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# Increasing Physical Activity in Childcare Outdoor Learning Environments: The Effect of Setting Adjacency Relative to Other Built Environment and Social Factors

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**Abstract**

The problem of childhood obesity can be addressed through study of how built environment characteristics can foster physical activity (PA) among preschool children. A sample of 355 behavior settings in 30 childcare center outdoor learning environments (OLEs) was studied using behavioral mapping techniques. Observers coded activity levels of preschool children across behavior settings. The level of PA observed in 6,083 behavioral displays of children aged 3 to 5 was modeled using multi-level statistical techniques. Both adjacency and centrality of play settings were found to be important factors in increasing the degree of PA, net the effect of numerous other variables. In addition, child-to-child interaction was found to foster

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PA (more for boys than girls) whereas a teacher's custodial actions limit PA. Results demonstrate that design of OLE form (particularly adjacency of behavior settings) and content (use of manipulable items such as wheeled toys and balls) facilitates higher levels of PA.

**Keywords**
physical activity, built environment, childcare centers, outdoor learning environment design

Although the media have widely reported a dramatic rise in obesity rates—tripling in the last three decades (Galson, 2008; Institute of Medicine, 2011)—it is perhaps less well known that rates have doubled even for preschool-aged children (Institute of Medicine, 2011). Recent research reports approximately 20% of preschool children are overweight or obese (Institute of Medicine, 2011; Larson, Ward, Neelon, & Story, 2011). Much recent research focuses on ways to prevent obesity for children above 5, but behaviors learned from birth to age 5 are more likely to track throughout childhood (Janz, Dawson, & Mahoney, 2000; Kelder, Perry, Klepp, & Lytle, 1994). L. Moore and colleagues (2003) emphasize the importance of establishing "an active lifestyle beginning very early in childhood" (p. 16). Introducing opportunities for active lifestyles, as well as healthy eating early on, may reduce and/or reverse the obesity epidemic (Institute of Medicine, 2011).

The two primary components to the complex problem of childhood obesity are physical activity (PA) and nutrition. Although dietary factors are important, this article focuses on factors accounting for variation in PA (Story, Nanney, & Schwartz, 2009). Studying children under 5 (here, ages 3-5) is particularly important because a majority of children spend the larger proportion of their waking hours in preschool environments (Capizzano, Adams, & Sonenstein, 2000; Cardon, Van Cauwenberghe, Labarque, Haerens, & De Bourdeaudhuij, 2008). According to the Federal Interagency Forum on Child and Family Statistics (2011), in 2007 about 55% of children ages 3 to 6 (not yet attending kindergarten) were enrolled in center-based care. This means childcare center outdoor environments are potentially a primary locale for supporting PA. As features of both the built and social play environment can negatively or positively affect activity levels (Farley, Meriwether, Baker, Rice, & Webber, 2008), the effect of outdoor learning environment (OLE) design on levels of PA is a potentially valuable topic for study, taking both types of factors into consideration. Below we refer to a preschool's outdoor "playground" as an "outdoor learning environment" (OLE, an official term of the NC Division of Child Development and Early Education since 2007).

A preschool OLE is an ideal location to encourage play (Frost, Brown, Sutterby, & Thornton, 2004), as play time is scheduled, and children are generally given equal opportunity to play. In theory, the opportunity for all children to play should increase levels of PA (Burdette & Whitaker, 2005). More opportunity to play is thought to equate to more play, although one study failed to confirm this assumption (Alhassan, Sirard, & Robinson, 2007). Thus, opportunity alone may be negated by environments with unattractive or non-existent play options and/or a lack of space (Boldemann et al., 2006). In a study of Raleigh (North Carolina) preschools, Raustorp and colleagues (2012) found moderate to vigorous PA (MVPA) only occurred 7.8% of the time outside and 1.8% of the time inside, equating to 46.8 min in outdoor MVPA[1] and 10.8 min in indoor MVPA, whereas 74% of outdoor time and 91% of indoor time was sedentary. Another study of North Carolina childcare centers found only 12% of the children participated in MVPA with 55% participating in sedentary activities, with an overall average intensity across the centers to be seated play or slow/easy movement (Bower et al., 2008). So, although childcare centers would seem an ideal location for promoting MVPA, the mere existence of childcare centers does not guarantee it. Greater understanding of the MVPA environment is required to achieve greater child participation.

The physical characteristics of preschool play settings may be important in fostering PA (Trost, Ward, & Senso, 2010). Large open areas, for example, may facilitate play, as might the availability of different types of play equipment. The types of activity possible, encouraged, supported, or "afforded" (see E. Gibson & Pick, 2000, on the concept of affordance) by the presence of equipment or other physical objects in a play setting are potentially important. A grassy setting designed for ball play, for example, may facilitate more PA than a slide. The type of ground surface might hinder or encourage PA, as might the arrangement of settings in which children engage in PA (Cardon et al., 2008). Thus, a variety of physical attributes could influence PA levels, pointing toward the need for empirical research to evaluate the effects of setting characteristics in conjunction with other factors such as the child's gender or the type of social interaction occurring in play and learning areas.

## Theoretical Foundation

Theories about what fosters greater levels of PA among young children can be divided between those accentuating attributes of the individual child and those focusing on characteristics of the built environment surrounding the child. An important individual-level characteristic is gender. According to sociological gender theory, girls and boys are socialized to behave differently, beginning at early ages (Verstraete, Cardon, De Clercq, & De Bourdeaudhuij, 2006). Specifically, higher intensity PA is expected more from boys than girls (Cardon et al., 2008; Nielson, Bugge, Hermansen, Svensson, & Bo Anderson, 2012; Raustorp et al., 2012). Thus, we hypothesize male children will display greater PA, all else being equal, than female children.

The characteristics or attributes of built environment settings may afford PA to varying degrees. For example, the flat, continuous, soft surface of open fields may encourage running, playing tag, and so on, compared with the movement limitations of manufactured play structures (Bower et al., 2008). Affordance theory (Cosco, 2006; E. Gibson & Pick, 2000) refers to specific relationships between child behavioral propensities and the immediate environment. Cosco (2006) links affordance to motivation of children who may engage in "climbing, balancing, catching, clinging, crawling, hanging, hopping, jumping, leapfrogging, rocking, rolling, running, skipping, sliding, spinning, walking, and so on," which can increase the chances that their motivations will be made manifest when "environments [are] designed to afford those activities" (p. 128). It may seem obvious that the likelihood of sliding is enhanced by the presence of slides, and catching by the presence of a ball. However, the relationship between affordance and child motivations may be more complex (as discussed below).

The ecological psychology concept of affordance provides a theoretical base for measuring behavioral links between designed physical settings and PA (J. Gibson, 1979). Affordance defines the functional possibilities that the physical features of a setting extend to a particular individual. The concept provides a powerful tool for environment–behavior analysis and has been embraced by a group of environmental design researchers and environmental psychologists, several of them researching children's environments (Kyttä, 2002). Heft (1988) published a taxonomy of affordances and presented a preliminary conceptual and operational framework. Kyttä (2002) used affordance measures in comparative studies of children's environments and mobility in Finland and Belarus. Fjørtoft (2001) applied affordance to interpret the results of a study of the impact on Norwegian preschool children's motor development and fitness of landscape topography and vegetation.

Adjacency (a commonplace concept applied in built environment practice, White, 1986) refers to the connectedness of behavior settings (i.e., "play settings" or "play areas")—specifically, the number of settings sharing boundaries with each other (see Technical Appendix I for details on play setting definition). In the current study, each center OLE was subdivided into behavior or play settings, defined as ecological units with defined spatial boundaries and physical components that differentiated the setting from adjacent settings (see Barker, 1976). Thus, a behavior setting is defined as a play area in which certain types of behavior are "encouraged" or likely to be observed commensurate with the affordance of the setting; for example, open field for running, slide for sliding, sand for sand play, and so on. Specifically, the juxtaposition of affordances, as measured by the adjacency of multiple behavior settings, is hypothesized to have a synergistic effect on the PA of children. As a child is engaged in one behavioral setting and sees the action in another play setting adjacent to the first setting, he/she is presented with a new opportunity or prospect (Appleton, 1975), and thus is more likely to be engaged in physical rather than sedentary activity as a result of behavior setting adjacency. As for the broader literature on adjacency, there are studies on indoor play settings that suggest that more "activity areas" in a daycare center, the more on-task behavior (i.e., behavior congruent with the affordance of those areas; see Kantrowitz & Evans, 2004, p. 556; G. T. Moore, 1986).

In addition to play setting adjacencies, other spatial characteristics potentially relevant to PA are centrality, clustering, and distance. Centrality refers to whether the play setting is more central to the OLE, and thus more visibly salient. Children in more central areas may feel they are at the center of the action and motivated to perform as their peers. Centrality of the play setting may also increase PA through a selection process. Children who want privacy and quiet time may seek outlying play areas rather than play in the center of the OLE.

Clustering refers to the grouping of play settings around each other. If play settings are clustered, children are more likely to see other affordances nearby. All else being equal, those play settings in a cluster would trigger more PA than non-clustered play settings through a visual triggering mechanism. Children would be more likely in clustered play settings to see other children, perhaps because the children seen would be more active and elicit mimicking behavior.

Finally, distance to the play setting from the entrance may be a factor in PA for a couple of reasons. Children may be more stimulated to be physically active after walking/running a longer distance to a play area. Alternatively, it could be hypothesized that children may find that the greater distance of travel to the play setting could tire them (if only a little) or that children seeking quiet would seek a play area further away from the entrance.

In summarizing the spatial relationships, we hypothesize, all else controlled for, the number of adjacencies, the centrality, and the clustering of the play setting will be positively associated with PA. We were unsure about how distance from the entrance to a play area would be related, thinking that it could be positively or negatively related to PA.

Finally, as mentioned above, gender is an important factor in PA studies. We hypothesize further that gender may interact with any of a variety of other independent variables pertaining to activity engaged in, type of affordance, and various social, physical, and spatial components of the immediate environment. As the literature on interaction effects involving gender and PA is sparse, we are unsure how gender will interact with these other factors. We will explore by testing several product terms involving gender (see results section below).

## Research Design and Method

### *Study Location*

A listing of all licensed childcare centers within the North Carolina central Piedmont, Research Triangle/Triad Region was obtained from the State of North Carolina Division of Child Development. Centers with enrollments between 40 and 85 children were selected (range of the majority of centers in North Carolina) within five counties of the region, including urban, suburban, and rural contexts. Letters of invitation were sent to all 152 selected centers. Thirty centers, representing variation in geographic size (acreage), enrollment size, and context (downtown, suburb, nonresidential areas) across the counties, were willing to participate in the study and are included in the analysis. Observations were conducted in October and November (2006) and April and May (2007), when temperatures for outdoor play are comfortable.

### *Data Collection Procedure*

To study child PA, behavior mapping was used because behavior and related setting attributes are coded simultaneously, thus providing a flexible method for understanding the dynamic impact of the built environment on behavior (Cosco, Moore, & Islam, 2010). The purpose of behavior mapping is to measure the spatial distribution of activity across sites and settings, recording simultaneously who is doing what, and where. Behavior mapping data are used to determine boundaries of behavior settings and to measure activity patterns afforded by those settings, their components and attributes. Results provide quantified descriptions of settings in terms of proportional amounts of activity afforded by each setting. Behavior mapping provides an objective, operational measure of use of the built environment spatially coded to yield predictable behavioral patterns that can be compared across settings and sites (Björklid, 1982; Francis, 2003; R. C. Moore, 1986; van Andel, 1984).

For the study reported here, the coding protocol adapted from Cosco (2006) involved systematically and sequentially scanning predefined zones in “rounds” of observation whereby level of PA and other social interaction and environmental attributes were coded for each child observed. Across the 30 centers, trained observers conducted a total of 6,125 observations in 355 target behavior settings. PA was coded using Children Activity Rating Scale (CARS; Cosco et al., 2010; DuRant, Baranowski, Puhl, & Rhodes, 1993; Puhl, Greaves, Hoyt, & Baranowski, 1990), a validated, reliable tool for recording children's PA on a 5-point scale (no movement, upper body movement only, some or "slow" locomotion, moderate locomotion, vigorous locomotion). Results provide a measure of the level of PA in each behavior setting (reliability coefficients are reported below).

Trained observers followed a pre-assigned path through the environment at preset intervals. Observational paths were systematically varied to avoid any possible bias in viewing sequence. Observation cycles were conducted at 7-min intervals (depending on size of site) during the morning and afternoon outdoor activity periods. Observers conducted between 5 and 9 cycles/site (mean of 8). The location of each child was marked by hand on a copy of the site base plan supported on a clipboard. Relational data were gathered using PDA (Personal Digital Assistant) devices (small handheld computers) including gender, level of PA, assigned setting number, ground surface type, presence of vegetation, teacher interaction with the child (custodial or negative), and interaction between the target child and another child. No more than four children were observed at a time and observations were conducted at 7-min intervals, both procedures limiting the chances that a child would be observed more than one time in any observation session. Data collection date, weather conditions, and observer name were recorded for each round. Because it was too difficult in practice to identify children across observation sessions, we treat each child in the analysis below as if they were independent observations within a play setting. As observations were conducted during a set period of undirected outdoor activity, children observed in one round typically were observed in subsequent rounds of the same observation session. Children could also be observed more than one time in the same round if they moved in the same direction as the observer's scan, but such movement was rare.

## Dependent Variable

Using Geographic Information Systems (GIS) (Environmental System Research Institute, Inc. 2008), we compiled data into a single behavior map for each of the 30 sites. Whereas 6,125 individuals were observed, PA was recorded for 6,083 behavior displays across 355 play settings—so 42 observation events were dropped from the analysis as the PA levels were not recorded (descriptive statistics are presented in Table 1 only for the analysis sample). The average child was engaged in some PA when observed, with an average of 2.98 or "some locomotion" on the 5-point scale. The average variation from the mean was about one (.99) point (so plus one is essentially "moderate locomotion" and minus one is "upper body movement only"). Fifty-four percent of the children observed were boys. Children were observed more than once, with a minimum of 7 minutes between observations so as to maximize the "independence" of the observations (e.g., a child running at the first observational scan would be not likely to be still running several minutes later, although some may have stopped and started running again).

## *Independent Variables*

The average OLE observed was 8,030 square feet and the average behavior setting size was about 640 square feet (the original variables were divided by 1,000 to show regression coefficients more comparable with those of other variable metrics). An average of 7.4 children were observed in a setting during an observation period, but the standard deviation of 9.9 suggests considerable variability in the number of children present.

*Spatial arrangement.* The *number of adjacent settings*, hypothesized to stimulate a synergistic effect among the children, varied from 1 to 17, with an average of 2.72 with a 2.26 standard deviation. The inter-quartile range (IQR) or the difference between the 75th percentile and 25th percentile is 2.0 adjacent settings. Stated another way, the average variation in the number of adjacencies of play settings observed in the sample of OLEs was two adjacent play settings. In coding the settings, it became apparent that a relatively long path sometimes could loop around several other settings thereby exhibiting a relatively large number of adjacencies. In the regression analysis described below, if a setting is a path (6% are paths), it is controlled for with a dummy variable to assess its association with PA, net the effect of numerous other variables. As some settings defined a relatively large area, not necessarily with a well-defined activity focus, a dummy variable was created to represent these left over "residual" or "connector" settings in the analysis. These areas could have higher PA levels as children were more likely to be walking or running through them to get to other settings (11% of the behavior settings were of this connector or residual character).

*Centrality* was measured with a dummy variable indicating whether the play setting was in the middle area of the OLE. Each of the OLE maps was examined and the middle or center play settings (22% of them we deemed central) given a code value of "one." *Clustering* was defined as the close proximity of the centroids of the play settings. About 47% of the play settings were part of a cluster (as defined by two of the researchers looking at the maps of the OLEs and visually assessing the proximity). Clustering is distinct from the adjacency measure in that the centroids had to be within 25 feet of each other to be considered in the same cluster; in fact, presence in a cluster was negatively associated with the number of adjacencies ($r = -.245$), a seeming paradox that will be commented on below. Centroids that were further apart disallowed a play setting from being considered part of a cluster. As it turns out, such a restriction tends to exclude open spaces from clusters ($r = -.137$), and include equipment in the cluster ($r = .220$), whereas adjacency was positively associated with open space ($r = .307$) and negatively associated with equipment ($r = -.198$). Another aspect of the cluster measure is that play settings in clusters tend to be small play structures (play house or small climbing structure) that would also be providing an affordance for more sedentary activities (however, there was no correlation between a child being in a play setting cluster and PA—contrary to what we hypothesized).

*Distance from the entrance* (or entrances, as some OLEs had more than one) was measured using GIS to calculate first the centroid of each play setting, and then the distance from the entrance(s). On average, play settings were 62 feet from the primary entrance, with an IQR of 45 feet. Here, only distances from the primary entrance are reported (analysis not reported here found that substituting distance from the secondary or tertiary entrance or in one instance four entrances were not statistically significant predictors of PA and are omitted from presentation in our models below).

*Setting characteristics.* Setting characteristics offer children a variety of affordances that could result in the behaviors that the affordances were designed for. For dramatic play, 12% of the settings met that criterion (having attributes for such play). Ten percent of the settings were described as gathering places (and, as expected, support less PA). Thirty percent of the settings were coded as open spaces. Five percent were classified as "planted areas" (not shown in Table 1); 25% had play equipment, and 6% of settings offered sand play.

*Presence of objects.* The presence of small tangible objects (sometimes including what is referred to as "portable play equipment" in the literature or as "loose parts"; Nicholson, 1973) could also affect PA. Some objects may be more "activity friendly" than others (Hannon & Brown, 2008). As often the engaged activities involved wheeled toys or a ball, for example, they would presumably be associated with more activity, so we have included dummy variables for such activities. Contact with another object (generally other

**Table 1.** Descriptive Statistics of Individual Characteristics and Observational Settings in Childcare Centers.

| | *M* | *SD* | Range | IQR |
|---|---|---|---|---|
| Physical environment (*N* = 355 play settings) | | | | |
| OLE size (in 1,000 sq. feet) | 8.03 | 2.76 | 2.92 to 12.00 | 5.63 to 10.89 = 5.26 |
| Setting size (in 1,000 sq. feet) | 0.64 | 0.86 | 0.01 to 5.0 | 12 to 0.80 = 0.68 |
| Number of children present per 1,000 sq. feet of setting per observation period | 7.39 | 9.86 | 0.13 to 62.50 | 1.53 to 9.20 = 7.67 |
| Number of adjacent settings | 2.72 | 2.26 | 1 to 17 | 1 to 3 = 2.0 |
| Setting is central | 0.22 | 0.41 | 0, 1 | |
| Setting in cluster | 0.47 | 0.50 | 0, 1 | |
| Distance to entrance (/100) (first entrance) | 0.62 | 0.34 | 0.04 to 1.85 | 0.37 to 0.82 = .45 |
| Residual setting | 0.11 | 0.31 | 0, 1 | |
| Drama | 0.12 | 0.33 | 0, 1 | |
| Gathering place | 0.10 | 0.31 | 0, 1 | |
| Open area | 0.30 | 0.46 | 0, 1 | |
| Path | 0.06 | 0.24 | 0, 1 | |
| Equipment | 0.25 | 0.44 | 0, 1 | |
| Sand area | .06 | .23 | 0, 1 | |
| Surface hard (proportion of total surface) | 0.21 | 0.41 | 0 to 1 | |
| Surface medium (proportion) | 0.29 | 0.44 | 0 to 1 | |
| Surface soft (proportion) | 0.50 | 0.41 | 0 to 1 | |
| | *M* | *SD* | Range | IQR |
| Individual-level traits (*n* = 6,083) | | | | |
| Physical activity level | 2.98 | .99 | 1-5 | 2 to 4 = 2 |
| Boy | 0.54 | .50 | 0, 1 | |
| Social environment | | | | |
| Child–child interaction | 0.77 | .42 | 0, 1 | |
| Teacher interaction positive | 0.54 | .50 | 0, 1 | |
| Teacher interaction with child negative/custodial | 0.43 | .50 | 0, 1 | |
| Activity type | | | | |
| Activity with ball | 0.04 | .19 | 0,1 | |
| Activity with wheeled toy | 0.11 | .31 | 0,1 | |
| Contact with other object | .70 | .46 | 0,1 | |
| Statistical control variables | | | | |
| Observation in April | .34 | .47 | 0,1 | |
| Observation in May | .16 | .37 | 0, 1 | |
| Observation in October | .44 | .50 | 0, 1 | |
| Observation in November | .06 | .23 | 0, 1 | |
| Observer 1 | .07 | .25 | 0, 1 | |
| Observer 2 | .47 | .50 | 0, 1 | |
| Observer 3 | .15 | .35 | 0, 1 | |
| Observer 4 | .16 | .37 | 0, 1 | |
| Observer 5 | .09 | .29 | 0, 1 | |
| Observer 6 | .06 | .24 | 0, 1 | |

*Note.* IQR = inter-quartile range; OLE = outdoor learning environment.

than a wheeled toy or ball, often other equipment) was also recorded. Surface classifications, soft (e.g., shredded rubber, sand, woodchips), medium (e.g., pine needles, grass, loose soil, soft gravel), or hard (e.g., asphalt, concrete), were also coded as the harder surfaces may encourage running behavior (Cardon et al., 2008).

*Social environment.* Child–child and teacher–child interactions were coded to capture the social environment. Coded teacher–child interactions include disciplining, speaking "negatively" to the child, or "custodial" interactions, such as, for example, asking the child to slow down, tying shoe laces, helping to remove a jacket if a child is too warm, and so on (custodial is defined here as a caring interaction to ensure the child is safe and comfortable). Forty-three percent of all children observed were characterized as having custodial or "negative" interactions with teachers, and thus they are rather common. We hypothesized that custodial/negative interaction would be associated with less PA.

### Control Variables

In addition to the more substantive variables discussed above, control variables included month of observation and a dummy variable for each observer. Although weather conditions were standardized by choosing North Carolina temperate months, variation in temperature still occurred, so the month may help capture possible variation. Inter-coder reliability coefficients (kappa) were calculated across a variety of types of settings. Specifically, kappas were .85, .71, .87, and .70 for PA in settings with composite structures, open areas, trees, and pathways, respectively, in a sub-analysis of 15 of the childcare centers on 3,000 observations with two observers. Thus, across a variety of built outdoor environments, observers are able to accurately determine the degree of PA displayed by the children. Although CARS' reliability of observers generally is well-established (Sirard & Pate, 2001), tendencies still existed for some observers to see more PA than others, so we control for each observer with a dummy variable. Observer 2 is used as the reference, the most frequently used observer, conducting 47% of the observations. This high percentage indicates he or she observed the average amount of PA and thus serves as an appropriate referent category for the other observer dummy variables.

## Results

Hierarchical linear modeling (HLM) techniques (Raudenbush & Bryk, 2002) were used to assess the relationship between the various physical and social environmental characteristics and the degree of PA. Using HLM terms, two levels make up the hierarchical structure of the data: the display of each child observed in observation sessions constitutes Level 1, and the play setting is Level 2.[2]

HLM allows the researcher to partition the data by level and calculate the intra-class correlation coefficient, which is the proportion of variability in the dependent variable existing between Level 2 units (here "play setting"). The proportion of variability is found to be 23.19%. Thus, of all the variance in PA Level 1, the individual child level, 23.19% occurred between settings. (Generally, most of the variability in a dependent variable measured at the individual level is due to variation across individuals than across aggregated units—here behavior settings—see Raudenbush & Bryk, 2002, p. 71.) These results justify looking at the setting characteristics, as nearly a quarter (23.19%) of the variability in PA can be accounted for by behavior setting characteristics.

Five models are presented in Table 2 below. The first model sets a baseline of comparison with the other models and consists of the statistically significant month and observer variables plus the various size measures (OLE, setting), as well as the concentration of children (density). Observer effects are omitted from the table for space considerations, but dummy variables for each observer (minus the referent observer) were included in the model to correct, in part, for variation in observer's reliabilities in perceptions of PA. No substantive differences in findings appear if the observer variables are omitted from the models. The coefficients for continuous variables presented in the model have been standardized by their IQRs to facilitate comparisons (dummy variables' coefficients remain as such). The IQR is considered more stable than the standard deviation, and thus more likely to be reproduced in other studies using the same variables (Quillian, 1995). In Model 1, the coefficient for playground size given a one-unit change of 1,000 square feet is −.047; so with an IQR of 5.26, the coefficient of −.247 is reported (5.26 × −.047), representing the resulting reduction in PA from an average increase in playground size (where average is the change from the 25th to the 75th percentile, i.e., the IQR). The intercept of 2.665 is the expected value of PA when the other variables in the model have values of 0. The continuous variables in the model were centered, so the intercept is the expected value at the mean of those variables. All other variables have values of zero or one (so-called "dummy" variables), so the intercept is the value when the person has a zero value on the dummy variables (e.g., females, observed in May/April, etc.). As shown in Model 1, boys' average PA level is .193 higher than that of girls, controlling for the other variables in the equation. Recall the average variation across children in PA is .99 (Table 1), so being male accounts for about

**Table 2.** Hierarchical Linear Models of Physical Activity (*N* = 6,083 Children; 355 Play Settings in 30 Centers).

| Variable | Model 1 Size | Model 2 Spatial attributes | Model 3 Other physical attributes | Model 4 Social attributes | Model 5 With interactions |
|---|---|---|---|---|---|
| Intercept | 2.665***[a] | 2.580*** | 2.830*** | 2.780*** | 2.834*** |
| Gender (1 = Boy; Girl = 0) | .193*** | .190*** | .161*** | .165*** | .051 |
| Physical environment | | | | | |
| OLE size (in 1,000 feet)[b] | −.247*** | −.231*** | −.183*** | −.184*** | −.189*** |
| Setting size (in 1,000 feet)[c] | .065*** | .014 | −.033 | −.036 | −.034 |
| Number of children present per 1,000 sq. feet of setting per observation period[b] | −.070*** | −.068*** | −.036 | −.042* | −.041* |
| Observation in October (referent = April/May) | .199*** | .193*** | .209*** | .192*** | .194*** |
| Observation in November (referent = April/May) | .239*** | .247*** | .261*** | .254** | .259*** |
| Number of adjacent settings[c] | | .065* | .073** | .077** | .074** |
| Setting in cluster | | .064 | .006 | −.000 | .001 |
| Setting is central | | .138* | .147** | .155** | .161** |
| Distance to primary entrance (per 100 feet) | | −.013 | .015 | .011 | .013 |
| Residual setting | | .133 | .094 | .098 | .096 |
| Path | | .167 | .046 | .032 | .056 |
| Gathering place | | | −.306** | −.284*** | −.283*** |
| Open area | | | .060 | .058 | .068 |
| Equipment | | | -.201** | .214** | .217** |
| Sand area | | | −.008 | −.009 | .011 |
| Activity with ball | | | .790*** | .792*** | .796*** |
| Activity with wheeled toy | | | .512*** | .516*** | .305*** |
| Contact with other object | | | −.463*** | −.474*** | −.472*** |
| Surface hard | | | −.035 | −.024 | −.023 |
| Surface medium | | | .100 | .089 | .093 |
| Social environment | | | | | |
| Child–child interaction | | | | .151*** | .090* |
| Teacher interaction with child negative/custodial | | | | −.113*** | −.113*** |
| Interactions | | | | | |
| Boy × Wheeled toy[c] | | | | | .351*** |
| Boy × Child-to-child interaction[c] | | | | | .108* |
| Intercept variance | .141*** | .134*** | .105*** | .103*** | .103*** |
| Gender slope variance | .070*** | .070*** | .071*** | .067*** | .052** |

*Note.* OLE = outdoor learning environment; IQR = inter-quartile range.
[a]Statistical significance * = .05 level. ** = .01 level. *** = .001 level.
[b]Variable has been grand-mean centered; all other variables are dummy variables unless otherwise indicated.
[c]Interaction term is a dummy variable; no IQR can be calculated.

one fifth (20%) of the average variation across children in PA, net the other variables in the model.

As mentioned above, larger OLEs (in square feet, times 1,000 to make the metric comparable) are associated with less PA on the part of the child, −.247, whereas larger behavior settings are associated with more PA on the part of the child, .065. The latter finding may be attributable to the kinds of activities more often found in larger, more open settings (e.g., more running, ball playing, etc.), whereas the former finding of OLE size suggests greater space separates settings more from each other, all else being equal[3] (i.e., greater distances between settings; possibly fewer children in a setting). The more children observed on average during an observation period, the less likely a child will be physically active (−.070). This could be interpreted as a "crowding" effect (not enough space to move freely), but it could be that when larger collectives of children occur (more children are present), the gathering becomes defined as one for social communication rather than PA. As for variations by month, for October's observations, there was .199 more PA than in April or May (the referent category—recall observations were done only in 4 months), whereas in November there was .239 more PA than in the referent months. It is unclear why October and November would have more PA than the spring months of April and May, but perhaps the end of the long hot North Carolina summer "releases" pent-up PA (speculative), or there could be an aging effect if the same children are observed in the spring. The intercept variance is .141 (down from .231 observed in a base model with no OLE setting attributes controlled for), representing a 39% decrease in the variation in the mean PA accounted for by the Level 2 (behavior setting level) variables in the model. Thus, the first model accounts for a substantial amount of the mean variation in PA across behavior settings. The slope of the gender effect, which is allowed to vary across settings, has a .070 variance (later, we show the variance of the slopes is reduced when product terms identifying interaction effects are included in the model).

Model 2 found in Table 2 shows the results of including in the model variables measuring various spatial aspects of the settings: the number of settings adjacent to a given setting, as well as the clustering, centeredness, and distance to entrance attributes. The variables from Model 1 have similar effects in Model 2 (except the effect for setting size, which has become statistically insignificant). In Model 2, the average change in the number of adjacencies in a setting is found to add .064 to the PA level. Stated another way, changing the number of adjacencies by 2 (the IQR) would result in .064 more PA ($2.0 \times .032 = .064$).

As for the other spatial attributes of the play settings, Model 2 indicates that a setting in a cluster of play areas is not associated with PA independent of the other variables in the model, but centrality is associated with PA. A play setting that is central to an OLE has .138 more PA, net the effects of other variables in the model. Distance from the entrance to the center of the play setting is not found to be statistically significant (in other models we tested a squared term for distance, looking for nonlinear effects, but found none; also we tested for distance from a second entrance, and it too was found to be statistically insignificant and is omitted here). Finally, in Model 2, we control for a methodological concern in how we defined adjacencies, as discussed above. Dummy variables for observational sites categorized as residual categories or as paths are included to account for the concerns raised above that some observational sites are measured to ensure multiple adjacencies. Here, these dummy variables have no statistically significant effect, but can be interpreted as correcting for any error introduced by defining adjacencies too liberally, as per the discussion above. So, the adjacency effect of .064 is especially robust because the model addresses the definitional criticism discussed earlier by including dummy variables for path and for residual area. Also note the remaining variation in mean PA has been reduced to .134, or down 42% from the base model consisting of no setting variables (compare also with Model 1 where the residual variation was down 39% from the base model—so an increase occurs in the explained setting-level PA variance from 39% to 42%). Thus, there has been some improvement in Model 2 in the explained variance of the intercepts across observational settings with inclusion of the spatial attributes of the play settings, especially adjacency and centeredness.

In the third model, various physical attributes (affordances) of the setting are included beyond the settings' spatial, path, and residual characteristics (see Model 3, the "other physical attributes" model). Comparing the variables' effects from the earlier models reveals little change. As for the effects of the physical attributes, if a setting is a gathering place, PA is reduced by .306; if an open area, PA is not affected; if equipment is present, PA is increased by .201; if the activity involves use of a ball, PA increases by .790, whereas activity involving a wheeled toy increases PA by .513. Contact with other objects, however, decreases PA by .463. Net the effects of the other variables, the degree of hardness of the surface area has no effect. Note, adding the various affordance measures to the adjacency model results in a 54.5% reduction in the variability in mean PA (.105 is .126 less than .231, or 54.5% of the variation in mean PA with no variables in the model).

Model 4 includes various social attributes of the child's environment, specifically if he/she is interacting with other children (increases PA by .151) or having a custodial or more generally negative interaction with a teacher (decreases PA by .113). Socializing with other children increases PA, whereas some form of "misbehavior," prompting teacher action, is associated with less PA. Importantly, relative to the adjacency hypothesis, the number of adjacencies has a strong effect in Models 2 through 4: adding 2 adjacent settings yields about a 7% increase in PA. The centrality effect is arguably larger, however, in that those play settings central to an OLE which result in about a 15% to 16% increase in PA (across models, recognizing that we are comparing an IQR effect for adjacencies with a dummy variable effect for centrality). So, regardless of the other variables in the equation, adjacency and centrality have consistent effects across models.

We next discuss other comparative magnitudes of the effects. In Model 4 in Table 2, we see more clearly that the adjacency effect (.076) and central location (.161) are similar in magnitude to the gender, OLE size, child–child interaction and negative teacher interaction IQR effects (.165, −.184, .151 and −.113, respectively), but substantially smaller in magnitude than gathering place (−.284), equipment (.214), and activities with ball (.792), wheel (.516), or other object contact (−.474). Thus, affordance characteristics generally have a stronger effect on PA than do spatial arrangements or social attributes.

In Model 5 in Table 2, we expand the analysis to show the results of the test of several interaction effects hypothesized to exist between gender and physical and social context. We were especially interested to see if boys were more likely to exhibit PA in the context of more adjacencies, but also if the gender variable's coefficient varied with other physical and social attributes. Based on broad theoretical grounds, we tested for interaction effects for gender and various physical and social attributes: adjacency, centrality, clustering, distance from entrance, OLE size, setting size, density of children in the setting, gathering, open area, path, equipment in setting, use of ball, use of wheeled toy, surface soft, surface hard, surface medium, child interaction, and child–teacher custodial/negative interaction. Of the 18 interactions tested for (moderated effects), not all could be tested for simultaneously due to multicollinearity concerns (variance inflation factors greater than 4.0; Belsley, 1991), such that the product terms with gender could only be included a few at a time. Only 2 of the 18 product terms were statistically significant in the models tested. Model 5 shows the coefficients wheeled toy by gender (.351) and child–child interaction by gender (.108). Boys with wheeled toys or interacting with other children exhibit even more PA than girls with a wheeled toy, and more than boys not using a wheeled toy, as well as more than girls interacting with others or boys not interacting with others. Although at some level it is disappointing to see only two statistically significant interaction effects, it is not unusual to find few such effects, as measurement error is compounded by use of the product terms (Cohen, Cohen, West, & Aiken, 2003; Jaccard, Turrisi, & Wan, 1990).

Finally, it should be mentioned that the variance in the gender slopes across models changes somewhat from .070 to .052 due largely to the presence of the cross-level interaction effects. This reduction, however, is a small proportion of the variance, suggesting that although there is systematic variation in the gender slope across settings, we have yet to identify important characteristics of those settings that may be associated with those variations.

## Discussion

This article represents the first to report the importance of several spatial measures (adjacency, location in a cluster of play settings, centrality, and distance from entrance) in children's OLEs. Through statistical modeling of PA, controlling for various size, spatial, physical, and social attributes of the child's experience in play settings, we show that a variety of such variables are predictive of PA levels. Adjacencies increase PA across all the models presented, with a consistent effect of between a 6.4% and 7.6% increase in a unit of PA per average change in adjacency across models. Location in the center of an OLE also is associated with increased PA, varying between 13.8% and 16.1% across models. Moreover, the adjacency and centrality effects do not vary by gender. Boys and girls seem to benefit similarly from the presence of other settings proximate to a given setting and from a central location of the play setting. The adjacency and centrality effects are independent, and both persist when distance from an entrance, and clustering are controlled. Methodological artifacts associated with how adjacency is defined (more adjacencies if a play setting is a path or a residual area) seem unable to explain association with PA as control variables are entered for both path (including a long loop) and a residual category (both categories of which children would likely be in transit to another setting, thus artificially contributing to an adjacency effect). Further controls for various other physical attributes of affordance fail to diminish the adjacency effect.

A play setting in a cluster (having at least one other play setting's centroid within 25 feet of the play setting's centroid) was found to be negatively associated with PA in the zero-order correlation, but was not statistically significant in any of the models. As suggested above, attributes of these nearby play settings, specifically consisting of structures with affordances for sedentary behaviors (playing "house,", sitting at a picnic table, etc.) that were not measured in our data collection process may be accounting for the lack of a positive effect on PA. As such, the results suggest that type of affordance in a nearby play setting, not physical proximity, plays an important role in generating PA. That is, if a child sees other children more physically active in a nearby setting, that may trigger more PA in the child, whereas seeing more sedentary children nearby may have the opposite effect.

The fact that adjacency of a play setting has a positive effect on PA, while being in a cluster of play settings does not, requires explanation. If it is not physical proximity of play settings, but the number of adjacent play settings that leads to more PA, what are the possible mechanisms other than proximity? One mechanism is visual cues from seeing multiple other play settings. Recall that young children are constantly moving. The mean PA in our sample is "some locomotion," meaning the children are on average walking. Doing so in a play setting with relatively many adjacent play settings may stimulate more PA through a visual mechanism (a "panorama" display of PA cues from adjacent play settings). A second plausible interpretation of the adjacency effect on PA is that there is a more complex set of interrelationships being captured by the variable number of adjacencies, such as more complex interactions of size of play area, play setting shape, or physical affordances (e.g., vertical elements to chase around) not otherwise measured in our models. Play settings with relatively many adjacent play settings tend to be larger, and thus associated with more PA. Seeing nearby children being more physically active may trigger increased PA in the child. It may be fruitful for future research to try to capture the extent to which children seem to notice children and their activities in adjacent settings.

As a play area's adjacencies have a smaller effect on PA than does another spatial attribute, centrality (being in the center of an OLE), it would seem important to try to account for the centrality effects. As suggested above, visual cues may be a factor. Children in the center of an OLE may see others around them "on all sides," and thus more likely to engage in PA. Alternatively, they may see themselves as part of the action and motivated to "perform," resulting in more PA. Presumably, all else being equal, there are more play areas visible and more synergy in a play setting in the middle of an OLE. It may also be the case that the play area in the center is one that has equipment (perhaps the most expensive or most interesting equipment, as that is given "center stage" in the OLE's design process).

Apart from spatial arrangement of play settings, it should be noted that affordance variables are more strongly related to PA than are the spatial measures. This is not entirely surprising as one would expect some correspondence between affordance and PA behavior (children run and kick soccer balls in a soccer field and not usually around picnic tables). Yet, as mentioned above, the effects of the spatial factors of adjacency and centrality are substantial and similar to the effects of other variables known to be associated with PA, such as gender, affordances such as open areas, pathways, medium-hard surfaces, and social characteristics as in peer or teacher interaction variables. So, although not the largest effects observed, spatial effects are substantial.

Also, it should be noted that gender is predictive of PA, and its effect is found to vary as a function of whether the child is using a wheeled device, or is interacting with other children. Boys on wheeled toys exhibit more PA than girls do or boys not using such devices. Also, boys in interaction with other children are more likely to display PA than girls or boys not interacting with others. More interesting perhaps is that we tested for gender interaction effects with a variety of variables and found no others to be statistically significant than the two mentioned. Thus, virtually all the factors that have been found to be predictive of PA for these preschool children have similar effects for both boys and girls (with implications for gender-neutral play setting design).

As for other notable effects found in the models, large OLEs were found to be associated with less PA, net the effects of other factors (i.e., the larger the total play area for a childcare center, the less the PA). As the coefficient is net that of all the other variables, the association could be interpreted as another form of an adjacency effect as more distance on average exists between the midpoints of observational settings in large play areas than in small ones (more space between the settings). So, if the midpoints of the observational zones were further apart in large play areas, the adjacent play areas would be less physically proximate and thus less stimulating of PA (yet, note the lack of a cluster effect as discussed above).

PA occurs more often in the fall months than the spring, leading us to speculate about a possible novelty effect, that is, excessively hot summers in North Carolina limit outdoor play time and the arrival of cool fall weather allows for more of it, an effect that has worn off by the spring—but this is purely speculative. Some of the decline could be due to aging (children observed are older in the spring), but here we lack a measure of age.

Generally, support is found for the importance of spatial variables, as well as more generally for affordance theory. Various physical characteristics of the settings, specifically the presence of equipment, or an open area, are associated positively with PA, whereas gathering places is negatively associated with PA. Thus, the type of activity "encouraged" by the physical environment seems to manifest itself in PA, depending on the affordance. The presence of a ball or a wheeled toy increases PA (the latter especially the case for boys), although contact with another object (not wheeled toy or ball) is negatively related to PA. The latter effect is interpreted to refer to contact with benches or seats (sitting), or on equipment that serves as a seat or support for resting (e.g., leaning). Such findings offer further support for affordance theory.

Net the effects of other variables in the model, the softness or hardness of the surface area has no association with PA. Previous research has found that hard surfaces are conducive to small boy children's PA (Cardon et al., 2008), but we did not find that to be the case here (although hard surface areas correlated .031 with PA, significant at .05 level; and medium surfaces correlated −.272 with PA, significant at .001 level). We suspect that because we control for wheeled toys, and for pathways (often having a hard surface) that we may have accounted for the relationship between hard surface and PA here.

As for social attributes of children's experience in settings, social interaction with other children generally is positively associated with PA, with a stronger relationship for boys than girls. Although social interaction has been associated with engaging in PA in older children and adults (Allender, Cowburn, & Foster, 2006; Smith, 1999), we know of no previous observational finding for preschoolers in OLEs. Some studies have shown that older children, especially girls, are more likely to engage in PA when interacting with networks of friends who have a propensity to engage in PA (Voorhees et al., 2008). We did find a statistically significant interaction effect between gender and peer association, suggesting that boys' PA benefits more than girls from peer interaction.

The association between social interaction and PA in general is subject to several interpretations. One interpretation is selection: More social children, who tend to interact more with other children, tend to be more physically active in general. A second interpretation involves spurious correlation: Children choose to engage in a social game that requires more PA (e.g., game of tag) than a non-social game (sliding down a slide). So, a prior variable "choice of the type of game" (social or not) is determining the degree of PA. A third possibility is causal: The interaction stimulates the child to be more physically active. Longitudinal data of child play over time would be necessary to help sort out these alternative interpretations. Why boys' PA seems to benefit from social interaction more than girls' is unclear. It could be that boys engage in more of the social games that encourage PA (e.g., tag).

Teacher intervention due to child's "misbehavior" requiring custodial or reprimanding behavior on the teacher's part is associated with less PA, possibly attributed to "helicopter parenting"—the adult presence is having an inhibitory effect on the PA level (Floyd et al., 2011). More likely, perhaps, is that the custodial or reprimanding behavior "slows down" the child as he or she may be under pressure to conform to the sanctioning adult. Put simply, listening to an adult may slow a child down.

Also notable, much of the variation in the gender slope remains after the interaction effect involving gender is found to be predictive of PA, suggesting other factors not tested in the analysis may be found to account (in future research) for the varying gender slopes. More research needs to be done on gender-specific models to help understand these dynamics.

It is clear that spatial arrangements of play settings are important. Specifically, adjacency theory is supported, which has potential policy implications for future OLE design, construction, and renovation. Designers who pay more attention to the locations of play settings (including centrality as well as adjacency) relative to each other may find the OLE is more active. Through design strategies involving adjacency, it is possible to encourage more PA. Play is both highly social and spontaneous for most children. The results suggest that when children are engaged in an activity in one area and see before them another activity in an adjacent setting affording something different, they may be more likely to join in—thus moving and increasing their PA. The possibility that adjacency increases social interaction is an important mechanism to explain increased PA, but more research must be undertaken to ascertain whether it is visual cues, social interaction, or some other factor that mediates the effect of adjacent play settings on PA.

The practical implications of the centrality findings are less apparent in that only a few play areas can be central to an OLE. Future research may try to examine the mechanisms for the positive association between centrality and PA, and perhaps an understanding of those mechanisms would lead to more practical implications.

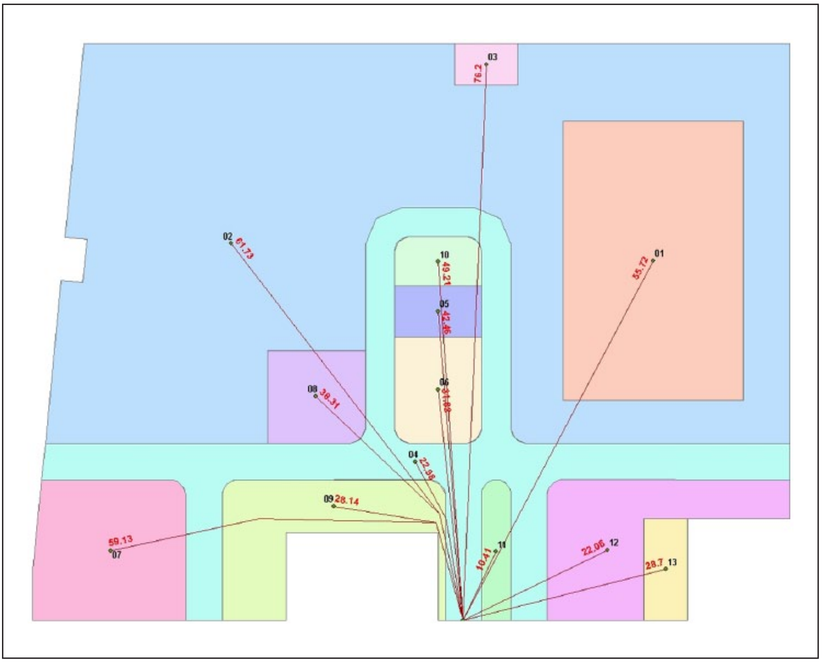
## Limitations and Contributions of the Study

The cross-sectional design limits the current research (as mentioned above), as it does not measure change in behavior due to the alteration of physical space, nor social interaction. Future research could address whether the adjacency effect is due to children taking in visual cues from nearby play settings. Such research could also provide for a more precise operational definition of adjacency. Also, future studies could be done at a larger scale to reduce the likelihood of multicollinearity issues, which here limited our ability to simultaneously test for large numbers of product terms in our tests of moderated effects. Mechanisms between a variable and the outcome (so-called intervening or mediating variables) need be identified to better understand how environments affect children varying in propensities for PA. For example, why exactly does adjacency have a positive association with PA? As it is not due strictly to physical proximity, perhaps social definitions or type of play make a difference. Further research could identify if there are optimal arrangements of types of affordances across play settings. Also, future research could be carried out in ways that keep track of individual child so as to identify how many times a child is observed during an observation session.

Despite these limitations, the current research has added to our knowledge base on the importance of outdoor built environment factors (especially affordance, spatial centrality, and adjacency) in preschoolers' PA. Spatial arrangement, or *form* (particularly adjacency and centrality of behavior settings), and physical objects, or *content* (equipment, use of wheeled toys and balls) of OLEs have been shown to be related to higher levels of PA. No previous study has shown that affordance in spatial arrangement (adjacency and centrality), as well as in the physical attributes of play settings, affect PA levels. Also, we show that increased social interaction between children leads to higher PA. More abstractly, we have shown that form, content, and sociality relate to PA. However, further research is needed to better understand the specific underlying mechanisms, especially for how adjacency and centrality work to bring about changes in PA.

## *Technical Appendix I.*

Maps Created by the Natural Learning Initiative, NC State University, Finalized June 2013



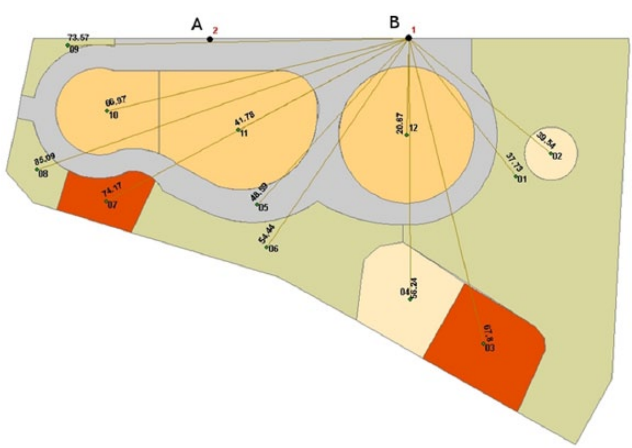

Maps of two Outdoor Learning Environments (OLEs), BBC, and BHF with distances from entrance to centroids of play settings.

Map of play area settings (above) for BBC OLE (photo below).

The above map and photograph illustrate the play area for OLE BBC. To compare the two, the slide structure in the photograph is Setting 01 on the map, and the oblong path Setting 04 can be seen surrounding the small red play house to the right in the picture (Setting 05 on the map). As can be seen, the settings are relatively close to one another, with settings 05, 06, and 10, by our definition, constituting one cluster. (Not seen in the photograph is another cluster with settings 12 and 13.) As can be seen, Setting 01 is defined by its borders, a low wooden retaining wall around the slide structure. Other borders lack a physical marker, but are defined more subjectively by the research staff as the space proximate to (or consisting of, in the case of an open field) an affordance. As for the number of adjacencies in BBC (the number of play settings contingent to or "touching" the border of a given play area), setting 10 has two (04, 05); setting 05 has three (04, 06, 10), whereas area 01 has only one adjacency (02). The cluster of 06, 07, and 08 is also judged by our criteria to be central to the OLE (centroids of the play settings are within 25 feet of each other). Setting 02 is an example of a residual area (mostly foreground area on the left side of the photograph). Distance to the centroid (midpoint) of each play area and the entrance was calculated using GIS. In the current case of BBC, there is only one entrance, but some OLEs had two (see BHF below) and one had four entrances.

Below we display a second OLE, BHF. The map shows play areas 10, 11, and 12 as central (area 10 is central because it would be perceived as such from entrance (A), settings 07 and 08 as one cluster, settings 03 and 04 another cluster, whereas 10 and 11 constitute a third cluster (so by our definition two settings or more can constitute a cluster). Distances are shown from the first entrance (B). The second entrance (A) on the left top of the map is shown but the distances are not displayed here. In the photograph the pathway (setting 05) is shown in what is a "Figure 8" pattern. The building (childcare center) is to the right and the play structure in the mid-right (with a climbing rope) is area 12 on the map, with areas 10 and 11 behind it. Area 01 is in the foreground, and constitutes a residual area. As for adjacencies in BHF, area 12 has one (05), whereas area 11 has 2 (05 and 10). The residual area 01 has five adjacencies (02, 03, 04, 05, and 06) and the pathway has eight (02, 06, 07, 08, 09, 10, 11, and 12).

Outdoor learning environment (OLE) is the official term (replacing "playground"), used since 2007 in the childcare rules for North Carolina (NC Division of Child Development and Early Education, *Child Care Rules*, Chapter 9 Condition of Outdoor Learning Environment, pp. 21-23. Effective date 09-01-12), where the research reported here was conducted. The rule change was lobbied for by a statewide group of NC early childhood professionals who wanted official recognition of the importance of outdoor play as a learning process fundamental to healthy childhood, particularly in relation to physical activity, engagement with nature, gardening, and edible landscapes.




**BHF - Distance in Feet (Entrance 1 to Centroid)**

**Map of** play area settings (above) for the BHF Outdoor Learning Environment (photo below).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## Notes

1. Minutes spent in moderate to vigorous PA (MVPA) are calculated by taking the percentage of MVPA in indoor and outdoor activities and multiplying by 600 min. Ten hours or 600 min was chosen as it represents the maximum time children can remain in childcare per day.

2. It was not practical to study the same children over time with the methods used here, precluding models of the child's behavior over time as a level of analysis; also, there are rather few center-level variables and centers themselves (30), so we minimize levels here to two, the child display of PA and the play setting.
3. In earlier models, the number of settings on a playground was also tested and has no effect on PA, net the other variables in the model, so it has been dropped from the models presented here.

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