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Children’s route choice behaviour

Comparing the actual and metrically shortest routes for active school travel

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ABSTRACT

Understanding the built environmental (BE) attributes associated with children’s navigation choices during active travel to school is of utmost importance since the findings can lead to targeted environmental interventions to promote active living among children. In active school travel (AST) literature GIS-calculated metrically shortest routes or circular buffers around home/school are generally assessed to identify the underlying BE features influencing children's route choice behaviour. However, this approach may fail to capture actual BE features children are exposed to during their active school trips and hence may result in misleading results. This study investigates the daily AST walking routes (n=21) of 9-10 years old children (n=79) in Newcastle upon Tyne, UK. The actual routes were examined against the corresponding shortest paths between the homes and the schools. Street design characteristics for each road segment along the actual and shortest routes were evaluated through detailed field surveys that captured 21 environmental attributes including street network design captured by various syntactic measures. Paired t-tests and Wilcoxon signed-rank tests were conducted for these environmental attributes and the effects of different BE variables in route selection were estimated in conditional logistic models. Results reveal that children prefer to walk along routes with increased metric accessibility, reduced setback distance, increased average footpath width, and available benches. This study contributes to the literature by broadening our understanding of the environmental attributes that may promote AST. Findings could also inform urban planners, designers and health professionals in their behaviour change interventions targeting active living promotion, especially for children.

KEYWORDS

Active school travel, route choice behaviour, built environment, street network design, Newcastle upon Tyne

1 INTRODUCTION

Childhood obesity and physical inactivity are two critical public health problems with multiple effects on children's health. Active School Travel (AST) is a potential health promotion strategy that could increase physical activity among children. The health benefits of AST go beyond physical activity and fitness, including better mental development (Singh et.al 2012), social wellbeing (Waygood et.al 2017) and development of children's sense of freedom and identity (Kirby and Inchley 2009); as well as economic benefits for the community (McDonald et.al 2020) and reduction of the air pollution due to traffic emissions (Khreis et.al 2016) . According to socio-ecological models (Sallis 2009), built environment (BE) has an important role in promoting health behaviours including AST. Similarly, various AST frameworks highlight the need to explore the role of built environment design features in further detail (Panter et.al 2008, Pont et.al 2010, Mitra 2013, Larouche and Ghekiere 2018, Mitra and Manaugh 2020). Previous studies found that the built environment is the strongest determinant of children's active behaviour patterns (Buck et.al 2015). Hence, understanding the underlying reasons of children's navigation choices is of utmost importance since the findings can lead to targeted environmental interventions to promote active living among children (Olsen et.al 2019).

2 THEORY

Existing evidence in AST literature suggest that home-school distance is the strongest predictor of walking to school (Schicketanz et.al 2021, Carver et.al 2019, Ikeda et.al 2019, Rothman et.al., 2018; Ikeda et.al 2018; Curtis et.al 2015; Oliver et al., 2014, Mitra 2013). However, children living within walkable distance of school may also be driven (Carver et.al 2019), which points to other reasons affecting school travel choice. Past studies have attempted to explore multiple neighbourhood and street design characteristics that may influence travel behaviour choices. Increased land use diversity has been shown mostly as a significant determinant of increased likelihood of walking to school (D'Haese et.al 2015), with specifically commercial and recreational uses being supportive of active school trips (Özbil Torun et. al 2020). However, land use diversity may be result to metrically shortest destinations and therefore better accessibility (Ikeda et.al 2018), hence there is still a lack of clear evidence if and how the variety of land uses may support AST. Similarly, mixed results exist for the effects of street connectivity on AST (Mitra, 2013). Although well-connected street networks were found to support AST (Ozbil et.al 2021), street connectivity may also encourage more car traffic (Giles-Corti et.al 2011). Although busy traffic appeared to have no associations with AST (Carver et.al 2019), increased traffic, major street crossings and street width are associated with traffic safety concerns, which could be a barrier to AST (Mitra 2013). Traffic-related walking safety is a strong determinant of AST (Pocock et.al 2019, Van Kann et.al2015), while traffic-calmed streets, cul-de-sacs (Buck et. al 2015), speed limits and crossing aids (Jauregui et.al 2016) in school neighbourhoods are associated with more active trips. Finally, walking and cycling facilities (D'Haese et.al 2015), as well as attractiveness and maintenance of the public space (Van Kann et.al 2015) are found to have no consistent associations with AST.

The lack of consistency in existing evidence regarding the role of environmental attributes in AST may be due to lack of a consistent methodological approach in assessing children's route choices (Larsen, N. Buliung & Faulkner 2016, Dessing et al. 2016). In AST literature, the neighbourhood buffer approach is broadly employed to assess the built environment around schools and homes. A neighbourhood analysis may provide a general assessment of an area, but this may be significantly different from the environmental attributes children are exposed to (Harrison et al. 2014). Therefore, one promising but not particularly explored (Shatu, Yigitcanlar and Bunker 2019; Dessing et al. 2016; Larsen, Buliung & Faulkner, 2016) approach that could enable us to understand the possible impact of the built environment on travel behaviour is to explore the underlying reasons of navigation decision-making by investigating the actual routes selected during navigation.

As early as 1985 Seneviratne and Morrall found that an important determinant of route choice for transportation is the metric distance (Seneviratne and Morrall 1985). This finding is supported by more recent studies (Agrawal et.al 2008, Borgers and Timmermans 2005), which suggest that minimal distance and therefore minimal time is the main reason underlying people's selection of the metric shortest route. However, a growing body of research has demonstrated that route directness, as a topological structure of the street network, plays an important role as metric distance in choosing a particular route (Helbing 1997). The significance of direction changes in travel behaviour has also been underlined in the theory of space syntax. The fact that direction changes influence the distribution of pedestrians is not surprising. Direction changes are associated with cognitive effort (Bailenson et.al 2000, Crowe et.al 2000). Thus, it seems intuitively plausible that pedestrian movement is drawn to those streets that act as a primary reference system, providing pedestrians with cues allowing them to locate themselves within the global environment. This is confirmed by research findings (Conroy-Dalton 2003) indicating that people orient themselves with respect to frames of reference that are as linear as possible and that pedestrians tend to maximize directionality during urban navigation by preferring least directional change routes (Shatu et.al 2019).

Another methodological limitation of AST studies is the use of estimated routes (i.e, GIS calculated metrically shortest routes) rather than the actual routes to school (Smith et.al 2021) due to lack of such data. Therefore, most of the existing evidence on children's active transportation to school represent the estimated route choices rather than actual routes, which might partially explain the variable results regarding BE features. However, recently, researchers have highlighted the significance of studying the actual routes (Moran et.al 2018, Broberg and Sarjala, 2015), as the assumed routes may not be representative of the actual ones (Ikeda et.al

2018). More specifically, both Dessing et.al (2016) and Buliung et.al (2013) found statistically significant differences for route structure and built environment variables measured along reported and GIS-based shortest school routes, challenging the conceptual and empirical validity of using the GIS-calculated school route in AST research. In addition, Shatu, Yigitcanlar & Bunker (2019) found that children may neither select the shortest nor the most direct route. This points to other environmental aspects, such as traffic lights (Dessign et al. 2016), traffic calming measures (Rodríguez et al., 2015), traffic exposure (Ikeda et al. 2018), ground floor attractions and width of footpaths (Argin et.al 2017) as well as street connectivity (Ikeda et al., 2018; Argin et.al 2017) along the route as potential determinants of route choice.

Considering the research above, this study aims to contribute to the existing but limited body of work regarding the built environmental correlates of route choice during AST. It addresses the above-mentioned research gaps by focusing on the comparison of the actual and GIS-based metrically shortest school routes using street-level, fine-grained data. The findings of this study can guide policy makers in developing more effective street-level interventions to promote children's active travel to school.

3 DATASETS AND METHODS

3.1 Participants and Study Area Context

This study focuses on Newcastle upon Tyne, UK, and its selected neighbourhoods. The city is the largest in the Northeast England with an area of 114 km2 and an estimated population of 300,000, approximately 34,000 of which are school year-aged children (https://www.newcastle.gov.uk/our-city/statistics-and-intelligence). The street network layout differs across the city, ranging from traditional grid-iron to cul-de-sac layout. The city is also interesting in that the percentages of children walking or cycling/scootering to school are relatively low (39% and 6% respectively) (Schools Health Education Unit 2019) while childhood obesity is quite high (37.5% for children aged 10-11 years) (PHE, 2020). In addition, the 2019 Wellbeing Survey shows that there are limited opportunities for physical activity for children and young people in the city (Schools Health Education Unit 2019). Recently the city has initiated new planning interventions and policies with an emphasis on active transport and accessible open spaces (i.e., the introduction of "low traffic neighbourhoods" (Chronicle live, 2021). These indicators set Newcastle Upon Tyne as a case study worthy of investigating children's route choice during AST.

Four physically and socially heterogeneous neighbourhoods in Newcastle upon Tyne were selected as case study areas based on a systematic quadripartite-matrix including street connectivity (space syntax measure of Integration[1]) levels and socioeconomic context (based on open source Index of multiple deprivation) (i.e. high connectivity and low deprivation) to ensure

[1] Integration calculates how close each street segment is to all the others within a set radius.

variability in case study areas (Figure 1). Five different primary schools, one of which was the pilot study school, located in these neighbourhoods were recruited between October 2019 and March 2020. A total of 192 randomly selected children attending these schools (aged 9-10 years) were invited to participate in the study. Written information sheets describing the study aims and procedures were sent to their parents through the schools. Following a purposive sampling, 145 children, who provided relevant consents (i.e., consent provided by both children and parents), were eligible to take part in the study. Ethical approval was obtained from the Ethical Committee of Northumbria University, Newcastle upon Tyne, UK (30 April 2019, Submission Ref: 15592).

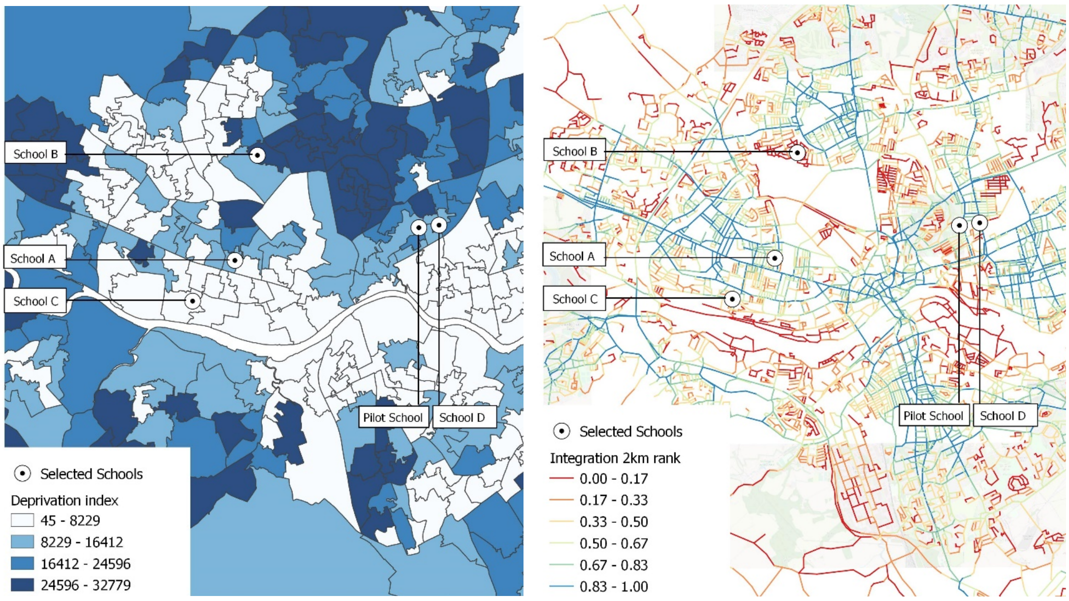

Figure 1: The location of selected schools on maps of (left) Deprivation Index, and (right) Integration (2km).

3.2 Instrumentation

Participating children attended a mapping activity where they were asked to draw their typical school routes (i.e., home to school) on pre-assigned maps and identified their mode of travel (e.g., walking, cycling, being driven). Children actively commuting (i.e., walk and cycle) to school (n=79, 55% of the sample) were included in this study. Each route was geocoded into QGIS (QGIS Development Team, 2009. QGIS Geographic Information System. Open Source Geospatial Foundation. URL http://qgis.org) to identify the individual street segments along the selected routes. Actual distances walked along the network and of the shortest routes were calculated. For each child, the metrically shortest route was also computed using Network Analyst tool in QGIS to be included in the subsequent comparative analysis with the actual route. Actual and shortest routes were created based on the street network data constructed using the street centrelines in OpenStreetMap (OSM), revised, and finalised manually based on satellite images (google View) (Figure 2). Differences in distance between the actual and GIS-derived shortest routes were calculated as a detour index based on Park et.al (2019), as shown below:

$$\text{RDI=} = \left(\frac{\text{actual route distance}}{\textit{shortest route distance}} - 1\right) x\ 100(\%)$$

where a value of zero indicates that the reported route is the shortest route.

To understand the underlying reasons for the selection of a particular route, the actual routes were compared against the corresponding GIS-based metrically shortest school routes using 21 route attributes. Reported routes with a 100% overlap with the shortest routes were excluded to be able to identify the possible BE determinants of route deviation and as suggested in the literature (Ben-Akiva et.al 1984, Ramming 2001). This yielded to 21 remaining routes to be analysed.

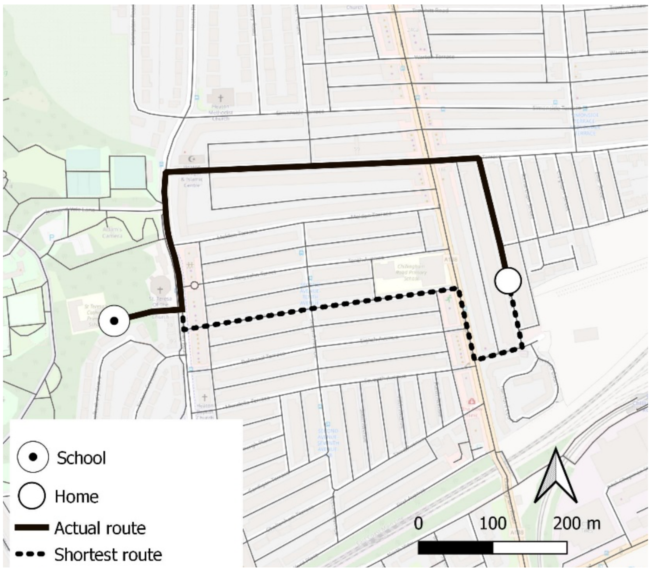

Figure 2: An actual versus metrically shortest route between home and school, as identified in QGIS using mapping activity results.

3.3 BE characteristics of the routes

For both the shortest and the actual routes, six categories of built environmental characteristics were determined for each segment along the routes through detailed field surveys and syntactic analyses: land use (i.e. number of ground-floor residential, commercial, etc. openings), placemaking features (i.e. setback distance, number of street trees, existence of benches), aesthetics (i.e. building and pavement maintenance), active travel infrastructure (i.e. width of footpath, width of cycling path), and traffic-environment (i.e. traffic crossings, zebra crossings) and street connectivity (i.e., syntactic measures of street network design) following earlier studies (Shatu et.al 2019, Dessing et.al 2016) (Table 1). Street network configuration of the entire city was evaluated by using angular segment connectivity, integration and normalised choice as well as metric and directional reach (Peponis et.al 2008) implemented in QGIS using the Place Syntax Tool (https://www.smog.chalmers.se/pst). The underlying motivation to include different syntactic measures is motivated by the variety of configurational qualities (metric, geometric and topological) captured by each measure. Integration calculates the distance from each segment to all the others within the system within a set radius. Normalised Angular Choice measures how often a segment falls on the shortest path between any two segments in the system by taking into account the depth of the segment in the system (Hillier et.al 2012). Metric Reach measures the total street length accessible from each street segment within a certain metric radius. Directional reach measures the total street length accessible from each street segment within a certain number of direction changes. Integration and Normalised Choice were calculated for radius n (global) and 3 (local) while metric reach and directional reach were computed for 800meters distance threshold since the actual routes within the study area were limited to a buffer of 800meters radii. Directional reach was computed for two direction changes subject to a 20° angle threshold. The 20° angle threshold was selected to set the threshold low enough to make the analysis sensitive to street sinuosity. Computing directional reach for two direction changes provides an estimate of how well a street segment is embedded in its surroundings from the point of view of directional distance. Similar to syntactic measures of integration and choice, these configurational measures are computed considering direction changes, but at the same time they are inherently parametric in that any specific angle of direction change can be set to identify a direction change. Hence, metric reach and directional reach can evaluate street connectivity robustly by discriminating between proximate street segments within an area.

Table 1: BE variables measured along the route.

Variable	Description[2]
Distance	total distance (in meters)
Land-uses	
Residential	the total number of doors normalised by 100 meters
Commercial	the total number of doors normalised by 100 meters
Vacant	the length of vacant buildings normalized by 100 meters (in meters)
Green Spaces	the total number of openings normalised by 100 meters
Placemaking	
Setback distance	the average setback distance between buildings and sidewalk (in meters)
Fence Height	the average fence height (in meters)
Benches[†]	presence of benches along the route (1 yes, 0 no)
Street Trees	the total number of street trees normalised by 100 meters
Active Travel	
Footpath width	the average footpath width (in meters)
Cycle path width	the average cycle path width (in meters)
On-street cycle path length	the total length of on-street cycle path normalised by 100meters (in meters)
Aesthetics	
Building maintenance	the average condition of the buildings (0 to 3, with 3 indicating excellent condition)
Pavement maintenance	the average condition of the footpath pavement (0 to 3, with 3 indicating excellent condition)
Traffic-environment	
Traffic crossings	the total number of traffic crossings normalised by 100 meters
Zebra crossings	the total number of zebra crossings 7normalized by100 meters
Street network design	
Integration (global)	continuous variable
Integration (local)	continuous variable
Normalised Angular Choice (NACH)	continuous variable
Metric Reach (800m)	continuous variable (in meters)
2-Directional Reach (20°, 2D)	continuous variable (in meters)

[†]The availability of benches along the street was measured through a dichotomous variable since there was not enough variation in the number of benches along the observed segments across the data set, with only a few segments having 2 benches at the most.

[2] All variables were calculated for each segment along the individual route.

3.4 Analysis

First, to indicate the factors potentially affecting route choice behaviour, the mean differences of each attribute were estimated and paired t-tests or Wilcoxon signed-rank tests (for characteristics that showed a normal and non-normal distribution respectively) were conducted (Stigell and Schantz 2011. This analysis identified whether the differences between each set of routes are statistically significant (Papinski and Scott 2011). Next, to avoid multicollinearity effect, a correlation analysis among the 21 explanatory factors was conducted and variables with stronger correlations (> 0.7) were not considered for further analysis. 7 variables excluded based on this analysis were: vacant building length and green space (both normalised by 100m), building maintenance, traffic crossings, local Integration, normalised choice, and Directional Reach (2-direction changes, 20°). Finally, the effects of different BE variables in route selection were estimated in an unadjusted and adjusted conditional logistic model separately for 21 individual routes and their shortest counterparts. The adjusted model was estimated using a step-wise exclusion of factors with statistical insignificance. Conditional logistic regression was used since the shortest and actual routes are not independent within a participant (Dessing et.al 2016). All statistical analyses were performed in SPSS version 26.

4 RESULTS

A total of 79 children (37 girls, 41 boys, 1 N/A aged 9-10) reported their actively commuted school routes between home and school. Descriptive data of study participants are shown in Table 2. From those, 72 walked to school and only 7 children cycled to school.

Table 2. General characteristics of participants.

	n	%
Gender		
Boy	37	46.83%
Girl	41	51.89%
N/A[1]	1	1.26%
School		
A	31	39.24%
B	11	13.92%
C	9	11.39%
D	22	27.84%
P[2]	13	16.45%
Means of travelling		
Walking	72	91.13%
Cycling	7	8.86%

1 No answer provided
2 Pilot study school

Out of the 79 participants that actively travelled to school, 56 walking routes and 4 cycling routes were reported, while 19 students did not report their routes. 63% of walking routes and 100% of cycling routes overlapped perfectly with their metrically shortest counterparts. The overall sample show that the mean trip distance was 954.69 meters and 1002.98 meters for the walking and cycling routes respectively. The distance children walked on average was found to be lower than the UK statutory walking distance of 2 miles (3.200 meters), up to which school children are expected to access school on foot (Department for Education 2014). The mean trip distance for the walking routes that diverged from their shortest route counterpart was 954.68 meters. However, children would have walked an average of 852.16 meters if they preferred to select the shortest one. This means that participants walked on average 102.52 meters (12.03%) extra distance.

4.1 Actual route versus metrically shortest route

The t-test/Wilcoxon signed-rank test results summarising the route attributes for 21 school routes (individual routes of students) that diverged from their shortest counterparts (i.e., those that did not overlap 100% with the shortest route) are shown in Table 3. Mean and standard deviation are summarised for both set of routes (actual and shortest) included in this study. The results also indicate the differences in the average values of these attributes between the actual and shortest routes. The paired t-test/Wilcoxon signed-rank test results identify whether the average values of each BE attribute are significantly different for each route type. A BE attribute with a relatively large difference and statistical significance (at the 95% and 90% confidence interval) indicates that it could be a partial reason for children preferring to take the actual route instead of its shortest counterpart.

As shown in Table 3, on average students walked about 955 meters, which is, as expected, longer than the shortest routes (average 852 meters). Table 3 shows that a significant difference exists between the actual and the metrically shortest routes for 8 attributes from each BE category, suggesting that these BE features might be partial underlying reasons for diverging from the shortest route and selecting a longer one. Hence, it can be suggested that children preferred to select alternative routes with certain BE characteristics, such as increased commercial land-uses and reduced setback-distance, rather than just minimizing the distance. As shown in Table 3, these students did not take the metrically shortest route probably because they preferred routes with maintained buildings and pavements, available benches, more zebra crossings, on-street cycle paths and commercial activities and increased integration but reduced setback-distance enroute. The independent effects of these features are analysed in a conditional logistic model in the following section.

Table 3. Comparison of BE attributes for each type of route based on paired sample t-test and Wilcoxon signed-rank test[c].

Route Attributes	**Actual Route (AR)**		**Shortest Route (SR)**		**Mean Difference (AR-SR)**
	mean	std.	mean	std.	sig.
Distance	954.69	506.44	852.16	449.48	.000[a]
Land-use					
Residential	7.331	3.888	5.662	4.166	.163[b]
Commercial	.606	1.132	.131	.207	.028[a]
Vacant (%)	1.288	.207	1.807	2.903	.161[a]
Green space	.233	.411	.366	.579	.313[b]
Placemaking					
Setback dist.	3.029	2.043	4.866	3.799	.015[b]
Fence height	1.204	.359	1.244	.487	.764 [b]
Benches (1,0)	.520	.512	.143	.359	.011[a]
Street trees	1.175	1.336	.820	.917	.213 [b]
Active Travel					
Footpath width	1.890	.571	2.095	.707	.333[b]
Cycle path width	.146	.204	.171	.388	.802[b]
On-street Cycle path length	2.129	5.715	.138	.632	.063[a]
Aesthetics					
Building maintenance (1,0)	2.19	.750	1.905	.539	.034[a]
Pavement maintenance (1,0)	1.90	.539	1.524	.512	.005[a]
Traffic-environment					
Traffic crossings	1.11	.61	1.18	.62	.180[b]
Zebra crossings	.190	.402	.048	.218	.000[b]
Street network design					
Integration (global)	.041	.086	.016	.001	.090[b]
Integration (local)	1.293	1.967	.895	.167	.372 [b]
Normalised Choice	1.413	2.118	.969	.128	.355[b]
Metric Reach (800m)	2666.975	4778.672	1658.208	321.387	.338[b]
2-Directional Reach (20°,2D)	29594.555	44644.912	25857.042	20074.985	.725[b]

[c] Excluding routes that perfectly overlapped with their shortest counterparts, which resulted in 21 sample sizes.
[a] Wilcoxon signed-rank test
[b] Paired t-test

4.2 BE attributes associated with route choice behaviour

Results of the conditional logistic regression analyses, both unadjusted and adjusted, of children's routes are shown in Table 4. The maximally adjusted model was found to be statistically significant with moderate explanatory power (R^2=0.60). The findings highlight that these children chose not to take the shortest route due to a possible trade-off between some BE features along the routes. The unadjusted model highlights that these factors mainly include the setback distance, the availability of benches, the connectivity of street network, and to some extent footpath width along the routes. According to the adjusted model, the odds of selecting a route is higher if it is attributed with reduced setback distance, highly connected street that offers increased metric accessibility (significant at the 0.1 level) and walking supportive facilities such as benches. Footpath width appeared to be statistically insignificant in the adjusted model.

Table 4. Conditional logistic regression model for selected routes.

Explanatory attributes	Outcome variable: actual routes (reported routes) compared to the metrically shortest routes			
	Unadjusted model		Adjusted model	
	Exp (B)	95 % CI	Exp (B)	95 % CI
distance	.998	.995-1.001	–	–
residential	1.073	.696-1.654	–	–
commercial	.816	.055-12.167	–	–
setback distance	.344[a]	.132-.901	.655[a]	.458-.939
benches (1,0)	19.495[a]	1.831-509.210	8.335[a]	1.375-50.545
street trees	.564	.187-1.699	–	–
fence height	8.933	.249-319.829	–	–
footpath width	4.754[b]	.553-40.844	–	–
cycle path width	1946.251	.608-6228295.68	–	–
on-street cycle path length	.626	.278-1.409	–	–
pavement maintenance	.127	.005-3.019	–	–
zebra crossings	.011	0.000-9.347	–	–
metric Reach (800m)	1.332[a]	.987-1.568	1.458[b]	.857-1.458
integration (global)	.005	.001-.087	–	–

OR odds ratio; *CI* confidence interval

– Not included in the adjusted model due to statistical insignificance in the unadjusted model.

[a] Significant at the 0.05 level.

[b] Significant at the 0.1 level.

4.3 Street-level observations along the routes

Apart from the statistical analysis of the differences of environmental attributes between children's actual routes (those modelled in section 4.1, n=21) and their shortest counterparts, in-depth visual observations were also conducted along the selected and avoided routes to better understand the individual behaviours during the school journey. The aim was to provide insight into the urban character of these route-pairs and visualise key differences in the quality of the urban environment at the street-level between the two alternatives that may depict possible underlying reasons of route selection. Snapshots along the selected (green) and the shortest (orange) routes are presented visually to highlight the key differences in the street-level environmental characteristics between the two options, in the four different neighbourhood areas of the study.

Figure 3 comparatively visualises snapshots along a student's selected route and its shortest counterpart in School A-area. These snapshots indicate that the student diverged from the shortest route to avoid the West Road (Figure 3b), a main road with busy car traffic and commercial land-uses and preferred to walk along a quiet alley (Figure 3a). Although the preferred alley might seem to be more prone to stranger-danger (i.e., raised walls severing the connection between homes and street, thus resulting in the dearth of eyes on the street), this could be attributable to the fact that this student was accompanied with their parent along the school journey, resulting in personal safety concerns (i.e., crime) being outweighed by traffic concerns (i.e., parental perception of traffic). Similarly, it was also observed that diverging from the shortest route, the child/parent were able to use the existing traffic lights to cross the main road (West Road) (Figure 3o). Although the metrically shortest route includes a car-filter located along a local street intersecting the West Road (Figure 3 ▭) to calm traffic, the absence of any traffic control features, such as traffic lights, for crossing the busy road acted as a strong deterrent to AST. This highlights that besides parental concerns of traffic safety, safety-related barriers resulting in challenges crossing busy roads were an important underlying factor of route choice. Hence, it can be argued that designing traffic control systems along busy roads might be a more effective intervention than planning car-filters along local streets in encouraging AST.

Figure 3: Selected route with walked segments, shown in green, and its metrically shortest counterpart, shown in orange, in School A-area.

In school B-area located in Kenton (Figure 4), further observations from children's selected and metrically shortest route options indicated further street-level design characteristics that may promote AST. Similar to School A, participants diverged from the shortest route to avoid walking along major roads with heavy traffic, preferring to travel along the local ones with residential land-uses. Interestingly, observations from the statistically modelled routes in this area pointed to a common preference of streets with large set-back distances, linked to front gardens, green verges and street trees, which contradicted with the findings of the previous statistical models. This highlights the need for in-depth area-based observations of individual behaviours in future studies instead of relying merely on city-based statistical analyses. Although greenery along the street appeared to be a preferable environmental attribute in route choice for children in Kenton, as demonstrated in Figure 4, children avoided green shortcuts (i.e., green streets/paths without any motorised traffic, (Figure 4d and f) at the expense of selecting a residential street with low-to-medium traffic volume. This could be due to children's and/or parents' safety concerns linked to anti-social behaviours (i.e., fear of strangers and/or crime) in such quiet, relatively isolated public spaces. In addition, observations along the travelled and avoided routes in this area highlighted active travel infrastructure as a mediating factor in route choice behaviour, pointing to traffic-related concerns (i.e., speeding cars) as important barriers to AST as personal safety concerns. For example, Figure 4h shows that students avoided residential streets with green spaces but without any available footpath. This is in line with the results of statistical analysis reported in Table 4.

Figure 4: Selected routes with walked segments, shown in green, and their metrically shortest counterparts, shown in orange, in School B-area.

Similarly, observations from the statistically modelled routes in School C-area (Figure 5) depicted a tendency to avoid green shortcuts related to anti-social behaviour. Interestingly, in-depth observations revealed that several students deviated from the shortest route, choosing to walk along a residential street with improved pedestrian-friendly infrastructure, including kerb build-outs and dedicated cycling paths narrowing the width of carriageway, as well as larger set-back distances, including front gardens, green verges and street trees (Figure 5a and b). Similarly, children deviating from the shortest route avoided specific streets with narrow footpaths and/or existing pavement car parking (Figure 5f). In addition, similar to observations in School A-area, streets with car-filters (Figure 5 ▭) were unfavourable by children and/or parents due to lack of safe crossing opportunities, such as zebra crossings or traffic lights. These observations point to the fact that concerns of neighbourhood safety -both traffic-related safety (i.e., high speed traffic) and personal safety (i.e., fear of strangers)- can act as barriers challenging AST. For example, Figure 5d shows that children avoided main roads with vacant buildings, choosing to walk along a local street with higher number of residential openings. On the contrary, children tended to avoid residential streets that were perceived to be unsafe due to fewer openings, and hence fewer eyes on the street (Figure 5f), preferring to walk along a main street with more car-traffic (Figure 5e).

Figure 5: Selected routes with walked segments, shown in green, and their metrically shortest counterparts, shown in orange, in School C-area.

Lastly, snapshots from the actual routes and the shortest options in School D- and Pilot school-areas (Figure 6) display similar patterns of preference. Children diverged from the shortest route to avoid major streets (Figure 6b) or streets with higher number of commercial activities and increased car traffic (Figure 6d), despite the presence of greenery, choosing to walk along residential streets (Figure 6a, e and i). Similar to individual route choice behaviours observed in School C-area, children in this neighbourhood and their parents preferred streets with green features (e.g., street trees, planters) and residential uses opening onto the street (Figure 6 g and i) as well as streets with improved pedestrian-infrastructure, including dedicated cycling lanes and kerb build-outs preventing cars parking on footpaths (Figure 6 c, g and i). On the contrary, alleys with high walls (and hence no available openings) and discontinuous and/or relatively narrow footpaths blocked with litter/litter bins were not preferred during the school journeys. Interestingly, participants shaped their route, diverging from the shortest one, to ease crossing the street using available traffic lights (Figure 6o1-3). In contrary to the individual behaviours observed in School A- and C-areas, children in this neighbourhood preferred to follow streets with available car-filters since these features were designed as extensions of the existing footpaths, not requiring additional street crossings (Figure 6 ▭1-3).

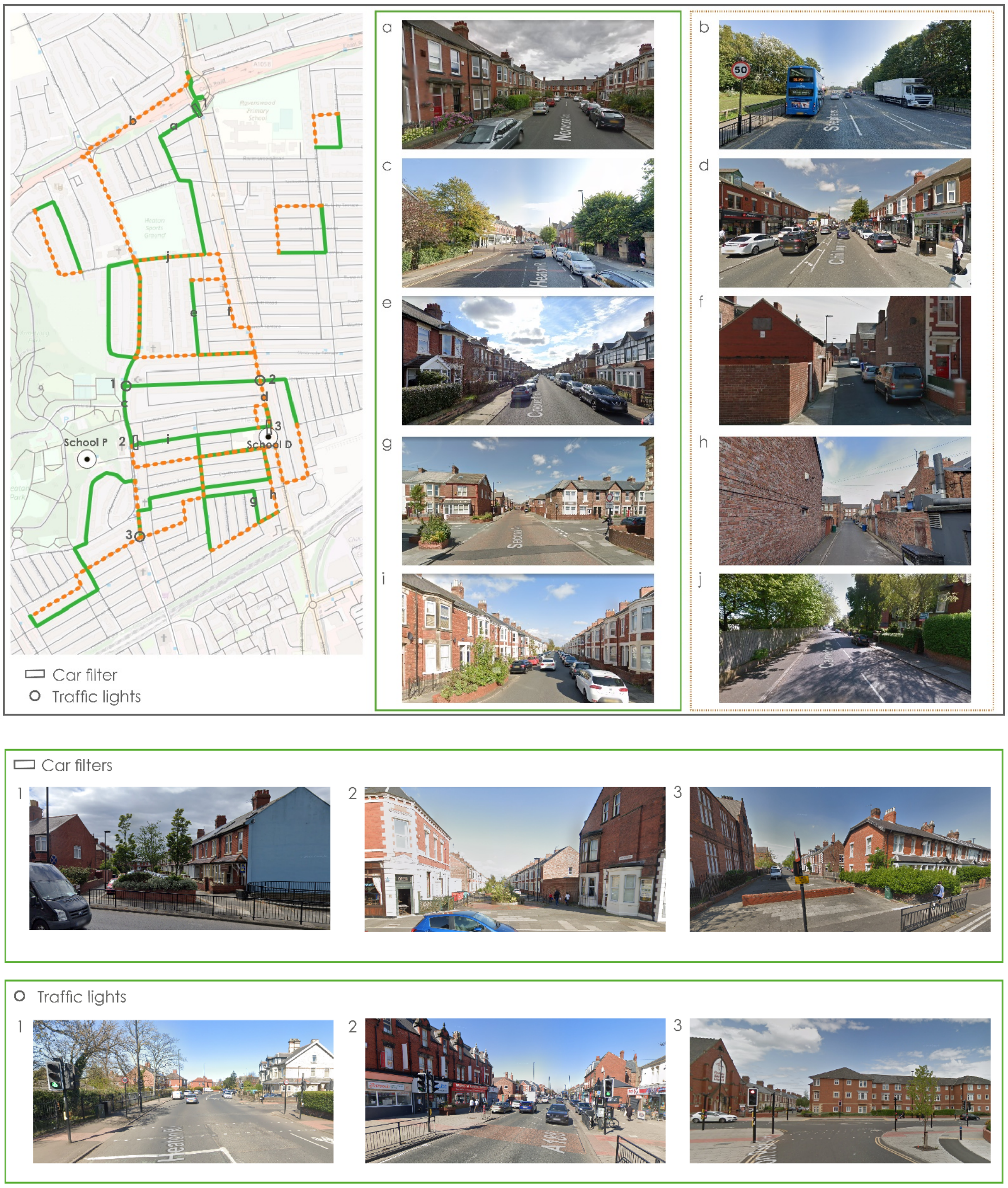

Figure 6: Selected routes with walked segments, shown in green, and their metrically shortest counterparts, shown in orange, in School D- and Pilot School-areas.

5 CONCLUSIONS

Using data from 5 different primary schools in physically and socially heterogenous neighbourhoods in Newcastle upon Tyne, UK, this cross-sectional study compared the street-level BE characteristics along the actual walking routes of school children to those of along their metrically shortest counterparts. Built environment for street segments along actual routes and metrically shortest ones was measured through detailed field observations and secondary data. Conditional logistic regression estimates were developed to statistically identify street-level built environmental factors underlying the differences in route selection. Investigating the statistical differences as well as in-depth observations between the pairs provided insight into the underlying reasons of children's navigation choice during active school journeys between home and school.

The average distance walked by children who actively commuted to school (55% of the entire sample) was 955 meters. This is considerably lower than the UK statutory walking distance of 2 miles (3.200 meters) (Department for Education 2014) and is in line with a study of Panter et.al (2010) who found that those children whose distance to school is less than 1km long are more likely to walk to school. The actual routes were 12% longer than their metrically shortest counterparts. This finding is a key indicator for promoting the planning and locating schools within walking distance to homes. However, the findings as presented in this research showed that distance was not a significant variable in route selection among these children during their school journeys. Rather our conditional logistic model estimates using data from children who did not choose the shortest route identified a range of street-level BE attributes as the potential determinants of route choice behaviour.

The findings show that on their journey to school, children preferred to walk along routes with increased metric accessibility, as measured by Metric Reach. Our results indicate that increased metric accessibility, potentiality of accessing multiple destinations from a street segment, is a significant correlate of route choice among children. This result resonates with the findings of Argin et.al (2017) who found metric accessibility to be significantly associated with route selection in Istanbul, Turkey (Argin et.al 2017). Similarly, Dessing et.al (2016) in the Netherlands and Ikeda et.al (2018) in New Zealand reported that actual routes had a higher average connectivity than the shortest routes. From a theoretical point of view, this finding highlights the necessity of measuring street connectivity through multiple syntactic measures to identify which specific characteristics of the street networks may promote active school travel. According to our results, if a route provides access to relatively more destinations/street segments within its surrounding context, students are more likely to take that path, rather than following the metrically shortest route (Exp(B)=1.458, 95% CI=0.857-1.458). From a design policy point of view, designing better connected street networks (i.e., denser connections, shorter blocks, more linear street segments, increased density of streets) between home and school can help create neighbourhoods that are considered attractive by children, encouraging for active transportation, and in the long-term creating a more liveable city (Koh and Yong 2013).

The final models indicate that setback distance, availability of benches, and the average footpath width along a route are significant predictors of route choice in addition to metric accessibility of the route. During their walking trips, children were less likely to cover routes with increased setback distance (Exp (B)= 0.655, 95% CI=0.458-0.939). This finding elaborates the importance of the proximity of the buildings on the footpath. Similarly, previous research highlighted the distance between the surrounding buildings and the footpath as an important factor for selecting a route (Shatu et.al 2019). Studies in relevant literature suggest that 'eyes on street' have a positive effect on children's active mobilities (McMillan 2007). Therefore, the reduced setback distance, between building and the footpath, along a route may encourage community surveillance that increases the perceived safety of streets, and in return enables more active trips. Moreover, on their route to school children mainly walked along routes with benches (Exp (B)=8.335, 95% CI=1.375-50.545). This is in line with previous findings (Shatu et.al 2019) and confirms the fact that designing streets as an attractive part of the public realm for people to stop and spend time could support more people and especially children to select an active mode of travel for their school trips. In addition, a positive effect of the increased average footpath width on route choice behaviour was shown in the unadjusted model, as identified in various contexts such as in Turkey (Argin et.al 2017) and in Australia (Shatu et.al 2019). Overall, these findings highlight the importance of street network design and placemaking for active transportation to school, beyond the significance attributed to distance.

Furthermore, some studies have shown that land-uses that engage children to stopover (e.g., commercial and retail activities) may be an indicator for route selection (Shatu et.al 2019). Although our Wilcoxon signed-rank test results highlighted that actual walking routes had a greater number of ground-floor commercial activities than the shortest routes between home and school, the adjusted models did not identify land-use as a significant predictor of route choice. This could be due to the mediating effects of other variables, such as setback distance. Similarly, although our paired sample t-tests and Wilcoxon signed-rank tests indicated a significant difference in the traffic environment (i.e., zebra crossings) and active travel infrastructure (i.e., cycle path length) along the actual routes, compared to the shortest ones, these did not appear as significant variables in the final models.

Investigating individual route choices during the journey to/from school that diverged from the metrically shortest routes indicated a few underlying street-level design features shaping route selection during AST in all four different neighbourhood areas, confirming and emphasizing the findings of the statistical analyses reported in 4.1 and 4.2. The observations along these routes highlighted that many children preferred or avoided streets with similar urban character attributable to land-use, placemaking, active travel and traffic environment. Observed routes indicated a possible trade-off between some BE features along the routes, resulting in a certain hierarchy of street selection: children usually avoided major roads with a higher number of commercial activities and increased car traffic and preferred to walk along local and residential streets with wider footpaths, front gardens, and green verges. However, a car traffic busy or commercial street would still be selected at the expense of alleys with high walls, streets with vacant buildings, or green short-cuts without motorised traffic, pointing to safety-related concerns (e.g., to avoid anti-social behaviour, stranger-danger, or litter).

Although footpaths through green spaces without motorised traffic were generally avoided, children preferred to walk along green streets -those next to green spaces or with street trees, planters, or a green verge between the footpath and the street, as long as they included continuous footpaths. In general, the quality of footpaths (i.e., continuity and width) appeared to be a dominant factor in children's route selection. Streets with wider footpaths were selected as opposed to streets/alleys with discontinuous and/or relatively narrow footpaths, even though this required walking for longer distances. Besides footpaths, other active travel features, such as dedicated cycling paths and kerb build-outs, were also observed to be important in children's route selection, even though they were not statistically significant in the previous models. Hence, future research should complement quantitative analyses with in-depth qualitative observations to achieve a comprehensive understanding of children's route choice behaviour. Street-level features related to traffic-environment, such as the availability of traffic lights, also emerged as facilitators of route choice during school journeys, easing the crossing of busy intersections and main arteries. Streets with car filters were only selected where the car filter was located at the beginning of the segment and acted as an extension of the footpath and not in cases where the car-filter acted merely as a traffic-calming measure, without any safe street-crossing opportunity. Hence, it can be argued that improvements to traffic control systems, in particular along busy arteries, might be more promising than designing car-filters to encourage active travel to/from school. Overall, in-depth street-level observations along the modelled routes highlighted pedestrian-friendly infrastructure, such as footpaths, traffic lights, and green streets, as enablers of AST.

5.1 Strengths and Limitations

This study contributes to the literature by broadening our understanding of built environmental characteristics of active transportation to school. It addresses some of the limitations of past studies by comparing actual routes with their metrically shortest counterparts using fine-grained built environment data at the segment-level, which are more sensitive to the actual exposure of children to the environmental, compared to larger units (e.g., buffers) that are commonly applied to represent environmental exposure during AST. Such a methodology may ignore important segments of children's journey (Timperio et.al 2018) and may overlook the actual environmental attributes that children are exposed to in their journey to school (Harrison et.al 2014). Thus, future research needs to conduct detailed on-site field observations along children's actual routes and apply various street connectivity measures at the street segment level, instead of using aggregate built environment data. Employing such a method would reveal the actual street design characteristics that may enable or discourage AST, in contrast with previous studies relying on GIS-estimated routes.

A limitation of the study was its limited sample size, especially after excluding the children who took the shortest route. More advanced data collection techniques, such as tracking participants via GPS devices or unobtrusive following, could yield to a larger sample size with relatively less effort and increased precision (Shatu et.al 2019). Another useful technique would be to conduct participant surveys after or during the trips to acquire both social information (e.g., whether the child is walking independently or accompanied) and information regarding their route choice (e.g., perceived barriers). Such a survey has been conducted in Schlossberg et.al's study (2007). Integrating the quantitative approach as employed here with such qualitative techniques might help shed more insight into route choice behaviour of children, which would in return inform urban planners, designers and health professionals in their behaviour change interventions targeting active living promotion, especially for children. Moreover, the models developed were in line with the linear assumptions widely adopted in previous studies investigating route choice behaviour (Dessing et.al 2016, Liu et.al 2020). However, these linear models can lack in capturing the complex relationship between the built environment and travel behaviours fully (Tao et.al 2020, Ding et.al 2018). Thus, further research should investigate the nonlinear effects of the BE features on route choice (e.g., through intervention studies that utilize multilevel design methodologies) to provide detailed insight into how certain built environmental characteristics influence children's route selection behaviour. These methodological limitations may have affected the study results, underestimating the relative importance of certain characteristics along the selected routes as well as the predictive power of the model.

In addition, this study was conducted in a UK inner-city setting, where topography is relatively flat, and little variation exists between street segments in terms of some BE features. Hence, further research is needed to test the generalisability of these results in different geographical locations. For example, children travelling in more suburban or rural neighbourhoods may be exposed to diverse street settings, which might influence their route choice behaviour. Conducting further research in diverse case study settings both within the UK and internationally could provide evidence on which design features are more preferred in different cultural contexts, which would help promote active travel among children.

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