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Preschool children’s physical activity in the home, childcare and neighbourhood environment: A latent profile analysis using device-based measures

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ABSTRACT
Based on the socioecological conceptual model, the physical environment within the home, childcare and neighbourhood domains are key factors that influence preschool children’s physical activity; however, the relative importance of each of these domains for preschool children’s physical activity is unclear. We explored the physical environment characteristics within three latent profiles of 115 preschool children aged 2–5 years based on where they accumulated moderate-to-vigorous physical activity (MVPA) across five GPS-derived environmental domains. The three profiles were “Active at home” (n = 41), “Active except close to home” (n = 61), and “Active except in local neighbourhood” (n = 13). Compared to other profiles, “Active at home” had fewer parks and playgrounds within their 500–1600 m neighbourhood. Findings suggest preschool children’s MVPA profiles are reflections of their physical environmental opportunities.

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KEYWORDS
Latent groups; preschoolers; active play; physical environment; device measured

Introduction
Physical activity is important for preschool children, as it reduces the risk of obesity and promotes good physical and mental health as well as development (Steinbeck, 2001). The World Health Organisation and countries including Canada and Australia have released 24-hour Movement Guidelines for the Early Years, which recommend children aged 3–5 years engage in at least 180 minutes of physical activity each day, including at least 60 minutes of energetic play (moderate to vigorous physical activity) (Australian Government Department of Health, 2018; Draper et al., 2020; Tremblay et al., 2017; World Health Organization, 2019). However, many preschool children do not meet the recommended amount of daily physical activity (Chaput et al., 2017; Christian et al., 2018; Vale & Mota, 2020). The Australian 2022 report card on physical activity for children and young people reported that only about one-quarter of children and young people (i.e., 0–18 year-olds) meet physical activity guidelines (Hesketh et al., 2023). In a large Western Australian study of 1596 preschool children aged 2–5 years old, only 34% met the recommended 180 minutes of physical activity per day (as measured by accelerometry). To ensure more preschool children meet physical activity guidelines, it is important to understand the factors that influence their physical activity behaviour.

The socioecological framework highlights that preschool children’s physical activity is influenced by individual, social, physical and policy environmental factors (Glanz et al., 2008). Reviews show that the physical environment influences preschool children’s physical activity in various ways and across different domains (e.g., home, childcare, neighbourhood) (Bingham et al., 2016; Terrón-Pérez et al., 2021). For example, within the home domain, physical environment factors such as yard size and the number of fixed and portable play equipment within the backyard are positively associated with preschool children’s physical activity (Armstrong et al., 2019). Similarly, within the childcare domain, portable and fixed play equipment and the size and use of outdoor space are positively associated with preschool children’s physical activity (Smith et al., 2016; Sugiyama et al., 2012; Tonge et al., 2016). Within the broader neighbourhood environment vegetation, parks and playgrounds are positively associated with preschool children’s physical activity (Benjamin-Neelon et al., 2019; Grigsby-Toussaint et al., 2011; Slater et al., 2016) however, mixed findings have been reported on the availability of recreational facilities and preschool children’s physical activity (Carson et al., 2014; Lu et al., 2019; Veitch et al., 2012). While the evidence to date highlights that the home, childcare and the neighbourhood environment are each important domains for young children’s physical activity, the relative importance of each of these domains for young children’s physical activity is unclear.

When exploring the influence of multiple environmental domains on preschool children’s physical activity, it is important to take hidden latent factors (i.e., variables that are difficult to measure directly) into consideration. Latent profile analysis is an appropriate approach to better understand profiles of preschool children and their environmental attributes. Latent profile analysis is a latent variable modelling analysis that identifies latent (i.e., underlying, undefined) subgroups of individuals
within a population (Vermunt & Magidson, 2004). The underlying assumption of latent profile analysis is that membership in unobserved profiles can be a causal or explanatory factor for the observed patterns of behaviour or scores across assessment indicators (Weller et al., 2020). Latent profile analysis thus assumes that individuals can be classified with varying degrees of probabilities into categories characterised by distinct profiles of personal and/or environmental attributes (Collins & Lanza, 2009; Spurk et al., 2020). Latent profile analysis has been used to study a variety of issues and populations, such as physical activity participation in medical students (McFadden et al., 2021) and GIS-measured walkability, transit, and recreation environments in relation to older adults’ physical activity (Todd et al., 2016). This multivariate approach is suitable for identifying the underlying characteristics and factors associated with common physical activity patterns across different physical environment domains (i.e., home, childcare and neighbourhood) and classifying each individual preschool child into a latent group based on where they engage in physical activity. By understanding the profiles of where preschool children accumulate physical activity across different environmental domains, we can determine the underlying physical environment attributes that facilitate or hinder preschool children’s physical activity.

Data from device-based measures such as accelerometry and Global Positioning System (GPS) data can provide objective location-based physical activity data to better understand where young children are physically active across different environmental domains. However, to our knowledge only a handful of studies have used device-based physical activity measures combined with GPS or Geographic Information Systems (GIS) data to explore the relationship between the different physical environments and preschool children’s physical activity (Benjamin-Neelon et al., 2019; Lovasi et al., 2011). For example, Benjamin-Neelon et al. (2019) used device-based measures of physical activity and found that greater time in green space was associated with more physical activity in preschool children. Lovasi et al., (2011) also used device-based measures of physical activity to explore urban social and built environment correlates of preschool children’s physical activity, and found that mixed land use, street trees and parks were positively associated with greater mean activity counts. However, neither of these studies used device-measured “location-specific” physical activity (i.e., combined accelerometry and Global Positioning Systems (GPS)) data to explore the attributes of different physical environment domains (i.e., home, childcare and neighbourhood) influencing preschool children’s physical activity. This evidence gap requires addressing to provide objective information on the relative contribution of different physical environment domains on preschool children’s physical activity.

Understanding where preschool children accumulate physical activity in different physical environment domains is a key evidence gap. Device-based measures of preschool children’s physical activity behaviour and location as well as the physical environmental attributes of those locations is required to address this evidence gap. Moreover, a latent profile approach provides a way to identify the underlying characteristics associated with common physical activity patterns across different physical environment domains. Thus, the aim of this study was to investigate the profiles of preschool children based on which environmental domains they accumulate moderate to vigorous physical activity (MVPA), and to explore the underlying characteristics and attributes of the physical environmental features within each profile.

**Methods**

**Study sample**

This study was a part of the larger Play Space & Environments for Children’s Physical Activity (PLAYCE) Study (Christian et al., 2016). The PLAYCE baseline study was a large cross-sectional observational study based in metropolitan Perth, Western Australia, investigating the environmental, social and parental influences on preschool children’s physical activity behaviour in the Early Childhood Education and Care (childcare) centre, home and neighbourhood domains (Christian et al., 2016, 2018). The protocols and methods of the PLAYCE study have been published (Christian et al., 2016). A tiered recruitment process was used, where childcare centres were recruited and then parents approached. Ethics approval was granted by The University of Western Australia Human Research Ethics Committee (#RA/4/1/7417 and 2020/ET000353).

From the PLAYCE study sample of 1596 preschool children from 104 childcare centres, 30 childcare centres were randomly selected to be included in the current sub-study. Of these 30 ECCE centres, 11 were classified as low socio-economic status (SES), 11 as medium SES and eight as high SES centres. Recruitment of children was not equal across centres (range 3–15 children per centre). A total of 385 preschool children aged 2–5 years were recruited from these 30 childcare centres. Data on the child’s physical activity, location of physical activity, as well as child and parent sociodemographic information were collected once per participant between February 2016 and November 2017.

**Measurements**

**Sociodemographic factors**

Child and parent sociodemographic information including residential (home) address, child age and sex as well as parent age and sex were collected via the PLAYCE parent survey (Christian et al., 2016). Home and childcare SES was determined by the Australian Bureau of Statistics Socio-Economic Index For Areas (SEIFA) using the child’s residential suburb and childcare suburb (Australian Bureau of Statistics, 2008). The decile ranking score was split into tertiles and classified as low SES, medium SES and high SES. The SEIFA is statistically reliable as a socioeconomic indicator (King, 2001).

**Preschool children’s MVPA**

Device-measured physical activity data were collected via the ActiGraph GT3X+ accelerometer-based motion sensor (ActiGraph Corporation, Pensacola FL) over seven consecutive days. This device has moderate-to-strong validity for measuring preschool children’s physical activity behaviour (Pate et al., 2010). Daily time spent in MVPA was determined using
established cut-points developed by Pate et al. (>420 counts/15 seconds for MVPA) (Pate et al., 2006, 2010). Fifteen seconds epochs were used to accommodate the typical physical activity behaviour in preschool children. Intervals with more than 20 consecutive minutes of zero counts were defined as non-wear time and removed from analyses (Christian et al., 2016).

**Locations and amount of preschool children’s MVPA**

Preschool children also wore the Qstarz Q-1000XT GPS devices (Qstarz International Co., Ltd, 2009) over the same seven-day period. GPS devices were configured to capture the location data every 15 seconds. This device has a median dynamic accuracy of 2.9 metres under varying environmental conditions (Schipperijn et al., 2014). GPS data were merged with accelerometer data to determine the locations where preschool children did MVPA.

The GPS-derived locations of where preschool children accumulated MVPA were classified into five environmental domains: 1) home, 2) childcare, 3) <500 m from home, 4) 500–1600 m from home, and 5) >1600 m from home. The home and childcare domains were classified by geocoding the child’s home and childcare address in the Geographic Information System (GIS) software programme ArcGIS Pro. A polygon with a 10-m buffer was created around the cadastral parcels of each geocoded home and childcare centre address. By creating a 10 metre buffer around the home and childcare parcel polygons, any potential discrepancies in the GPS location data were accounted for. The 500 m, 500–1600 m and the >1600 m from home domains were classified by using three separate road network buffer zones defined in GIS using each participant’s home as the central polygon. The area outside the home parcel (and the 10-m buffer) and up to 500-m buffer around each home was labelled the “<500 m from home” domain. The 500–1600 m metre buffer around each home was labelled the “500–1600 m from home” domain. Areas further than 1600 metres from a child’s home were labelled as the “>1600 m from home” domain. Since preschool children’s travel is dependent on their parents, these buffers were chosen as they represent a short walking distance (500 m is equivalent to a 10-minute walking distance), a long walking distance (1600 m is equivalent to a 30-minute walking distance) (Bohannon & Andrews, 2011) and car-based travel (>1600 m). Distances greater than 1600 m from home reflect places outside the neighbourhood and typically require travel via a motor vehicle.

Preschool children’s minutes of MVPA in each environmental domain were identified using a PostgreSQL database. Mean minutes of MVPA per day spent in each of the five environmental domains (home, childcare, <500 m from home, 500–1600 m from home, >1600 m from home) were calculated.

**Data preparation**

Accelerometry data were combined with GPS data and processed with the Human Activity Behavior Identification Tool and data Unification System (HABITUS) application (University of Southern Denmark, 2022) which was based on algorithms from the personal activity location measurement system (PALMS) software (Jankowska et al., 2015). Accelerometer and GPS data were matched and merged for each 15 second epoch.

The combined accelerometry and GPS data were exported and then cleaned to remove data with location or physical activity errors, as well as data from participants who did not meet the inclusion criteria: data on at least three weekdays and one weekend day with a minimum of 8 hours wear time per day, including at least one weekday with a minimum of 1 hour wear time at childcare. These inclusion criteria were chosen to ensure that physical activity behaviour during weekdays, weekend days as well as childcare days were captured. After data cleaning, valid data for 115 participants remained.

**Physical environmental characteristics of the home, childcare and neighbourhood**

Each child’s home location was geocoded using the child’s home address. A polygon of each home backyard space was created and the size was calculated in ArcGIS Pro to provide an estimate of the amount of outdoor space available for preschool children’s physical activity at home.

Similarly, a polygon of each childcare centre’s outdoor play space was created its area measured in ArcGIS Pro to determine the size of the outdoor space for each childcare centre. Childcare centre quality was based on the Australian National Quality Standards (NQS) (ACECQA, 2012). The NQS (ACECQA, 2012) sets the national benchmark for early childhood education and care services and consists of seven quality areas: 1) Quality area 1 – Educational programme and practice, 2) Quality area 2 – Children’s health and safety, 3) Quality area 3 – Physical environment, 4) Quality area 4 – Staffing arrangements, 5) Quality area 5 – Relationships with children, 6) Quality area 6 – Collaborative partnerships with families and communities and 7) Quality area 7 – Governance and leadership. Briefly, the NQS assesses each childcare centre as either working towards, meeting or exceeding the seven quality areas. Quality area 2 focuses on supporting and promoting children’s physical activity (ACECQA, 2012).

For neighbourhood characteristics, a GIS map layer of the Perth and Peel region (Western Australia) with parks and playgrounds, schools, sports and recreation centres and shops (retail shops, supermarkets and shopping centres) features was imported from OpenStreetMap (OpenStreetMap contributors, 2016) into ArcGIS Pro for visualisation and analysis. A 500-m buffer and a 500–1600 m buffer were created for each participant’s residence to represent the <500 m neighbourhood domain and the 500–1600 m neighbourhood domain. The number of parks and playgrounds, sports and recreation centres, schools and shops within each domain were calculated.

**Analysis**

Descriptive statistics and Pearson’s correlation coefficients between all variables were calculated using SPSS 26. Latent profile analysis was performed with the five environmental domain-specific mean minutes of MVPA as outcome variables using Latent Gold v6. The number of possible profiles were determined by examining the Akaike Information Criterion (AIC), and the Bayesian Information Criterion (BIC), the Vuong-Lo-Mendell-Rubin (VLMR) p-value, Entropy R-squared and the interpretability of the profiles (Lo et al., 2001; Ram & Grimm, 2009; Schreiber, 2017). Lower AIC and BIC values indicate a better model fit. VLMR p-value smaller than 0.05 indicate that model with K profiles may be a better fit compared to model with (K-1) profiles. Entropy R-squared values closer to 1
indicate a better prediction of participant profile membership based on observed variable values.

After the profiles were identified, each profile was labelled with a name that highlighted the profile’s key MVPA domain characteristic. Descriptive statistics for the home, childcare and neighbourhood domains for each profile were calculated. Independent t-tests were performed to explore if there were any statistically significant differences between profiles in terms of the physical environmental characteristics and attributes of each domain, i.e., home (SES, backyard size), childcare centre (SES, NQS rating and size of centre), and >500 and 500–1600 m neighbourhood (number of parks and playgrounds, sports and recreation centres, schools and shops). The profiles capture time spent in different physical environment domains, not the percentage of MVPA at each physical environment domain.

**Results**

The mean age of participants was 3.2 years and 53.9% were boys. The majority (58.4%) of parents who completed the survey, in most instance the mother (82.6%) had a tertiary education or higher, 41.5% were employed full time and 42.5% were part-time. Over 65% of preschool children’s homes were located in high SES suburbs, and over 28% of childcare centres attended were located in high SES suburbs. On average, preschool children wore the accelerometer and GPS devices for more than 11 hours (710.1 minutes) per day and engaged in 91.0 minutes of MVPA per day (Table 1).

### Table 1. Characteristics of sample (n = 115).

<table>
<thead>
<tr>
<th></th>
<th>% or mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child age</td>
<td>3.2 (0.7)</td>
</tr>
<tr>
<td>Child sex (male)</td>
<td>53.9%</td>
</tr>
<tr>
<td>Parent education</td>
<td></td>
</tr>
<tr>
<td>Secondary, apprenticeship &amp; diploma</td>
<td>41.6%</td>
</tr>
<tr>
<td>Tertiary and postgraduate</td>
<td>58.4%</td>
</tr>
<tr>
<td>Parent employment</td>
<td></td>
</tr>
<tr>
<td>Full-time</td>
<td>41.5%</td>
</tr>
<tr>
<td>Part-time</td>
<td>42.5%</td>
</tr>
<tr>
<td>Other*</td>
<td>16.0%</td>
</tr>
<tr>
<td>Home SES</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>17.4%</td>
</tr>
<tr>
<td>Mid</td>
<td>17.4%</td>
</tr>
<tr>
<td>High</td>
<td>65.2%</td>
</tr>
<tr>
<td>Childcare Centre SES</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>44.4%</td>
</tr>
<tr>
<td>Mid</td>
<td>27.8%</td>
</tr>
<tr>
<td>High</td>
<td>27.8%</td>
</tr>
<tr>
<td>Childcare Centre Outdoor Size</td>
<td>684.2 m² (405.1)</td>
</tr>
<tr>
<td>Daily device wear time (mins)</td>
<td>710.1 (90.3)</td>
</tr>
<tr>
<td>MVPA per day (mins)</td>
<td>91.0 (28.2)</td>
</tr>
</tbody>
</table>

*No paid job, unpaid work, full time students, home duties.

### Latent profiles of preschool children’s physical activity by physical environment domain

The model fit indices for the latent profile analysis are shown in Table 2. Model solutions with 3, 4 and 5 profiles had the smallest BIC, suggesting that these solutions fit the data better than the 2 or 6 model solutions. Although the AIC decreased for each additional profile, both class error and entropy R² indicated that the model fit does not improve with a more complex model. The model solution with three profiles had the smallest class error and largest entropy R² indicating that this model had the smallest proportion of classification error and better prediction of participants profile membership based on observed variables. Furthermore, when looking at the results for the 4, 5, 6 model solutions, some overlap appeared in the profiles, suggesting that they did not represent a distinct group of preschool children. Although there is no “gold standard” for identifying the optimal number of profiles in a given sample, past studies have highlighted that apart from goodness-of-fit indices and tests of statistical significance, it is also useful to select the model which makes the “most sense” in terms of representation and interpretation of the results (Marsh et al., 2009). Therefore, the model solution with three profiles was selected as the final model.

The three profiles identified were labelled as the “Active at home” (n = 41), “Active except close to home” (n = 61), and “Active except in local neighbourhood” (n = 13). Based on probability of profile membership for each preschool children, preschool children were assigned into one of the three profiles.

Profile mean (i.e., the average in each profile) accelerometer and GPS daily wear time is presented in Table 3. Between the profiles, “Active at home” had the highest daily wear time in the home domain (532.89 minutes, accounting for 80.55% of total daily wear time), and much lower daily wear time in the childcare (38.24 minutes, 5.78% of total daily wear time), 500–1600 m (5.56 minutes, 0.84% of total daily wear time), and >1600 m neighbourhood (82.02 minutes, 12.40% of total daily wear time) domains. “Active except close to home” had the highest daily wear time in the childcare (105.07 minutes, 16.36% of total daily wear time), 500–1600 m (44.57 minutes, 6.94% of total daily wear time) and >1600 m neighbourhood (192.58 minutes, 29.98% of total daily wear time) domains, and much lower daily wear time in the <500 m neighbourhood (1.41 minutes, 0.22% of total daily wear time) domain, compared to the other profiles. “Active except in local neighbourhood” had the highest daily wear time in the <500 m neighbourhood (62.09 minutes, 9.95% of total daily wear time) domain, compared to the other profiles.

Mean minutes of MVPA (i.e., the average daily minutes of MVPA in each profile) for the three profiles are presented in Table 4 and Figure 1. The “Active at home” profile spent the
The majority of their daily MVPA time at home with a daily average of 61.50 minutes (73.29% of total daily minute of MVPA). They also accumulated smaller amounts of daily MVPA in the childcare domain (8.39 minutes, 10% of total daily minute of MVPA), >1600 m neighbourhood domain (12.01 minutes, 14.32% of total daily minute of MVPA), and about a minute each in the <500 and 500–1600 m neighbourhood domains.

The “Active except close to home” group engaged in MVPA in all domains apart from within the <500 m neighbourhood domain: daily average of 29.82 minutes of MVPA time (31.66% of total daily minute of MVPA) at home, 29.80 minutes of MVPA (31.64% of total daily minute of MVPA) at childcare, 25.18 minutes of MVPA (26.73% of total daily minute of MVPA) within the >1600 m neighbourhood, 8.91 minutes of MVPA (9.46% of total daily minute of MVPA) in the 500–1600 m neighbourhood and less than 1 minute of MVPA (0.51% of total daily minute of MVPA) within the <500 m neighbourhood domain.

The “Active except in local neighbourhood” group did MVPA in all domains apart from the 500–1600 m neighbourhood domain: daily average of 32.5 minutes of MVPA time

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**Table 3. Accelerometer and GPS daily wear time (minutes and percent) in each environmental domain by profile.**

<table>
<thead>
<tr>
<th>Environmental domain</th>
<th>Active at home (n = 41)</th>
<th>Active except close to home (n = 61)</th>
<th>Active except in local neighbourhood (n = 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>%</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Home</td>
<td>332.89 (95.89)</td>
<td>80.55</td>
<td>298.65 (11.97)</td>
</tr>
<tr>
<td>Childcare</td>
<td>38.24 (24.20)</td>
<td>5.78</td>
<td>505.07 (69.92)</td>
</tr>
<tr>
<td>&lt;500m neighbourhood</td>
<td>2.88 (6.32)</td>
<td>0.43</td>
<td>1.41 (3.83)</td>
</tr>
<tr>
<td>500-1600m neighbourhood</td>
<td>5.56 (9.26)</td>
<td>0.84</td>
<td>44.57 (50.64)</td>
</tr>
<tr>
<td>&gt;1600m neighbourhood</td>
<td>82.02 (62.26)</td>
<td>12.40</td>
<td>192.58 (121.22)</td>
</tr>
<tr>
<td>Overall</td>
<td>661.59</td>
<td>100</td>
<td>642.28</td>
</tr>
</tbody>
</table>

---

**Table 4. Mean daily minutes of MVPA, percent of total daily MVPA, and percent of wear time in each environmental domain by profile.**

<table>
<thead>
<tr>
<th>Environmental domain</th>
<th>Active at home (n = 41)</th>
<th>Active except close to home (n = 61)</th>
<th>Active except in local neighbourhood (n = 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>%</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Home</td>
<td>61.50 (24.65)</td>
<td>73.29</td>
<td>29.82 (14.43)</td>
</tr>
<tr>
<td>Childcare</td>
<td>33.50 (5.45)</td>
<td>10.00</td>
<td>29.80 (20.66)</td>
</tr>
<tr>
<td>&lt;500m neighbourhood</td>
<td>0.88 (1.25)</td>
<td>1.00</td>
<td>0.48 (1.03)</td>
</tr>
<tr>
<td>500-1600m neighbourhood</td>
<td>1.16 (1.47)</td>
<td>1.39</td>
<td>8.91 (9.60)</td>
</tr>
<tr>
<td>&gt;1600m neighbourhood</td>
<td>12.01 (7.70)</td>
<td>14.32</td>
<td>25.18 (16.76)</td>
</tr>
<tr>
<td>Overall</td>
<td>83.93 (4.27)</td>
<td>100</td>
<td>94.19 (3.48)</td>
</tr>
</tbody>
</table>

*Percentage of total daily minutes of MVPA.
†Percentage of MVPA out of wear time spent in each environmental domain by profile.

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**Figure 1.** Mean daily minutes of MVPA spent in each of the five environmental domains.
(32.98% of total daily minute of MVPA) at home, 24.67 minutes of MVPA (25.04% of total daily minute of MVPA) at childcare, 21.35 minutes of MVPA (21.67% of total daily minute of MVPA) within the <500 m neighbourhood, 18.74 minutes of MVPA (19.03% of total daily minute of MVPA) in the >1600 m neighbourhood domains and about a minute (1.28% of total daily minute of MVPA) within the 500–1600 m neighbourhood domain.

The percentage of MVPA time based on wear time spent in each environmental domain are presented in Table 4. Specifically, within the home domain, the “Active at home” profile spent the highest percentage (11.54%) of their wear time in MVPA, while the “Active except close to home” and “Active except in local neighbourhood” spent 9.98% and 10.70% of their wear time in MVPA within the same domain, respectively. Within the childcare domain, the “Active except in local neighbourhood” profile spent the highest percentage (30.23%) of wear time in MVPA, while the “Active at home” profile spent 21.94% and the “Active except close to home” profile spent 28.36% of wear time in MVPA within the same domain. Within the <500 m neighbourhood domain, the “Active except in local neighbourhood” profile spent the highest percentage (34.39%) of wear time in MVPA, while the “Active at home” profile spent 30.56% and the “Active except close to home” profile spent 34.04% of wear time in MVPA within the same domain. Within the 500–1600 m neighbourhood domain, the “Active at home” profile spent the highest percentage (20.86%) of their wear time in MVPA, while the “Active except close to home” profile spent 19.99% and the “Active except in local neighbourhood” profile spent 13.07% of wear time in MVPA within the same domain. Within the >1600 m neighbourhood domain, the “Active at home” profile spent the highest percentage (14.64%) of wear time in MVPA, while the “Active except close to home” profile spent 13.08% and the “Active except in local neighbourhood” profile spent 11.24% of wear time in MVPA within the same domain.

**Domain-based physical environment attributes of each latent profile**

Domain-specific environmental attributes (number of neighbourhood parks and playgrounds, sports and recreation centres, schools and shops; home SES and backyard size; childcare SES, size and quality) were examined to determine if differences in these attributes explained the three profiles.

On average, the “Active except close to home” had significantly more parks and playgrounds (p < 0.05) within the 500–1600 m neighbourhood domain compared to the “Active at home” profile (38 vs. 28) (Table 5). The “Active except close to home” also had more sports and recreation centres (p = 0.05) within the 500–1600 m neighbourhood domain compared to the “Active except in local neighbourhood” (1 vs 0.3). The “Active except close to home” had significantly fewer schools (p < 0.05) within the <500 m neighbourhood domain compared to the “Active except in local neighbourhood” (0.6 vs. 1.2). No statistically significant differences were found between profiles in terms of access to shops or SES at the home and childcare centre suburb level (Table A1).

Within the home domain, the mean home backyard size in the “Active except in local neighbourhood” profile was significantly larger than those in the “Active except close to home” profile (p < 0.05, results not shown). No statistically significant difference in home SES was found between profiles.

Childcare centres in the “Active except close to home” profile on average were larger (71 vs. 52 approved places) and of higher quality (86% vs. 67%) compared to the “Active except in local neighbourhood”. However, none of these differences were statistically significant (results not shown). No statistically significant difference in childcare centre SES was found between profiles.

**Discussion**

This study classified preschool children into subgroups based on where they accumulated physical activity within the home, childcare and neighbourhood domains, and explored the relative importance of each of these domains for young children’s physical activity using device-measured location-specific data. Based on preschool children’s physical activity behaviour across these domains, three distinct profiles emerged. The “Active at home” profile was characterised by high levels of daily MVPA in the home domain and low levels of daily MVPA in all other domains. The other two profiles had similar levels of daily MVPA in all domains except the <500 m neighbourhood (“Active except close to home”) and 500–1600 m neighbourhood (“Active except in local neighbourhood”) domains. No statistically significant differences in SES at the home or childcare centre suburb level were found between profiles; however, there were distinct differences in the physical environment attributes of different profiles.

“Active at home” were characterised by high wear time and high amounts of mean daily MVPA time spent within the home domain (61 minutes, 73% of total daily minutes, 12% of the wear time at home) and low wear time and low mean daily MVPA time spent within the other domains (range 1–12 minutes). This could be explained in part by having more MVPA-promoting features in the home physical environment. However, there was no statistically significant difference in yard size between the “Active at home” profile and the other profiles. Alternatively, the lack of MVPA-promoting features in the “Active at home” neighbourhood environment could also be in part explain why they spent more time at home and the home was the main source of daily MVPA. This was found to be true in part with “Active at home” having significantly less access to parks and playgrounds within the 500–1600 m neighbourhood domain compared with the “Active except close to home” profile. Furthermore, among the profiles, the “Active at home” profile spent the least amount of time in the childcare domain. This may explain why they spent more time in the home domain (i.e., because they attended less childcare) and thus were more active in this domain. It is important to note that the “Active at home” profile also had limited access to parks and playgrounds in their local neighbourhood, further justifying why they were most active at home rather than the other
domains. This finding aligns with the results by Grigsby-Toussaint et al (Grigsby-Toussaint et al., 2011), which showed that greater access to greenspace within the neighbourhood is associated with greater outdoor play time in preschool children. This suggests that the physical environment characteristics of different environmental domains can either support or hinder physical activity opportunities for preschool children, defining where and how they are active.

The “Active except close to home” profile did on average between 9 and 30 minutes of daily MVPA within each of the domains except the <500 neighbourhood domain (0.5 minute). This domain also had the least average daily wear time (1.4 minute) in this profile. The “Active except in local neighbourhood” profile had a similar profile, except this profile had little wear time (9.6 minutes per day) and did almost no daily MVPA (1.3 minute, 13% of daily wear time) within the 500–1600 m neighbourhood domain. Differences in the physical environment attributes of these profiles appear to explain these findings in part; the “Active except close to home” profile had significantly fewer schools within the <500 m neighbourhood compared to the “Active except in local neighbourhood” profile, and significantly more parks and playgrounds in their 500–1600 m neighbourhood compared to the “Active at home” profile. Previous studies have shown that the time preschool children spend playing outdoors is positively associated with access to parks and playgrounds (O’Connor et al., 2013). These findings are also consistent with the findings in the systematic review by (Terrón-Pérez et al., 2021), which highlighted that places that offer physical activity opportunities, such as the presence of open space and green space are positively associated with preschool children’s physical activity behaviour.

Furthermore, distance to school has been reported to be associated with school-aged children’s physical activity, out of school hours times (Oliver et al., 2015). In addition, the presence of school open space has been positively associated with preschool children’s physical activity using device-based measures (Terrón-Pérez et al., 2021). In Australia most of the open spaces in schools, such as ovals and playgrounds can be accessed by the public after school hours, providing physical activity opportunities for preschool children especially when visiting schools to collect their siblings with their parents. Although this specific finding may not be generalisable to countries where school grounds are closed to the public. Overall, these findings highlight that young children are likely to spend more time and engage in physical activity in physical environments with certain attributes such as school ground, parks and playgrounds that are accessible close to home (<500 m – about 10-minute walking distance) and in the local neighbourhood (500–1600 m – about 10 to 25-minute walking distance). This aligns with the findings of prior studies, which show that neighbourhood parks and playgrounds are important locations for preschool children’s physical activity (Benjamin-Neelon et al., 2019; O’Connor et al., 2013).

To our knowledge, only two studies have examined the locations preschool children engage in physical activity using device-measured physical and location data combined with GIS data (Benjamin-Neelon et al., 2019; O’Connor et al., 2013), and our findings are consistent with the results of these two studies. For example, a longitudinal study by Benjamin-Neelon et al., (2019) explored the association between NDVI-measured green space exposure and device measured minutes of physical activity in preschool children (3–4 years old, n = 102 at baseline, n = 87 at follow-up) and found a positive association between time spent in green space and minutes of MVPA. The study by O’Connor et al., (2013) (n = 15), which utilised accelerometer, GPS and GIS (Google Earth) data to identify the destinations in the neighbourhood physical environment (e.g., parks, community centres) associated with preschool children’s physical activity counts. The study found that preschool children’s physical activity was positively associated with neighbourhood park access. Although both studies are limited by small sample sizes, the findings of these studies and the current study align, highlighting that local parks may play an important role in supporting preschool children’s physical activity.

Our findings also align with studies that investigated the relationship between device-measured physical activity and the physical environment in older children. For example, Almanza et al., (2012) showed that children with daily exposure to green spaces for over 20 minutes engaged in MVPA at a rate
almost five times higher than those children who had very little or no exposure to such areas. Ward et al., (2016) found that greater time in greenspace was associated with increased physical activity in school-aged children. In addition, Mitchell et al., (2016) and McGrath et al., (2016) both showed that greenspaces, such as parks and playgrounds were associated with increased physical activity in school-aged children. Furthermore, Klinker et al., (2014) showed that school-aged children’s proportion of time spent in MVPA was particularly high in sports facilities and playgrounds. Overall, our findings highlight that similar to school-aged children, access to parks and playgrounds may be important for preschool children’s physical activity.

While a handful of studies in school-aged children have examined time spent and duration of physical activity by physical environment domain, none to date have investigated the attributes of these domains nor profiles of domain-specific physical activity in school-aged children or preschool children. Given that not all preschool children attend childcare every weekday, future research may consider exploring the latent profiles of preschool children’s domain-specific physical activity behaviour on childcare weekdays versus non-childcare weekdays.

Strengths and limitations

This study has several strengths. It used device-measured location-specific data in a latent profile analysis resulting in interpretable clusters of where preschool children accumulated MVPA. The combination of accelerometry, GPS and GIS data provided high-quality device-based information on profiles of preschool children’s domain-specific physical activity levels, as well as the physical environment attributes (i.e., number of parks, sport and recreation centres) of environmental domains.

A limitation of this study is the relatively small sample size ($n = 115$) and that it only included preschool children who attended childcare in the Perth and Peel regions of Western Australia. Small sample sizes in latent profile analysis can result in convergence failures and poor function fit indices. The small sample size was due to the strict inclusion criteria. The inclusion criteria were applied in order to capture location-specific physical activity data on childcare days, non-childcare weekdays, as well as weekend days, so only those participants who had both valid GPS and accelerometry data were included in the analysis. The strict data inclusion criteria resulted in a sample size of 115 preschool children, with the majority coming from neighbourhoods with high SES levels. Nonetheless, this sample provided 2,504,049 data points, each of which represented a 15 second epoch. Due to this strict inclusion criteria, the sample included in this study was skewed towards families from high SES neighbourhoods. Thus the findings may only be generalisable to children living in cities with similar a culture and land use patterns, specifically those living in high SES neighbourhoods and attending childcare. This limitation has also been shown in past studies using strict GPS and accelerometer inclusion criteria (Mavoa et al., 2018). Despite these limitations, latent profile analysis is useful for exploring and explaining patterns of behaviour across different indicators by detecting latent heterogeneity in samples, even with smaller samples (Weller et al., 2020). Future studies using combined GPS and accelerometry data will need to review their inclusion criteria to include more children from low SES backgrounds.

When interpreting the findings of this paper, it’s crucial to consider of the limitations associated with latent profile analysis. For example, the latent profile approach categorises individuals into profiles based on the likelihood of being in specific profiles, and the accuracy of profile assignment is not guaranteed. Also, because this relies on probabilities, the exact percentage or count of sample members within each profile cannot be determined. Wear time was not adjusted in this study. It is important to be aware that the profiles identified in this study are based on time spent at a location, and not the proportion of active time at a location. It is also important to note that the reported wear time and minutes of MVPA represent averages within each profile and this may entail a considerable degree of variability. In our latent profile analysis, normal distribution was assumed for minutes of MVPA. Thus, the findings should be interpreted with caution, as this approach can compromise the accuracy of model fit indicators.

This study did not measure specific park sizes. However, a previous review suggested that access to greenspace, regardless of park size may influence preschool children’s physical activity levels (Terrón-Pérez et al., 2021). Furthermore, more specific variables on the quality of childcare practices related to physical activity, such as educator modelling of physical activity and programming physical activity were not available for this study. Future studies should explore childcare educator physical activity practices to further understand the relationship between the childcare environment and preschool children’s physical activity. In addition, physical environment characteristics were obtained from the open sourced OpenStreetMap, and it is possible that not all shops and other destinations such as sports and recreation centres were captured. Furthermore, other neighbourhood environmental factors which may influence where preschool children accumulate MVPA such as neighbourhood safety and traffic exposure were not included. Further research is needed to examine these features in each domain to further our understanding of the relationship between the physical environment and preschool children’s physical activity profiles.

Conclusion

Based on where MVPA was accumulated within the home, childcare and neighbourhood domains, preschool children were grouped into three profiles: “Active at home”, “Active except close to home” and “Active except in local neighbourhood”. The “Active at home” profile had fewer parks and playgrounds within their 500–1600 m neighbourhood compared to the other profiles. The “Active except close to home” profile had fewer school areas within the <500 m neighbourhood, but more parks and playgrounds in their 500–1600 m neighbourhood compared to the other two profiles. The “Active except in local neighbourhood” profile had more school areas within the <500 m neighbourhood compared to the other profiles. It is recommended future policy and planning consider access to schools, parks and playgrounds within the local neighbourhood as important locations where preschool children spend time and are physically active.
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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Authors’ contribution

PB led the development of the manuscript. JS led the development and delivery of the HABITUS programme. HC acquired the funding and led the development and oversaw the PLAYCE study with contributions from JS and MR. PB led the analysis with contribution from HC, JS, and MR. JS provided GIS support and guidance. All authors contributed to the development and gave final approval of the manuscript.

References

## Table A1. Differences in home and child care suburb-level socio-economic status (SES) between the three profiles.

<table>
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</table>

*Profile 1 = profile “Active at home”, profile 2 = profile “Active except close to home”, profile 3 = profile “Active except in local neighbourhood”. Δ Cohen’s d