added, is hilly, a fact that Lee did not mention or make allowance for. The effects of slopes, corners, and intersections were mitigated in this experiment, as described above, by the choice of Oxford Road. Possibly as a result of these precautions and contrary to what Lee reported, this study found no significant differences between men and women; in fact women's average error for inward directions was slightly greater, 0.47 compared with 0.42 for men. A further negative post hoc test is worth mentioning; could student's ability to assess distances be related to their spatial reasoning ability as expressed by their marks awarded in their design course? Tests failed to find any correlation between marks in design at the end of the 1st year and estimation errors.

Although Lee (1970) used a valence hypothesis (that is, desirable destinations are seen as closer) to interpret his results, he noted that some of his entertainment destinations that he expected to be attractive to students were perceived as relatively distant (Lee, 1970), a result he regarded as paradoxical. The hypothesis that estimates increase with time can go some way to explain Lee's observation of the effect of direction on distance as well as his valency paradox. Journeys will seem to get longer over time if their perceived length is related to their complexity, and the more time we spend in a place, the more we notice about it. From this, it follows that the more often we take a journey, the longer it becomes to us—that we have, so to speak, to take time to learn its length. Seen from this point of view, Figure 2 shows us that students take 3 years to learn journeys into town from the Students Union, whereas journey outwards are understood more quickly. And this is plausible because students in Manchester live and work mostly to the areas outwards from the university or, to be more exact, outwards from the Manchester Metropolitan University Union, and it is over this range that estimates are closest amongst the years. Notice that the difference between inward and outward estimates diminishes from the 1st to 3rd year and that all average estimates increase with time. By the 3rd year, students make as great an error in inwards journeys as they did with outward journeys in the 2nd year. This suggests that the differences between inward and outward journeys will diminish and likely vanish as the years pass. The differences are caused by new students being more familiar with one direction than the other. In this way, distances increasing over time at different rates can explain Lee's results including his paradoxical results.

DISCUSSION

The predictions of the feature-accumulation hypothesis cannot normally be distinguished from the predictions of either the competing route-segmentation hypothesis or the scaling hypothesis (Montello, 1997). This experiment does, however, allow some sort of test to be made. The route segmentation hypothesis predicts that segmented routes are subjectively longer than unsegmented routes, and the scaling hypothesis gives a reason why this might be so. It tells us that the psychophysical function for estimated distances is the measured distances raised to a power less than unity. Distances estimated in one piece will therefore seem less than those that are assessed as a sum of parts. What is changing that could cause the gradual increase in estimated distances observed in this experiment? The segmentation of the journey by road junctions, landmarks, and so forth is an unlikely candidate for change. Yet something does seem to be changing gradually; the feature accumulation hypothesis tells us what this might be. It is by the continuous accumulation of detail and enrichment of incident that a route grows in our minds and seems larger year on year.

Testing in a complex environment has revealed that distances increase over time. This in turn allows us to explain why, in certain circumstances, it might seem shorter to walk into rather than out of town. This illustrates the value of testing in real complicated places as opposed to reduced-cue environments. The freshest responses were 2 months old; it would have been interesting, if it had been possible, to obtain estimates of distance after the routes had been walked for the first time, one would like to know how low estimates could go. Is there a large jump in estimate the second time a journey is undertaken? This might help explain why in new surroundings, outward walks often seem much shorter than the return trip. This ought to be tested in real environments.

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