# DISTANCE ESTIMATION IN A SMALL-SCALE ENVIRONMENT

**ANDREW CROMPTON** *is a lecturer at Manchester University School of Environment and Development. His research interests connect cognitive science and architecture.*

**FRANK BROWN** *is a senior lecturer at Manchester University School of Environment and Development. He has a particular interest in the spatial morphology of buildings and settlements.*

ABSTRACT: In a test of cognitive distance perception, participants estimated a walk in a picturesque village to be, on average, twice as long as an equal-length journey in a city. It is unlikely that any or all of the factors at present known to influence distance perception can account for such a large difference. A small correlation between estimate size and subject's height in the village but not the city suggests that distance estimates were based on different factors in the two places and that the scale of our interaction with our environment may influence our judgment of distance. It is hypothesized that small-scale places without cars may seem much larger than expected and that space may, so to speak, be made as if out of nothing by appropriate design.

***Keywords:*** *cognitive distance perception; urban scale*

## URBAN COGNITIVE DISTANCE PERCEPTION

Anyone who has spent time walking in a complicated, car-free city, such as Venice or Fez, will find it easy to believe that it is somehow larger than one would expect from looking at a map. The parts of Venice that tourists visit have about the same area as Manhattan's Central Park, yet as if enlarged by its complexity, Venice seems bigger than that. Can impressions of this sort be given any quantitative support? An experiment set out to compare estimates of walking 500 m along a straight road in the city of Manchester with

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estimates of the same distance in the small-scale, superpicturesque village of Portmeirion, in North Wales.

Distance perception is usually investigated by arranging a walk both with and without some factor whose influence on perception is to be assessed; some examples are described below. Often this has involved using simplified or reduced-cue environments in a laboratory. By these means, it has been discovered that the more turns, slopes, intersections, and features a walk has, the longer it appears. Taken together, these tests of distance judgment are thought to support the feature accumulation theory, namely, that the more information there is to be observed about a journey, the longer it will seem (Montello, 1997).

One wonders how long a journey could be made to appear if all the factors that increase perceived distance work together. Portmeirion was chosen because it fulfils all the known requirements for appearing large. It is also, as the feature accumulation theory would lead one to expect, a place where there is a lot to see. In fact, the village charges for admission and tourists wander around its car-free lanes looking at things, unlike in Manchester, where pedestrians mostly look downward or forward. So this experiment compares distances in interesting and mundane places. Working in real places has this drawback: It is harder to attribute differences in judgment to differences in the journey than it would be if one worked in the laboratory, but this difficulty ought to be faced as there are good reasons for avoiding reduced-cue environments, as will now be explained.

## REAL AND REDUCED-CUE ENVIRONMENTS

Cognitive distance perception, or knowing how far apart places are, is one of the ways we orient ourselves and understand urban space. This is different from psychophysical distance perception, which judges distances to objects in plain view. A city is necessarily observed a little at a time, and across scales of hundreds of meters and upward, our spatial knowledge must involve integrating perceptions with memories. Or so one might think; the processes by which we do this are unclear. Montello (1998) gives an overview of the problem. Observing that no time is needed to construct a model of our environment before learning about it, he argues against the dominant view that we learn about landmarks and then routes before developing a metric mental map. Instead, he believes that from the first exposure to a novel place, we are able to acquire metric information. His remarks might lead us to think that we are predisposed to understand complicated places directly, and if that is the case, then perception experiments performed in reduced-cue environments may give misleading results.

And this is exactly what has been found in a most interesting recent cognitive neuroscience experiment that attempts to explain subjective visual space statistically. Yang and Purves (2003) scanned campus and woodland scenes with a laser ranger, measuring the distances to all the objects in the field of view. It was observed that the probability that an object is a particular distance from an observer follows a remarkably uniform pattern: The probability is at a maximum at 3 m and tails off exponentially for greater distances. They then ingeniously used this result to explain no fewer than six illusions of distance perception experienced in reduced-cue environments. Their theory is that the visual system has evolved to make the best statistical guess about distances and other features of visual scenes based on past experience. It is when this expectation is upset, such as happens in empty places or in reduced-cue perception experiments, that we experience minor illusions of perception. For example, the specific distance tendency, the tendency of people to estimate the distance of isolated objects as being about 3 m away, arises because that is the average distance to actual objects in natural scenes people encounter.

Yang and Purves (2003) also noted that their probability distribution of distances to objects in view is scale invariant, meaning that scaled versions of a natural scene will, in statistical terms, be much the same. So, for example, if everything is doubled in size, the most probable distance to an object does not also double, as you might expect, but remains at 3 meters. This paradoxical behavior occurs because the survey has a finite resolution, and when resized, the scene reveals sufficient hitherto unobserved items to keep the probability-distance relation as it was before. In short, the environments they studied were fractal; statistically, they resembled enlarged parts of themselves. This is rather like the way photographs of natural scenes, treated as collages of patches of a similar shade, have been found to be statistically scale invariant (Ruderman, 1997). This has implications for perception of space: If we were able to shrink ourselves—to halve our own size, say—the world would not close in on us, but in some respects—distances to objects around us, for example—it would in fact stay the same. And yet at the same time, relative to us, the world would be made much larger.

This odd behavior becomes clearer when it is realized that the size of a fractal is a slippery concept that depends on the scale at which it is measured. A well-known example of this is the coastline of Britain, whose length increases without limit when it is examined in greater and greater detail (Mandelbrot, 1983). It is for this reason that a person carefully stepping along the shoreline would not walk as far as the dog following her. If we assess the size of a space by assessing, as Gibson puts it, its affordances—that is, by imagining how we can use and occupy it—then a fractal space will seem bigger the smaller we become. Fractal spaces ought therefore to appear bigger to children than to adults, and there is evidence that this is sometimes the case (Crompton, 2001). Those who think small will feel fractal places to be larger than those who think big. The implication for cognitive distance perception is this: A walk in a fractal environment might seem longer if we interact with it at a small scale. To sum up, our psychophysical distance perception is adapted to a natural world that is fractal, and the size of that world depends on the scale at which we interact with it. Will our cognitive distance perception be similarly affected in a complex place with an odd scale? An experiment to test this cannot really be done in a laboratory.

## EXPERIMENTAL METHOD

The subjects were 1st-year architecture students who had been in Manchester for 2 months when they were asked to estimate distances between 0.1 and 2.0 miles up and down Oxford Road in the university district of the city. Sitting in a lecture room, they estimated the walking distance from the steps of their students union to familiar destinations by marking a horizontal scale about 150 mm long at the considered point. Each scale had graduations at mile and one-tenth mile intervals up to 3 miles at the end of the scale and was accompanied by a little photograph and description. Also recorded were the students' names and their height, which was measured standing in their shoes when the questionnaire was complete. This was part of a wider survey of distance estimation, which discovered that distances seemed greater the longer subjects had known them; these results have been published separately (Crompton, in press). One of the distances to be estimated, a journey of 514 m ± 10 m (0.32 miles) from the students union to the art gallery, was used in this study.

The students were then taken to Portmeirion, an Italianate holiday village in North Wales built between about 1930 and 1975 by the architect Clough Williams-Ellis. The ostensible purpose of the visit was sightseeing and sketching, but once there, they were given a handout, shown in Figure 1, asking them to estimate the distance between the entrance arch and a point at the end of the main route through the village where they were to spend the day. As with the Manchester measurements, spoken and written instructions asked them not to collude or count paces but to indicate what they felt the

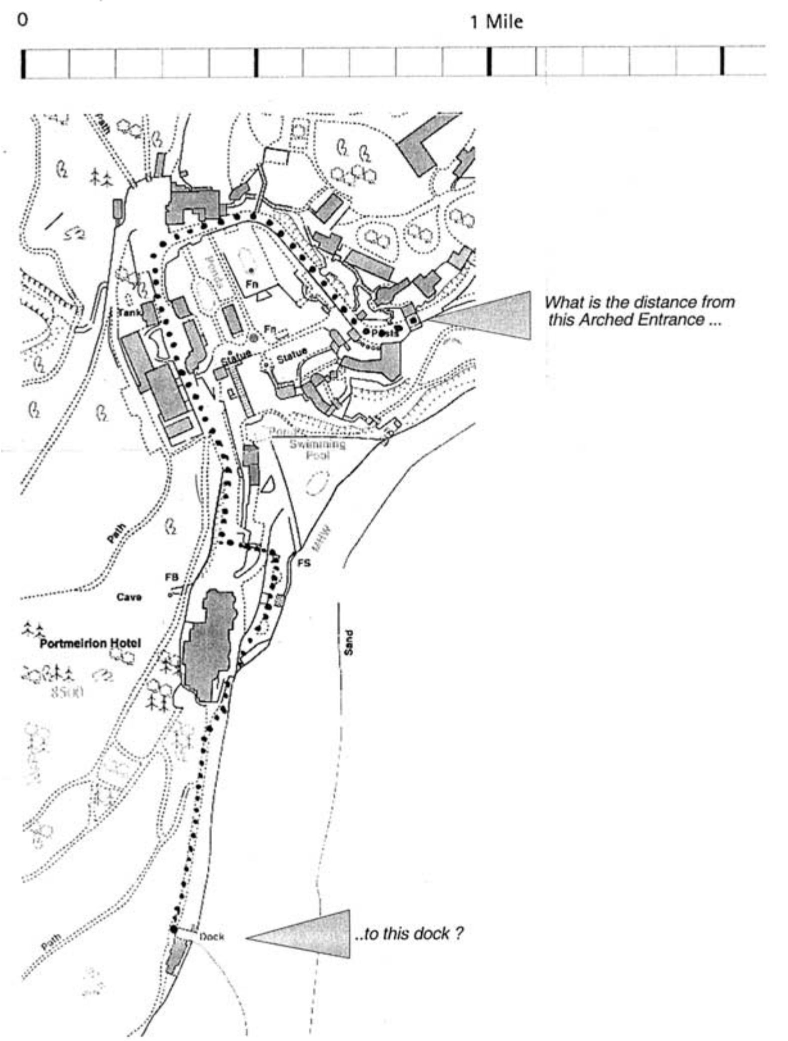


**Figure 1: Handout Used in Portmeirion Experiment Showing Walking Route To Be Estimated**

distance had been by marking a scale set out in increments of 0.1 mile up to 1.5 miles at the end of the scale. The actual distance, measured from an Ordnance Survey map, happened to be 500 m ± 2 m (0.31 miles).

**Figure 2: Oxford Road, Manchester, and Portmeirion Compared**

Photographs comparing Manchester and Portmeirion walks are shown in Figure 2. The differences between them may be summarized as follows: Oxford Road is a straight, level route with a lot of traffic going from the center of the city through the university. Along it lie many substantial buildings and places of interest to students. Pedestrians mostly walk purposely. In Portmeirion, on the other hand, visitors wander about. The village, whose informal layout can be seen in Figure 1, is built to a smaller than normal scale, with many little places to pause and sit or to look at the view. Most of its buildings are reputed to be approximately seven-eighths normal size. The eaves' height of a typical house was measured at 4,550 mm, which compares with 5,300 mm for a more normal dwelling (7/8 = 0.875, and 4,550/5,300 = 0.86, so seven eighths is a plausible figure). Parts of old buildings have been imported and recycled in unusual ways, giving an appearance of picturesque sham antiquity. On high ground, a romantic tower and domed building seem imposing from below but become rather small when approached. There is no traffic in the narrow lanes. Buildings are laid out informally in a garden setting surrounded by mature woodland dotted with follies, with paths and vistas connecting places in unexpected ways. Throughout the village, outcrops of finely fissured slate give a peculiar impression of being miniaturized. Portmeirion has a mix of differently sized spaces, from the intimate to the huge open space of the bay across which distant hills are visible. This complexity makes it good place to play hide-and-seek. Curiously, this was a theme of *The Prisoner*, a television drama from the 1960s that was filmed in the village. The lack of familiar street furniture, signs, or other objects in common with more ordinary places deprives the visitor of references for scale and contributes to Portmeirion's otherworldly atmosphere.

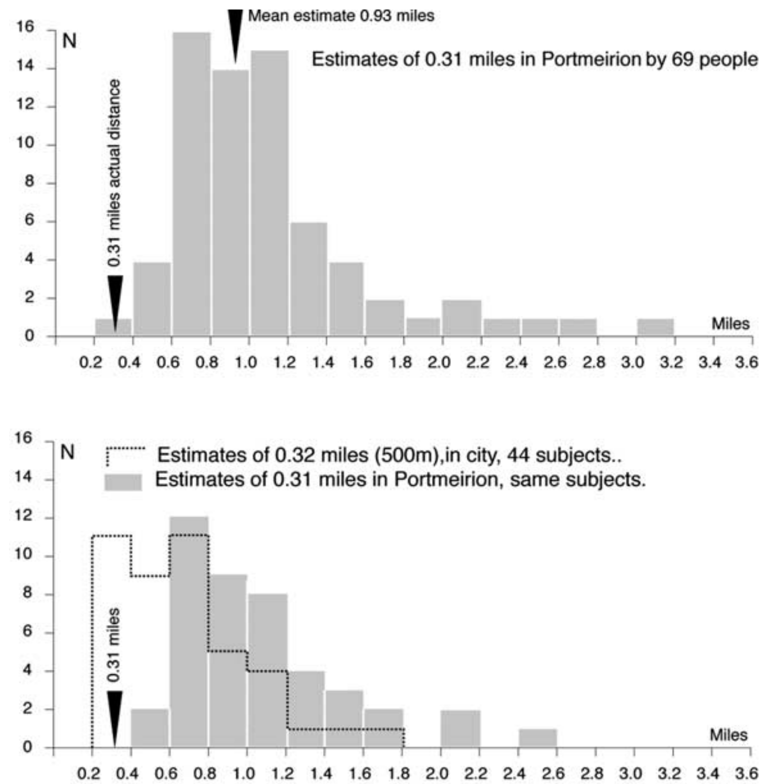


**Figure 3: Histogram of Distance Estimates**

## RESULTS

Of the 69 students who took part in the Portmeirion experiment and the 44 who took part in the Manchester experiment, 41 took part in both and were used for within-group comparisons. The lower part of Figure 3 compares estimates for the Manchester journey with estimates made at Portmeirion. The average Manchester guess was 0.50 miles, and the average Portmeirion guess was 0.93 miles, that is, 3 times the actual distance, a result that came as something of a surprise. All but 1 of the 69 Portmeirion respondents overestimated the distance, often very considerably. Of course, these estimates relate to each student's personal understanding of what is a mile, which is an uncertain quantity. Of more interest is the ratio of each student's guess made in

Portmeirion to the guess he or she made in Manchester. Dealing now with the students who took part in both parts of the experiment (and making a tiny correction for difference in journey length), this ratio ranges from 0.7 to 4.6, with three large outliers. Even if we disregard these values, the average value of the ratio is 2.1, so we can say distances in Portmeirion seem on average to be about twice a long as those in Manchester. With the outliers included, the average ratio goes up to 2.9. All this may be seen in the histogram in Figure 3, where the distribution of estimates of the walk in Manchester and Portmeirion are compared; the distributions are of a similar shape but pushed to the right for Portmeirion. A paired *t* test, two-tailed, without the outliers, shows that the probability that differences between Portmeirion and Manchester could have arisen by chance was less than 0.00016, confirming what is evident in the lower part of Figure 3, namely, that the estimates of 500 m are significantly different in the two locations. With the outliers included, the difference is even more pronounced. This shows that the differences are not caused by a few large wild guesses.

Subjects had their height measured standing in their shoes, the idea being to see if subjects used their own size as a measure of distance. The tallest half guessed the Portmeirion walk to be on average 0.76 miles; the shortest half guessed on average 1.03 miles. To see if this difference was meaningful, a regression analysis looked for a correlation between height and estimate, and a modest negative correlation was found, that is, small people guess longer ($F = 6.4$, $df = 48$, $p < 0.014$). $R^2$ was 0.12, so perhaps 12% of the estimate can be attributed to height. No correlation between participant height and estimate was found in the Manchester estimates; only in Portmeirion was there a connection between height and estimate.

## DISCUSSION

Estimating walking distances in absolute units such as miles always seems to result in an overestimation, a curious fact that deserves investigation. Among many other examples that could be mentioned, Lee (1970), guessing distance in miles in Dundee, found overestimation factors of between 1.14 and 1.35. Similar figures are reported in Canter and Tagg (1975), and Redlick, Jenkins, and Harris (2001) even found overestimation factors of around 1.7 for participants judging distances from optic flow in virtual reality headsets. Seen in this context, overestimating distances by a factor of around 1.5 in Manchester appears normal. However, the overestimation of distances in Portmeirion by a factor of 3.0 looks peculiar. One would like to ask, What is special about this place?

First, we can dismiss any idea that distance perception is influenced by travel time and that the difference is caused by walking slower in Portmeirion than in Manchester. Studies have failed to find a connection between estimated distance and time; Montello (1997) has more details. To put this result in context, it is worth going through some of the experimentally established influences on distance perception. Distances seem to increase as the number of turns goes up (Sadalla & Magel, 1980). A city journey seems farther if we increase the number of intersections en route. This is an example of the principle that breaking a walk into segments makes it seem longer (Sadalla & Staplin, 1980b). It has been found that journeys of 100 m uphill and downhill in parkland were overestimated by a factor of 1.15 compared with a walk on level ground (Okabe, Aoki, & Hamamoto, 1986). Making subjects learn names associated with a route also increases its subjective length (Sadalla & Staplin, 1980a). A related problem is the sense of size of space. Coeterier (1994), questioning people using photographs of open fields, identified boundary height, ground texture, and the presence of isolated elements to be factors that influenced perception of size and concluded that the more relationships there were to be discovered in a landscape, the bigger it will seem. These last three results support information storage models of perception, such as the feature accumulation theory. Which of these factors apply differently in Manchester and Portmeirion? The segmentation of the journey by intersections is about the same in both cases, but the route through Portmeirion is hilly in parts and has several turns. Typical overestimation factors for slopes and turns of 1.15 and 1.2 are not enough, however, to explain the difference in perceived distance.

Because of the difficulties of constructing a suitable control when working in real environments, this experiment is not capable of determining for certain which of the differences are responsible for the increase in apparent distance. Nonetheless, the result is very suggestive and the simple fact that distances can be perceived to be twice as long in one place compared to another ought to be of interest to urban designers. This increase goes well beyond what may be expected by changing one or other factors, such as turns or slope, which are at present known to influence perception. If we accept the feature accumulation theory that the way to make a place appear large is to make it interesting and complicated, then it would seem that vastly more information is absorbed during a walk in Portmeirion than it is in Manchester. How can this be the case? After all, Manchester is not without its incident and interest. An explanation might be as follows: Portmeirion, being a mixture of landscape and buildings, is a scaling fractal similar to the campus scenes scanned by Yang and Purves (2003). Its perceived size is therefore a function of the scale at which one interacts with it. All the little incidents; places to stop, sit, and look; and the things that give Portmeirion its charm and human scale will therefore make it seem larger than places where one keeps moving, where there are few places to linger, and scale is determined by cars. The slight correlation between participant height and distance estimate found in Portmeirion but not in Manchester supports this. In a strange place lacking familiar references that give a sense of scale, visitors to some degree use their own bodies as a clue for sizing their environment, and those who used the smaller measure saw the place as being larger. A small change in the scale of measurement will lead to significant increases in size if the environment is fractal.

## CONCLUSION

Whereas natural scenes such as woodland always seem to be fractal, the built environment is not necessarily so, although it often is both at large scales (Batty & Longley, 1994) and at a small scales (Crompton, 2001, 2005). In fact, if Yang and Purves (2003) are to be believed, then we are predisposed to expect places to be like Portmeirion, and it might be more profitable to look at the question from the other side and ask, How do we, perhaps inadvertently, make distances seem small? According to this study, the answer would be to make the environment plain and interact with it at a large scale, perhaps by being in a car or maybe by ignoring one's surroundings. Distances will therefore seem smaller in places where people look at their feet and there is a lot of traffic. This also suggests that distances traveled by car will seem shorter than walking because they insulate us from our surroundings. This could have an influence on the decision to travel by car rather than by foot. Furthermore, if our idea of what constitutes a mile is based on a journey made in a car, then it will, so to speak, be a short mile. Because our most certain knowledge of measured distance nowadays comes from odometers, this perhaps explains why walking distance estimates are nearly always overestimates, an idea that ought to be put to an experimental test.

Would the same results be found in Venice or Fez as in Portmeirion? Clearly, more research is needed, and although the difficulties of organizing large groups in these places are obvious, it would be worthwhile to repeat the experiment in places with unusual scales, large as well as small. Perhaps such experiments could give the phrase *bigger than it appears* some quantitative meaning. Seen in this way, space in the built environment may not be an absolute quantity but, by appropriate design, may be within our power to create from nothing as if it were a commodity.

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