# Measuring Children's Independent Mobility: Comparing Interactive Mapping with Destination Access and Licence to Roam

Julie Bhosale, Scott Duncan, Tom Stewart, Basile Chaix, Yan Kestens, Grant Schofield

10/03/2023

## Working Title:

Measuring children's independent mobility with a mixed method approach: Comparing interactive mapping with destination access and license to roam.

Julie Bhosale, Scott Duncan, Tom Stewart, Basile Chaix, Yan Kestens, Grant Schofield


## Abstract

*Background*

There is currently an absence of a standardised definition and measurement protocol for determining children's independent mobility (IM). The adoption of a mixed methods approach may provide a more comprehensive and reliable assessment technique. To this end, the development of an interactive online mapping application offers the potential to capture geographically-defined mobility data. The aim of this study was to compare children's independent roaming areas collected using VERITAS-IM (an online mapping application) with traditional independent mobility measures.

*Methods*

Independent parental licences (IM Licence) and allowances to go to certain locations in the neighbourhood unsupervised (IM Index) were collected through a questionnaire. Participants then completed a computer assisted personal interview using the VERITAS-IM online mapping application, where they geolocated places they had been independently mobile (either by themselves or with friends, in the absence of an adult) in the previous six months and last seven days. Geospatial data were imported into ArcGIS; novel measures of independent mobility destination (IMD) and boundary (IMB) area and distance were generated and compared to (1) IM Licences (parental permission to travel without adult supervision) and (2) an IM Index (calculated from the summed ranked responses of a location based questionnaire).

*Results*

Data were collected and analysed for 219 children aged 11-13 years. Significant relationships were found between the VERITAS-IM derived measure IM Boundary Area (IMBD Area) and traditional measures of IM (IM Licence and IM Index). A significant difference was found between IMB Area and IMD Area for both 7-days (-1.01 $km^2$) and 6-months (-0.528 $km^2$) as well as between IMB Distance and IMD Distance for 7-days (-0.747 km). No significant difference was found between IMB Distance and IMD Distance for 6-months (-0.194 km).

*Conclusion*

Our data indicate that the perceived degree of independent mobility in children is heavily dependent on the assessment method. The outcomes of this study further highlight the need for a consensus in the definition and measurement of unsupervised mobility in youth. We suggest that combining the VERITAS-IM online mapping application with traditional IM indices in future research could provide

complementary information that leads to a richer understanding of how and why children travel independently.

## Introduction

Children's independent mobility (IM) is defined as the freedom to play and travel in the neighbourhood without adult supervision, either alone or accompanied by peers[1]. The benefits of independent, spatial movement for children's health is well recognised. Children's IM has been associated with increased physical activity[2-4] and improved social interactions[5], cognitive development [6, 7] and self-efficacy [8]. It has been proposed that children who experience restrictions on their ability to roam independently miss opportunities for fundamental physical[4, 9-11] and phsyso-social development[12, 13]. However, there is compelling evidence that children's IM has declined over the last four decades [14-17]. The potential impact of declining IM on children's wellbeing [10] has resulted in a growing body of literature in this area[18].

Investigation into current rates of independent roaming has been conducted in a number of countries. Recent studies have examined children's IM in Canada[4], Belgium [3, 9], Australia [19], Portugal [2] and the United Kingdom[11, 20]. However, comparability between these studies is limited due to disparities in how IM has been defined and measured[3, 18]. Children's IM has previously been determined through self- or proxy-reported parental licences (parental permission for children to go and/or travel to certain places on their own) [4, 9, 11, 14, 19, 21-23], active transport behaviours to and from school [13, 24, 25], photo-voice methodology[26, 27], and portable global positioning system (GPS) receivers [28, 29]. There are strengths and limitations to each of these methods[17] but there is currently no consensus for a standardised measure[18]. Conceptual differences between where children are allowed to roam and where they actually roam further cloud the issue. Accurate, standardised measurement of IM is crucial for collecting longitudinal data, identifying populations at risk of low mobility and to gain an understanding of the associations that inhibit or promote IM[1, 30]. Accordingly, this information is also vital for the development of social and environmental policies, which can impact important planning decisions, including neighbourhood design[1].

It is acknowledged that the determinants of children's IM involve a complex interaction of numerous environmental and psychosocial variables at government, community and individual levels[1, 23]. Moreover, children's natural autonomous roaming in the neighbourhood is often unstructured and includes a range of informal environs not specific to a certain distance or location[1]. One dimensional measurement techniques, such as 'binary' parental licenses (e.g., Do you allow your child to cross main roads by themselves?) or singular maximum distances, do not capture these environs and may not provide the full picture of a child's spatial mobility. Recently, it has been suggested a mixed methods approach to collecting children's IM data is required to provide a multidimensional understanding of how and why children travel independently[18] .

Online mapping has emerged as a potential technique to accurately recall parental licences and independent distances travelled while acquiring more comprehensive information on perceptions, experiences and spaces[31-33]. Research using softGIS mapping techniques in children have yielded encouraging results in this regard[33]. We recently explored IM in New Zealand children aged 11-13 years by measuring the maximum distance travelled independently (IM Maximum) from the home residence via publically-available online mapping software (Google Maps). A positive correlation was found between IM Maximum and a more traditional measure of IM, an index of perceived allowances ($\rho = 0.568$, $P = 0.007$)[17]. This finding highlights the potential of online mapping to provide an accurate, quantifiable measure of children's IM. However, functional limitations in the public mapping software precluded the capture of other potentially influencing variables such as travel mode, companionship, and journey frequency. These have been identified as factors influencing children's IM and could be collected with a custom-designed interactive mapping programme[34].

The Visualisation and Evaluation of Route Itineraries, Travel Destinations, and Activity Spaces (VERITAS) is an advanced online mapping application with the potential to provide comprehensive geographically-defined estimates of IM. Through a computer assisted personal interview (CAPI), VERITAS combines survey questions and electronic maps to help promote recall of allowances and accurately geolocate independent locations, boundaries and mobility spaces[32]. VERITAS was originally developed for a longitudinal study investigating cardiovascular risk factors in relation to neighbourhood characteristics in France (RECORD study)[35]. A recent study has assessed the feasibility of using VERITAS with an adolescent population (12-18 years old)[34]. Given there is consistent evidence to demonstrate that older children are granted greater independent licences[15, 16, 21, 23, 36], trialling VERITAS on a pre-adolescent population is warranted. As the use of online mapping to measure IM is still in its infancy, it is also important to understand the relationship between conventional measures of IM and those derived from VERITAS. The aim of this study was to compare estimates of IM distance and area collected using VERITAS with two traditional IM measures.

# Methodology

## Participants and procedure

All children from four intermediate schools (school years 7-8) in the Auckland region were invited to participate in the study. Schools were purposively selected to obtain participants from a range of socio-demographic and ethnic backgrounds. Two schools had the highest socioeconomic decile rating (10), while the third had a decile rating of 6, and the fourth a decile rating of 3. All children were given an information sheet, a questionnaire, and consent/assent forms to take home. Only children who gave their written assent and had their parent or guardian provide written consent were selected to participate in the study. At a designated time during school hours (between July-November 2013) the children completed a CAPI under supervision of a research assistant. The research assistant explained the protocol of the CAPI, which was completed on a laptop computer running an online mapping programme (VERITAS-IM) and took approximately 20 minutes. Ethical approval for the study protocol was obtained from the AUT Ethics Committee (AUTEC 12/257).

## Instruments

*Questionnaire*

Demographic information including gender, ethnicity, and the number and age of siblings were collected via a questionnaire. Two key measures of children's IM were also collected: IM Licence and IM Index. Parental licence questions (IM Licence) were replicated from those used in earlier studies [14, 21, 22]. Participants were asked if they were allowed to do the following either by themselves or with friends (without an adult): travel to and from school, cross main roads, cycle main roads, catch a bus/train, or go out after dark. Participants were given the option to respond with either yes, no or not sure.

IM Index was derived from a questionnaire used in a previous international study[11] and has been previously trialled in a pilot study[17]. Participants' degree of independent roaming (alone or with friends, without adult supervision) to 12 locations (local shops, big shopping centre, park, sports centre, swimming pool, library, school, cinema, friend's house, other outdoor places [beach, river, bush], bus stop or train station and local streets) was reported. Frequency of allowance to go to these locations was selected from four options; never, sometimes, often or always. In the instance certain locations were not available participants could select an option “I do not go there”. The responses were assigned a ranked (never = 0, sometimes =1, often = 2 and always = 3), summed to give a total value, which was then divided by the number of locations (excluding those of “I do not go there”) to calculate a final IM Index. Neither of the questionnaire-based estimates of IM provides geospatial information.

*VERITAS-IM*

The original VERITAS application (VERITAS-RECORD)[32] was translated from French to English and customised specifically to investigate children’s IM (VERITAS-IM). A series of eight key questions were populated within the interactive maps, which harnesses embedded Google Maps functionality. Initially, participants located their primary home residence which forms a central location point for the remaining interactive mapping questions (1). Participants were then guided to geolocate places where they had been independently mobile (either by themselves or with friends, in the absence of an adult) in the previous six months (2). For each location information on transport mode, frequency and companionship was also collected. Participants then identified which locations were visited in the last seven days (3). Data on locations for organised sport (4), locations participants desired to be independently mobile (5), and the transport route to (6) and from school (7) were then collected. The final question asked participants to draw a polygon shape around their maximum perceived IM area; the area around their home where they can be independently mobile (8). All data were saved to a secure server at the completion of the survey.

*Creation of VERITAS-IM Measures*

VERITAS map and questionnaire data were downloaded from our server and imported into ArcGIS 10.1 (ESRI, Redlands, CA, USA) before being visually inspected for any errors. The VERITAS data were used to create six distinct measures of IM in ArcGIS displayed in Figure 1; IM Boundary Defined Area, IM Boundary Defined Distance, IM Destination Defined Area (6-Months and 7-Days) and IM Destination Defined Distance (6-Months and 7-Days).

IM Boundary Area (IMB Area) was calculated as the area inside the perceived IM boundary polygon. IM Boundary Distance (IMB Distance) was calculated as the Euclidean distance (i.e. as the crow flies) from the home residence to the furthest point in the perceived IM boundary polygon. IM Destination Area was calculated using convex hull geometry techniques, whereby all locations identified by participants as being travelled to independently during the last 6-Months (IMD Area 6-Months) and 7-Days (IMD Area 7-Days) were enclosed in the smallest possible convex polygon, respectively. IM Destination Distance was calculated as the Euclidean distance from the home residence to the furthest identified location travelled to independently in the last 6-Months (IMD Distance 6-Months) and 7-Days (IMD Distance 7-Days). If the participant did not travel anywhere, they received a zero (i.e. the boundary of their residence was not included).

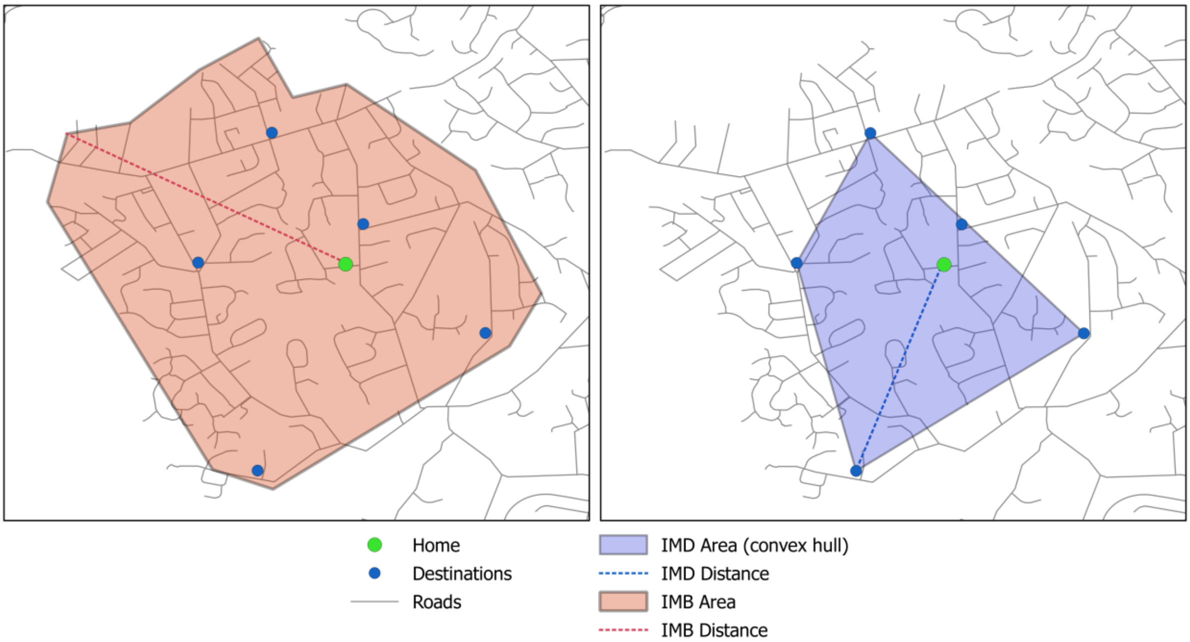


Figure 1. VERITAS-derived measures of IM

## Data Analysis

Observation of the descriptive statistics revealed that none of the IM variables were normally distributed, and subsequently non-parametric techniques were used throughout the analyses. IM Index was compared with IMB Area and IMB Distance using Spearman's rank order correlation and linear regression. Differences in IMB Area/Distance by IM License were assessed using Mann-Whitney U tests. Differences between IMB Area/Distance and IMD Area/Distance (both 7-days and 6-months) were quantified by calculating the median percent difference and 95% limits of agreement. A negative percent difference indicates IMD underestimation of the IMB median values, while a positive percent difference indicates overestimation. The consistency of percent difference across the spectrum of Area/Distance estimates was investigated using Spearman's rank order correlation. Statistical significance was set at $p < .05$, and all analyses were conducted using IBM SPSS Statistics (V. 20).

## Results

A total of 219 children (113 male and 106 female) aged 11-13 (age calculated from year of birth as at December 2013) agreed to participate in this study. The majority of participants were of European decent (n=161, 74%), Maori/Pacific Island (n=21, 10%), Asian (n=16, 7%), and other (n=7, 3%); 6% was not specified. Number of siblings ranged from 0-6 siblings, mean 1.9 (SD=1.3).

A significant correlation was observed between IM Index and IMB Area ($\rho = 0.462$, $P < 0.001$) and between IM Index and IMB Distance ($\rho = 0.409$, $P < 0.001$). Subsequent regression analysis revealed a significant linear trend between IM Index and IMB Area (IMB Area = 3.95 x IM Index - 0.98, $R^2 = 0.10$, $P < 0.001$) and between IM Index and IMB Distance (IMB Distance = 0.99 x IM Index - 0.70, $R^2 = 0.12$, $P < 0.001$). In other words, the IMB Area increased by nearly 4 $km^2$ with every one unit increase in IM Index, whereas IMB Distance increased by 1 km across the same change in IM Index; however, only 10% and 12% of the variance in IMB Area and IMB Distance was explained by IM Index, respectively. IN addition, IMD Area estimates showed that 26.0% of children did not independently travel to any destinations in the 7-day period, with 7.8% not independently travelling in the 6-month period.

Table 1 shows the median IMB Area grouped according to the six parental IM Licences. The majority of participants were permitted to travel to and from school, cross main roads, and travel on buses/trains unsupervised (69-88%). Few participants were permitted to cycle main roads or be out after dark unsupervised (17-46%). There was a clear link between all licenses and perceived IMB Area (with the exception of the out after dark licence), such that the presence of a parental IM restriction was associated with a significantly smaller IMB Area (difference range: 1.26 to 1.52 $km^2$). The median IMB Area ranged from 1.46 to 2.45 $km^2$ in participants who were permitted to travel unsupervised in the six selected contexts, and from 0.12 to 0.43 $km^2$ in participants who were not.

**Table 1.** Median IM Boundary Area (IMB Area) grouped by IM Licenses.

| Licence | | IMB Area ($km^2$) | | | |
|---|---|---|---|---|---|
| | | **N** | **Median** | **IQR** | **Min, Max** |
| Allowed to travel to school unsupervised | Yes | 180 | 1.46 | 0.38, 5.04 | 0, 75.8 |
| | No | 32 | 0.18* | 0.02, 1.19 | 0, 30.8 |
| Allowed to travel from school unsupervised | Yes | 187 | 1.49 | 0.38, 5.12 | 0, 75.8 |
| | No | 25 | 0.12* | 0.02, 0.80 | 0, 6.1 |
| Allowed to cross main roads unsupervised | Yes | 180 | 1.48 | 0.38, 5.16 | 0, 15.8 |
| | No | 28 | 0.22* | 0.06, 2.19 | 0, 30.9 |
| Allowed to cycle main roads unsupervised | Yes | 83 | 2.45 | 0.72, 7.65 | 0, 67.6 |
| | No | 96 | 0.43* | 0.10, 2.26 | 0, 75.8 |
| Allowed to travel on buses/trains unsupervised | Yes | 129 | 1.91 | 0.48, 7.43 | 0, 75.8 |
| | No | 59 | 0.39* | 0.11, 1.64 | 0, 7.9 |
| Allowed to be out after dark unsupervised | Yes | 31 | 2.45 | 0.38, 5.22 | 0, 59.7 |
| | No | 149 | 0.8 | 0.20, 3.60 | 0, 75.8 |

*Significantly different from 'Yes' ($P < 0.05$).

Table 2 shows the median IMB Distance grouped according to the six parental IM Licences. Excluding the licence to go out after dark, there was a distinct relationship between all licenses and IMB Distance. The presence of a parental IM restriction was associated with a significantly smaller IMB Distance (difference range: 0.86 to 1.16 km). The median IMB Distance ranged from 1.68 to 2.15 $km^2$ in participants who were permitted to travel unsupervised in the six selected contexts, and from 0.57 to 1.36 $km^2$ in participants who were not.

Table 2. IM Boundary Distance (IMB Distance) ground by IM Licences

| **Licence** | | IMB Distance (km) | | | |
|---|---|---|---|---|---|
| | | **N** | **Median** | **IQR** | **Min, Max** |
| Allowed to travel to school unsupervised | Yes | 180 | 1.68 | 0.86, 2.81 | 0.01, 16.52 |
| | No | 32 | 0.77* | 0.43, 1.77 | 0.03, 9.81 |
| Allowed to travel from school unsupervised | Yes | 187 | 1.72 | 0.89, 2.90 | 0.01, 16.52 |
| | No | 25 | 0.57* | 0.27, 1.61 | 0.03, 3.27 |
| Allowed to cross main roads unsupervised | Yes | 180 | 1.68 | 0.86, 3.07 | 0.02, 16.52 |
| | No | 28 | 0.85* | 0.47, 1.78 | 0.03, 10.47 |
| Allowed to cycle main roads unsupervised | Yes | 83 | 2.15 | 1.12, 3.89 | 0.02, 16.52 |
| | No | 96 | 0.99* | 0.48, 1.92 | 0.03, 10.83 |
| Allowed to travel on buses/trains unsupervised | Yes | 129 | 2.02 | 1.07, 3.63 | 0.02, 16.52 |
| | No | 59 | 0.91* | 0.47, 1.78 | 0.03, 3.89 |
| Allowed to be out after dark unsupervised | Yes | 31 | 1.84 | 0.89, 2.95 | 0.02, 16.52 |
| | No | 149 | 1.36 | 0.64, 2.40 | 0.03, 11.53 |

* Significantly different from 'Yes' ($P < 0.05$).

Comparisons between IMB Area, IMD Area 6-Months, and IMD Area 7-Days are presented in Table 3. Area values calculated using recalled destinations (IMD) were significantly lower than boundary area estimates (IMB). On average, IMD Area underestimated IMB Area by 100% (7-day method) and 88% (6-month method), with differences in the two methods noticeably greater for males than for females. Furthermore, the degree of underestimation was consistent across the distribution of IMB Area values. Similar results were observed between IMB Distance and IMD Distance when the latter was determined over seven days, with a median underestimation of 67% (Table 4). In contrast, the two methods were more equivalent when IMD was determined over six months; in fact, the percent difference was significantly different from zero in males only.

**Table 3.** IM Area

| | N | IMB Area (Median, IQR) | IMD Area (Median, IQR) | Difference in area[A] (Median, IQR) | ρ IMB, IMD[B] | Median difference[C] (%) | P[D] | ρ IMB, %diff[E] | 95% LOA[F] (%) |
|---|---|---|---|---|---|---|---|---|---|
| 7-days | | | | | | | | | |
| Male | 113 | 2.08 (0.404, 5.88) | 0.002 (0.000, 0.134) | -1.82 (-5.57, -0.359) | 0.363* | -99.9 | 0.000 | 0.036 | -100, 104 |
| Female | 106 | 0.639 (0.180, 2.46) | 0.001 (0.000, 0.021) | -0.529 (-2.05, -0.155) | 0.437* | -99.9 | 0.000 | 0.074 | -100, 249 |
| All | 219 | 1.26 (0.304, 4.53) | 0.002 (0.000, 0.081) | -1.01 (-4.38, -0.192) | 0.414* | -99.9 | 0.000 | 0.064 | -100, 155 |
| 6-months | | | | | | | | | |
| Male | 113 | 2.08 (0.404, 5.88) | 0.254 (0.003, 2.22) | -1.30 (-3.92, -0.095) | 0.546* | -88.9 | 0.000 | 0.100 | -100, 2740 |
| Female | 106 | 0.639 (0.180, 2.46) | 0.121 (0.001, 0.874) | -0.212 (-1.44, -0.003) | 0.660* | -86.2 | 0.000 | 0.185 | -100, 1340 |
| All | 219 | 1.26 (0.304, 4.53) | 0.160 (0.002, 1.49) | -0.528 (-2.68, -0.038) | 0.595* | -87.9 | 0.000 | 0.112 | -100, 2370 |

[A] Difference in area = IMD Area - IMB Area

[B] Spearman's rank correlation coefficient for IMD Area and IMB Area; *P < 0.05

[C] Percent difference = (Difference in area / IMB Area) x 100

[D] Probability that median percent difference = 0 (One-Sample Wilcoxon Signed Rank Test)

[E] Correlation coefficient between the IMB Area and the percent difference

[F] 95% limits of agreement = median percent difference +/- 2.5$^{th}$ and 97.5$^{th}$ percentiles

**Table 4.** IM Distance

| | N | IMB Distance (Median, IQR) | IMD Distance (Median, IQR) | Difference in distance[A] (Median, IQR) | ρ IMB, IMD[B] | Median difference[C] (%) | P[D] | ρ IMB, %diff[E] | 95% LOA[F] (%) |
|---|---|---|---|---|---|---|---|---|---|
| 7-days | | | | | | | | | |
| Male | 113 | 1.88 (0.950, 3.24) | 0.536 (0.000, 1.49) | -0.959 (-2.14, -0.230) | 0.324* | -67.7 | 0.000 | -0.024 | -100, 507 |
| Female | 106 | 1.20 (0.606, 2.15) | 0.0523 (0.000, 1.34) | -0.488 (-1.34, -0.063) | 0.396* | -63.4 | 0.000 | 0.084 | -100, 868 |
| All | 219 | 1.57 (0.734, 2.72) | 0.531 (0.000, 1.41) | -0.747 (-1.77, -0.135) | 0.363* | -67.3 | 0.000 | 0.027 | -100, 622 |
| 6-months | | | | | | | | | |
| Male | 113 | 1.88 (0.950, 3.24) | 1.49 (0.562, 3.68) | -0.244 (-1.14, 0.166) | 0.491* | 20.9 | 0.026 | 0.123 | -1310, 100 |
| Female | 106 | 1.20 (0.606, 2.15) | 1.30 (0.434, 3.92) | -0.136 (-0.564, 1.23) | 0.587* | 14.7 | 0.747 | 0.031 | -1080, 100 |
| All | 219 | 1.57 (0.734, 2.72) | 1.34 (0.473, 3.79) | -0.194 (-0.747, 0.565) | 0.526* | 19.0 | 0.199 | 0.095 | -1050, 100 |

[A] Difference in distance = IMD Distance - IMB Distance

[B] Spearman's rank correlation coefficient for IMD Distance and IMB Distance; *$P < 0.05$

[C] Percent difference = (Difference in distance / IMB Distance) x 100

[D] Probability that median percent difference = 0 (One-Sample Wilcoxon Signed Rank Test)

[E] Correlation coefficient between the IMB Distance and the percent difference

[F] 95% limits of agreement = median percent difference +/- $2.5^{th}$ and $97.5^{th}$ percentiles

## Discussion

Children's freedom to play and roam in their neighbourhood without adult supervision continues to decline, which may have a significant impact on their physical and psycho-social health[18]. Presently, a comprehensive understanding of children's IM is hindered by the lack of a standardised measure which takes into account the complex nature of a child's mobility. In the search for the 'ideal' IM definition, online mapping software has been developed to allow children to explicitly pinpoint where they can and cannot travel independently. The novelty of this study was the use of an innovative online mapping application, VERITAS-IM. Previously explored for use in an adolescent population[34], VERITAS-IM combined survey questionnaires with independent distances and areas to quantify IM in children aged 11-13 years old. In addition, the measures derived from VERITAS-IM enabled comparison between destination based IM (i.e. identifiable locations participants independently roam to) both acutely (7-Days) and chronically (6-Months) with boundary based IM distance and area (i.e. where participants perceive they are allowed to go). Despite the clear advantages of such a thorough process over conventional questionnaire-based estimates of IM, it is important in the first instance to understand how, if at all, these various measures relate to each other.

Our initial comparison between VERITAS-IM-derived measures and IM Index in the present dataset revealed some notable similarities. This indicates that the quantifiable measures derived from the VERITAS-IM online mapping application are, to a degree, positively related to a more spatial measure of IM (IM Index). A similar correlation was found in our previous pilot study comparing IM Index with an IM measure derived from Google Maps[17]. Clearly children who are granted more permissions to go to certain places independently experience a greater perception of overall independent roaming area and distance. The IM Index is survey-based and therefore offers a cost-effective measure suitable for population-based studies and longitudinal research; however, the VERITAS application has an increased capacity to measure children's sense of space and distance beyond specified locations. In addition, contrary to other simple tools, VERITAS-IM, allows the geolocate of children's roaming area of children, and therefore it could potentially be used in combination with GIS data to see how IM licences translate to different areas taking into account built environment variables. Furthermore, the amalgamation of VERITAS-IM with GPS as a prompting tool could provide a more objective IM measure.

The use of parental IM licences as a proxy estimate of children's IM has been popular in previous research [14, 21, 22]. The IM licences employed in this study were based on two landmark English studies [14, 21] and a previous New Zealand study[22]. Our findings indicate that children who had more liberal parental allowances (IM Licences) had a substantially larger perceived IM area (IMBD Area). Conversely, children who had had parental restrictions placed on their movement (with the exception of going out after dark) had significantly smaller perceived roaming areas. These results provide the first quantitative evidence that children with greater parental freedoms experience a significant and meaningful increase in their perceived IM area, which likely translates to an increased physical roaming distance. Given the historical popularity of IM licences, the relationship between this methodology with an online mapping application is important to enable comparability between studies. As with the IM Index, parental licences represent a straightforward measurement technique feasible in large samples. They are also able to overcome the challenges faced when using online mapping procedures in intergenerational comparisons, as the online map may not accurately represent the historical landscapes when adults were children. Despite these advantages, IM licences are still essentially a one dimensional measure of IM and fail to capture variables which may inhibit or promote children's IM. The online mapping application VERITAS-IM is promising in this regard as we can go beyond traditional measures that only provide a sense of how much children are allowed to roam independently by actually mapping both perceived extent of permitted areas and actual destinations.

Our results also indicated that destination based estimates of IM area and distance were significantly lower than boundary based estimates. Given that children's IM is not always destination driven, it is possible that this deviation is a reflection of children's tendency to roam independently without a specified end destination. The perceived IM boundary area that participants identified would therefore encompass areas which no destination markers. In addition, the difference between IMB and IMD estimates was significantly greater for males than it was for females. It is possible that this is a reflection of the substantial evidence that boys are permitted to roam further than girls [15, 21, 22, 37, 38]; subsequently, boys may wander unsupervised to unspecified locations more so than girls. There was very little difference between boundary-based distance and destination-based distance when assessed over six months, which may suggest that children only roam to their maximum IM boundary occasionally (i.e., once or twice in six months).

Given the novelty of the VERITAS-IM measures, this study holds important methodological implications for the field of children's IM. The use of an online mapping application which encapsulates children's unstructured, independent roaming in the neighbourhood as well as travel mode and companionship data, allows for more comprehensive evidence to be collected and may offer a standardised IM measurement technique[18]. In addition, the development of a measurement technique which can quantify maximum independent roaming distances, locations and boundaries has the potential to significantly further current understanding of the changes in children's unsupervised roaming. Moreover, it is widely acknowledged that children and youth can have difficulties accurately recalling information, which may decrease the reliability and validity of a questionnaire[39, 40]. The interactive nature of the mapping process is likely to have helped facilitate children's recall of local destinations, parental licences and their perceived boundaries. This aligns with the findings of a previous study using a similar version of VERITAS with adolescents[34]. Furthermore, previous studies have identified the importance of exploring children's perspectives in IM[27]. It was found that the use of a CAPI enabled collaboration between the researchers and child, allowing them to describe their experiences while being visually prompted by the map. The importance of offering children opportunities to explain their experiences in a number of mediums has been previously highlighted and can help to assist their recall[17, 27].

Although there are potential benefits to using an online mapping application to measure children's IM, research in this area is still in its infancy. It is important to note that the data collected through this methodology are still essentially self-reported information. One of the major limitations of the VERITAS-IM mapping application was that each question required a marker to be placed on the map. This may have implied that something was required to be marked at each question. In the instance that a participant did not need a marker placed on the map (for example there were no locations they were allowed to go unsupervised) a marker was placed on the home location. Another potential limitation regarding the destination measurements is that the calculated area may have included areas that children could not access, such as oceans. In addition, given the need for a CAPI, investigations with youth using VERITAS-IM or a similar online mapping application may require more time and resource than traditional questionnaire-based methods, and would be more appropriate for small- to medium-sized samples.

## Conclusion

In summary, significant similarities between the online mapping application VERITAS-IM and traditional measures of IM were found. The development of a novel IM measure which captures geographically defined data has important methodological implications. There still remains an absence of a standardised IM measure with contingent differences in how IM is defined. Given the complex nature of children's autonomous movement, a mixed method approach combining interactive mapping software with traditional measures in future investigations may significantly help to further understanding in this area.

## References

1. Badland, H., et al., *Development of a system models to visualise the complexity of children's independent mobility.* Children's Geographies, 2015: p. 1-10.
2. Marquez, E., et al., *Independent Mobility and its relationship with moderate-to-vigorous physical activity in middle-school portuguese boys and girls.* Journal of Phyical Activity and Health, 2014. 11: p. 1640-1643.
3. De Meester, F., et al., *Parental perceived neighborhood attributes: associations with active transport and physical activity among 10–12 year old children and the mediating role of independent mobility.* 2014.
4. Stone, M., et al., *The freedom to explore: examining the influence of independent mobility on weekday, weekend and after-school physical activity behaviour in children living in urban and inner-suburban neighbourhoods of varying socioeconomic status.* International Journal of Behavioral Nutrition and Physical Activity, 2014. 11(5).
5. Brown, S., ed. *Play: How It Shapes the Brain, Opens the Imagination, and Invigorates the Soul*. 2009, Avery Publishing Group: New York.
6. Burdette, H., *Resurrecting free play in young children: Looking beyond fitness and fatness to attention, affiliation and affect.* Archives of Pediatrics Adolescent Medicine, 2005. 159: p. 46-50.
7. Tamis-LeMonda, C., et al., *Fathers and mothers at play with their 2- and 3- year olds: contributions to language and cognitive development.* Child Development, 2004. 75: p. 1806-1820.
8. Bunker, L., *The role of play and motor skill development in building chilren's self-confidence and self-esteem.* The Elementary School Journal, 1991. 91(5): p. 467-471.
9. Ducheyne, F., et al., *Individual, social and physical environmental correlates of 'never' and 'always' cycling to school among 10 to 12 year old children living within a 3.0 km distance from school.* International Journal of Behavioral Nutrition and Physical Activity, 2012. 9(142).
10. Brockman, R., R. Jago, and K. Fox, *The contribution of active play to the physical activity of primary school children.* Preventative Medicine, 2010. 51(2): p. 144-147.
11. Page, A., et al., *Independent mobility in relation to weekday and weekend physical activity in children aged 10-11 years: The PEACH Project.* International Journal of Behavioral Nutrition and Physical Activity, 2009. 6(2).
12. Gill, T., *No Fear: Growing up in a risk averse society*. 2007, London: Calouste Gulbenkian Foundation.
13. Mackett, R., et al., *Children's local travel behaviour - how the environment influences, controls and facilitates it.* CAPLE Project 2007.
14. Shaw, B., et al., *Children's Independent Mobility: a comparative study in England and Germany (1971-2010)*. 2013, Policy Studies Institute: London.

15. O'Brien, M., et al., *Children's independent spatial mobility in the urban public realm.* Childhood, 2000. 7(3): p. 257-277.
16. Fyhri, A., et al., *Children's active travel and independent mobility in four countries: Development, social contributing trends and measures.* Transport Policy, 2011. 18: p. 703-710.
17. Bhosale, J., et al., *A pilot study exploring the measurement of intergenerational differences in independent mobility.* Journal of Transport & Health, 2015.
18. Bates, B. and M. Stone, *Measures of outdoor play and independent mobility in children and youth: A methodological review.* Journal of Science and Medicine in Sport, 2014 (0).
19. Veitch, J., et al., *Are independent mobility and territorial range associated with park visitation among youth?* International Journal of Behavioral Nutrition and Physical Activity, 2014. 11(73).
20. Carver, A., et al., *Independent mobility on the journey to school: A joint cross-sectional and prospective exploration of social and physical environmental influences.* Journal of Transport & Health, 2014. 1(1): p. 25-32.
21. Hillman, M., J. Adams, and J. Whitelegg, eds. *One false move...a study of children's independent mobility*. 1990, Policy Studies Institute Publishing: London.
22. Tranter, P. and E. Pawson, *Children's access to local environments: a case-study of Christchurch, New Zealand.* Local Environment, 2001. 6(1): p. 27-48.
23. Pacilli, M., et al., *Children and the public realm: antecedents and consequences of independent mobility in a group of 11–13-year-old Italian children.* Children's Geographies, 2013. 11(4): p. 377-393.
24. Yang, X., et al., *Active commuting from youth to adulthood and as a predictor of physical activity in early midlife: The Young Finns Study.* Preventive Medicine, 2014. 59: p. 5-11.
25. Schoeppe, S., et al., *Associations between children's independent mobility and physical activity.* BMC Public Health, 2014. 14(91).
26. Hume, C., J. Salmon, and K. Ball, *Children's perceptions of their home and neighborhood enviornments, and their association with objectively measured physical activity: a qualitative and quantitative study.* Health Education Research: Theory & Practice, 2005. 20(1): p. 1-13.
27. Mitchell, H., R. Kearns, and D. Collins, *Nuances of neighbourhood: children's perceptions of the space between home and school in Auckland, New Zealand.* Geoforum, 2007. 38: p. 614-627.
28. Mavoa, S., et al., *Linking GPS and travel diary data using sequence alignment in a study of children's independent mobility.* International Journal of Health Geographics, 2011. 10(64).
29. Christensen, P., et al., *Children, mobility and space: using GPS and Mobile Phone Technologies in Ethnographic Research.* Journal of Mixed Methods Research, 2011: p. 1-20.
30. Oliver, M., et al., *Combining GPS, GIS and accelerometry: methodological issues in the assessment of location and intensity of travel behaviours.* Journal of Physical Activity and Health, 2010. 7(1): p. 102-108.
31. Freeman, C. and R. Quigg, *Commuting lives: children's mobility and energy use.* Journal of Environmental Planning and Management, 2009. 52(3): p. 393-412.
32. Chaix, B., et al., *An interactive mapping tool to assess individual mobility patterns in neighborhood studies.* American Journal of Preventive Medicine, 2012. 43(4): p. 440-450.
33. Kyttä, M., A. Broberg, and M. Kahila, *Urban environment and children's active lifestyle: softGIS revealing children's behavioral patterns and meaningful places.* American Journal of Health Promotion, 2012. 26(5): p. e137-e148.
34. Stewart, T., et al., *A novel assessment of adolescent mobility: a pilot study.* International Journal of Behavioral Nutrition and Physical Activity, 2015. 12(18).
35. Chaix, B., et al., *Cohort profile: residential and non-residential environments, individual activity spaces and cardiovasular risk factors and diseases - The RECORD Cohort study.* International Journal of Epidemiology, 2011.

36. Timperio, A., et al., *Personal, family, social and environmental correlates of active commuting to school.* American Journal of Preventative Medicine, 2004. 30(1): p. 45-51.
37. Kytta, M., *The extent of children's independent mobility and the number of actualised affordances as criteria for child-friendly environments.* Journal of Environmental Psychology, 2004. 24: p. 179-198.
38. Badland, H., et al., *Measuring children's independent mobility: comparing objective and self report approaches.* Children's Geographies, 2011. 9(2): p. 263-271.
39. Helmerhorst, H., et al., *A systematic review of reliability and objective criterion-related validity of physical activity questionnaires.* Int J Behav Nutr Phys Act, 2012. 9: p. 103.
40. Sallis, J. and B. Saelens, *Assessment of physical activity by self-report: status, limitations and future directions.* Research Quarterly for Exercise and Sport, 2000. 71(2): p. 1-14.