Geographical Research

# Viewing obesogenic advertising in children's neighbourhoods using Google Street View

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*Received 11 January 2018 • Revised 25 April 2018 • Accepted 11 May 2018*

## Abstract

The advertising of unhealthy food and beverages forms an important component of obesogenic environments. Such marketing to children is a key health determinant because of its impact on dietary preference and food purchasing behaviour. The location of outdoor advertising is important in exploring obesogenic environments and children's neighbourhoods. The aim of this study is to explore issues involved in the use of Google Street View to examine outdoor food and beverage advertising. The implications for using Google Street View in the context of neighbourhood built environment research and grass-roots advocacy are discussed. The study was conducted within walkable distances from 19 primary and intermediate schools in Auckland, New Zealand, where "walkable" was defined as limited by 800 m road network boundaries, which are equivalent to school buffer boundaries. Google Street View allows for centrality of data collection, coding, and storage. However, challenges exist with the method because 727 (29.4%) of a total of 2,474 outdoor advertisements that were identified were not able to be categorised because images were unclear, not in English, blocked, or at angles where detail cannot be deciphered. Specific to outdoor advertising for food and beverages, the results presented here show that children are exposed to a significantly greater number of unhealthy advertising than other advertising, P=0.001, eta-squared statistic (0.45) indicates a large effect size. Overall, the results show promise for the use of Google Street View in the study of obesogenic environments.

**Keywords** *Google Street View; outdoor advertising; children; built environment; obesogenic environments; New Zealand*

## Introduction

Children are particularly vulnerable to the marketing of unhealthy food and beverages. In children's neighbourhoods, the presence of unhealthy outdoor advertising contributes to the "normalisation" of consumption of these unhealthy products. This effect is important because globally unhealthy diets remain a leading risk factor for death and disability (GBD 2015 Risk Factors Collaborators, 2016; Kaczorowski *et al.*, 2016) and corporations are predominantly concerned with selling their products, not the health and wellbeing of their consumers. Health institutions and regulatory bodies define unhealthy food and beverages as those that are high in energy, fat, sugar, and/or salt (Australian Government Department of Health, n.d.; Kaczorowski *et al.*, 2016; World Health Organization, 2015). Globally, consumption of unhealthy food and beverages in childhood plays a major part in the current childhood obesity epidemic and has been linked to metabolic and cardiovascular diseases in later life (Sahoo *et al.*, 2015).

Drivers of unhealthy food consumption in children are multifaceted and complex. Among the myriad contributing factors that support those consumption patterns, neighbourhood settings—which are key places in which children spend time—are increasingly obesogenic or obesity-promoting. In such settings, the prevalence of advertising can exacerbate young people's exposure to messages and encourage unhealthy behaviours (Swinburn *et al.*, 2011; Vandevijvere & Swinburn, 2015). Advertising is of particular interest because demonstrable positive impacts on health behaviours at the population level arise when advertising policy changes (Cairns *et al.*, 2013). Repeated exposure to advertising unhealthy food and beverages from all sources, for example on television, on social media, in store, and in the outdoor environment, combine and contribute to the normalisation of consumption of these unhealthy products (Pettigrew *et al.*, 2013).

It is important to study how unhealthy food and beverages are marketed to children and to examine the neighbourhood settings for outdoor advertisements in order to better understand how obesogenic environments are produced or might be dismantled (Lesser *et al.*, 2013; Swinburn *et al.*, 2011). Evidence shows that marketing unhealthy food and beverages to children increases their consumption of and preferences for these products (Sadeghirad *et al.*, 2016). Yet corporate marketing budgets allocated to their promotion and sale still specifically target children, are increasing in monetary value, and their applications to advertising remain largely unregulated (Cairns *et al.*, 2013; Linn & Novosat, 2008; Vandevijvere & Swinburn, 2015).

One way to study these dynamics is to use Google Street View, a freely available online mapping tool that allows users to see panoramic views from many positions on a road (https://mapstreetview.com). Google Street View is the most widely accessible form of omnidirectional imagery (Kelly *et al.*, 2013). Omnidirectional camera systems collect images from many directions to create panoramic views of streetscapes. Not all areas globally have been mapped by Google Street View, yet it has coverage across all seven continents. Urban areas unaffected by global conflicts are regularly updated (Google, n.d.). Google Street View has been used in ecology research to assess species habitat (Olea & Mateo-Tomás, 2013); in built environment research looking at cycling paths to school (Vanwolleghem *et al.*, 2014); in neighbourhood social observation research (Odgers *et al.*, 2012); and even as an automated system for monitoring demographic trends and predicting politics (Gebru *et al.*, 2017).

The authors are unaware of other research using Google Street View to assess the existence and spatial distribution of outdoor marketing promoting unhealthy food and beverages within walking distance from schools in New Zealand, defined as within an 800 m road network from school gates (Badland & Oliver, 2011). This study specifically builds upon works investigating the distribution of food outlets around New Zealand Schools (Maher *et al.*, 2005; Vandevijvere *et al.*, 2016) and smoke-free signage around schools (Wilson *et al.*, 2015) and reporting on field audits of food and beverage advertising around schools (Missbach *et al.*, 2017). The study aims to explore the use of Google Street View to examine outdoor food and beverage advertising within walkable distances from the schools included in the Neighbourhoods for Active Kids study (Oliver *et al.*, 2016). The objective of this research is to add to the body of knowledge on obesogenic environments for children and the utility of Google Street View in geographical health research. The results of the research may be used to inform neighbourhood advertising policies at the local level and government regulations on advertising to children. Additionally, the research may be used to inform future obesogenic environment research and be simplified for use in grass-roots, community level advocacy for health promoting neighbourhoods. The remainder of the paper is organised as follows: background, methods of approach to the study, findings, discussion, and conclusion sections.

## Background

Schools are often central components of children's neighbourhoods, both during school time and as recreation settings outside school hours where such use is permitted (Badland *et al.*, 2015). Research by Vandevijvere *et al.* (2016) using food outlet density data derived from Geographic Information Systems (GIS) has demonstrated the differential availability of unhealthy food outlets around New Zealand schools in areas of relative socio-economic deprivation or advantage. Although research investigating the impact of tobacco and alcohol marketing on young people has also focused on schools' catchment areas or buffer zones (Luke *et al.*, 2000), less is known about outdoor food advertising in these zones (Maher *et al.*, 2005).

Many challenges related to assessing the obesogenic nature of outdoor environments have been described in the literature and include burdensome challenges associated with conducting field audits (Badland *et al.*, 2010; Griew *et al.*, 2013; Kelly *et al.*, 2013) and a lack of transparency and unwillingness to share data by advertising agencies and members of the food industry (Reeve, 2013; Stuckler & Nestle, 2012). Despite these challenges, a more detailed investigation of the extent to which children are exposed to unhealthy food and beverage marketing is essential, because children are particularly vulnerable to the marketing of unhealthy foods and beverages and are subject to repeated exposure, especially if that exposure occurs on regular trips to school through much of any given year (Kelly *et al.*, 2008; Sadler *et al.*, 2016; Signal *et al.*, 2017; Smith *et al.*, 2013; Walton *et al.*, 2009).

Literature suggests that global positioning system and activity tracking data can show the duration of exposure to unhealthy food outlets and associated advertising on routes to and from schools. Analysis also suggests that such exposure has a significant effect on food purchasing behaviours of adolescents (Sadler *et al.*, 2016). In the USA, those travelling to school by active means such as walking have longer durations of exposure to unhealthy outdoor advertisements and food outlets and mostly live in urban areas (Vander Veur *et al.*, 2013). Yet regardless of their urban, suburban, or rural location, children are influenced by the environments around their schools, and where those have high levels of food advertising and large numbers of foot outlets, their dietary behaviours and values are affected (Macdiarmid *et al.*, 2015; Smith *et al.*, 2013).

Literature summarising public health research shows that virtual audits of place can replace observational field audits of built environment characteristics (Badland *et al.*, 2010; Wilson *et al.*, 2012). A pilot study in New Zealand that used Google Street View to assess smoke-free signage around schools showed modest sensitivity (52%) and sound specificity (97%) compared with in-place observational audits (Wilson *et al.*, 2015). Likewise, Griew *et al.* (2013) used Google Street View to conduct streetscape audits investigating broad neighbourhood level environmental characteristics. They compared Google Street View with field audits and found sound agreement between methods. These studies demonstrate the possible utility of Google Street View as a tool to virtually audit outdoor environments. However, this field is in its infancy and ongoing testing, and refinement is needed. An important first step in this emerging evidence base is to identify pragmatic issues affecting the use of new technologies such as using Google Street View for environmental audits.

## Methods of approach to the study

This study supplements a larger cross-sectional study, Neighbourhoods for Active Kids (Oliver, *et al.* 2016) of 1,102 children attending nine intermediate and ten primary schools, located across nine ethnically, socio-economically, and geographically diverse neighbourhoods in Auckland, New Zealand. The schools were purposively recruited by use of a neighbourhood matrix. For the purposes of this study, a neighbourhood is defined as the area around a state coeducation intermediate school (teaching students in years seven and eight) and a contributing primary school (teaching students in years one to six). The neighbourhood matrix allows for diversity across features of neighbourhood-level socio-economic status by school decile, walkability, and destination accessibility. *School decile ratings* range from one to ten and indicate the socio-economic status of the neighbourhood students are drawn from. A decile–one school is from the ten per cent of schools with the highest proportion of students from communities experiencing socio-economic disadvantage. A decile–ten school is from the ten per cent of schools with the lowest proportion of students from communities experiencing socio-economic disadvantage. For this study, deciles have been combined into low (one–three), medium (four–seven), and high deciles (eight–ten). Neighbourhood *walkability* was calculated using a school-specific walkability index (Giles-Corti *et al*., 2011). *Destination accessibility* was measured using the Neighbourhood Destination Accessibility Index–Child (NDAI–C), a spatially derived, objective index that quantifies access to destinations commonly frequented by children (Badland *et al*., 2015). General neighbourhood and school characteristics are provided in Table 1, and the stages of data collection are outlined in Figure 1. For further details regarding Neighbourhoods for Active Kids methodology, please refer to Oliver *et al*. (2016). This study did not include human participants.

Around each of the 19 schools in the study, an 800 m road network buffer was created in ArcGIS version 10.3, using road centreline data obtained from the 2015 Core Logic transport dataset. The road network buffers that were generated accounted for all formal entry points into each school. School buffer boundaries were then uploaded into Google Maps and colour-coded to allow ease of viewing overlapping areas.

An initial period of formative data collection and training of two research assistants informed the data collection protocol. During that period, all 19 school buffer boundaries were mapped. The final data collection protocol includes information on travelling the school buffer boundaries in Google Maps, on how to identify outdoor advertisements, and on how to code them for category and target audience; these are described in detail in the succeeding texts. The data collection protocol is available from the corresponding author upon request. Inter-rater agreement between both research assistants was required to be 90 per cent before they were able to undertake formal data collection. The 19 school areas were then randomly assigned to the research assistants using the RANDOM function in Microsoft Excel. Formal data collection was completed individually by the research assistants between March and July 2017. Once data for each school were collected, they were checked by the study manager (author 1), and ongoing training was conducted, and feedback given as needed to ensure accuracy of categorisation (Figure 1). During data collection, the study manager was available to assist research assistants with advertisement identification and categorisation as needed.

Table 1 School and neighbourhood characteristics

| Neighbourhood<br>Auckland Ward | Walkability tertile<br>(1 low medium, 3 high) | NDAI-C tertile<br>(1 low, 2 medium, 3 high) | School number | School type | School decile<br>(1 most deprived, 10 least deprived) | School decile tertile<br>(1–3 low, 4–6 medium, 8–10 high) |
|---|---|---|---|---|---|---|
| Waitakere | 1 | 1 | 18 | Intermediate | 3 | Low |
| | | | 19 | Primary | 9 | High |
| North Shore A | 1 | 1 | 20 | Intermediate | 6 | Medium |
| | | | 24 | Primary | 5 | Medium |
| Albany | 1 | 1 | 11 | Intermediate | 10 | High |
| | | | 14 | Primary | 10 | High |
| | | | 21 | Primary | 4 | Medium |
| North Shore B | 2 | 2 | 27 | Intermediate | 6 | Medium |
| | | | 28 | Primary | 9 | High |
| Albert-Eden-Roskill | 2 | 3 | 13 | Intermediate | 9 | High |
| | | | 12 | Primary | 10 | High |
| Manurewa | 3 | 1 | 22 | Intermediate | 2 | Low |
| | | | 23 | Primary | 1 | Low |
| Howick | 3 | 1 | 25 | Intermediate | 5 | Medium |
| | | | 26 | Primary | 8 | High |
| Manurewa–Papakura | 3 | 3 | 10 | Intermediate | 1 | Low |
| | | | 15 | Primary | 2 | Low |
| Waitemata and Gulf | 3 | 3 | 16 | Intermediate | 9 | High |
| | | | 17 | Primary | 8 | High |

NDAI-C, Neighbourhood Destination Accessibility Index–Child.

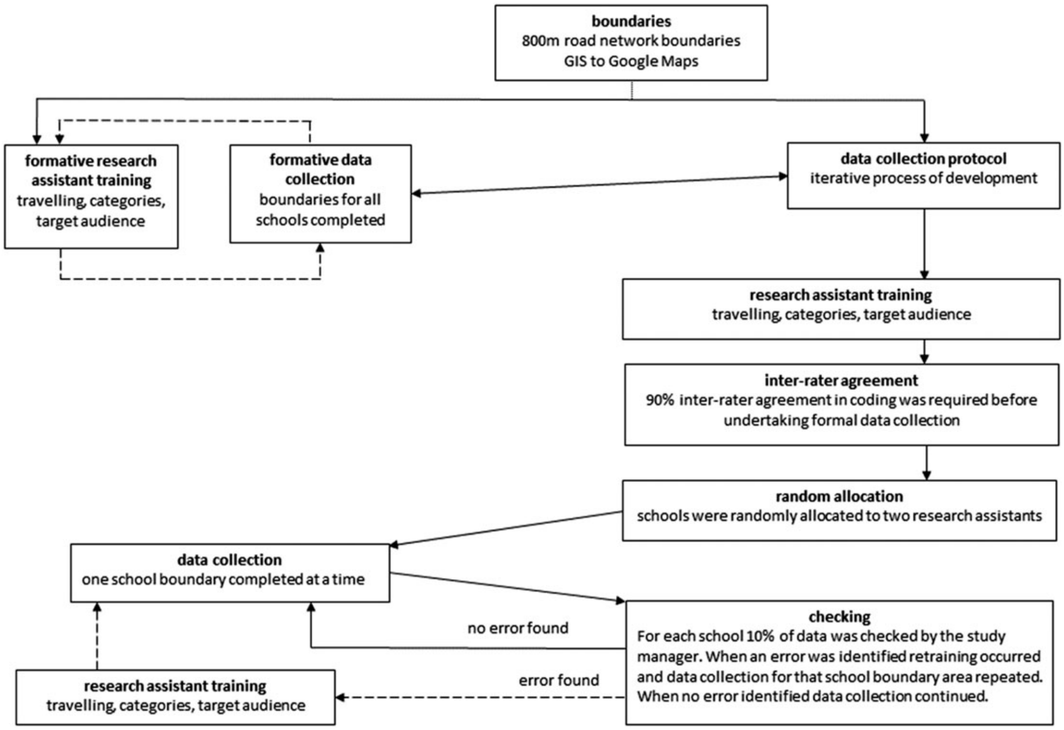


Figure 1 Flow chart of processes involved in data collection. GIS, Geographic Information Systems

Research assistants were trained to "travel" within school buffer boundaries in Google Street View. Included in the training was guidance about how to manoeuvre around streets, zoom in, zoom out, and identify outdoor advertisements from different angles. Outdoor advertisements were defined as 'stationary objects containing either a recognisable logo and/or an intended message' (Maher *et al*., 2005). The advertisements included all billboards, signs, flags, banners, balloons, neon signs, stickers, and bus shelter advertisements that were large enough to be seen on a 15 inch computer screen; with an identifiable logo or text; and located completely or partially on public land. Outdoor advertisements that included only symbols or only words identifying retail outlets were included. For many locations, Google Street View has the ability to show past and most recent image-captures, but in this study, only the most recent image capture was used. The omnidirectional imagery stored in Google Street View and used in this study was captured from November 2009 to December 2015, the average being in January 2015.

A distinction was made between outdoor advertisements located on publicly accessible footpaths and grass verges and those advertisements that were set clearly within the boundaries of businesses or private properties. When an outdoor advertisement was partially located on a publicly accessible footpath or grass verge and partially located within the boundaries of businesses or private properties boundaries, it was included. Advertising on the façade of buildings was excluded, as was mobile advertising on taxis, buses, cars, mobile food trucks, and coffee carts. All A-frame double-sided bus shelter and standing signs, where advertisements appear on two sides, were identified and coded twice—once for each side. Not all advertisements are the same on both sides, so each side was identified and coded individually to ensure accurate information was captured.

Once an outdoor advertisement was identified, one screenshot for each advertisement or two for each double-sided advertisement was saved to allow for data checking by the study manager. The Map Tool in Google Street View was used to correctly identify the closest street address for each outdoor advertisement. The distance measurement tool in Google Maps was used to calculate the shortest distance when walking or driving from the outdoor advertisement to the school. More detailed instructions on data collection and data entry can be found in the data collection protocol available upon request from the corresponding author.

In consultation with a New Zealand registered dietician (author 2), categories were assigned to each outdoor advertisement identified. Foods that reflect dietary patterns associated with increased risk of obesity and dental caries in childhood are processed, energy-dense, nutrient-poor foods (World Health Organization, 2016) and are collectively termed "unhealthy" in this study. When food and beverages were promoted together in one advertisement, they were put into a combined category "food and beverage". Outdoor advertisements were also assigned to categories listed in Table 2.

All advertisements that were not labelled "unable to categorise" were assigned a target audience: (a) adult only, (b) child only, or (c) adult and child. In this study, a child refers to those that attend primary or intermediate school. In New Zealand, this commonly refers to children aged five to 13 years. Target audiences were assigned according to World Health Organization (2007) guidelines for classifying marketing to children, as follows:

1. The type of product or service being marketed. *Is it intended exclusively for children or is it very interesting to them?*
2. The way the marketing is presented. *Does it use colours or images that will appeal to children or are likely to be popular with children? Does it involve characters with whom children are likely to identify?*
3. The place and time of the marketing campaign. *Is the marketing conducted in a place frequented mainly by children?*

If either criterion 1 or 2 was met, then the advertisements were labelled as being marketed to children. Guideline 3 was considered met as all advertisements in this study were located within a close walking distance from schools. It is common for marketing design of foods and beverages to appeal to both adults and children. The response option (c) 'adult and child' was used when a research assistant decided that the advertisement was marketed to children and would also appeal to adults. During data collection, when research assistants were uncertain about categories or target audience, decisions were made in consultation with the study manager and study dietician.

Finally, descriptive information was recorded about the time taken to code an area and in instances where advertisements were in overlapping school buffer boundaries on the grounds that in New Zealand, primary and intermediate schools are often proximate or adjacent.

At the completion of coding for each school, the study manager used the RANDOM function in Microsoft Excel to audit a randomly selected ten per cent of outdoor advertisements coded for that school. Differences in coding were discussed with

Table 2 Advertisements identified by category

| Category name | Examples | Frequency *N* | % |
|---|---|---|---|
| Non-food residential | Real estate advertising: for sale, for rent, open home | 301 | 12.2 |
| Non-food other | Advertisements for services: insurance, telecommunications, clothing | 1,015 | 41.0 |
| Food unhealthy | Junk food: chocolate, pizza | 134 | 5.4 |
| Food other | Fruits and vegetables, take away chicken and rice, yoghurt | 138 | 5.6 |
| Food and beverage unhealthy | Fast food meal combo's: burger, chips and a soft drink | 12 | 0.5 |
| Food and beverage other | Milk and bread advertised together, Thai beef salad and a coffee | 22 | 0.9 |
| Beverage alcoholic | Beer, wine, spirits, ready to drink mixes | 41 | 1.7 |
| Beverage sugar sweetened | Soft drinks, energy drinks, sports drinks, juice, flavoured milk | 23 | 0.9 |
| Beverage diet and zero calorie | Beverages that are labelled as being reduced sugar or artificially sweetened | 2 | 0.1 |
| Beverage other | Milk, water | 51 | 2.1 |
| Unable to categorise—image unclear | N/A | 436 | 17.6 |
| Unable to categorise—blocked | N/A | 152 | 6.1 |
| Unable to categorise—angle | N/A | 132 | 5.3 |
| Unable to categorise—not in English | N/A | 15 | 0.6 |
| | Total | 2,474 | 100.0 |

research assistants, who then checked all previously collected data where the specific coding had applied. Another ten per cent random selection of all outdoor advertisements collected by the research assistants was checked by the study manager before approval was given to continue to the next school boundary.

Once data collection and checking were complete, the spreadsheet was cleaned and imported into IBM SPSS version 24 for analysis. Specific to outdoor advertisements for food and beverages, paired sample *t*-tests were used to compare "unhealthy" and "other" combined categories with the marketing categories "child only," "child and adult," and "adult only." Pearson's correlation was conducted to investigate the relationship between deprivation as measured by school decile and advertisements classified as "healthy" and "other."

Using ArcGIS v.10.5.1, kernel density maps were created to visualise the density and proximity of food and beverage advertising to children within the 800 m buffer boundaries around each school. Unlike the traditional count method within an area buffer, kernel density estimates the density of each data point (in this instance, outdoor advertisements) within an 800 m search radius around each point. The kernel density estimate cell size used was 10 m × 10 m. In kernel density estimates, advertisements that are located close together are given higher values than are advertisements located farther apart. Kernel density maps are useful for visualising both the density and proximity of advertising within school boundaries and provided in the succeeding texts.

## Findings

Several findings emerged from the analysis of the data. First, the time taken for research assistants to travel along the school buffer boundaries using Google Street View, then identify outdoor advertisements, and then classify what they observed took between one and ten hours per school buffer boundary—averaging four hours and 23 minutes each. School buffer boundaries with high average NDAI-C tertile scores took longer than did those with low average NDAI-C tertile scores and that was regardless of the decile and walkability rating of the schools.

Second, a total of 2,474 outdoor advertisements were identified within the 19 school buffer boundaries (Table 2). Of those advertisements, 727 (29.4%) could not be categorised, mostly because the image was unclear, blurry, fuzzy, or pixelated (*n*=436, 17.6%).

Table 3 Categories combined for use in mapping

| Combined GIS codes | Categories | Marketing | Frequency N | Frequency % |
|---|---|---|---|---|
| Other food beverage marketed to children | Food other<br>Food and beverage other<br>Beverage other | Child | 45 | 1.8 |
| Other food beverage marketed to adults | Food other<br>Food and beverage other<br>Beverage other | Adult | 166 | 6.7 |
| Unhealthy food beverage marketed to children | Food unhealthy<br>Food and beverage unhealthy<br>Beverage sugar sweetened<br>Beverage diet and zero calorie | Child | 152 | 6.1 |
| Unhealthy food beverage marketed to only adults | Food unhealthy<br>Food and beverage unhealthy<br>Beverage sugar sweetened<br>Beverage diet and zero calorie<br>Beverage alcoholic | Adult | 60 | 2.4 |
| Non-food all | Non-food residential<br>Non-food other | Adult | 1,316 | 53.2 |
| Unable to categorise | Image unclear<br>Blocked<br>Angle | N/A | 735 | 29.8 |
| | Not in English | Total | 2,474 | 100 |

GIS, Geographic Information Systems.

Third, of the advertisements that could be identified ($n$=1,747, 70.6%), the most frequent category of advertising was "non-food other" (41%), followed by "non-food residential" (12.2%), "food other" (5.6%), and "food unhealthy" (5.4%) (Table 3).

These categories were combined into two others: "unhealthy food and beverages" or "other food and beverages." The majority of food and beverage advertising was marketed to "adults only" ($n$=226, 53.4%), with 197 (46.6%) marketed to "children and adults." No advertisements were coded as being marketed to "children only." All instances of advertisements that had children as a target audience as defined by WHO criteria (World Health Organization, 2007) were also considered as being appealing to adults. In all of these cases, the target audience was therefore coded as "children and adults."

Fourth, for food and beverage advertisements classified as such, there was a statistically significant difference in the number of outdoor advertising of "other food and beverages" (M=2.37, SD=2.71) compared with "unhealthy food and beverages" (M=8.00, SD=7.31), $t(18)$=-3.817, P=0.001 (two-tailed). The eta-squared statistic (0.45) indicated a large effect size. There was a statistically significant difference for advertisements marketed to "adults only" for "other food and beverages" (M=8.74, SD=7.978) versus 'unhealthy food and beverages' (M=3.16, SD=2.949), $t(18)$=3.113, P=0.006 (two-tailed). The eta-squared statistic (0.35) indicated a large effect size. There was no statistically significant difference in the number of "other food and beverages" marketed to "children and adults" or to "adults only" (M=11.1053, SD=9.67181) compared with "unhealthy food and beverages" marketed to either "children and adults" or to "adults only" (M=11.1579, SD=8.74492), $t(18)$ =0.036, P=0.971 (two-tailed). The combined categories were mapped in ArcGIS version 10.5.1.

Fifth, then, the results of the kernel density maps show that the density of food and beverage advertising marketed to children may differ by neighbourhood deprivation measured by school decile regardless of neighbourhood walkability and destination accessibility. However, this difference was not supported by statistical analysis (P>0.05). For example, School ID 15, a low-decile school, and School ID 16, a high-decile school, are both located in highly walkable neighbourhoods with high NDAI-C tertile scores (Table 1). The kernel density maps show that the density of unhealthy food and beverage advertisements is inversely related to other food and beverage advertisements between the two schools. School ID 15 has a greater density of unhealthy

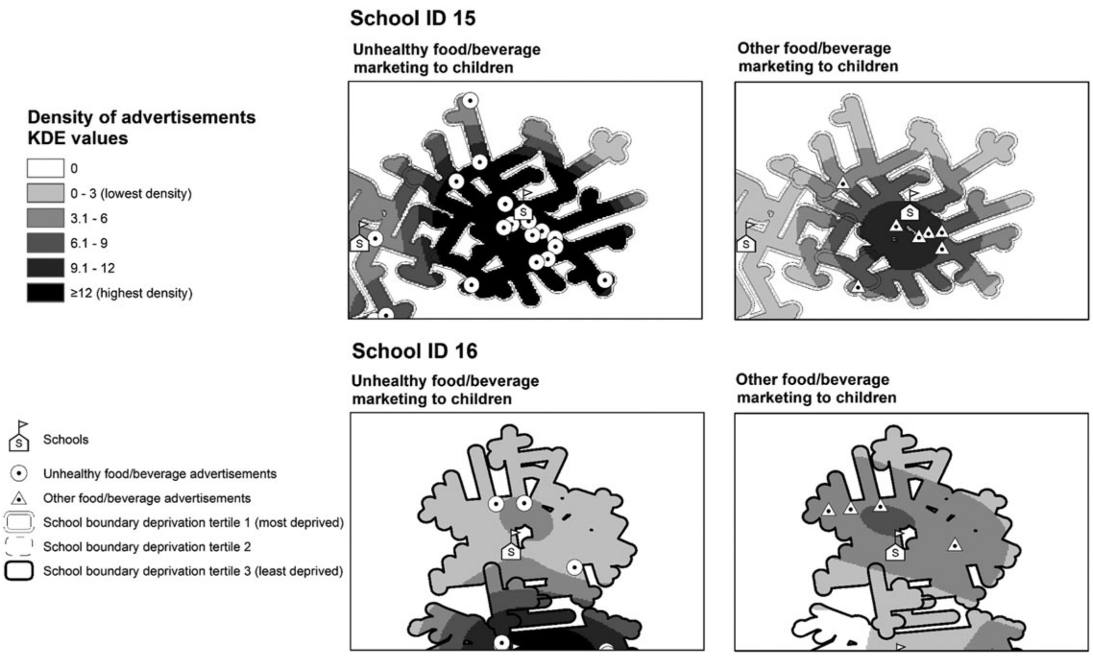


Figure 2 Kernel density maps, for example, schools in highly walkable neighbourhoods. KDE, kernel density estimate

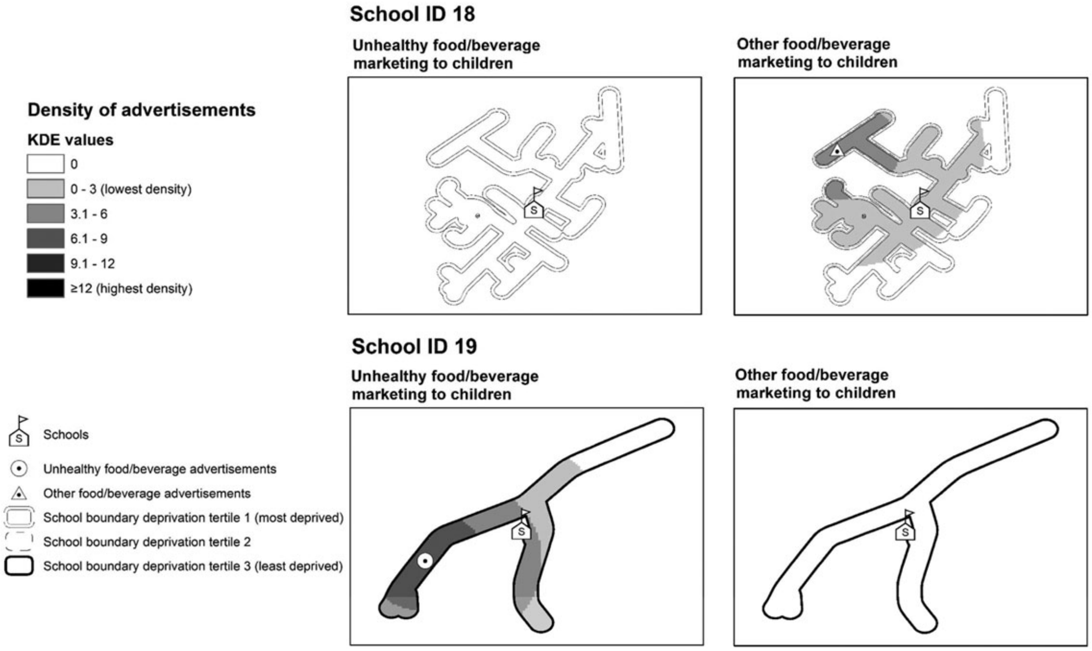


Figure 3 Kernel density maps, for example, schools in low walkable neighbourhoods. KDE, kernel density estimate

advertising in the school boundary than School ID 16. Likewise, School ID 16 has a greater density of other advertising in the school boundary than exists in the zone affecting School ID 15 (Figure 2).

For schools in neighbourhoods with low walkability and low destination accessibility, there was little observable difference in the density of unhealthy food and beverage advertising marketed to children between different levels of deprivation. For example, School ID 18, a low-decile school, and School ID 19, a high-decile school, both have low densities of unhealthy food and beverages marketed to children and other food and beverage advertisements marketed to children (Figure 3).

## Discussion

The aim of this research was to use Google Street View to examine outdoor food and beverage advertising within walkable distances from 19 primary and intermediate schools in Auckland, New Zealand. The major findings of this study were that Google Street View shows promise as a tool to examine outdoor food and beverage advertising but is not without limitations. The greatest limitation was found for low image quality, which resulted in nearly a third of advertising left uncategorised. Additionally, the data show that a significantly greater number of advertisements for unhealthy food and beverages are marketed to children than are advertisements for other food and beverages.

Of the outdoor food and beverage advertisements marketed to both children and adults, there were significantly more advertisements for unhealthy food and beverages than for other food and beverages. These findings support calls from public health practitioners and policy makers to reduce exposure of unhealthy food and beverages to children (Vandevijvere & Swinburn, 2015). The results also show that of the advertisements marketed only to adults, there were statistically more advertisements for other food and beverages than unhealthy food and beverages. This inverse relationship is explained by the results that no advertisements were categorised as being marketed only to children; thus, adults are exposed in both categories.

While not a statistically significant finding in this research, there is an additional link between socio-economic deprivation and distribution of unhealthy food and beverage outlets in New Zealand. A study by Vandevijvere *et al.* (2016) reported shorter overall distances to fast food, take away, and convenience food outlets from urban schools in low-decile areas of high deprivation than from urban schools in high-decile areas of low deprivation. Future research is needed to confirm whether, how, and to what extent links exist between socio-economic deprivation and distribution of unhealthy food and beverage outdoor advertising in New Zealand.

Using the method described, Google Street View shows promise in public health research. Although not a primary aim of this study, when analysing the descriptive data, clear patterns emerged in line with other research in New Zealand on obesogenic environments (Vandevijvere *et al*., 2016). The results from our study show that children attending schools in areas of high deprivation had greater overall exposure to advertising and that children at schools in highly walkable neighbourhoods in high deprivation areas were more exposed than others to unhealthy food and beverage advertising marketed directly to them.

It is known that direct marketing to children influences food purchasing behaviour on the way to and from school (Cairns *et al*., 2013) and research from New Zealand shows that food outlets selling unhealthy food and beverages are located within school catchments (Vandevijvere *et al*., 2016). This research helps to round out understandings of obesogenic environments affecting New Zealand schools and their communities. Children are exposed to food outlets within walkable distances from the school gate (Vandevijvere *et al*., 2016), and the current research shows that they are also exposed to advertising along the way. It is likely that current advertising standards and codes are insufficient to protect children and young people from unhealthy marketing and its associated harms (Swinburn *et al*., 2017; Powell *et al*., 2013). Policies and interventions to remove outdoor advertisements from environments children regularly frequent such as the areas around schools may be a useful step towards protecting them from the harmful effects of marketing of unhealthy foods and beverages; this warrants further investigation.

This is the first study that we are aware of, and certainly the first in New Zealand, to use Google Street View to capture detailed features of obesogenic environments around schools. Google Street View shows promise for use in studies with large and geographically dispersed samples because of the centrality of data collection, reduced need for travel, and other concerns over fieldwork practicalities, for example, researcher safety and finances (Rundle *et al*., 2011; Griew *et al*., 2013). A strength of Google Street View is that it is freely available online. Data can be collected without the need for costly up-front purchases such as software or wearable cameras, and supervisors are on-site to monitor and help with data collection, quality assurance, iteration, and categorisation as needed. Google Street View has another strength in the ease with which screenshots can be taken and archived for quality-control review and data checking at later points in time (Rundle *et al*., 2011).

However, Google Street View has limitations. Google Street View images are taken from vehicles travelling down roads and paths, representing cars driving down the street, rather than at the level of pedestrians. Sometimes, A-frame signs on sidewalks were obscured by parked vehicles, rubbish bins, and, where people were standing in front of them—the blurring out of their facial features being a software feature Google installed for privacy (Rundle *et al*., 2011; Google, n.d.). As seen in other studies, small items, especially those located on the sidewalk surface or low to the ground, were difficult to discern in Google Street View (Wilson *et al*., 2015). However, as technology develops, and enhanced image quality capabilities are put into Google Street View, it is expected that the specificity of data able to be extracted from Google Street View will improve. Nevertheless, it was impossible to categorise nearly 30 per cent of outdoor food and beverage advertising because of poor image quality.

Another limitation of Google Street View as a tool for capturing detailed features of outdoor environments is that we were unable to determine the size of outdoor advertisements. Future research could investigate ways of collecting approximate sizes based on comparisons with other known features captured in the frame—for example, doors, sign posts, or people.

A third limitation is that this study focused only on outdoor advertisements located on publicly accessible footpaths, and grass and other verges, and thus, it is not wholly representative of outdoor advertising around schools. The owners and lessees of retail outlets, particularly food and beverage outlets, advertise the goods and services they provide on the outside of their premises to entice customers inside (Bryden *et al*., 2012; Iveson, 2012). To reduce research assistant burden, and because of time and resource constraints, advertisements on the outside of buildings were not included in the study (Bader *et al*., 2017). Thus, the methods and results presented here must be approached in that light: it is likely that the results are conservative.

A fourth limitation is that we did not know how many outdoor advertisements meeting the inclusion criteria may have been missed by both research assistants. Nevertheless, the data checking process focused on correct categorisation of outdoor advertisements enabled us to identify formative data collection, and research assistant training thoroughly covered all aspects of travelling in Google Street View and identifying advertisements. It was useful that the study manager was available to provide personal assistance to the research assistants as needed during data collection.

A final limitation of this study is that ground-truthing was not operationally possible in this research due to financial and time constraints. However, in the USA, a comparison of Google Street View built environment and associated field audits conducted in 2008 and 2009 found substantial to near perfect agreement between methods (Wilson *et al*., 2012). Likewise, physical activity environment research conducted in the UK and research on smoke-free signage in New Zealand found that Google Street View audits have sufficient sensitivity when compared with field audits (Griew *et al*., 2013; Wilson *et al*., 2015).

In this light, future research opportunities exist to compare Google Street View with wearable cameras in the investigation of children's exposure to food and beverage marketing in their neighbourhoods. In the meantime, this study has contributed to ongoing developments in research methods using Google Street View for virtual audits of place by identifying issues that exist when using Google Street View to assess detailed levels of obesogenic environments. This small but growing body of research would benefit from ground-truthing specific to the level of outdoor advertising of food and beverages and would complement other validation studies investigating the physical activity built environment (Wilson *et al*., 2012).

Because children are vulnerable to repeated exposure to advertising, it is important to consider the marketing of unhealthy food and beverages to children holistically, including exposure at home, in shops, online, through peer-to-peer networks, and in outdoor environments. Therefore, other future research opportunities exist to evaluate the cumulative effects of marketing to children, to see if removing outdoor advertisements from the environment close to point of purchase influences food purchasing behaviour and consumption. Opportunities also exist to monitor outdoor advertising around schools over time and to consider areas where Google Street View has updated images and where existing versions are available online.

It should also be possible to build upon the results obtained in this study and work by Sainsbury *et al*. (2017), who assessed the nutritional quality of food and beverage products advertised on a metropolitan train network against national healthy eating standards. Because screenshots of all advertisements used in our study have been archived, new research to assess the nutritional quality of outdoor advertisements identified in this study is planned.

Research involving virtual audits of space will also be enhanced as Google Street View adopts 3D and virtual reality (VR) imagery, and Google VR becomes more accessible and covers greater areas (Anguelov *et al*., 2010). It is expected that many of the outdoor advertisements that could not be identified in this study—such as those currently obscured by blocked by cars or those recoded at an odd angle—will be identifiable with 3D and VR technology in Google Earth VR (https://vr.google.com/). At present, coverage by Google Earth VR is not yet wide enough for use in this research context, and other operational issues, such as those preventing users from becoming nauseous, are currently being addressed at Google (Käser *et al*., 2016).

Through new technology, Google Trek (https://www.google.com/maps/about/treks/#/grid) has emerged as a new omnidirectional image capture system that is mounted into a backpack and worn by a person while walking on paths, walkways, and footpaths. Google Trek allows Google Street View to increase its scope of coverage from roads only to those roads, walkways, and footpaths. Like Google VR, coverage is not yet wide enough for use in this research context. At present, Google Trek is used mainly in popular tourist locations such as the Grand Canyon, USA, and Angkor Wat, Cambodia, and it is not clear if Google plans to expand coverage to also include walkways and footpaths in urban areas. Should Google do so, and coverage is greatly increased, new and enhanced opportunities for the use of Google Street View in research will emerge.

Constrained research budgets are becoming increasingly common, and the free availability of Google Street View online is attractive to many researchers and interested lay persons alike. The interface is user-friendly, and many lay persons and researchers are familiar with its basic features and operations. With enhanced image-capture capabilities, the user-friendly, free characteristics of Google Street View make it attractive for use in studies with participatory mapping or citizen science components. Furthermore, grass-roots advocacy is possible with the help of Google Street View. Concerned individuals and community groups are able to access and use Google Street View to document and monitor the obesogenicity of their neighbourhoods. Using a simplified, flexible method to the one employed in this study, lay persons are able to "travel" around their neighbourhoods in Google Street View, use the screenshot function to save and file examples, and then use these images as "evidence" when advocating for their neighbourhoods.

## Conclusion

This research has explored the utility of Google Street View to examine food and beverage advertising around schools in Auckland, New Zealand. Google Street View is a useful virtual audit tool allowing for centralised data collection, ease of characterisation of outdoor advertisements, and a robust, iterative process to ensure accuracy of coding, data collection, and data storage. Challenges include deciphering details of outdoor advertisements when image quality is poor, often due to Google's own privacy settings, and the fact that omnidirectional camera images cannot capture detailed information about advertisements that are blocked or at odd angles to the camera. Nonetheless, as technology develops and image quality capabilities are updated, it is expected that the specificity of data capable of being extracted from Google Street View will be enhanced. In terms of outdoor advertisements and obesogenic environments, the results presented here show that children attending schools selected for this study may be exposed to a greater number of unhealthy food and beverage advertisements than to healthier alternatives.

The future of Google Street View as a tool to conduct virtual audits of place and monitor the obesogenic environment is bright. New research opportunities exist to use Google Street View to monitor obesogenic environments over time and to link findings to policy shifts related to purchasing behaviour and dietary intake. Likewise, technology developments specifically in the field of virtual reality and wearable omnidirectional camera imagery will lead to additional improvements in the quality of Google Street View image capture. It will also advance the scope of areas covered including the potential to use Google Street View in citizen science and participatory mapping research projects as well as grass-roots advocacy for communities wanting to live in health promoting environments. Overall, the research demonstrates the potential for the use of Google Street View in the study of obesogenic environments and associated matters.

## Conflict of interest

The authors declare no conflict of interest.

## Acknowledgements

The authors would like to thank Dylan Harris and Samuel Gomez for their work as research assistants on this study. S. M. was supported by a National Health and Medical Research Council of Australia Early Career Fellowship (grant number 1121035). This study was supported in part by the Health Research Council of New Zealand (grant number 14/436). M. S. is supported by a Health Research Council of New Zealand Sir Charles Hercus Research Fellowship (grant number 17/013).

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