The Role of Angularity in Route Choice
An Analysis of Motorcycle Courier GPS Traces

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Abstract. The paths of 2425 individual motorcycle trips made in London were analyzed in order to uncover the route choice decisions made by drivers. The paths were derived from global positioning system (GPS) data collected by a courier company for each of their drivers, using algorithms developed for the purpose of this paper. Motorcycle couriers were chosen due to the fact that they both know streets very well and that they do not rely on the GPS to guide their navigation. Each trace was mapped to the underlying road network, and two competing hypotheses for route choice decisions were compared: (a) that riders attempt to minimize the Manhattan distance between locations and (b) that they attempt to minimize the angular distance. In each case, the distance actually traveled was compared to the minimum possible either block or angular distance through the road network. It is usually believed that drivers who know streets well will navigate trips that reduce Manhattan distance; however, here it is shown that angularity appears to play an important role in route choice. 63% of trips made took the minimum possible angular distance between origin and destination, while 51% of trips followed the minimum possible block distance. This implies that impact of turns on cognitive distance plays an important role in decision making, even when a driver has good knowledge of the spatial network.
Keywords: Navigation and wayfinding, spatial cognition, distance estimation, route choice, spatial network analysis

1 Introduction

It is known that route angularity has an effect on the perception of distance. Sadalla and Magel show that, within laboratory conditions, a path with more turns is perceived as being longer than a path with fewer turns [1]. However, where navigation of a learned environment is concerned, we tend to assume that people will optimize the cost of their journey in terms of energy expended when walking, and in terms of time-efficiency when driving. That is, we would expect the physical cost constraint to overcome the cognitive cost of moving from origin to destination, and therefore observe experienced drivers taking the shortest block or Manhattan distance between origin and destination. In Bachelder and Waxman's proposed functional hierarchy of navigation strategies, it is unsurprising that the highest learned behavior is route optimization through distance

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minimization [2]. ‘Distance’ being the physically shortest distance. Below this comes navigation using the topological network, navigation by landmark, and only at the lowest level is angle considered an important factor, through path integration, or minimizing the angle to the destination.

That angle is a low level navigational strategy is reinforced by how we mentally process angles. Sadalla and Montello show that memory of turns tends to be categorized into distinct units of orthogonal directions rather than a continuous understanding of angle between locations [3]. This grouping of angles together would appear to affect our ability to navigate by using a least-angle heuristic, making it efficient in unknown environments but too susceptible to error to be usable in learned environments [4]. Although Montello shows that the physically shortest path is not always preferred within an urban environment [5], this effect again appears to be due to path integration rather than a higher level navigational strategy. Montello also shows that the direction of travel is important to the route choice. This finding indicates path integration, as a true minimal path would be the same in both directions. Furthermore, even the extent of the angular effect on perception of distance seems to be susceptible to experimental conditions. Heft shows that, if a non-laboratory set up is used and there are distractions in the environment, then the route angularity effect is not necessarily replicable [6].

Given this body of evidence, the proposal that minimization of route angularity is employed as a high-level navigation strategy might seem an unusual direction to take. However, the angularity of a route can work as a useful proxy for the number turns, and therefore as a mechanism to underpin any strategy that minimizes cognitive load for memory. Although turns may be discretized in our heads following Sadalla and Montello [3], the angle gives useful indicator of whether or not we might perceive the turn, without having to work out a schema for quantization. It also allows us to circumvent problems to do with decisions about when a turn becomes a turn. For example, when several small turns over a short distance turn into a perceived change of direction. As an overriding factor, though, the route angularity effect itself is important, as it shows that our conception of distance is mutable. That is, if we are to minimize distance, then we must form a plan of action in response to our cognitive map. In this situation, we may well plan to reduce the complexity of the route in favor of a reduction in the physical distance that it presents us, especially where the means of transport is mechanical rather than corporeal. Indeed, distance memory is notoriously difficult to pin down, but it appears to be more dependent on information or events encountered during a journey rather than the time taken or effort expended through it [7]. In this respect, a path that minimizes turning also minimizes the number of views along it, and so it can be stored in a compact manner, and once again the minimization angle may be thought of as a proxy for the minimization of cognitive distance.

In transportation analysis, however, the mechanism for route choice is almost universally assumed to be the shortest time between locations, and it is often assumed that the participant has access to a perfect map. Nevertheless, there is limited acknowledgment of different route choice within traffic analysis through the field of space syntax. Space syntax originated as a theory of the interaction of space and society, in which twin processes of movement and socialization occurred [8]. Movement was posited to be along continuous lines and socialization within convex areas. This theory led to the construction of an 'axial map' representing the linear movement paths, which was then analyzed to construct minimum turn paths between spaces. One problem with early models was that a turn constituted any move from one line to another, regardless of intersection angle, even a slight bend in the road. In response, various researchers turned either to joining sets of lines into continuous paths [9, 10] or analyzing the angle between them [11, 12]. In particular, a form of angular analysis which calculates the *betweenness* [13] has been shown to correlate very well with both pedestrian and vehicular aggregate movement levels [14]. In betweenness, the shortest (angular) path is calculated between all pairs of street segments in the system. For each segment that lies on one of the shortest paths, a count is incremented, so that a segment that lies on many shortest paths has a high betweenness rating. Further refinements to the method have moved away from axial lines altogether, and instead use road-center lines complete with topological constraints (such as no-left turn restrictions or one-way streets), again with a demonstration of high correlation with observed movement using a range of measures either angularly or turn-based [15, 16].

Despite much correlative evidence, no direct causal link between movement strategy and observed movement levels has established within the field of space syntax[1]. It is suggested that the construction of paths from all segments to all other segments represents an approximation to all possible origins and destinations, and that paths taken by people tend to be the shortest angular paths rather than the shortest block distance paths. However, the observations can only be linked to aggregate numbers. While space syntax maps of angular betweenness identify main roads [16, 18], those showing metric betweenness show 'taxi-driver' paths ferreting through back streets [15]. This result in itself leaves the methodology open to criticism. It is suggested that once people learn an environment, they will take these back street rat-runs. That is, rather than the good correlations indicating some underlying cognitive feature of the environment, it is argued that they merely indicate that most people are still learning the environment using path integration, and once they have attained full knowledge, they will move to the taxi-driver routes.

This paper – inspired by the debate around angular versus block distance within space syntax – examines the routes taken by a set of people knowledgeable about the available paths, who would be most expected to minimize physical distance covered. Motorcycle couriers make many deliveries every day within a confined area. This paper examines routes taken by couriers belonging to

[1] There is indirect evidence, such as experiments by Conroy Dalton into the route decisions people make within complex building environments [17], but this does not tie directly back to the angular paths used at the urban level to construct betweenness measures.

a single company during the month of October 2008, from global positioning system (GPS) tracking data for each courier. Approximately 50 couriers are observed, for a total of 2425 delivery trips. The courier company is based in London, and almost all the journeys take place within the central West End and City areas, with a typical journey length of 1.2km (more details follow in the coming sections). Motorcycle couriers are used for two reasons. Firstly, due to the number of deliveries they make in a constrained area, they have good knowledge of the road network. Secondly, they do not rely on the GPS data to navigate, so the observed trace represents the rider's own navigation rather than a route suggested by the GPS system. Instead, the GPS system is used by the company to allocate drivers to nearby pickups for delivery. As delivery is often urgent, the riders should be taking time-critical decisions to inform their chosen path, and we would expect them to take the minimum physical distance between origin and destination. However, in this paper, it is shown that the path chosen by the couriers is more often the minimum angular path than the minimum block distance path.

2 Background

There is potential to use global positioning system (GPS) in a range of cognitive contexts, and Dara-Abrams sets out a framework for spatial surveying and analysis using GPS within spatial cognition studies [19]. Furthermore, traditional travel diaries may be replaced with GPS trackers giving more accurate recordings of participants' movements [20]. Yet GPS data has been rarely used for explicit determination of route choice, despite at first seeming the ideal option for data gathering about wayfinding decisions. There may be a number of reasons for this: GPS can only reliably be used in outdoor environments; purchasing units for individual studies can be relatively expensive; and, unless dedicated units are used, typically the GPS will have been used to guide the participant, making navigation data redundant. Thus, on the whole, information mining does not seem to take place at the level of the road unit. GPS information can be used to give population statistics, such as the diurnal movement of commuters, or to derive location-based data from clusters. For example, Jiang et al. have used GPS traces to characterize patterns of movement by taxi in terms of power law distribution and relate this to a Lévy flight pattern [21]. At a more detailed level, Ashbrook and Starner use GPS both to suggest areas of interest, and to predict movement between them using a Markov transition-probability model [22]. Individual studies also exist in an attempt to link angle with behavior. For example, Mackett et al. give GPS units to children to follow their movement. However, the angular analysis they make is simply in terms of the number of turns made, not compared to potential route choices [23].

There have been studies from the transportation research field that do explicitly consider the geometry of routes that are taken. For example, Jan et al. have made an analysis of the routes taken by 216 drivers within the Lexington, Kentucky area over the period of a week [24]. Their main observations concern the difference between the shortest block distance path and the participants' actual routes. As the study is from the field of transportation analysis, Jan et al. are principally concerned with route allocation, and therefore alternative hypotheses concerning other cognitive models of route choice are not explicitly considered. Li et al. make a similar study for 182 drivers in Atlanta, Georgia, but once again route allocation is the paramount consideration [25]. Therefore, the regularity of commuters using one or more routes is examined, and a logit model prepared in order to predict which routes will be taken according to the probabilistic observation, rather than an investigation into cognitive hypotheses about how the drivers are making decisions.

Despite the difference in motivation for their study, Jan et al. do make the observation from individual instances within the data that it appears that some road users stick to the freeway as long as possible, but do not present a quantitative analysis of the routes in these terms. As Jan et al. point out, this seems a reasonable heuristic for movement between locations. From a cognitive perspective, we might add that the freeway path involves relatively fewer decision points, and is relatively free-flowing, although it is frequently not the shortest angular path. The driver must double back or make another diversion to get to their final destination, and so the case of commuters may well differ from those of motorcycle couriers. In particular, it would seem that sticking to freeways is the province of a less knowledgeable user of the road system, and when we look at traces in the following sections, we find tentative support for this hypothesis. More particularly, though, the paper is concerned with angularity as a possible navigation strategy, and this will form the major part of the analysis presented here.

3 Methodology

The methodology for this research follows three stages. Firstly, a subset of credible GPS data is extracted from raw data about courier locations at specific times, and split into individual trips from origins to destinations. Secondly, the trips are attached to a base map, and topological constraints on the possible routes are enforced in order to generate a set of sample trips, for which actual road distance followed and angle turned can be calculated. Thirdly, two forms of analysis are performed. In one, the block distance and the angular distance traveled are compared against a minimal trip using the same starting and destination road segment. In the other, the aggregate number of trips is compared to a space syntax analysis of the road network using betweenness. All the import and analysis algorithms reported were coded as a plug-in to UCL's Depthmap program [26].

3.1 Trip Segmentation

The GPS data used for the study are in the form of *xml* files downloaded from a courier company who track their deliveries[2]. Each *xml* file contains a series of rows containing a courier identifier (a short alphanumeric code), a courier type (pushbike, motorbike, van and so on), the location in WGS84 format (longitude and latitude), a notional speed on an arbitrary scale, a heading and a timestamp. For the purposes of this paper, we took the courier types 'motorbike' and 'large motorbike'. While pushbike traces would have been interesting to examine, there were too few in the sampled data set. The data were collected for every day through October 2008 between 10am and 4pm. The choice of month was to take a working month where weather is typically not extreme. The time period is chosen to exclude rush hours, which might bias the drivers away from congested streets.

Once the lines for motorbikes were extracted, the data were then subdivided into trips for each courier. The data contain a timestamped location approximately every 10 seconds for each courier, although this may vary considerably according to ability to pick up a signal within a high rise area or in a tunnel. For most of the time, the timestamp in combination with the speed attribute, can be used to pick up when the courier has stopped or is moving, although GPS typically drifts around, and erroneous speed, heading and location data is frequently encountered. However, in relation to stops it can be difficult to tell the difference between a delivery or pickup and a stop at a traffic light. The couriers are incredibly efficient, and can often pick up and drop within a couple of minutes. For the purposes of this paper, we took 90 seconds stationary (speed below '2.5' – roughly equivalent to 2.5mph though not exactly), to be indicative of a stop. Due to GPS drift, starting up again is only registered when two consecutive rows show movement away from the stop point. The short stop requirement may accidentally pick up inter-traffic light journeys, but this is perhaps not too far removed from the journeys undertaken: what is not immediately obvious is that motorcycle courier trips are typically very short, both physically and temporally. This is due to the nature of the job. A motorcycle courier picks up an urgently needed document and takes it to another company, typically still within the center of London. In any case, to prevent overly short or overly long journeys, only trips between 500m and 5000m in length were recorded. Furthermore, the journeys take place in a very restricted area. Almost all the trips (well over 95%) were within the central area of the West End and City of London (see figure 1). However, a few journeys do go outside the central zone, well into the surrounding counties. In order to capture the majority of the sort of trips being undertaken, only trips within a 20km $\times$ 20km region containing the center of London were retained[3]. Other trips were removed due to clearly erroneous GPS data: locations can and often do completely misread. As there was a significant amount of data available, trips were simply excluded altogether if a reading suggested a speed over 20ms^{-1} (approximately 45mph – the urban limit in the UK is 30mph). After

[2] The data are free and may be obtained from http://api.ecourier.co.uk
[3] Ordnance Survey grid coordinates $520\,000, 170\,000$ to $540\,000, 190\,000$

paring down the trips, 2425 individual origin-destination trips were identified, comprising location points joined through a continuous time period.

Fig. 1. All GPS traces within the central London area (colored by trip duration), with the base map shown in the background. The area shown is approximately $8\text{km} \times 6\text{km} \approx 50\text{km}^2$. (Map data: OpenStreetMap)

3.2 Trace Attachment

The GPS traces obtained in the previous section are very approximate records of journeys taken. In order to ensure an accurate path is taken, the traces were next attached to an 'Integrated Transport Network (ITN) layer' base map supplied by Ordnance Survey. The map includes the topological information such as one way streets and no-right turns. Thus it is possible to derive the path that must actually have been driven from the data. Path reconstruction such as this is relatively unusual to attempt with GPS traces. Typically, algorithms need to find out where a vehicle is at the current time and where it is heading, and if a mistake is made it can be corrected quickly. In our case however, we only have points approximately every 10 seconds, and we must be careful to construct the most plausible path between locations. Figure 2 shows an actual GPS trace and its mapping to the base map. The driver starts on the Western side, drives North around a roundabout before heading South and then East. The traces were attached by what might at first seem a very lax method. All road segments within a 50m buffer of each location point are considered as possible routing segments provided they are within 30 degrees of the heading. However, if a tighter radius is used, then, due to inaccuracies in the location data, dead ends can easily be included, or the actual path missed.

Once the candidate segments have been identified, the path finding algorithm works by connecting up the shortest path between one candidate segment and the next, including at least one candidate segment for each location node along the path. The 'shortest path' is of course problematic for the purposes of this paper. Although usually we might just say the shortest block distance path, in order to be fair to both hypotheses we construct two variations: one using the shortest angular path between consecutive candidate segments and the other using the shortest block distance path. All measures concerned are then applied to the path identified with the appropriate distance rule.

Fig. 2. Sample GPS trace (black) and the path as attached to the topological base map data (thick gray). This example uses OpenStreetMap data rather than the OS ITN layer used for the actual experiments.

There are a couple of caveats to using this method. Firstly, that the trip is truncated somewhat by the 50m buffer distance selecting shorter paths at the beginning an end (see figure 2 for an example). Secondly, and more importantly, in order to impose a route that follows the general behavior of riders, no immediate doubling back along roads is allowed. This is the equivalent of a no U-turn rule. Of course, in certain instances, drivers may well have made a U-turn. In addition, it is to be expected that riders may bend the rules occasionally or perform unexpected behaviors. A few paths generated seemed to take very tortuous paths to reach their destinations, and these would seem to occur when such anomalies have occurred. As these are very rare, they do not make a significant impact on the results.

3.3 Trip Analysis

Once plausible origin to destination routes were constructed, the routes taken were analyzed fairly simply. Firstly, the 'actual' path taken was compared to the shortest possible path between the origin segment for the trip and the destination segment for the trip. For each of these cases, the shortest path was compared to the path constructed using the same metric between candidate nodes to eliminate bias in the construction of the 'actual' path. That is, an 'actual' path constructed using angular shortest path between location nodes along its length was compared to the shortest angular path possible between the origin location and destination location, and similarly for the block distance path.

In addition, space syntax analysis using the *betweenness* measure was performed, which counts the number of times a segment is on the shortest path (either angular or block distance) between all pairs of origins and destinations in the systems. We can constrain this measure to look at just trips of length up to 1500m, based on finding that the length of trace attachment trips in the previous section averages about 1500m (more details about the statistics of the trip lengths are given in the next section). This test cuts in the opposite direction through the data to the per courier analysis. It is intended to discover if couriers on average make use of streets which are well connected to others, either angularly or based on block distance, following findings that angular betweenness appears to correspond to road designation, with main roads having high betweenness [16, 18]. This is somewhat different to what the courier does in response to a particular origin and destination, and is compared to the overall numbers of couriers using each segment of road, shown in figure 3.

4 Results

4.1 Individual Trip Measures

2425 trips were analyzed. The average block path length was 1380m with a standard deviation of 700m. Angle was measured using the space syntax convention of 90 degrees being '1.0' [14]. So a 180 degree turn is '2.0', and continuing straight on is '0.0'. This makes it easier to count 'numbers of 90 degree turns', or effectively give a number of 'turns', if turns approximate 90 degrees, as they would on a grid system. Using this convention, the average angular path length was 5.34 with a standard deviation of 3.64.

We then compared the actual path length against the shortest possible path length for both angular and block distance paths. The results are shown in table 1. In order to further elucidate these results, they are displayed in figure 4 using a logarithmic scale for the fractional ratio of actual path length to possible path length. The optimal fraction is 1.00, where the path taken is the shortest

Fig. 3. Counts of the number of couriers that used each road segment for the central area of London. The inner London ring road (part of which is visible in the top left corner) is largely avoided. (Map data: OpenStreetMap)

possible route. The couriers take this optimal path a surprising number of times, either taking the shortest block distance path or the shortest angular path in 71% of cases. It should be noted that in 43% of cases, they take a path which is both the shortest angular and shortest block distance path, so in these cases we are unable to distinguish which strategy they are using to guide their path. Of the remainder though, 70% of the time, when the courier takes a shortest path, it is the angular shortest path rather than the block distance shortest path. It has to be noted that in all cases the differences are very small. A lot of the time, the courier takes a trip within a small percentage difference of the actual minimum possible path, be it angular or metric.

The results are for the most part unsurprising: these are short trips and we would expect them to show good optimization of the route taken. However, it is interesting that, when they take a shortest path, it tends to be the angular shortest path rather than the metric shortest path. This suggests that even for short trips where the route is well known, the angular shortest path is the preferred option. This may be less unexpected than at first thought. Making a turn is a time consuming business. One must slow down, perhaps wait for oncoming vehicles to clear, and, on a motorbike lean from side to side. A straight path involves significantly less effort.

From a space syntax perspective, it is immaterial whether the effect is due to a cognitive distance difference or due to a physical effort different. However, it is useful to consider the evidence available to find the difference between the

Table 1. Cumulative number of paths within a factor of the minimum possible path distance for angular and block measurements of the path ($n = 2425$)

Fraction of minimum	Angular		Metric	
1.00	1531	(63%)	1232	(51%)
1.01	1574	(65%)	1332	(60%)
1.05	1637	(68%)	1643	(68%)
1.10	1738	(72%)	1863	(77%)
1.20	2010	(83%)	2143	(88%)
1.50	2237	(93%)	2258	(93%)
2.00	2419	(100%)	2424	(100%)

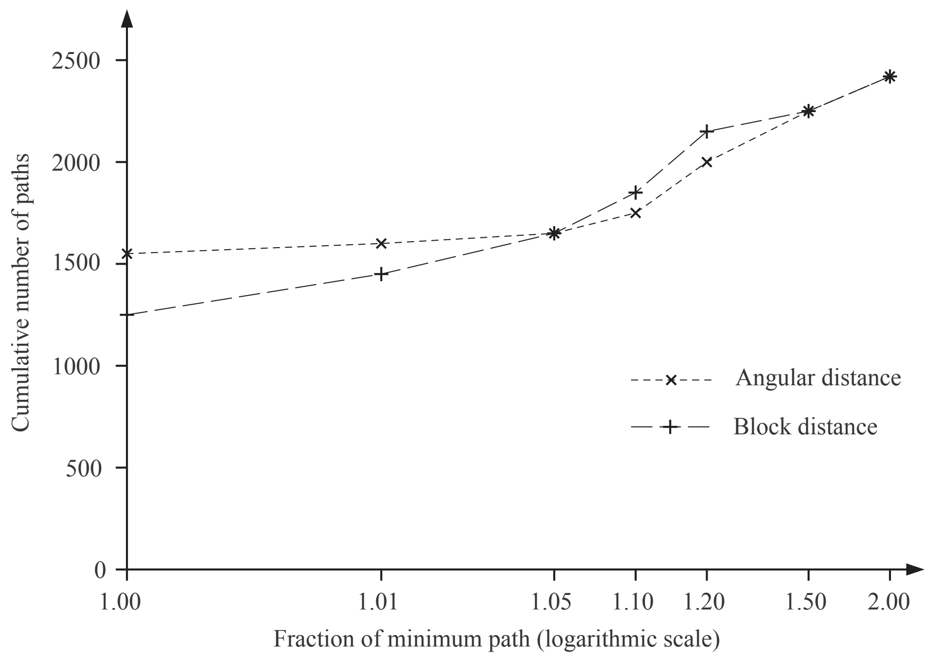

Fig. 4. Cumulative numbers of paths within a factor of the minimum possible distance paths for angular and block measurements of the path.

two hypotheses. If the effort hypothesis were true, then we would expect to see an appreciable decrease in journey speed as the angular turn increases[4] In order to attempt to detect this effect, the average speed was calculated for each journey. This was then compared to the total path angle of the the journey. If the effort hypothesis were true, we would expect to see a correlation between the speed and turn, as turning would slow down the journey speed. In fact, no correlation between speed and total angular turning for the path is observed ($R^2 < 0.01$). This is further backed up by a large difference between correlation of trip duration and angle ($R^2 = 0.31$) as opposed to the correlation of trip duration and path block-distance length ($R^2 = 0.66$). That is, traveling further physical distance is correlated with increased trip duration, but making more turns is much more weakly correlated with increased trip duration, and hence the trip duration is less dependent on angle turned. Therefore, given the cost of turning seems to have little effect, it is more likely that angle is reduced due to an increase in cognitive difficulty in order to process more turns. As discussed in the introduction, we might suggest that the views along a street segment are relative stable, and thus each turn will lead to a significant increase in memory required to learn the route, and so higher turn journeys will increase cognitive distance.

4.2 Aggregate Trip Measures

By contrast to the individual trip measures, the aggregate trip measures were not found to be informative. If we refer to figure 3, it can be seen that the couriers are confined to, for the most part, a very small subset of streets within London. In particular, it is clear that couriers do not tend to use main ring roads, and their journeys would therefore be unrelated angular betweenness as we have described it: a measure which relates to main roads [18]. However, at such small distances, an average of 1.5km, the main roads are not actually picked out by angular betweenness, as shown in figure 5.

This observed difference to the literature on angular betweenness is due to the fact that in the literature examples, angular betweenness is run of radii up to 80km rather than just 1.5km. In the high-radius case, many trips from outside the city center take place and are transferred through the ring road structure [18]. Hence, in the low radius case much more local possibilities of movement are picked up, spread more evenly across the center. However, if figure 3 and figure 5 are compared, it is clear that angular betweenness is still not correlated to the movements of the couriers. While the angular betweenness does not favor any particular origins and destinations, the paths that the couriers take are very much biased by the contingencies of the specific pick-up and drop locations. Most

[4] Ideally, we might extract from the data a time-cost table for turns from each segment to each other segment, to determine the exact cost of any turn. However, a number of assumptions have been made already with regards to route, and time and speed are sampled coarsely. Therefore, the argument in the text uses the average journey speed instead.

Fig. 5. Space syntax measures of the central London area (angular betweenness radius 1.5km). At this radius, which reflects local journeys, the inner London ring road (part of which is visible in the top left corner) is not highlighted. (Map data: OpenStreetmap)

of the courier routes cut directly through the middle of the map, presumably reflecting jobs transferring documents between companies located at the heart of the City and the West End of London. This is further backed up by our previous findings: the couriers *are* taking, for the most part, the shortest angular and block distance paths between origins and destinations, so this result must be biased by the actual origin and destinations. Otherwise, as the betweenness measure is simply a sum of shortest paths, the sum of courier paths would *have* to be correlated to betweenness. To confirm the results, linear regression tests were performed, and a weak positive correlation with betweenness was observed. For angular betweenness the figure was $R^2 = 0.09$, and for block-distance betweenness the value was $R^2 = 0.07$. This result is again indicative of a preference to angular rather than block-distance once again, but in the aggregate case it is too weak to form definitive evidence.

5 Conclusion

Results from the field of space syntax suggests that, on aggregate, vehicular numbers correlate with measures of the road network based on minimum angle rather than minimum block distance as might initially be expected [14, 15]. This tends to imply that navigation may well be based on minimizing angular rather than block distance. However, there has been no established link between cognition and this strategy. It could equally be a physical phenomenon of the properties of road networks that results in the observed movement within them, as it could be a cognitive one. As a response, this paper attempts to uncover if there is a cognitive aspect by looking at the route choice decisions of motorcycle couriers. Motorcycle couriers know the street network very well, and hence they will be expected to optimize the block distance between origin and destination. We find, however, that despite often taking the shortest block distance path, couriers prefer the shortest angular path. Where it is possible to make a preference, they choose the shortest angular path 70% of the time.

It is of course easy to conflate angular choice with other strategies such as path integration. However, given the courier data, the proportion of exact angular routes is so high that it leaves little room for consideration of other factors. For example, it might be expected that turns will be taken toward the beginning of a journey [17], but as the couriers are, for much of the time, choosing an exactly minimum path, any turns that are made are in fact necessary for the minimal path to be followed, rather than because they are early or late in the journey. Alternatively, the opposite may be the case: that the minimal angular path is a result of a path integration decision at the beginning of the journey, that then impacts on automatically following the minimum angular path later.

However, as evidence for space syntax, and that angular routes play a strong part in route choice, the evidence that links individual route choice to a preference for the shortest angular route in secion 4.1 is compelling. That said, there remains much to be done. Such a restricted data set tells us little about other factors in general route choice decisions. Factors such as landmarks and other informational structures need to be added to the analysis, as do many other components that can help bring the cognitive map into the routine study of urban travel, including investigating the decisions made by drivers with different levels of experience of the system [27].

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