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Impact of changing road infrastructure on children's active travel: A multi-methods study from Auckland, New Zealand

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A R T I C L E I N F O

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A B S T R A C T

Introduction: Built environment infrastructure that supports active travel may help increase rates of children's active travel to school. Knowledge gaps exist in terms of how small-to-medium scale, school-focused infrastructural changes might impact children's active school travel and associated variables along the pathway to behaviour change. The aim was to work with a regional transport agency to evaluate the impact of infrastructural changes in a school neighbourhood.
Methods: Children in school years 5–8 and their parents/caregivers from two schools involved in a school travel intervention were invited to participate. The study area was identified in partnership with Auckland Transport (responsible for delivering all intervention elements). Children completed a geographic informations systems survey that captured behaviours and neighbourhood perceptions. Parents completed a telephone interview to measure neighbourhood perceptions and reasons for school travel mode. Tube counters and video cameras were used to measure traffic speeds and volume, and counts of pedestrians and cyclists, respectively. Baseline measures were taken in 2015 (traffic data) and from May-July 2016 (all other measures), infrastructural works were delivered from November 2016 to May 2017, and follow-up measures were repeated in May-June 2018.
Results: At baseline, 123 children and 88 parents participated. At follow-up, 152 children and 91 parents participated. Reductions in traffic speeds but increases in traffic volumes were observed post the intervention. Positive and negative shifts in child and parent neighbourhood perspectives were observed. Distance to school, convenience, and traffic saftey concerns were raised as key factors of importance by parents and children. Overall, rates of car use for the school trip increased, while video observation showed an increase in pedestrians.

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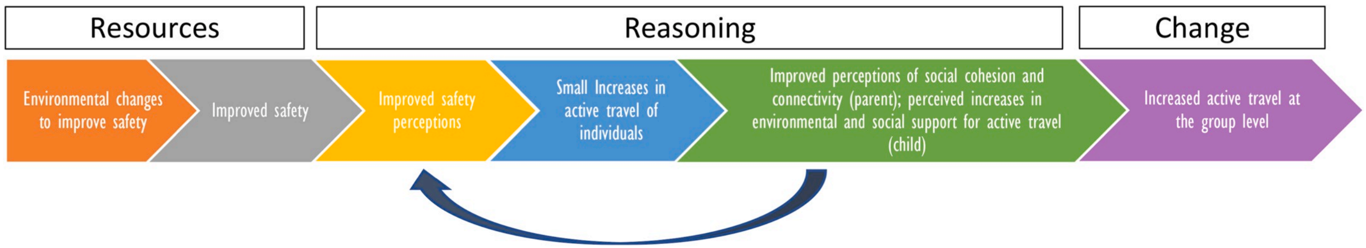

Fig. 1. Hypothesised pathway for infrastructural changes to increase children's active school travel.
Notes: Environmental changes to improve safety comprise the intervention elements; Improved safety includes slower speeds and reduced traffic volume; Improved safety perceptions includes child and parent perceptions about their neighbourhood and safety from traffic; Active travel is measured through child self report of usual mode of transport to school; Perceptions of social cohesion and connectivity capture sense of connections with others in the neighbourhood, contributing to a sense of safety; Child perceptions of a supportive built and social environment are likely to be associated with increased neighbourhood safety perceptions.

Conclusions: Reversing declines in active travel may require more intensive, community-wide interventions that substantially improve neighbourhood safety and perceptions of safety. Longer term follow-up may be necessary to understand the true effect of the intervention.

1. Background

Enabling children to get to school actively (e.g., walking, scootering, cycling, wheeling) is important for promoting child (Faulkner et al., 2009; Larouche et al., 2014) and environmental (World Health Organization, 2018) health. A limited evidence base provides causal links between built environment infrastructure that supports active travel modes and children's active travel to school (Smith et al., 2017). Evidence suggests multiple infrastructural components (e.g., installation of, or improvement to existing, pedestrian crossings, sidewalks/footpaths, traffic calming features, etc.) are required for meaningful differences in active school travel to occur.

Examples of large scale and comprehensive infrastructural interventions to support children's active school travel (Mackie et al., 2018; McDonald et al., 2013) and active travel in general (Aldred et al., 2019; Goodman et al., 2014) exist in industrialised nations internationally. However, smaller scale, school-specific interventions tend to be more common-place, oftentimes led by local urban planning and transport agencies in partnership with schools. Yet, such interventions are infrequently evaluated (or are not comprehensively evaluated), resulting in a lack of knowledge regarding the efficacy of these investments. For researchers, collaborating with practitioners to evaluate natural experiments overcomes financial and pragmatic feasibility barriers of natural experiment design and implementation. Optimally, a symbiotic relationship may be achieved with researchers providing agencies with in-depth measurement of changes and related outcomes not otherwise captured.

It is likely that at the group level, behaviour change does not occur immediately, and instead takes time (Goodman et al., 2014). Behaviour change theories and school travel models posit a range of pathways from infrastructural changes to behaviour change, recognising the role of self-efficacy (Marcus et al., 1992), theory of planned behaviour (Murtagh et al., 2012), and child and parent perceptions about neighbourhood safety and social connectivity (Ikeda et al., 2019). In addition, a self-reinforcing scenario may exist, whereby an increase in culture/visibility of community active travel may interact with school programmes and infrastructural environments to support ongoing increases in active school travel (Hawley et al., 2019).

New Zealand has relatively low levels of active school travel (Aubert et al., 2018) accompanied by high and increasing rates of vehicle travel (New Zealand Transport Agency, 2019). Car ownership has also been rising to the point that the country has one of the highest car ownership rates in the world (Environmental Health Indicators New Zealand, 2017; New Zealand Transport Agency, 2019). Infrastructural initiatives to support active travel modes and shifts away from private motor vehicle use are increasing across the country including in Auckland (Auckland Transport, 2018), the country's largest city, home to one-third of the nation's population (Statistics New Zealand, 2013). Auckland Transport is responsible for managing and running Auckland's transport network, including maintenance and development of transport infrastructure and related operations (Auckland Transport, 2019). Auckland Transport's 'Safer Communities programme 2015–2018' involved engineering treatments coupled with road safety education and promotion initiatives. The objective was to improve road safety, increase active travel to school and other community destinations, and increase public transport patronage. These objectives were underpinned by strategic goals of reducing road traffic trauma and morning congestion (Abley Transport Consultants, 2015).

Knowledge gaps exist in terms of how such small-to-medium scale, school-focused infrastructural changes might impact children's active school travel and variables along the pathway to behaviour change in New Zealand. The aim of our study was to work with Auckland Transport to evaluate a Safer Communities intervention (described below), taking a comprehensive approach to understanding the potential changes in active school travel and associated variables that may occur as a consequence of small-scale, school-centred street infrastructural interventions to improve pedestrian safety. This project is novel in a number of ways, in particular the collaboration with a regional transport agency in undertaking the research, the comprehensive suite of measures employed to understand change, and the triangulation of objective measures and child and parent perspectives using mixed methods.

2. Methods

2.1. Context and protocol

This is a quasi-experimental study to assess changes in children's active school travel after neighbourhood street infrastructural changes for improved safety. A neighbourhood in Auckland, New Zealand was chosen in partnership with Auckland Transport. Considerations were the timing of scheduled Safer Communities programme implementation aligning with the research timeline and the opportunity to line up with existing research being conducted in the area (Oliver et al., 2016).

A proposed behaviour change scenario informing in the current study is outlined in Fig. 1. Drawing from Panter et al. (2019), we conceptualise and discuss the mechanisms by which change occurs in terms of the resources (i.e., intervention components), and the reasoning (i.e., the process of human behaviour change).

2.2. Intervention design and delivery

The intervention was part of the Safer Communities Programme 2015–2018. Building on learning from previous programmes, including projects with members of the current research team (Mackie et al., 2018), the aim of this broader programme was to identify priority communities in which to focus on improving safety and accessibility across the local community, with schools as a focal point. The intervention was also designed to work in parallel with existing road safety education and active school travel encouragement initiatives. A predictive approach, based on assessing road safety risk and typical walking times, was used to identify the geographical areas in the region in which there was greatest potential to improve both road safety and the amount of active travel (Abley Transport Consultants, 2015). The intervention evaluated in this study was one of the geographical areas identified.

The intervention consisted of three stages: investigation, detailed design and formal community consultation, and construction. Specific infrastructure treatments were identified based on investigations by engineers, in conjunction with school and community feedback. Treatments had to fall below a cost threshold, with larger projects falling outside the budget scope of the programme. The physical infrastructure elements, described in Table 1 and Fig. 2, had a total cost of approximately NZ$700,000 (design to construction). These treatments were in addition to some existing road safety infrastructure in the area, for example a signalised crossing on a high volume road and electronic warning signs to alert drivers to the presence of a school.

To some extent, all schools in the intervention area were involved in road safety and active travel initiatives both prior to and during the intervention, with varying areas of focus and levels of activity. Examples of promotional activities that occurred between 2016 and 2018 are: road safety messages in school newsletters, promotions to park further from the school and walk the remaining distance, promotions to encourage parents to drive slowly and park safely if near school entrances, and student leadership groups. Some schools also patrolled school crossings and provided bike and scooter parking. All infrastructural elements delivered are outlined in Table 1, and visuals are provided in Fig. 2.

2.3. Research protocol

Measures were drawn from the hypothesised pathway for behaviour change (Fig. 1). Measures of traffic speed, traffic volume, and road user behaviour were undertaken at key points throughout the neighbourhood as detailed below. Baseline data from children and their parents/caregivers were drawn from two schools (one intermediate school (junior high) and a contributing primary school (elementary school)) participating in the Neighbourhoods for Active Kids study (conducted in 2015/16), of which the methods have been reported previously (Oliver et al., 2016). These two schools were invited to participate again in 2018, following infrastructural intervention in the study neighbourhood. At each data collection wave, the research team visited schools during school time to undertake participatory mapping of neighbourhood perceptions and use including mapping of school routes with students in school years 5–8 (approximate ages 8–13 years). Parents completed a computer-aided telephone interview (CATI) in their choice of English, Samoan, Tongan, Chinese, or Korean language. The interview measured parent/caregiver neighbourhood perceptions and socio-demographic characteristics of their child, themselves, and their household. Measures specific to the current study are detailed below. All child surveys and physical measures were undertaken prior to the intervention (May 2016) and replicated post intervention delivery (May-June 2018). Parent CATI interviews were conducted between May and August 2016 at baseline, and June to August 2018 at followup.

Video cameras collected data on road user behaviour from 16 June to 5 July in 2016, and from 7 June to 14 June in 2018. Traffic volume and speed data were collected pre-intervention in 2015 (March 2015 at one site, and November 2015 at the remaining sites) and repeated in June 2018 post intervention delivery.

Ethical approval was provided by the host institution ethics committees (AUTEC, 14/263, September 3, 2014; MUHECN September 3, 2014; UAHPEC September 9, 2014).

2.4. Measures

2.4.1. Child and household socio-demographic characteristics and child's usual travel mode to school

Parents reported their child's biological sex (male, female), current employment status, and car availability: "How many working cars are available to your household?". Household-level socio-economic status was assessed using an item from the New Zealand Index

Table 1
Infrastructural elements and timing of delivery by site, in order of proximity to schools.

Site	Project	Treatment delivered	Date completed
1	a	Relocation of crossing 20 m to the east to improve visibility of pedestrians by oncoming and turning motorists	November 2016
1	b	Pram crossings and tactile paving added	November 2016
1	c	Formalised bus stop through painting road markings to demarcate bus stop area	December 2016
2	a	Pedestrian refuge island installed including pram crossings and tactile paving	January 2017
3	a	Pedestrian refuge added to existing median barrier, path upgrade, and removal of corner barrier to improve safe and convenient crossing. Addition of speed table in the slip lane to slow traffic turning left	May 2017
3	b	Pedestrian refuge island, pram crossings, and tactile paving added	May 2017
4	a	Roundabout installation with pedestrian refuges on each approach, pram crossings and tactile paving	February 2017
5	a	Installation of four speed humps, with cycle cut-throughs	January 2017

Fig. 2. Examples of infrastructural interventions implemented in the study area.

of Socioeconomic Deprivation using the following item: "In the LAST 12 MONTHS, have you personally been forced to buy cheaper food so that you could pay for other things you needed?" (Salmond et al., 2006). School type was used as an indicator of age and stage, and classified as primary (school years 5–6) or intermediate (years 7–8).

2.4.1.1. Child's usual mode of travel to school. Children were asked "How do you usually get to school?", with response options being: walk; bike; scooter (non-motorised); public bus, train, or ferry; car, motorbike/scooter, or taxi; or another way.

2.4.2. Parent measures

2.4.2.1. Parent-reported reasons for school travel mode. Parents were asked "What are the main reasons your child gets to school by (usual travel mode to school)?" Response options were developed from previous research (Oliver et al., 2011b) and included: distance from home to school, safety (from traffic), safety (from others), ease/convenience, children's health/fitness, encouraging their child's independence, needing someone to go with them, concerns about bullying, being able to spend time together, the child spending time with friends, the amount they have to carry to school, or 'other'. Parents could select any number of reasons that applied to their child's usual school travel mode.

2.4.2.2. Parent neighbourhood environment perceptions for active travel. Parent perceptions about what they thought would make their neighbourhood better for their child's independent mobility were gathered through one open-ended item: "What would make your neighbourhood a better place for (Child Name) to walk, bike or scooter by (Himself/Herself)?" Responses were coded using a previously used framework (Smith et al., 2019a) into eight topics: less, slower, and safer traffic; more and safer crossings; safer and designated cycle lanes; more and better walking paths; safety from others; more and better destinations; better social environment; 'other'.

2.4.2.3. Parent perceptions of neighbourhood safety and social connectivity. Measures of parent neighbourhood perceptions replicated those used in Lin et al. (2017) as detailed below. In all instances a five-point Likert response scale was used, with responses ranging from 1 (strongly disagree) to 5 (strongly agree). Scores were averaged for each respondent, with higher scores indicating more positive perceptions of neighbourhood safety, cohesion, or connectedness. A higher score denoted more positive neighbourhood social environment perceptions.

Safety. Parents responded to the following eight statements: "There are safe places for children to play in our neighbourhood", "It's a good place to bring up children", "I feel safe walking down my street after dark", "I worry about the number of crimes committed in our neighbourhood" (reverse coded), "Graffiti and vandalism are problems" (reverse coded), "Roaming dogs are a problem in our neighbourhood" (reverse coded), "It's a good place to buy a home", "Bullying is a problem in our neighbourhood" (reverse coded).

Social cohesion. Parents responded to the following seven items: "People are willing to help", "Neighbours watch out for kids", "It's a close knit neighbourhood", "I could borrow $10 from a neighbour". "If there is a problem with neighbours we can deal with it", "The neighbours cannot be trusted" (reverse), and "People will take advantage of you" (reverse).

Social connection. Parents responded to the following five statements: "Parents in this neighbourhood know their children's friends", "Adults in this neighbourhood know who the local children are", "There are adults in this neighbourhood that the children can look up to", "Parents in this neighbourhood generally know each other", "You can count on adults in this neighbourhood to watch out that children are safe and don't get in trouble".

2.4.3. Child measures

2.4.3.1. Children's likes and dislikes about their route to school. Participants were asked to map their usual route to school and then asked open ended questions about their likes, dislikes, and perceptions about their route to school.

2.4.3.2. Children's perceived road and neighbourhood safety. Perceived road safety was measured using the statement "The roads around my school are busy with traffic before and after school." A 5-point Likert scale was used: All of the time, most of the time, sometimes, hardly ever, never (Mullan, 2003).

Perceived neighbourhood safety was assessed using two statements: "If I am out with an adult, I feel safe in my neighbourhood" and "If I go out without an adult, I feel safe in my neighbourhood." A 5-point Likert scale was used ranging from all of the time to never (Mullan, 2003).

2.4.3.3. Child perceived social and environmental support for active school travel. Children were provided a statement "I live in a place which allows me to walk/bike/scooter to school every day if I wanted to" with five response options: Strongly disagree, disagree, not

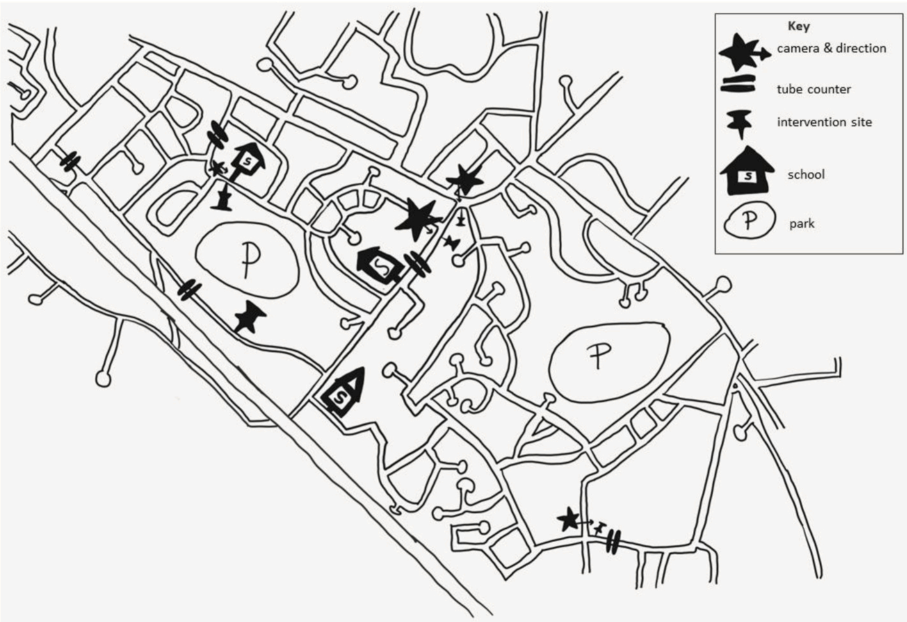

Fig. 3. Location of intervention components, camera sites, and tube counters.

sure, agree, strongly agree (Murtagh et al., 2012).

2.4.4. Objective measures of the traffic environment

2.4.4.1. Traffic speeds and volumes. Routine tube count data collected by the transport agency were utilised for traffic speed and count data. Data were collected over seven full days at five locations (Fig. 3). Data for the duration of 08:00–09:15 and 14:45–16:00 on weekdays only were extracted to represent the school morning and afternoon peak periods. The following variables were calculated for each direction separately, and both directions together: speed mean and standard deviation, 85th percentile speeds, and vehicle volumes.

2.4.4.2. Pedestrian and cyclist counts. Inconspicuous video cameras were set at four sites, proximal to key infrastructure changes, over 2 week days and one Saturday at baseline and follow-up (Fig. 3). In the interest of feasibility and specificity, data were analysed for weekdays only in the school morning and afternoon peak periods (i.e., 08:00–09:15 and 14:45–16:00). Data were coded for number of pedestrians and number of cyclists observed in a specific field of view using protocols established in previous projects (Mackie et al., 2012; Macmillan et al., 2018). Reported counts reflect the combined number of adults and children – the protocol was unable to distinguish between adults and children within an accepted level of reliability. Inter-rater agreement was established prior to coding using 1 h and 15 min of footage across three sites in the highest volume afternoon peak period. The percentage agreement between two raters was 95.74% for pedestrians and 100% for cyclists. All data were subsequently coded by one coder.

2.5. Data analysis

Differences between baseline and follow-up for travel mode and child perceptions of their neighbourhood were assessed using the chi-square statistic. Remaining data were analysed descriptively and percentage changes from pre-intervention to post-intervention were calculated. For traffic speeds, standardised mean differences were calculated and Cohen's criteria for interpreting the

Table 2
Sex of child participants, usual travel mode to school, and child perceptions pre-intervention and post-intervention.

Variable	Pre-intervention						Post-intervention						Overall change from pre to post (%)
	Contributing Primary (n = 47 children, 33 parents)		Intermediate (n = 76 children, 55 parents)		Total (n = 123 children, 88 parents)		Contributing Primary (n = 56 children, 33 parents)		Intermediate (n = 96 children, 58 parents)		Total(n = 152 children, 91 parents)		
	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)	
Sex													
Female	26	(55)	41	(54)	67	(54)	27	(48)	58	(60)	85	(56)	2
Male	21	(45)	35	(46)	56	(46)	29	(52)	38	(40)	67	(44)	−2
Usual mode of transport to school													
Walk	22	(47)	33	(44)	55	(45)	21	(38)	24	(25)	45	(30)	−15
Bike	0	(0)	3	(4)	3	(2)	1	(2)	0	(0)	1	(1)	−1
Public transport	0	(0)	2	(3)	2	(2)	1	(2)	5	(5)	6	(4)	2
Car, motorbike, scooter or taxi	25	(53)	37	(49)	62	(51)	33	(59)	65	(68)	98	(65)	14
Other	0	(0)	0	(0)	0	(0)	0	(0)	1	(1)	1	(1)	1
Child perceptions – roads around school busy with traffic													
Most or all of the time	14	(30)	51	(67)	65	(53)	23	(41)	62	(65)	85	(56)	3
Sometimes	27	(57)	25	(33)	52	(42)	24	(43)	32	(34)	56	(37)	−5
Hardly ever/never	6	(13)	0	(0)	6	(5)	9	(16)	1	(1)	10	(7)	2
Child perceptions – feel safe in neighbourhood when out **with** an adult													
Most or all of the time	38	(81)	61	(80)	99	(80)	46	(82)	86	(91)	132	(87)	7
Sometimes	6	(13)	13	(17)	19	(15)	10	(18)	9	(9)	19	(13)	−2
Hardly ever/never	2	(4)	1	(1)	3	(2)	0	(0)	0	(0)	0	(0)	−2
Don't go out with an adult	1	(2)	1	(1)	2	(2)	0	(0)	0	(0)	0	(0)	−2
Child perceptions – feel safe in neighbourhood when out **without** an adult													
Most or all of the time	8	(17)	29	(38)	37	(30)	13	(23)	43	(45)	56	(37)	7
Sometimes	11	(23)	30	(39)	41	(33)	6	(29)	35	(37)	51	(34)	1
Hardly ever/never	18	(38)	10	(13)	28	(23)	19	(34)	10	(11)	29	(19)	−4
Don't go out without an adult	10	(21)	7	(9)	17	(14)	8	(14)	7	(7)	15	(10)	−4
Child perceptions – I live in a place which allows me to walk/bike/scooter to school if I wanted to													
Agree/strongly agree	30	(65)	58	(78)	88	(73)	35	(64)	69	(73)	104	(70)	−3
Disagree/strongly disagree	16	(35)	10	(14)	26	(22)	13	(24)	16	(17)	29	(19)	−3
Not sure	0	(0)	6	(8)	6	(5)	7	(13)	9	(10)	16	(11)	6

magnitude of differences was employed (small 0.20–0.49; medium 0.50–0.79; large 0.80–1.00) (Cohen, 1988). All quantitative data analyses were conducted in SPSS v.25.

Children's open-ended responses were coded in NVivo v.12 using content analysis according to a previously developed matrix of children's perceptions of the route to school (Egli et al., 2019a). Parent's open ended responses were coded in SPSS v.25 according to a coding framework used previously to understand parent reported neighbourhood needs for their child's independent mobility (Smith et al., 2019a). Differences in dominant topics observed at each time point for children and parents were examined descriptively to determine whether any meaningful shift in perceptions had occurred. Results from all data sources were triangulated and considered in light of the proposed pathway to behaviour change are presented in Fig. 1.

3. Results

3.1. Child and household sociodemographic characteristics and usual mode of travel to school

Overall, 123 children (54% female, 38% primary school aged) and 88 parents participated in the pre-intervention data collection, and 152 children (56% female, 37% primary school aged) and 91 parents participated at follow-up (Table 2). The dominant mode of travel to school was car, followed by walking at both time points. The proportion of children travelling to school by car increased by 15% post-intervention (χ^2 (1) $= 8.11, p < 0.01$). Overall, biking rates were low and there was a minor increase in the use of buses to get to school post-intervention. With the exception of two parents at baseline, all reported having at least one working car available in their household. There was no significant difference in employment status of parent respondent between baseline and follow-up (χ^2 (3) $= 3.09, p = 0.378$). Over half were in full time employed work at both time points (56% at baseline, 58% at follow-up). A slight decline in those working part time, and a slight increase in those reporting home duties and not looking for work was observed at follow-up compared with baseline. Almost half of parents reported having to buy cheaper food in order to pay for other things that were needed at both time points (47% at baseline, 45% at follow-up). Participant and household characteristics were largely similar to those of the school community at both time points (www.educationcounts.org.nz).

Table 3
Descriptive statistics for key topics derived from parent responses to the question "What would make your neighbourhood a better place for (Child Name) to walk, bike or scooter by (Himself/Herself)?" pre-intervention and post-intervention.

Topic Subtopics	Pre-intervention n = 88		Post-intervention n = 91		Change in percentage from pre to post
	n [a]	% [a]	*n* [a]	% [a]	
Safety from traffic: Less, slower, and safer traffic	**12**	**(13.6)**	**10**	**(11.0)**	**−2.6**
Less busy traffic	0	(0)	1	(1.1)	1.1
Slower speeds	2	(2.3)	2	(2.2)	−0.1
Traffic calming infrastructure (e.g., humps)	9	(10.2)	7	(7.7)	−2.3
Lowering speed limits	4	(4.5)	4	(4.4)	−0.1
Reducing dangerous driving	0	(0)	2	(2.2)	2.2
Safety from traffic: More and safer crossings	**2**	**(2.3)**	**7**	**(7.7)**	**5.4**
Safety from traffic: Safer and designated cycle lanes	**1**	**(1.1)**	**0**	**(0)**	**−1.1**
Safety from traffic: More and better walking paths	**1**	**(1.1)**	**0**	**(0)**	**−1.1**
Safety from others	**23**	**(26.1)**	**9**	**(9.9)**	**−16.7**
Reduced "stranger danger"	6	(6.8)	1	(1.1)	−5.7
Community surveillance	8	(9.1)	6	(6.6)	−2.5
Reduced crime (drugs and gang activity)	4	(4.5)	1	(1.1)	−3.4
Fewer roaming dogs	4	(4.5)	3	(3.3)	−1.2
Reduced perceived danger from others especially youth	6	(6.8)	2	(2.2)	−4.6
Less bullying	3	(3.4)	0	(0)	−3.4
More and better destinations	**4**	**(4.5)**	**1**	(1.1)	−3.4
More destinations in the neighbourhood	1	(1.1)	1	(1.1)	0
More and better facilities at the destinations	3	(3.4)	0	(0)	−3.4
Better social environment	**3**	**(3.4)**	**4**	**(4.4)**	**1.0**
More connected community	2	(2.3)	4	(4.4)	2.1
More children/people out and about	2	(2.3)	0	(0)	−2.3
Others	**15**	**(17.0)**	**2**	**(2.2)**	**−14.8**
Better street lighting	8	(9.1)	1	(1.1)	−8.0
Child too young	2	(2.3)	0	(0)	−2.3
Positive Comments	1	(1.1)	0	(0)	−1.1
Safer neighbourhood	2	(2.3)	1	(1.1)	−1.2
Other	1	(1.1)	0	(0)	−1.1
More walking school buses (adult accompanying group of children to school)	2	(2.3)	0	(0)	0
Better upkeep of public spaces	1	(1.1)	0	(0)	−1.1

[a] Data are presented for the number and percentage of parents who noted these topics and subtopics. Note: *n* and % of topics do not equate to the total of all the subtopics due to some parents mentioning more than one subtopic in one topic.

3.2. Parent measures

3.2.1. Parent-reported reasons for school travel mode

Reasons most frequently cited by parents for their child's usual mode of travel to school are provided in Fig. 4, for all travel modes, and separately for the two dominant travel modes (car and walking). Distance to school was the most frequently reported reason for travel mode to school at all time points, for all travel modes to school. Convenience was the next most frequently cited reason for the travel mode, again across both time points and travel modes. Thereafter, reasons differed between car travel and walking. For example, promoting their child's health was the third most cited reason for children who walked, and this reason was not cited for children who travelled by car. The third and fourth most cited reasons for travelling by car were ensuring safety from others and concern about safety from traffic, respectively. Safety from others was not raised by parents of children who walked to school, and concerns about safety from traffic was only noted by 2% of these parents. There was a general decline in proportion of parents reporting each reason between baseline and follow-up, with the exception of convenience, which increased over time for all travel modes (overall increase from 11% at baseline to 19% at follow-up).

3.3. Parent neighbourhood environment perceptions for active travel

Table 3 provides descriptive information for parent-reported needs to make their neighbourhood better for their child to walk, bike, or scooter about independently before and after the intervention. Considerably fewer parents reported concerns about safety from others post the intervention compared with the baseline interview. Similarly, substantially fewer parents reported "other" concerns, particularly with regard to a need for better street lighting. Conversely, increases in transport environment related needs (less, slower, and safer traffic; more and safer crossings) were observed at the follow-up survey.

3.4. Parent perceptions of neighbourhood safety and social connectivity

No meaningful change was observed in safety scores for parent perceived neighbourhood safety, social cohesion, or social connection (Table 4). Overall there was a slight decrease in perceived neighbourhood safety, and minimal increases in perceived social connection and cohesion.

3.5. Child measures

3.5.1. Children's likes and dislikes about their route to school

Prior to the intervention the most common travel mode mentioned by children was walking and this was reported by them to be both fun and convenient, and an important opportunity for social interaction when accompanied by friends and/or siblings:

> "when I am coming home from school I walk with friends, I talk and if I see another friend we will stand and talk and we sometimes dawdle"

Children also spoke to traffic volume and dangerous driving as things they didn't like about their route when walking to school. They commented on *"lots of traffic"* being bad for their health *"because of car fumes"* and also in terms of being dangerous when crossing the road:

> "it's hard to check to see if cars are coming when crossing the streets (because they drive so fast and I can't see them coming)"

Traffic volume was also reported negatively for children who were driven to school because of the extra time costs:

> "being stuck in traffic means I am late to school".

Children's comments were largely similar post the intervention, again noting the fun and convenience of walking, and the social opportunities that this activity offered to them. Children also mentioned liking walking to school because of it being *"fast and easy"* and *"short and quick"*. Safety from traffic was also raised in keeping with the baseline data collection. Compared with the baseline survey, more children mentioned feeling safe in general when walking to school:

> "[when walking] people can see me and if I am in danger someone could help me"

Table 4
Mean (SD) parent neighbourhood perception scores pre-intervention and post-intervention.

Variable	Pre-intervention						Post-intervention						Overall % change from pre to post
	Contributing Primary		Intermediate		Total		Contributing Primary		Intermediate		Total		
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	
Safety	2.86	0.60	2.64	0.47	2.73	0.54	2.78	0.62	2.58	0.42	2.65	0.51	−0.08
Social cohesion	2.74	0.68	2.38	0.56	2.51	0.63	2.63	0.53	2.39	0.39	2.48	0.46	0.03
Social connection	2.53	0.61	2.44	0.64	2.47	0.62	2.50	0.58	2.47	0.56	2.48	0.56	0.01

"I like it cos its safe to walk"

3.6. Children's perceived road and neighbourhood safety

There was a 5% decrease overall in children reporting that roads around their school were sometimes busy with traffic, with accompanying increases in those reporting roads were busy all/most of the time and conversely, they were hardly ever/never busy (Table 2). Intermediate school aged children were more likely to report their roads being busy all/most of the time at both time points. An increase of 7% was observed for children reporting they felt safe when out in their neighbourhood, whether accompanied or not.

3.7. Children's perceived social and environmental support for active school travel

The proportion of children who reported being not sure whether they lived in a place which allowed them to actively travel to school increased after the intervention, with concomitant decreases in the proportion agreeing or disagreeing to this statement (Table 2). Older children were more likely than younger children to agree or strongly agree that they lived in a place that allowed them to actively travel to school if they wanted to.

3.8. Objective measures of the traffic environment

3.8.1. Traffic speeds and volumes

With the exception of location C (near Site 4), tube counter data indicated reductions in traffic speeds across all areas, with standardised mean differences in speeds ranging from −0.26 km/h to −2.03 km/h (Table 5). A large effect was observed at location D, with a two standard deviation decrease in speed (−2.03 km/h). Similarly, mean speeds at the 85th percentile had reduced across all areas except at location C. A particularly large decline was observed at location D, which had the highest pre-intervention 85th percentile speed (mean of 58.36 km/h to 45.65 km/h), and was close to Site 5 where speed humps were installed. Conversely, traffic volumes had increased in all areas except at location A.

3.8.2. Pedestrian and cyclist counts

With the exception of one site, an increase in the number of pedestrians (ranging from 9.42% to 18.04%) was observed (Table 6). Conversely, although numbers of cyclists were low pre-intervention, dramatic reductions were seen (reductions of between 76.92% and 80.00%) in all areas except one.

Notes: For sites 1–3, counts are based on two days of video footage, during weekdays in the school morning and afternoon peak periods (i.e., 0800–0915 and 1445–1600). Counts for site 4 include the afternoon peak period only, due to morning sunstrike. Counts include adults and children for all sites.

3.9. Triangulation of results

Variables examined in the current study have been considered along the hypothesised pathway to behaviour change. Changes are represented graphically in Fig. 5. Changes are presented in terms of whether they are likely to have a positive or negative impact on active school travel. Overall, both positive and negative shifts were observed across the behaviour change scenario in terms of the resources (i.e., safety was improved in some but not all aspects and reasoning (in that perceptions improved in some aspects but reduced in others)). While a significant increase in reported car travel as the usual mode of travel to school was observed, video observation revealed an increase in observed pedestrians (adults and children) after the infrastructural intervention. These changes are

Table 5
Changes in mean vehicle speeds, 85th percentile speeds, and traffic volume between pre-intervention and post-intervention measurements.

Tube Location	Closest Road Treatment Site	Vehicle speed – mean (*SD*), km/h			Vehicle speed – 85th percentile (km/h)			Number of motor vehicles per day (tube counts)		
		Pre	Post	Standardised mean difference (Cohen's *d*)	Pre	Post	% change	Pre	Post	% change
A	Site 1	39.02 (5.87)	37.34 (7.03)	−0.26	44.76	44.14	−1.38%	569	535	−5.98%
B	Site 2	45.28 (6.53)	42.14 (9.24)	−0.40	51.52	50.15	−2.65%	1415	1662	17.52%
C	Site 4	46.56 (6.88)	46.90 (6.94)	0.05	52.66	52.99	0.63%	1408	1628	15.64%
D	Site 5	52.57 (6.45)	40.58 (5.38)	−2.03	58.36	45.65	−21.79%	857	903	5.37%
E	Site 5	45.63 (6.70)	40.12 (8.18)	−0.74	51.66	47.43	−8.19%	1408	1633	15.95%

Notes: Data were collected using road tube counters and are for both directions during school morning and afternoon peak periods (i.e., 0800–0915 and 1445–1600) over five weekdays.

Table 6
Changes in counts of pedestrians and cyclists from video footage between pre-intervention and post-intervention measurements.

Camera Location (Road Treatment Site)	Number of pedestrians			Number of cyclists		
	Pre-intervention	Post-intervention	% Change	Pre-intervention	Post-intervention	% Change
Site 1	743	813	9.42%	8	19	137.50%
Site 2	741	839	13.23%	46	10	−78.26%
Site 3	704	831	18.04%	39	9	−76.92%
Site 4	216	196	−9.26%	5	1	−80.00%

contextualised in some consistent barriers and enablers to active school travel. For example children frequently noted traffic safety concerns at baseline and follow-up, and distance to school remained the primary parent-reported reason for both car and walking modes to school. There was an increase in parents reporting convenience as a main reason for their child's usual travel mode to school, irrespective of actual travel mode.

4. Discussion

The aim of this study was to take a comprehensive approach to understanding the potential changes in active school travel and associated variables that may occur as a consequence of small-to-medium scale, school-focused infrastructural interventions to improve pedestrian safety. Novel aspects of the research included the collaboration with a regional transport agency, the range of measures employed to understand change, and the triangulation of objective measures and child and parent perspectives using multiple methods.

Counter to expectations, findings showed no significant increase in active school travel after the intervention. Rather, a reduction in walking for the school journey was observed, with a concomitant increase in car travel. A number of possible explanations exist for this finding. Firstly, it is possible that this pattern aligns with secular changes in school travel modes either nationally or locally. Although rates of active school travel in New Zealand children are low and have declined over recent years, limited evidence suggests that rates may have actually been stable or increased slightly over the time period the study was conducted (Smith et al., 2019c). In terms of travel for all purposes, vehicle travel rates continue to increase across the country (New Zealand Transport Agency, 2019). Socio-demographic and geographic differences in children's active school rates exist across the country in ways that are not consistent over time (Hawley et al., 2019; Smith et al., 2019c). It is possible that regional or neighbourhood-specific changes in normative behaviours and values had occurred in the study area that are not captured by the national-level data, however without a control group this is impossible to determine.

Concerns about safety from traffic (particularly speeding cars, high traffic volumes and no safe places to cross roads) is a significant barrier to parents enabling active travel in children residing in Auckland (Smith et al., 2019b) and internationally (Ikeda et al., 2018; Wilson et al., 2018). While slower speeds were observed at the follow-up of this study, an increase in traffic volume was found, which may have discouraged active school travel. Some parent and child neighbourhood safety perceptions improved, including child sense of safety when in the neighbourhood and less parents reported a need for improved safety from others and lighting (albeit these are unlikely to be attributable to the intervention). Children's perceptions about busy traffic around the school also shifted away from the centreline, but this shift was small and was bi-directional (increases in children reporting both high and low traffic volume). The shift in increased perception of busy traffic was predominantly observed in the younger age group, suggesting a potential geographical variation between the schools or an age-related difference in concern. Variability in exposure to traffic volume could also exist depending on time of arriving at school, mode of travel, and previous experience leading to expected norms. Counter-intuitively, an increased proportion of parents reported their neighbourhood needed safer places to cross after the intervention. Recognising that perceived and objective measures of the neighbourhood built environment do not often agree (Arvidsson et al., 2012; McGinn et al., 2007), it is possible this finding may reflect the intervention acting as a stimulus for parents to recognise the value of such infrastructure, rather than a negative reflection on the intervention itself.

When asking parents the main reasons for their child's mode of travel to school, distance to school was the greatest reason across both time points and all travel modes. This study adds strength to advocacy for maintaining local schools and school zoning (rather than super-sized schools with large catchment areas) (Braza et al., 2004; Kearns et al., 2009; Talen, 2004; Witten et al., 2003). In addition it highlights the need to consider flexible transport options including public transport as well as novel approaches to minimising the impact of distance on travel modes (e.g., park and walk strategies) (Smith et al., 2019d). Given distance thresholds are higher for cycling than walking (D'Haese et al., 2011) strategies to increase the extremely low rates of cycling in this area are also warranted.

After distance, convenience was the most frequently cited reason by parents at both time points and for all travel modes and this increased from baseline to follow-up. It is unlikely this was related to the employment status of parents, given more parents reported home duties and not looking for work at follow-up compared with baseline. Innovative strategies are required to make active modes the most convenient travel modes for the school trip, particularly given the pervasiveness of car ownership. These might include reframing how 'convenience' is considered – for example promoting walking or cycling children to school as a way of parents getting their daily dose of physical activity. Focusing on promoting children's health can also be used as a motivational lever. Children also value time spent with their parents on the school journey (Egli et al., 2019a), so helping parents see the school trip as valuable bonding time with their children can take pressure off other time periods of the day. Workplaces can support active school travel through allowing for 'glide time' or 'flexitime' (i.e., flexibility in start and end working hours) and work from home days – ultimately improving time efficiency and convenience for active school travel.

In contrast to decreases in reported active school travel, video footage around the study area indicated increased numbers of pedestrians (children and adults) during the pre-school and post-school hours. It is possible that the intervention resulted in increased levels of walking in community residents for general trips including the school journey. However, numerous limitations for the video observation data need to be considered here. Video sites were not necessarily mutally exclusive, and thus pedestrians could be 'counted' at multiple sites. Similarly because the cameras were at specific locations only, changes could reflect people changing where they walk rather than changing travel modes. Counts do not necessarily directly reflect walking trips, as videos outside school gates could reflect park and walk behaviours. Data were collected across two days only meaning that changes could be attributable to chance or natural variation in people's behaviours. Increases in pedestrian counts could be indicative of overall population increases in the area, although this is unlikely given a minimal increase (5%) in school rolls between 2016 and 2018 (Ministry of Education, 2018).

Overall, an increase in car use for the usual mode of travel was found after the intervention, while an increased number of pedestrians of all ages was also observed. Findings showed both positive and negative shifts in neighbourhood perceptions, and consistent barriers and supports for active school travel at both time points. Enacting change in school travel likely requires scaled up and comprehensive approaches that extend beyond the intervention examined in this study (Aldred et al., 2019). Minor infrastructural upgrades can improve location-specific safety and reduce risk of road traffic injuries, but may be insufficient to generate wide-scale improvements in school travel modes. This also suggests there are complex considerations in the design of active school travel interventions, for example negotiating the balance between focusing on localised specific safety issues and interventions directly outside or near school gates, as well as a broader community focus that can contribute to changing active travel community norms. Status quo budgets may not be enough to allow for the level of changes needed to influence active school travel behaviour, and therefore innovative, low-cost interventions may need further consideration as part of the overall solution (such as temporary street closures and 'school streets' (City of Edinburgh Council, 2019)).

Changes are also reliant on broader school and community contexts – including social relationships, programmes and supports (Hawley et al., 2019; Smith et al., 2019d). One of the advantages of larger-scale, community-wide interventions is that they may be more likely to influence community norms about travel, which in turn can influence school travel. A recent systematic review of infrastructural interventions to promote walking and cycling in general revealed the importance of improving accessibility and safety, irrespective of the baseline environmental context (Panter et al., 2019). It is also possible that insufficient time has elapsed to see a meaningful shift in active school travel, with evidence from the UK iConnect study indicating changes in travel behaviours can take at least two years post intervention completion (Goodman et al., 2014).

4.1. Strengths and limitations

This study has a number of limitations in addition to those noted earlier. The absence of a control neighbourhood limits the ability to understand changes in the context of broader trends in school travel modes. Being a quasi-experimental study provides a general understanding of change but having independent ("non-equivalent") groups at each time point provides no understanding of longitudinal within-individual behaviour changes. It is possible some of the younger participants from the baseline survey participated in the follow-up measurements, however this information was not collected. It is also possible that changes between times were simply due to different groups at each time point, which is a key limitation of a non-equivalent quasi-experimental design. Overall, the samples were relatively similar in terms of age, sex, car access, and socio-economic status across both time points. Even so, the study findings should be interpreted with caution.

As is commonly in quasi-experiments and natural experiments, the inclusion of baseline measures was opportunistic, and thus measures and protocols were not designed specifically to test change as would occur in a controlled trial. Opportunistic traffic volume and speed data meant that data were not collected during the same months at baseline and follow-up so it is possible seasonality may have played a part in differences observed. However, while the region experiences seasonal differences (e.g., summers are warm and humid, winters are mild), these differences are not as extreme as in other regions of the country. For example Auckland experiences a small annual mean daily temperature range of 7.9 °C and plentiful rainfall year round (Chappell, 2013). Consequently, between-day differences in Auckland weather patterns (particularly with regard to rainfall and sunlight hours (Oliver et al., 2011a)) are more likely to play a role in travel and activity behaviours than a given season or month.

Calls to improve rigour in evaluating infrastructural interventions for health include the use of valid and reliable tools (and objective measures where appropriate), measurement of individual exposures to interventions, inclusion of well matched control and intervention sites, appropriate adjustment of counfounders, and improved response rates and representativeness (Benton et al., 2016; Smith et al., 2017). Yet, such intervention evaluations are rare (Macmillan et al., 2018, 2020), likely due to the prohibitive expense of infrastructural interventions, competing/misaligned priorities between researchers, transport engineers, and policy-makers; and lack of connection and collaboration between these stakeholders (Mackie et al., 2018; Witten et al., 2018). Thus, quasi-experiments and natural experiments play an important role in contributing to the predominantly cross-sectional evidence base.

Strengths include the use of multiple methods to gather information from parent and child perspectives, and the integration of perceived and objective measures to understand the complexity of behaviour change in relation to an infrastructural intervention. Measuring changes across the proposed pathway to behaviour change and including contextual descriptive findings have provided a more nuanced understanding of the potential impacts of infrastructural interventions than previous research. In line with previous research (Egli et al., 2019b; Fusco et al., 2012; Race et al., 2017; Wilson et al., 2018; Wurtele and Ritchie, 2005) this study demonstrates the utility of understanding children's perspectives in gaining a holistic understanding of environmental barriers and enablers to active school travel.

5. Conclusion

Varying degrees of changes were observed along the pathway to behaviour change. Distance remains the strongest factor associated with active school travel decision-making. We have revealed new insights that can help support infrastructural interventions for active school travel. In particular, making active travel the convenient option for parents is essential, and concerns about traffic safety remain a consistent barrier. Despite this school travel intervention, we saw decreases in active travel and increases in car travel at follow-up. Our analysis was unable to show the cause of this, but we speculate that these changes were due to trends in travel in the wider area. If such trends were present, this intervention was insufficient to counter them, at least within this time period. Reversing declines in active travel may require more intensive, community-wide interventions that substantially improve neighbourhood safety and perceptions of safety. Longer term follow-up of behaviour change may also be necessary to understand the true effect of the intervention.

Author statement

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Declaration of competing interest

None.

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References

Abley Transport Consultants, 2015. Auckland Transport Safer Communities 15/18. Author, Auckland, New Zealand.
Aldred, R., Croft, J., Goodman, A., 2019. Impacts of an active travel intervention with a cycling focus in a suburban context: one-year findings from an evaluation of London's in-progress mini-Hollands programme. Transport. Res. Part A 123, 147–169.
Arvidsson, D., Kawakami, N., Ohlsson, H., Sundquist, K., 2012. Physical activity and concordance between objective and perceived walkability. Med. Sci. Sports Exerc. 44, 280–287.
Aubert, S., Barnes, J.D., Aguilar-Farias, N., Cardon, G., Chang, C.K., Delisle Nystrom, C., Demetriou, Y., Edwards, L., Emeljanovas, A., Gaba, A., Huang, W.Y., Ibrahim, I.A.E., Jurimae, J., Katzmarzyk, P.T., Korcz, A., Kim, Y.S., Lee, E.Y., Lof, M., Loney, T., Morrison, S.A., Mota, J., Reilly, J.J., Roman-Vinas, B., Schranz, N., Scriven, J., Seghers, J., Skovgaard, T., Smith, M., Standage, M., Starc, G., Stratton, G., Takken, T., Tammelin, T., Tanaka, C., Thivel, D., Tyler, R., Williams, A., Wong, S.H.S., Zembura, P., Tremblay, M.S., 2018. Report card grades on the physical activity of children and youth comparing 30 very high human development index countries. J. Phys. Activ. Health 15, S298–S314.
Auckland Transport, 2018. Auckland Regional Land Transport Plan 2018-2028. Author, Auckland, New Zealand.
Auckland Transport, 2019. Statement of Intent 2019/20-2021/22. Author, Auckland, New Zealand.
Benton, J.S., Anderson, J., Hunter, R.F., French, D.P., 2016. The effect of changing the built environment on physical activity: a quantitative review of the risk of bias in natural experiments. Int. J. Behav. Nutr. Phys. Activ. 13.
Braza, M., Shoemaker, W., Seeley, A., 2004. Neighborhood design and rates of walking and biking to elementary school in 34 California communities. Am. J. Health Promot. 19, 128–136.
Chappell, P.R., 2013. The Climate and Weather of Auckland, second ed. National Institute of Water and Atmospheric Research, Auckland, New Zealand.
City of Edinburgh Council, 2019. School Streets. Tackling congestion at the school gates. Author, Edinburgh, Scotland. http://www.edinburgh.gov.uk/streetsahead/info/35/school_travel/87/school_streets.
Cohen, J., 1988. Statistical Power Analysis for the Behavioral Sciences, second ed. Erlbaum, Hillsdale, NJ.
D'Haese, S., De Meester, F., De Bourdeaudhuij, I., Deforche, B., Cardon, G., 2011. Criterion distances and environmental correlates of active commuting to school in children. Int. J. Behav. Nutr. Phys. Activ. 8, 88.