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Article in *Journal of Environmental Psychology* · June 2017

DOI: 10.1016/j.jenvp.2017.05.007

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Time spent outdoors during preschool: Links with children's cognitive and behavioral development



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ARTICLE INFO

Article history:

Received 27 June 2016

Received in revised form

28 May 2017

Accepted 31 May 2017

Available online 1 June 2017

Keywords:

Outdoor education

Outdoor hours

Attention restoration

Digit span

Inattention

Hyperactivity

ABSTRACT

This study examined the concurrent and long-term relations between the amount of time children attending daycare spend outdoors and their cognitive and behavioral development during preschool and first grade. We applied a multi-informant design using cognitive testing and ratings from parents and teachers to follow 562 Norwegian preschoolers (298 girls; mean age at first assessment = 52.45 months, $SD = 15.96$) over a period of four years. Children's attention skills were tested with the digit span test while teachers rated their behavior. Growth curve analyses showed a positive relation between outdoor hours and children's digit span scores, and an inverse relation between outdoor hours and inattention-hyperactivity symptoms, controlling for a host of possible confounds. Results indicate that outdoor time in preschool may support children's development of attention skills and protect against inattention-hyperactivity symptoms.

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1. Introduction

In Western countries, the proportion of mothers returning to the labor market shortly after having a child has grown over the past decade. Several indicators suggest that this growth has not yet peaked (Bell, Donkin, & Marmot, 2013; Hegewisch & Gornick, 2011). Consequently, the effects of daycare on children's health and development has received much attention (Burger, 2010; Vermeer & van IJzendoorn, 2006). Daycare centers' pedagogical approaches have become increasingly diverse, and, today, a number of daycares offer outdoor activities and play-based learning approaches. For example, daycare centers differ in the quantity of outdoor activities offered (Copeland, Khoury, & Kalkwarf, 2016; Ministry of Education and Research, 2006). In Scandinavia, daycare centers increasingly offer high quantities of outdoor time; some centers offer up to 9 h of daily outdoor time, irrespective of weather and season (Borge, Nordhagen, & Lie, 2003). Given the increased diversity in the use of outdoor activities and pedagogical approaches in early childcare, there is a need to know whether such

various approaches promote children's cognitive and behavioral development.

Some literature indicates that exposure to outdoor environments may be beneficial for children's health and cognitive development (Chawla & Nasar, 2015; Gill, 2014). Thus, one might expect developmental differences between children attending daycare centers offering the recommended minimum of 1 h outdoor time per day and those attending centers that offer 7–9 h per day. Such differences in development may be visible in the short term or the long term once the children start attending formal school. Moreover, the relation between outdoor time and children's development may be linear, but curvilinear or threshold links are also possible. For example, a specific number of outdoor hours may be enough for a beneficial effect, or there may be a dose-response relationship. It is also possible that the relation between outdoor time and cognitive-behavioral development is explained by other qualities particular to the daycare centers, such as ideology and type, or that it is confounded with socio-economic status (Geoffroy et al., 2007). Thus, a longitudinal perspective and a continuous approach to outdoor time need to be adopted while controlling for a host of confounding factors to isolate the effect of outdoor time on children's development and determine the nature of this association. These are the goals of the present study, which is set in

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Norway, a leading country with respect to the use of outdoor time in daycare centers (Borge et al., 2003).

1.1. A historical-philosophical perspective

In Scandinavia, it is considered to be common sense that the outdoor environment promotes health and prevents mental and somatic problems (Borge et al., 2003). This idea is inspired from philosophers, such as Thoreau and Muir, who established a fascination for the wilderness and laid the roots for later environmentalists (Naess, 1984). In line with this concept, Froebelian kindergartens were established in Germany, the United Kingdom and the United States of America during the 19th century. The concept of “kindergarten” meant a garden for - not of - children. Froebel believed that placing children literally in the garden would engage them to play and act out in the real world, which was deemed to be good for intellectual development (Bruce, 2012). Similarly, Rousseau advocated child-rearing principles of “back to nature”, sending children to the woods, and Dewey created an educational approach based on school gardens where children might discover mathematics from seeds and gardens (Chung & Walsh, 2000). Of course, these philosophical ideas remain only ideas if not backed up by empirical evidence.

In Norway, daycare centers usually offer between 1 and 9 h of daily outdoor time. In accordance with government guidelines, daycare centers are often placed in spots that secure good weather conditions and that are rich in vegetation (Ministry of Education and Research, 2006). The intention is to stimulate play, shield from noise and traffic, and promote an appealing context. The daycare centers are encouraged to provide children with climbing structures, large sandboxes, hard surfaces (asphalt and concrete), and a place to hose off the children before going back indoors. Children may play with mud and sand in the rain, and need solid rain-proof clothing and warm shoes. In winter time, slopes and hills enable skiing and tobogganing (a simple sled used on snow by the children to ride downhill). Some daycare centers have access to an outdoor environment that is large, without fences, and distant from the buildings. Often, the buildings are old-fashioned cabins or turf huts. In Scandinavia, specific shelters (*lavvu*) in the shape of a tepee have an open fire, benches with reindeer skins to keep the children warm, and a place to store bags and food. In sum, the outdoor environment is rich in fresh air and provides experiences of seasonal changes, physical activity and allows for noisy activities requiring lots of space.

1.2. Daycare environments and children's development

Studies show that the daycare centers' structural environments may be associated with the quality of care that is provided (NICHD Early Child Care Research Network, 2000) and children's cognitive development (Peisner-Feinberg et al., 2001). For example, child-adult ratio, group size, and caregiver's education level and involvement with the children are factors associated with the quality of care that is provided (NICHD Early Child Care Research Network, 2000). Further, the quality of daycare has been associated with children's cognitive development and attention skills (NICHD Early Child Care Research Network, 1998; Wylie, Hodgen, & Thompson, 2003). The effects of daycare on children's development also tend to be moderated by child and family characteristics, such as child's gender and family harmony (Bekkhus, Rutter, Maughan, & Borge, 2011; Côté, Borge, Geoffroy, Rutter, & Tremblay, 2008), parents' socioeconomic status (Geoffroy et al., 2007), and child temperament (De Schipper, Tavecchio, Van Ijzendoorn, & Van Zeijl, 2004). There are also a number of empirical studies showing short-term gains from exposure to environments similar to those offered

in outdoor daycare centers (Chawla & Nasar, 2015; Gill, 2014). For example, in a large cross-sectional study, Kuo and Faber Taylor (2004) found that children diagnosed with ADHD showed lower levels of parent-reported inattention and hyperactivity symptoms following after-school activities in green outdoor settings than following activities in built outdoor or indoor settings. However, to our knowledge, no previous large-scale studies have investigated whether the quantity of time spent outdoors during daycare is associated with children's development in the short and long run.

Attention restoration theory gives credence to a possible positive link between exposure to outdoor environments and children's cognitive and behavioral functioning (R. Kaplan & Kaplan, 1989). Attention restoration theory suggests that natural elements found outdoors help focus attention. Nature may bolster children's attention and self-regulatory skills by allowing neural inhibitory mechanisms to rest and recover from use (Berman, Jonides, & Kaplan, 2008). For example, the indoor noise level of daycare centers is sometimes comparable to highway noise, with potentially adverse effects on child well-being (Werner, Linting, Vermeer, & Van Ijzendoorn, 2015). Outdoor time may be beneficial because the outdoor environment allows for restoration of attentional resources that have been depleted by noise and other distractions. Of note, although attention restoration theory largely explains short-term effects of exposure to nature, working memory has been described as a bottleneck for cognitive functioning (Vogel & Machizawa, 2004). Short-term benefits of outdoor time on attention may thus translate into long-term benefits by allowing children to engage in advanced learning activities (i.e. readiness to learn) (Fitzpatrick & Pagani, 2012). For example, children might engage in longer and more focused sequences of play, and they might be able to perform more complex tasks, as their attention skills are enhanced (Ruff & Lawson, 1990). Accordingly, children spending a lot of time outdoors during their preschool years may develop more self-regulatory and cognitive skills than their counterparts who are confined to indoor daycare. As a consequence, they could also become better prepared for formal school.

However, the opposite is also possible, in that indoor environments may encourage the use of effortful attention, which is beneficial for cognitive development. In line with a strength model of self-regulation (Baumeister, Vohs, & Tice, 2007), children's attention skills might mature faster in environments that require high levels of effortful attention, because of continued practice in dealing with conflicts and distractions. Also, the indoor daycare environment resembles the formal school and workplace environments where the children will spend many years. At least in the long-term, outdoor time may therefore have iatrogenic effects on attentional development if the demand for effortful attention in the outdoor environment is too low. Children spending a lot of time outdoors during preschool might thus miss out on effortful attention practice and therefore become less prepared for school.

So far, a few studies on this topic provide support for a positive link between exposure to natural environments and children's attention skills (Dadvand et al., 2015; Kuo & Faber Taylor, 2004; Mårtensson et al., 2009; Taylor, Kuo, & Sullivan, 2002; Wells & Evans, 2003). For example, a recent study that followed urban school children for one year, found that the level of vegetation surrounding homes, schools and commuting routes, as measured by satellite photos, were associated with improved working memory and a reduction in inattentiveness in 7–10 year old children (Dadvand et al., 2015). Also, Wells and Evans (2003) found that high amounts of vegetation near the homes of children mitigated the association between life stress and children's psychological distress and self-worth. In fact, Mårtensson et al. (2009) found that preschool children playing in green outdoor environments were rated by teachers as showing less inattentive behavior.

However, some of the above mentioned studies are limited by cross-sectional designs (Kuo & Faber Taylor, 2004) and small samples (Wells & Evans, 2003). In addition, none of the studies examined whether the relationship between outdoor time and children's behavioral and cognitive development is linear or nonlinear. Even if exposure to outdoor daycare during preschool is associated with better developmental adjustment, it is possible that this "positive effect" diminishes once children enter the more contrived and less outdoor-oriented formal school setting. Longitudinal research covering the transition from preschool to elementary school is necessary to address this issue. Finally, and importantly, few of the naturalistic large scale studies controlled for possible confounders.

1.3. The present study

1.3.1. Covariates

The quantity of daily outdoor activities may be related to and confounded by type of daycare centers. Nature-based daycare is a type of daycare with centers that offer up to 9 daily hours of outdoors activities. These centers are placed in green settings, surrounded by vegetation and with high emphasis on qualities of the outdoor environment. However, other types of daycare centers may be placed in both urban and rural settings and usually offer 2–6 daily hours of outdoor activities (Ministry of Education and Research, 2006). These activities might be set in contexts that are more or less high in quality. With this study, we want to examine whether outdoor time in naturalistic settings is beneficial for children, independent of type of daycare and daycare quality.

Our study included a variety of daycare centers in terms of the quantity of time spent outdoors and the type or quality of the environment, such that the possible overlap or interactive effect could be examined and controlled. However, it is possible that these centers differ in other aspects that may be important for children's development. For example, the quality of the daycare centers may also be associated with the quantity of outdoor time they offer. Moreover, children may be selected to daycare centers in terms of demographic or family factors, which could possibly confound an association between outdoor time and children's development. High parental education and income, as well as family harmony, have been found to be associated with group daycare attendance in Norway, indicating that social selection to group daycare in Norway works in the opposite direction from those in North America (Bekkhuis et al., 2011). Thus, we will control for potential confounding factors, such as socioeconomic status and family harmony, to avoid possible selection bias. Children who attend daycare centers offering high quantities of outdoor time may also come from families that use nature extensively after school hours or during weekends. To control for such an effect, we included parents' extracurricular use of nature with the child and use of nature on their own as control variables. Finally, in order to account for other important risk factors that may be related to children's development through gene-environment correlations, we included measures of children's temperament and parents' inattention-hyperactivity symptoms and psychological functioning as control variables. These variables represent phenotypic manifestations of both parents' and children's genetic liability.

1.3.2. Study objectives and hypotheses

The main objective of this study was to examine whether the time devoted by 28 daycare centers to outdoor activities is linked, both concurrently and prospectively, to children's cognitive skills and behavior, net of a host of confounding factors. In this study, we focused on the number of hours spent outdoors and children's adjustment according to a dose-response perspective. As already

mentioned, attention restoration theory and empirical findings from the previously indicated studies suggest that high exposure to outdoor settings may foster cognitive and behavioral development. However, it is theoretically possible that this is only a short-term effect. Specifically, although children with high outdoor exposure may enjoy a better cognitive and behavioral development during the preschool period, they may have difficulties adjusting to a contrived environment once they start formal school. Finally, even if the link between outdoor time and children's development is found to be generally beneficial over time, it remains to be seen whether outdoor time (i.e., between 2 and 9 h daily) is linearly incremental or whether there is an optimal dose after which the trend becomes reversed or levels off (i.e., quadratic and a threshold effect respectively).

Based on previous research on the effect of exposure to outdoor environments (Amoly et al., 2014; Berman et al., 2008; Dadvand et al., 2015) and our goal to examine children's behavioral and cognitive development, we chose inattention symptoms, hyperactivity symptoms and digit span as our outcomes of interest. These measures correspond to the main outcomes examined in previous studies environments (Amoly et al., 2014; Berman et al., 2008; Dadvand et al., 2015) and are good indicators of cognitive and behavioral functioning. Importantly, we controlled for gender, daycare center quality, children's temperament, maturational age, socioeconomic status, parent mental health symptoms, family harmony, and the use of nature after school hours. Finally, as the putative effect of outdoor time could vary across genders (i.e., boys may benefit from outdoor time more than girls because they can channel their higher need for physical activity; alternatively, girls may benefit from outdoor time more than boys because of the opportunities for social interactions fostered by unstructured outdoor activities), we also explored the potential moderating effect of child gender.

2. Methods

2.1. Participants

The 562 children participating in this study were part of a longitudinal study taking place in two suburban municipalities with populations of approximately 15 000 and 9000 (Statistics Norway, 2014c). These municipalities were typical of Norway and situated near Oslo, the capital of Norway. The median income after taxes for households with children in these municipalities was NOK 623 000 (98 000 \$), while the median income for Norway, except Oslo, was NOK 633 000 (100 000 \$) (Statistics Norway, 2017b). The average number of people in households was 2.32 in the two municipalities, while the Norwegian average was 2.22 (Statistics Norway, 2017a). There were 33 daycare centers in total and all centers agreed to participate. Five minor family centers with 4–8 children were closed down during the study, leaving 28 centers for the current study. Out of the entire population of children born between 2000 and 2005 (N = 1507), a total of 996 children were eligible as they attended one of the daycare centers, whereas the parents of 619 (62%) children agreed to participate by giving their informed written consent. Participants were included in the study if they were registered with at least one response from the child, parent or teacher (n = 562). Of these, 555 children participated at the first data collection, while 516 children participated at the fourth and final data collection. At the first data collection, children's age ranged between 12 and 78 months (Mean age = 52.45 SD = 15.96). Since some children had attended daycare for some years by the first data collection, we asked parents when the children had first enrolled in daycare. A total of 205 (36.48%) children first enrolled in daycare between the age of 1 and 2 years, 206 (36.65%) children

enrolled between the age of 2 and 3 years, 133 (23.67%) children enrolled between the age of 3 and 4 years, and 18 (3.20%) children enrolled between the age of 4 and 6 years.

2.2. Demographics

In this sample, the average maternal educational level was higher than the Norwegian national average in 2007 (Statistics Norway, 2014b); 45% of mothers had some form of tertiary education compared to 28% in Norway. This reflects a possible social selection among parents choosing to send their children to group daycare (Bekkhuis et al., 2011; Borge, Rutter, Côté, & Tremblay, 2004). However, the children attending daycare centers that offered high quantities of outdoor activities did not differ from the children in daycare centers offering low quantities of outdoor activities in terms of socioeconomic status and gender.

The mean age of the mothers at the child's birth was 29.3 years (SD 4.3), which is close to the national average (Statistics Norway, 2014a), and only 1.9% of mothers in the study gave birth at age 20 or earlier. Only 1.4% of the children were living in a household with four or more siblings. The mothers' mean age was 34 years (SD 4.7), 93% were married or cohabited with the child's father or other partner, 84% of mothers and 96% of fathers were employed at the time of the first data collection and the median household income was approximately NOK 623 000. This income was slightly lower than the national Norwegian average for households with children aged 0–5, but higher than the regional average for the two municipalities where the families lived.

2.3. Procedure

The sample was followed longitudinally from 2006 to 2009 with annual data collections in 28 daycare centers and 13 elementary schools. As illustrated in Fig. 1, the sample consisted of six cohorts born between 2000 and 2005. At each data collection, cohorts were purposefully excluded from the study if the children were younger

than 3 years or older than 7 years. Similar to an accelerated longitudinal design, data from a total of 135 three-year-olds, irrespective of the time of data collection, comprised the baseline measure that was coded as time = 1. In the same manner, four-year-old children comprised time 2 (n = 272), five-year-old children comprised time 3 (n = 402), six-year-old children comprised time 4 (n = 486) and lastly, seven-year-old children comprised time 5 (n = 396). The children aged seven years were just about to finish first grade of elementary school.

Data collections were performed each spring to ensure that the teachers had become familiar with the children. Data were drawn from parent- and teacher-rated questionnaires, standardized tests administered individually, and interviews with daycare managers. Parents were asked to complete a questionnaire to provide information about the family and the child's personality and behavior. Teachers were asked to complete separate questionnaires regarding each child's behavior. The same procedure was repeated at all four data collections. Daycare managers were interviewed retrospectively in 2011 to obtain information about the daycare centers. The Norwegian Regional Committee for Medical Research and the Norwegian Data Inspectorate approved the study.

2.4. Measures

2.4.1. Inattention and hyperactivity

Teachers completed the Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997, 2001). From ages 3 to 6, daycare staff (preschool teachers) completed the questionnaire, whereas first grade school teachers completed the questionnaire for seven-year-olds. The SDQ is a brief behavioral screening instrument that assesses the level of externalizing symptomatology in children, which has been validated in a Norwegian population sample (Heiervang, Goodman, & Goodman, 2008). Teachers were instructed to give their answers on the basis of the child's behavior over the last few months. Response options ranged from true (0), somewhat true (1) and not true (2). The items measuring hyperactivity symptoms were

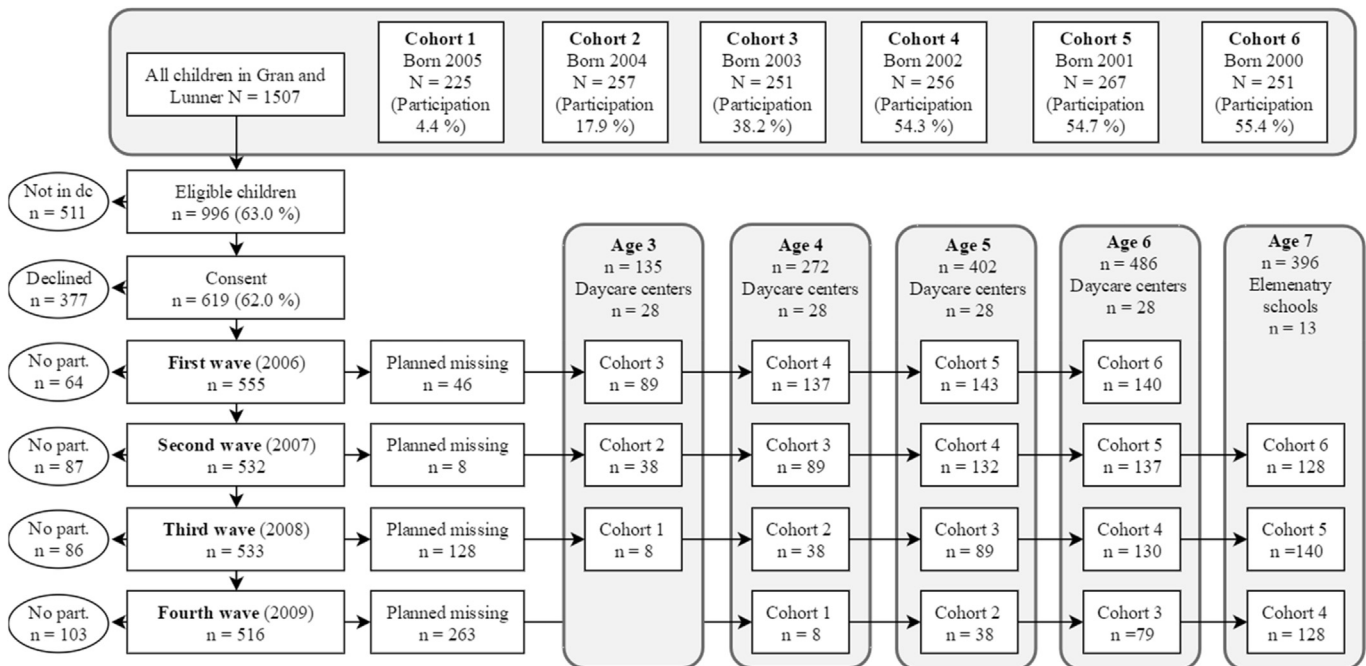


Fig. 1. Flow Chart Illustrating Study Design. Note. No part = no participation; Not in dc = not enrolled in daycare.

1) *restless, overactive, cannot keep still*, 2) *squirmy, fidgety*, 3) *quickly changes from one activity to the other* ($\alpha = 0.86$). The items measuring inattention were 1) *easily inattentive and has poor concentration*, and 2) *complete tasks, has good concentration* ($\alpha = 0.71$). Finally, we summarized the mean score.

2.4.2. Digit span

The digit span is a subtest of the Weschler Intelligence Scale for Children (WISC-IV) that measures executive functions, such as attention and short-term memory (Sattler, 2008). Children were individually tested by trained students in a quiet, separate room at the daycare centers. The examiner read aloud sequences of numbers to the children, who were then asked to repeat these number sequences back to the examiner. The test consisted of two tasks with 16 trials each. In the first task, the numbers were repeated back by the child in the same order, whereas in the second task the child was asked to repeat the numbers in the reverse order. Each task started with two-digit trials and increased by one digit every two trials until the trials reached nine digits. The tasks were discontinued when the child had failed two successive trials. One point was assigned for each correct trial. Since 96.6% of the children between ages 40 and 52 months and 68.9% of the children between ages 52–64 months got zero points for the backward test, the backward digit span was excluded from the analysis due to insufficient variation in score results for the youngest children.

2.4.3. Children's temperament

Information about child temperament was gathered at time 2 from parent interviews using the Toddler Temperament Scale (Carey & McDevitt, 1978). This is a nine-item scale with questions about toddler temperament. The items probe for the following aspects of temperament: Activity level; regularity and routine of physical symptoms; adjustment to new routines; reaction to new or unfamiliar situations; sensitivity to sensory input and stimulation; intensity of emotional reactions; average daily mood; regulation of behavior at home; regulation of behavior in play with children; regulation of behavior in unfamiliar public situations. All items were coded on a 1 to 5 Likert scale where 1 indicated the easiest temperament and 5 indicated the most difficult temperament. All items were averaged to provide a composite temperament score with higher values indicating more difficult temperament. The internal consistency was adequate ($\alpha = 0.50$).

2.4.4. Daycare center quantity of outdoor time

The number of daily outdoor hours at each daycare center was obtained from daycare managers. The leaders were asked questions concerning the amount of daily hours spent outdoors in fall-winter and in spring-summer, respectively. Most daycare centers tended to offer fewer hours outdoors in fall-winter ($M = 3.89$, $SD = 1.81$, range 1–9) than in spring-summer ($M = 6.51$, $SD = 2.06$, range 3–9). The correlation between the scores was moderate ($r = 0.37$). For each daycare center, the numbers of daily outdoor hours in fall-winter and in spring-summer were averaged together to create a composite score reflecting the number of daily hours spent outdoors throughout the year.

2.4.5. Daycare center quality

Information about daycare center quality was collected from interviews with the daycare managers. Based on previous research on structural indicators of daycare quality (NICHD Early Child Care Research Network, 2000), the following indicators were assessed: Staff education level, employment stability, child-caregiver ratio, child group size and staff sensitivity towards children.

Staff education level was extracted by calculating the number of full time positions for three different education levels: 1) Unskilled,

2) skilled and 3) higher education. The “unskilled” category included employees without relevant education. However, most unskilled employees had completed high school. The “skilled” category included employees with two years vocational training after high school and employees with one year of relevant college education. The higher education category included employees with three to four years of formal preschool teacher education in college or university. The number of full time positions within each category was multiplied with 1 for the “unskilled” category, with 2 for the “skilled” category, and with 3 for the higher education category. The weighted scores were then averaged ($M = 1.98$; $SD = 0.40$). Employment stability was measured by asking managers how they would rate the employment stability of their daycare center. Three options were possible: Unstable (1 point), relatively stable (2 points) and stable (3 points) ($M = 1.15$; $SD = 0.58$). Child-caregiver ratio was based on the number of children in each daycare center, divided by the number of teachers. The scores ranged from 2 to 8.10 ($M = 5.2$, $SD = 0.55$). Group size was reported by managers. The number of children in each class ranged from 4 to 24 ($M = 17.19$, $SD = 5.00$). The interviewer registered whether the daycare manager mentioned sensitivity towards children during the interview. If sensitivity was mentioned as an important value, this item was scored 1. It was scored 0 if not mentioned; 59% of managers mentioned sensitivity to children during the interview. Finally, a composite score was created by averaging the z-transformed scores (Cohen, Cohen, West, & Aiken, 2013).

2.4.6. Socioeconomic status

At the first assessment, parents reported information about mothers' and fathers' income levels and mothers' and fathers' highest education. Education level ranged from junior high school (1) to higher university degree (6). Income level ranged from no income (1) to more than 500 000 NOK (6). 500 000 NOK is approximately 77 000 US\$. The four variables were averaged to provide a composite SES score.

2.4.7. Parents' psychological functioning

At the first assessment, parents completed an eight-item version of the 25-item Hopkins Symptom Checklist (Strand, Dalgard, Tambs, & Rognerud, 2003). The scale consists of eight items measuring symptoms of anxiety and depression. Items were rated on a 4-point scale according to how much parents felt bothered by these symptoms, from 1 (not at all bothered) to 4 (very much bothered). The scores were averaged into a measure of psychological symptom load ranging from 1.00 to 3.63. The internal consistency was adequate ($\alpha = 0.83$). Short-form versions of SCL correlate highly with the total score of the original scale and have good psychometric properties (Strand et al., 2003).

2.4.8. Parents' own inattention-hyperactivity symptoms as a child

At the fourth assessment, parents were asked to complete the Strengths and Difficulties questionnaire. The parents were instructed to give their answers on the basis of their own behavior when they were a child. Response options ranged from *not true* (0) to *somewhat true* (1) and *true* (2). The items measuring hyperactivity symptoms were 1) *restless, overactive, cannot keep still*, 2) *Squirmy, fidgety*, 3) *quickly changes from one activity to the other*. The items measuring inattention were 1) *easily inattentive and has poor concentration*, and 2) *complete tasks, has good concentration*. Finally, we summarized the mean score. The internal consistency was adequate ($\alpha = 0.71$).

2.4.9. Family harmony

Family harmony was measured at the first assessment using a scale from the Ontario Child Health Study (Boyle et al., 1987; Côté

et al., 2008). The scale consists of 13 items that parents rated on a 4-point scale, from (1) completely agree to (4) completely disagree. The items focused on interpersonal support, conflict resolution, and the emotional climate in the family. A total score was created as the sum of all items. High scores indicate high levels of family harmony. The internal consistency was adequate ($\alpha = 0.85$).

2.4.10. Family use of nature

At the first assessment, parents were asked the questions “How often do you spend time in the forest, park or mountains with your child?” and “How often do you spend time in nature by yourself?” The items were coded on a scale ranging from 0 (never) to 4 (five times or more weekly).

2.5. Analytic strategy

The dataset was analyzed using IBM SPSS Statistics Version 20. We used multilevel mixed modeling to test whether growth curves for each of the two dependent variables (composite inattention-hyperactivity symptoms, digit span scores) were predicted by the quantity of outdoor hours in daycare. Covariates were included when they were significantly correlated with outdoor hours and at least one of the dependent variables, as indicated by bivariate correlations (see more details below and Table 2). Covariates that were excluded from the final models based on these criteria include parents' psychological functioning, parents' use of nature, and parents' use of nature with the child after daycare or school hours.

Subjects were included in the study if they were registered with at least one response. Overall, there were 20.39% missing data points. Missing data was handled with full information maximum-likelihood estimation in SPSS. To rule out a possible attrition bias, independent t-tests were used to examine whether children with complete data differed from children with incomplete data on any of the variables. No significant differences were found.

In multilevel models, a hierarchy consists of lower-level observations nested within higher-level observations. In this study, multilevel models were run as a three-level model, where repeated outcome measures (level 1) were nested within children (level 2), who were nested within daycare centers (level 3). The repeated observations of inattention-hyperactivity symptoms and digit span scores were included as level 1 variables. Child and family level variables (age in months, socioeconomic status, family harmony, parents' inattention-hyperactivity symptoms as a child, child temperament, and gender) were included as level 2 variables, while daycare level variables (daycare type, daycare quality and outdoor hours) were included as level 3 variables. Outdoor hours, child temperament, family harmony, gender, age in months, parents' inattention-hyperactivity symptoms as a child, daycare quality, daycare type, socioeconomic status and time of assessment were treated as fixed effects. Time was centered at baseline (i.e., the first assessment) and coded as 1 (age 3), 2 (age 4), 3 (age 5), 4 (age 6) and 5 (age 7). Both linear and nonlinear effects of time were tested. Time² was included to test for nonlinear effects and was coded as 1 (age 3), 4 (age 4), 9 (age 5), 16 (age 6) and 25 (age 7). The dependent variables were tested separately in two models that each comprised four steps. The first step included a fixed effect (to estimate the mean) and a random effect (to estimate the variance) of the Level 1 intercept of the repeated measures in addition to random effects of the level 2 and 3 intercepts. In the second step, we added fixed main effects of main predictors (outdoor hours, time and time²), and control variables (gender, age in months, daycare quality, daycare type, socioeconomic status, family harmony, temperament, parents' inattention-hyperactivity symptoms as a child). The third step also included a two-way interaction between outdoor hours and time. This allowed to test whether the association between

outdoor hours and the dependent variable was constant throughout the five-year assessment period. In the fourth model, an interaction between outdoor hours and a quadratic time effect was added. This allowed to test whether the association between outdoor hours and the dependent variable was exponential in size. Interactions between outdoor time and gender, daycare quality and child temperament were also tested, but none were found and these analyses are thus not presented for parsimony. The best fitting models were established using -2LL difference tests (which are equivalent to chi-square difference tests) between nested models.

3. Results

3.1. Bivariate correlations between key variables

Distributional properties of study variables are presented in Table 1. Table 2 shows the bivariate correlation coefficients between study variables. On the bivariate level, outdoor hours showed a negative correlation with inattention-hyperactivity symptoms that reached significance at age 4, age 5 and age 6. Amongst the control variables, nature-based daycare centers showed a negative correlation with inattention-hyperactivity symptoms that reached significance at age 4, age 5 and age 6. Boys showed significantly higher inattention-hyperactivity symptoms than girls at age 4, age 5, age 6 and age 7. Daycare center quality showed a negative correlation with inattention-hyperactivity symptoms that reached significance at age 3, age 4, age 5 and age 6. Socioeconomic status showed a negative correlation with inattention-hyperactivity symptoms that reached significance at age 5, age 6 and age 7. Child temperament showed a significant positive correlation with inattention-hyperactivity symptoms only at age 7. Family harmony showed a significant negative correlation with inattention-hyperactivity symptoms at age 6. Parents' retrospective ratings of their own inattention-hyperactivity symptoms as a child were positively correlated with their child's inattention-hyperactivity symptoms at age 6, while children's age in months was positively correlated with their inattention-hyperactivity at age 7.

Outdoor hours were positively associated with digit span scores at age 5, age 6 and age 7. Daycare quality was also positively correlated with digit span scores at age 6. Similarly, socioeconomic status was positively correlated with digit span scores at age 5, age 6 and age 7. Child temperament showed a negative correlation with digit span scores that reached significance at age 4. Girls showed higher digit span scores than boys at age 4 and at age 7. There was a significant and positive correlation between age in months and digit span scores at age 7, and a significant and positive correlation between family harmony and digit span scores at age 5.

3.2. Growth curve analyses

3.2.1. Inattention-hyperactivity symptoms

Table 3 shows the results from the mixed linear growth curve analysis with inattention-hyperactivity symptoms as dependent variable. The unconditional model (step 1) revealed a significant, negative effect of time ($b = -0.18$, $p < 0.01$), indicating that, on average, hyperactivity levels decreased with increasing age. The results from the second step indicated that boys and children from lower SES families showed higher inattention-hyperactivity levels than girls ($b = 0.26$, $p < 0.01$) and children from higher SES families ($b = -0.08$, $p < 0.01$). Family harmony was associated with low inattention-hyperactivity symptoms ($b = -0.01$, $p < 0.01$), and age in months was positively associated with inattention-hyperactivity symptoms ($b = 0.00$, $p < 0.01$). Daycare center quality was negatively associated with inattention-hyperactivity symptoms

Table 1
Descriptive and frequencies statistics for study variables.

Variable	Range	Mean	SD	Skew	Kurtosis	N	Plannedmissing	MissingNAT
Outdoor hours	2.00–9.00	5.20	1.60	0.60	0.25	562	0	0
Girls						298	0	0
Age in months	12.00–78.00	52.45	15.96	−0.37	−0.67	562	0	0
SES	1.50–6.00	3.62	0.86	−0.01	−0.39	536	0	26
Temperament	1.33–3.10	2.29	0.28	0.04	0.55	440	0	122
Family harmony	4.00–52.00	44.82	5.80	−1.40	5.10	521	0	41
Parent in-hy	0.00–1.80	0.27	0.32	7.85	3.89	330	0	232
Parent RPH	1.00–3.63	1.24	0.35	10.49	2.75	535	0	27
Nature with child	0.00–4.00	1.50	0.76	0.48	0.46	524	0	38
Parent in nature	0.00–4.00	1.15	0.92	0.63	0.14	525	0	37
Nature based DCC						66	0	0
DCC quality	−1.62–2.84	0.00	1.00	0.40	0.05	562	0	0
In-hy age 3	0.00–2.00	0.54	0.50	1.03	0.62	119	420	23
In-hy age 4	0.00–2.00	0.48	0.54	1.30	1.00	246	283	33
In-hy age 5	0.00–2.00	0.42	0.48	1.24	0.96	374	148	40
In-hy age 6	0.00–2.00	0.40	0.49	1.38	1.40	441	46	75
In-hy age 7	0.00–2.00	0.48	0.49	1.11	0.70	356	135	71
Digit span age 3	0.00–7.00	1.16	1.82	1.60	1.92	91	420	51
Digit span age 4	0.00–10.00	3.36	2.20	−0.18	−0.69	237	283	42
Digit span age 5	0.00–13.00	4.83	2.00	−0.14	1.08	365	148	49
Digit span age 6	0.00–14.00	5.60	1.96	−0.01	1.58	448	46	68
Digit span age 7	0.00–14.00	6.24	1.81	0.25	1.15	379	135	48

Note. Missing NAT = missing not at random; Planned missing = purposefully missing due to design; Outdoor hours = Number of daily outdoor hours in daycare center; DCC = daycare center; SES = socioeconomic status; Parent in-hy = parent inattention-hyperactivity symptoms as a child; Parent RPH = parents' recent psychological health; In-hy = inattention-hyperactivity symptoms.

($b = -0.03$, $p < 0.01$), while parents' inattention-hyperactivity symptoms as a child was positively associated with their child's inattention-hyperactivity symptoms ($b = 0.18$, $p < 0.01$). There was no significant main effect of outdoor hours on the intercept of inattention-hyperactivity symptoms. The results from the third step revealed a significant main effect of outdoor hours on inattention-hyperactivity symptoms ($b = -0.06$, $p < 0.05$). The results from the fourth step revealed a significant effect of a three-way interaction between outdoor hours and time² on inattention-hyperactivity symptoms ($b = 0.01$, $p < 0.05$). Post hoc probing of the interaction (Holmbeck, 2002) indicated that children attending daycare who spent more time outdoors showed fewer inattention-hyperactivity symptoms at ages 4, 5, 6 and 7, controlling for a host of confounding factors. When testing inattention and hyperactivity separately as dependent variables in the mixed linear growth curve analyses, the analyses revealed similar results for both inattention and hyperactivity.

The graph in Fig. 2 illustrates the development of inattention-hyperactivity symptoms from age 3 to age 7. The line marked with dots represents low levels of outdoor hours which corresponds to 3 daily outdoor hours, while the line marked with diamonds represents high levels of outdoor hours, which corresponds to 7 daily outdoor hours. As can be seen, children exposed to consistently low levels of outdoor hours showed unchanged levels of inattention-hyperactivity symptoms throughout all assessment times. In contrast, children exposed to consistently high levels of outdoor hours, while initially not significantly different from children exposed to low levels of outdoor hours, showed a dramatic decline of inattention-hyperactivity symptoms from age 3 to age 5 and retained these low levels also at age 6. However, their levels of inattention-hyperactivity symptoms increased again as they entered school at age 7.

3.2.2. Digit span forward

Table 4 shows the results from the mixed linear growth curve analysis with scores from the digit span test as dependent variable. The unconditional model (step 1) revealed a significant effect of time, indicating that, on average, digit span scores increased with

increasing age ($b = 2.72$, $p < 0.01$) with a slight tapering off at higher ages. The results from the second step showed a positive and significant main effect of outdoor hours on the intercept ($b = 0.21$, $p < 0.01$). Moreover, girls and children from higher SES families showed better performance at the digit span test than boys ($b = -0.46$, $p < 0.01$) and children from lower SES families ($b = 0.36$, $p < 0.01$). Also, age in months was positively associated with digit span scores ($b = 0.01$, $p < 0.01$). The results from the third step revealed no significant interaction between outdoor hours and time, while results from the fourth step revealed significant interactions between outdoor hours and time ($b = 0.30$, $p < 0.05$), and outdoor hours and time² ($b = -0.04$, $p < 0.05$). As illustrated in Fig. 3, while children with high and low levels of outdoor hours did not differ with respect to performance on the digit span at age 3, the former showed consistently higher levels of digit span performance than the latter from age 4 onward until after school entry (i.e., age 7).

4. Discussion

The goal of our study was to investigate whether exposure to outdoor environments is associated with children's cognitive and behavioral development throughout daycare and the first year of elementary school. Results from growth curve analyses revealed an inverse dose-response relation between daily outdoor hours and teacher-rated inattention-hyperactivity symptoms. The relation was strongest when the children were five and six years old and decreased again when children entered elementary school. Finally, the results also revealed a positive dose-response relation between outdoor hours and the children's attention skills as measured by the digit span test. This relation was also strongest when the children were 5 and 6 years, before declining in strength at age 7.

Our finding that the number of daily hours spent outdoors is associated with lower inattention-hyperactivity symptoms and higher digit span test scores indicates a positive association between outdoor activities in preschool and cognitive-behavioral development.

Table 2
Pearson's bivariate correlation matrix for study variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1. Outdoor hours	0.01																						
2. Gender	-0.06	0.03																					
3. Age in months	-0.01	-0.02	-0.05																				
4. Temperament	0.07	-0.03	-0.02	-0.05																			
5. SES	-0.06	-0.02	-0.04	-0.18**	0.01																		
6. Family harmony	0.02	0.03	0.03	0.12*	-0.21**	-0.12*																	
7. Parent in-hy	-0.02	-0.05	-0.03	-0.09	-0.01	0.16**	-0.10																
8. Nature with child	0.00	0.03	0.11*	-0.11*	0.13**	-0.02	-0.02	0.45**															
9. Parent in nature	-0.02	0.05	0.09*	0.13**	-0.10*	-0.28**	-0.16**	-0.16**	-0.06														
10. Parent RPH	0.47**	-0.01	0.01	0.01	0.00	-0.02	0.06	0.05	0.02	0.00													
11. Nature DCC	0.05	-0.02	0.02	-0.07	-0.06	0.00	-0.02	0.05	-0.04	-0.03	-0.13**												
12. DCC quality	-0.16	-0.13	-0.04	0.00	-0.18	-0.05	0.02	-0.15	-0.15	-0.03	-0.11	-0.29**											
13. In-hy age 3	-0.17**	-0.19**	0.02	0.01	-0.08	-0.05	0.14	0.06	-0.02	0.08	-0.18**	-0.14*	0.51**										
14. In-hy age 4	-0.23**	-0.24**	-0.05	0.05	-0.19**	-0.06	0.10	0.00	-0.09	0.01	-0.18**	-0.12*	0.35**	0.48**									
15. In-hy age 5	-0.16**	-0.27**	0.05	0.07	-0.15**	-0.13**	0.22**	0.01	-0.09	0.07	-0.15**	-0.10*	0.47**	0.39**	0.57**								
16. In-hy age 6	0.01	-0.28**	0.17**	0.17**	-0.12*	-0.08	0.10	-0.03	-0.05	-0.01	0.05	-0.01	0.41**	0.41**	0.55**								
17. In-hy age 7	-0.04	0.06	0.11	-0.11	0.16	0.08	-0.16	-0.07	-0.07	0.04	0.00	-0.07	0.32**	0.27*	0.02	0.24*							
18. Digit span age 3	0.10	0.18**	-0.04	-0.20**	0.07	-0.06	-0.01	-0.09	0.00	-0.06	0.10	-0.01	0.08	-0.24**	-0.20**	-0.18*	0.24*						
19. Digit span age 4	0.19**	0.09	0.03	-0.09	0.27**	0.12*	0.05	-0.06	0.03	-0.10	0.00	0.05	-0.35**	-0.22**	-0.21**	-0.18**	-0.20**	-0.08	0.40**				
20. Digit span age 5	0.15**	0.08	0.04	-0.10	0.18**	0.06	0.01	-0.04	-0.01	0.01	-0.04	0.10*	-0.37**	-0.13	-0.23**	-0.24**	-0.29**	0.21	0.33**	0.50**			
21. Digit span age 6	0.11*	0.15**	0.22*	-0.01	0.15**	-0.01	-0.08	-0.08	0.07	-0.06	0.00	0.04	0.10*	-0.07	-0.11	-0.19**	-0.16**	0.44**	0.32**	0.38**			
22. Digit span age 7																							

Note: Gender is coded 1 for boys and 2 for girls. Nature DCC is coded 0 for conventional and 1 for nature based day care center; Outdoor hours = number of daily outdoor hours; SES = socioeconomic status; Parent in-hy = parent inattention-hyperactivity symptoms as a child; Parent RPH = parents' recent psychological health; DCC quality = day care center quality; In-hy = inattention-hyperactivity symptoms; Pm = planned missing.
p* < 0.05. *p* < 0.01.

4.1. The positive effect of time spent outdoors

In his attention restoration theory, Kaplan (1995) suggested that natural environments encourage activities fostering optimal development of the nervous system. As demonstrated in a recent study, 40 s of restorative “micro-breaks” of greenness is enough to sustain attention (Lee, Williams, Sargent, Williams, & Johnson, 2015). Furthermore, children in outdoor settings engage in focused play, peer conflict resolution, and in teacher-directed activities. Outdoor daycare settings may thus offer rich opportunities for both effortless and effortful attention, allowing children to switch back and forth between the two states of attention. This is also in line with a recent review by Gill (2014) who argues that green environments are a necessary part of a balanced diet of childhood experiences.

An experimental study would be necessary to confirm a causal relation between frequent exposure to natural environments and children's cognitive and behavioral development. Moreover, the reason as to why outdoor environments are beneficial for cognitive and behavioral development remains unclear, and future research should address this issue. Effects of outdoor time on children's behavioral and cognitive functioning are probably multifactorial, and it is possible that factors other than attention restoration are at play. For example, children who are frequently outdoors may be more physically active, which could ameliorate attention and decrease hyperactive behavior and hence foster cognitive skills. In line with this notion, physical activity has been associated with better cognitive functioning in children diagnosed with ADHD (Gapin & Etnier, 2010) and is associated with structural growth in the prefrontal cortex and hippocampus (Erickson, Leckie, & Weinstein, 2014), areas of the brain that are important for working memory. Future studies should use accelerometers measuring children's activity levels (Storli & Hagen, 2010) to examine the mediating effect of physical activity on the association between exposure to outdoor environments and children's cognitive and behavioral functioning. Another alternative explanation of the beneficial effects of outdoor activities on child development is that air quality in outdoor environments is superior to that of indoor environments. Poor air quality in schools is associated with poor cognitive performance in children (Bakó-Biró, Clements-Croome, Kochhar, Awbi, & Williams, 2012). Measures of carbon monoxide levels in daycare centers could be conducted to test whether air quality at least partially explains the association between exposure to outdoor environments and children's levels of hyperactivity-inattention and digit span performance. Furthermore, children who spend the better part of the day outdoors are exposed to high levels of daylight. Light exposure is the principal cue permitting circadian rhythm regulation in animals (Cao et al., 2015) and is associated with attention (Cajochen, 2007), sleep, and emotions (LeGates, Fernandez, & Hattar, 2014). Thus, future studies should also examine exposure to daylight as a potential explanatory mechanism.

As in any non-experimental study, however, another alternative explanation can be the presence of a selection effect. Although children exposed to high versus low levels of outdoor hours did not differ in terms of their inattentive-hyperactive behavior or their digit span performance at the first assessment time (age 3), they may have differed on other, non-measured characteristics. Ideally, randomized controlled trials should be used to test our research question. However, an experimental intervention would be difficult to implement. Children would have to be randomized to various types of daycare, and it would not be possible to offer the intervention to control participants after the study, as the children age and commence school. Furthermore, the preschool period may be a critical time when children are especially susceptible to effects of

Table 3
Fixed effects estimates and variance-covariance estimates for models of the predictors of inattention and hyperactivity symptoms (n = 517).

Parameter	Model 1	Model 2	Model 3	Model 4
Intercept	0.74 (0.08)**	Fixed effects 0.54 (0.11)**	0.55 (0.11)**	0.53 (0.11)**
Time	-0.18 (0.05)**	Level 1 (repeated measures) -0.19 (0.04)**	-0.19 (0.05)**	-0.19 (0.05)**
Time ²	0.03 (0.01)**	0.02 (0.01)**	0.02 (0.01)**	0.02 (0.01)**
Gender		Level 2 (children and families) 0.26 (0.03)**	0.26 (0.03)**	0.26 (0.03)**
Age in months		0.00 (0.00)*	0.00 (0.00)*	0.00 (0.00)*
SES		-0.08 (0.02)**	-0.08 (0.02)**	-0.08 (0.02)**
Temperament		0.08 (0.07)	0.08 (0.07)	0.08 (0.07)
Family harmony		-0.01 (0.00)**	-0.01 (0.00)**	-0.01 (0.00)**
Parent in-hy		0.18 (0.07)**	0.18 (0.07)**	0.18 (0.07)**
Nature DCC		Level 3 (day care center) 0.15 (0.08)	0.15 (0.08)	0.15 (0.08)
DCC quality		-0.03 (0.01)**	-0.03 (0.01)**	0.03 (0.01)**
Outdoor h		-0.02 (0.02)	-0.06 (0.03)*	-0.04 (0.05)
Outdoor h/time			0.01 (0.01)	-0.05 (0.03)
Outdoor h/time ²				0.01 (0.00)*
Intercept	0.08 (0.01)**	Random parameters Level 2 (children) 0.06 (0.01)**	0.06 (0.01)**	0.08 (0.01)**
Intercept	0.01 (0.01)*	Level 3 (daycare center) 0.01 (0.00)	0.01 (0.01)	0.01 (0.01)
-2*LL (np)	1725.28 (14)	1613.97 (23)	1610.46 (24)	1605.18 (25)

Note. Gender is coded 1 for boys and 2 for girls. Nature DCC is coded 1 for nature-based and 0 for conventional; Standard errors are in parentheses. Np = number of parameters. SES = socioeconomic status; Temperament = child temperament; Parent in-hy = parent inattention-hyperactivity symptoms as a child; DCC quality = daycare center quality; Outdoor h = number of daily outdoor hours; 2*LL = 2*log likelihood.
*p < 0.05. **p < 0.01.

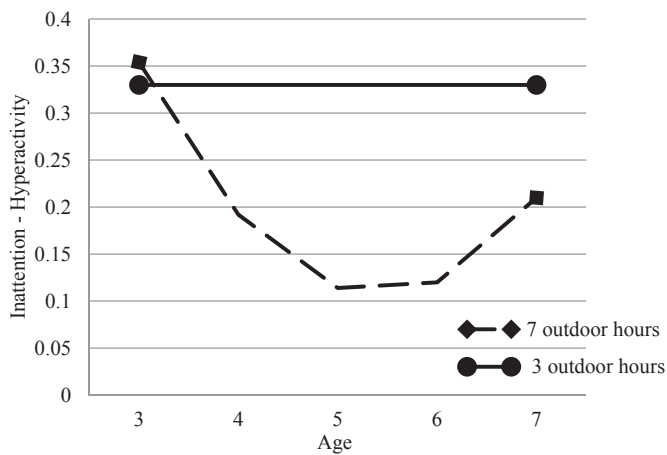


Fig. 2. Inattention-Hyperactivity Growth Curves for High and Low Levels of Outdoor Hours.
Note. Post hoc probing of interaction effects (Holmbeck, 2002); Outdoor hours = daily outdoor hours.

their environment, so receiving the intervention at a later time might not have the same effect. Nevertheless, our study is in line with previous studies that have applied longitudinal designs to investigate how various daycare characteristics are related to children's development (Belsky et al., 2007; Côté et al., 2008; NICHD Early Child Care Research Network, 2000). Teacher reporting bias might also have affected the results of this study. Outdoor time in green settings may positively affect teachers' mood, attention and impulsivity (Berry, Repke, Nickerson, Conway Odum, & Jordan, 2015; Berto, 2005; White, Pahl, Ashbullby, Herbert, & Depledge, 2013). Teachers may therefore experience the children's inattention-hyperactivity symptoms as less disturbing when outdoors, and rate the children's symptoms as better because they themselves are better equipped to deal with such symptoms.

Future studies might consider effects of outdoor time on teachers' attention skills and on the interactions between teachers and children.

Furthermore, it is possible that non-measured environmental or genetic factors influencing children's hyperactivity symptoms and digit span test scores also influence the type of daycare they are exposed to. For example, socioeconomic status may act as a confounding variable if it is associated with both parents' choice of daycare centers and their children's levels of inattention-hyperactivity symptoms and digit span test scores. Likewise, it is possible that outdoor-based daycare centers do better on quality indicators such as group size, child-adult ratio, staff education levels and employment stability. More physically active or outdoor-oriented parents may more readily decide to send their child to an outdoor daycare center. To control for such possible selection effects, parents' use of nature by themselves and with the children after school hours, were explored as possible confounders, but were not associated with the number of daycare center outdoor hours. However, in accordance with previous research (Côté et al., 2008; De Schipper, Tavecchio, Ijzendoorn, & Van Zeijl, 2004; Geoffroy et al., 2007), being a boy, low socioeconomic status, low family harmony, difficult child temperament and low scores on daycare quality indicators were associated with higher levels of inattention-hyperactivity symptoms, whereas only child gender and family socioeconomic status were associated with digit span scores. Because these possible sources of selection effects were controlled in this study, they are unlikely alternative explanations for our findings. Nevertheless, other uncontrolled confounding variables cannot be ruled out.

Surprisingly, daycare center quality was significantly associated with inattention-hyperactivity scores in our models. The Norwegian government strictly regulates structural and dynamic quality (Department of Early Childhood Education and Care, 2014; Solheim, Wichstrøm, Belsky, & Berg-Nielsen, 2013). For example, all daycare centers in the sample were high in structural quality parameters, when compared to the daycare centers used in the

Table 4
Fixed effects estimates and variance-covariance estimates for models of the predictors of digit span scores (n = 513).

Parameter	Model 1	Model 2	Model 3	Model 4
Intercept	-1.09 (0.34)**	Fixed effects -1.04 (0.48)**	-1.02 (0.47)*	-0.97 (0.47)*
Time	2.72 (0.21)**	Level 1 (repeated measures) 2.68 (0.21)**	2.67 (0.21)**	2.65 (0.21)**
Time ²	-0.25 (0.03)**	-0.25 (0.03)**	-0.24 (0.03)**	-0.24 (0.03)**
Gender		Level 2 (children and families) -0.46 (0.13)**	-0.46 (0.13)**	-0.46 (0.13)**
Age in months		0.01 (0.00)*	0.01 (0.00)*	0.01 (0.00)*
SES		0.36 (0.08)**	0.36 (0.08)**	0.36 (0.08)**
Temperament		-0.32 (0.26)	-0.32 (0.26)	-0.32 (0.26)
Family harmony		0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
Parent in-hy		0.15 (0.27)	0.15 (0.27)	0.14 (0.27)
Nature DCC		Level 3 (day care center) 0.24 (0.34)	0.25 (0.34)	0.25 (0.34)
DCC quality		0.02 (0.04)	0.02 (0.04)	0.02 (0.04)
Outdoor h		0.21 (0.06)**	0.14 (0.12)	-0.27 (0.24)
Outdoor h/time			0.02 (0.03)	0.30 (0.14)*
Outdoor h/time ²				-0.04 (0.02)*
Random parameters		Level 2 (children) Intercept 0.66 (0.23)**	0.66 (0.23)**	0.66 (0.23)**
Intercept	0.90 (0.23)**	Level 3 (daycare center) Intercept 0.11 (0.07)	0.11 (0.07)	0.11 (0.07)
-2*LL (np)	5782.07 (14)	5728.97 (23)	5728.58 (24)	5724.50 (25)

Note. Gender is coded 1 for boys and 2 for girls. Nature DCC is coded 1 for nature-based and 0 for conventional; Standard errors are in parentheses. Np = number of parameters. SES = socioeconomic status; Temperament = child temperament; Parent in-hy = parents' inattention-hyperactivity symptoms as a child; DCC quality = daycare center quality; Outdoor h = number of daily outdoor hours; 2*LL = 2*log likelihood.
*p < 0.05. **p < 0.01.

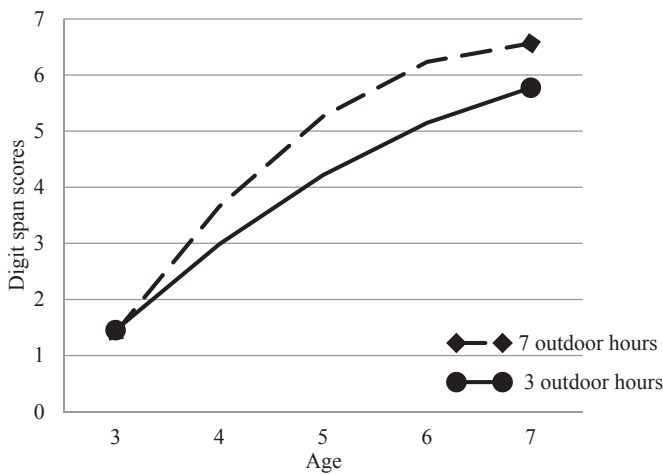


Fig. 3. Digit Span Scores Growth Curves for High and Low Levels of Outdoor Hours. Note. Post hoc probing of interaction effects (Holmbeck, 2002); Outdoor hours = daily outdoor hours.

NICHD study (NICHD Early Child Care Research Network, 2000). In other countries with greater variability and less governmental support and quality regulations, daycare quality may play an even larger role (Bennett, 2008). Importantly, however, daycare quality did not explain the observed association between exposure to outdoor hours and children's cognitive and behavioral functioning.

4.2. Strengths, limitations, and implications

All daycare centers in the municipalities agreed to take part in the study, representing a variety of forms and models of daycare centers. The study used a multidisciplinary approach, including cognitive tests and interviews with the children, parental questionnaires and in-depth interviews with daycare management. The

children were prospectively followed from preschool to elementary school, while the study was of a cross-sectional nature during the preschool years. Against that background some limitations should be mentioned. We did not have explicit measures of mechanisms underlying our findings. This means we can only speculate why children who are exposed to outdoor environments have lower levels of inattention-hyperactivity symptoms and higher scores on the digit span test than children exposed to indoor daycare environments. Also, we did not have a pre-treatment assessment of the children's behavior and cognitive skills as all children had attended daycare for at least one year by the first assessment. The explanation for our findings may be multifactorial, and future studies should test to what extent attentional restoration mediates the relation between outdoor hours in preschool and cognitive-behavioral functioning. Other possible explanations such as physical activity levels, daycare center air quality, daylight exposure and child-teacher interactions should also be explored as possible underlying mechanisms.

5. Conclusion

Overall, the findings from this study suggest that high exposure to outdoor environments might be a cheap, accessible and environmentally friendly way of supporting and enhancing children's self-regulatory capacities and cognitive development. It may also be a safe intervention for children suffering from attention disorders. For some children, high doses of nature may be an effective alternative to medication. This is however still speculative, and research on clinical populations is required. Nature is easily accessible even in urban areas. Large cities usually have parks and vegetation. Placing daycare centers near parks enables daily trips to green environments.

Acknowledgments

Funding: This work was supported by the Norwegian Research

Council [grant number 142592, 170560/V50].

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