

Contact with nature and executive functions: A pilot study with Spanish preschoolers

Noelia Sánchez-Pérez¹, María Gracia-Esteban², Rebeca Santamaría-Gutierrez³, Ginesa López-Crespo⁴

Abstract: In the last decades, studies have suggested that contact with nature might impact positively on children's Executive Functions (EF), although results are not consistent across studies. The present research aimed to explore a set of contextual factors (family socioeconomic status, residential area, and contact with nature) and their relations with preschoolers' EF. Specifically, the research proposed to examine whether there were differences in preschoolers' EF between rural/urban environments, to analyze the relation between exposure to natural surroundings and EF, and the potential interaction between contact with nature and family socioeconomic status in explaining children's EF. A total of 56 preschoolers (30 boys, 26 girls) aged 4-6 years ($M = 4.86$, $SD = .82$) participated in the study. Families reported children's contact with nature and EF through validated questionnaires. Results suggested that rural/urban environments were not related to children's EF, but preschoolers who had more contact with nature exhibited higher Working memory skills. Moreover, mothers' lower education was related to more difficulties in preschoolers' Working memory when they have less contact with nature, but spending more time in natural surroundings seems to buffer that negative relation between lower maternal education and children's EF. These preliminary findings highlight the relevance of the exposure and contact with nature for early childhood years.

Article History

Received: 01 March 2023

Accepted: 16 May 2023

Keywords

Executive functions; Self-regulation; Working memory; Nature contact; Preschoolers

Introduction

Executive Functions (EF), defined as a set of high-order cognitive skills including working memory/updating, inhibition, and shifting/flexibility (Miyake et al., 2000), support important mechanisms in individuals' self-regulatory goal pursuits (Hofmann et al., 2012), such as to allow children to pay attention (Diamond, 2013), achieve goals (Cortés Pascual et al., 2019), solve problems (Garon et al., 2008) and manage relationships (Wilson et al., 2022). Not surprisingly, EF have been found to be a relevant predictor for academic performance across the lifespan (Ahmed et al., 2018; Alloway & Alloway, 2010; Blair, 2016; Clark et al., 2010; Miller & Hinshaw, 2010), children's mental health and well-being (Brown & Landgraf, 2010). Their relevance lies in the support of children' socio-emotional adjustment (Jacobson et al., 2011; Riggs et al., 2006) and academic performance throughout infancy (Becker et al., 2014; Blair & Razza, 2007; Morgan et al., 2019), childhood (Bull & Scerif, 2001; Gathercole et al., 2004) and adolescence (Gathercole et al., 2004; Samuels et al., 2016). By contrast, difficulties in voluntarily managing thoughts, emotions, and behavior have been related to different neurodevelopmental disorders (Crisci et al., 2021; Otterman et al., 2019), internalizing and externalizing problems (Clark et al., 2002), as well as poor adjustment to the social environment (Hughes et al., 2000).

Given the powerful impact that these skills exert on human development, research has been focused on factors that facilitate EF, with the ultimate goal of enhancing their development and mitigating possible

¹ University of Zaragoza, Faculty of Social and Human Sciences, Department of Psychology and Sociology, Teruel, Spain, e-mail: noeliasanchez@unizar.es, ORCID: <https://orcid.org/0000-0002-6112-9639>

² University of Zaragoza, Faculty of Social and Human Sciences, Department of Psychology and Sociology, Teruel, Spain, e-mail: mariagracia0720@gmail.com, ORCID: <https://orcid.org/0009-0009-4740-3599>

³ University of Zaragoza, Faculty of Social and Human Sciences, Department of Psychology and Sociology, Teruel, Spain, e-mail: rsantamariagutierrez@gmail.com, ORCID: <https://orcid.org/0009-0001-1588-1854>

⁴ University of Zaragoza, Faculty of Social and Human Sciences, Department of Psychology and Sociology, Teruel, Spain, e-mail: glopezcr@unizar.es, ORCID: <https://orcid.org/0000-0002-9928-7317>

difficulties. Within this line, previous studies have analyzed how different aspects of personality, socioeconomic characteristics, and parenting practices are associated with the development of self-regulation skills (e.g. Conway & Stifter, 2012; Hackman et al., 2015; Latzman, 2009; Lucassen et al., 2015; Sarsour et al., 2011; Schoemaker et al., 2012; Unsworth et al., 2014). However, less well known is the possible impact that the environment (e.g., urban *versus* rural settings, exposure to nature) and its interaction with family context (e.g. family socioeconomic status -SES-) might have on the development of EF. In this sense, the present study aimed to examine the potential differences in preschoolers' EF depending on their residential area (urban *versus* rural areas), to study the relation between preschoolers' contact with nature and difficulties in FE, and to investigate whether contact with nature moderates the effect of family SES on EF difficulties.

Executive Functions: Skills and Development

Executive Functions are considered as a construct composed of a set of independent, but related constructs such as Inhibition, Flexibility and Working memory (Diamond, 2013; Lehto et al., 2003; Miyake et al., 2000). Neuroanatomically, these skills are related to the prefrontal cortex (Carlson et al., 2013; Müller & Kerns, 2015; Zelazo et al., 2016), that is operative since the first year of life, but its development is not finished until adulthood (Casey et al., 2000; Garon et al., 2008). Since the neurodevelopment of EF is associated with this region, it is not surprising that critical improvements take place at preschool years (Garon et al., 2008), although these skills are present at early stages of life (Garon et al., 2008). Regarding each EF component, *inhibition* has been defined as “the ability to control the own attention, thoughts, behavior, emotions to override a strong internal predisposition or external lure, and instead do what's more appropriate or needed” (Diamond, 2013); *cognitive flexibility* is characterized as the ability to switch between multiple tasks, operations, or mental sets (Miyake et al., 2000), including the possibility of thinking about something from different perspectives (Diamond, 2016), and *working memory* (WM) is considered as the ability to work with information (Alloway & Copello, 2013), which can be stored and processed for short periods of time when cognitive activities occur (Gathercole et al., 2004).

Considering the early development of EF (Anderson, 2002; Best & Miller, 2010; Casey et al., 2000; Cowan et al., 2006; Garon et al., 2008; Kibbe & Leslie, 2013), together with the fact that preschool years are related to a fast growth of motor, language, social and cognitive skills (Anderson & Reidy, 2012), it is crucial to investigate the factors influencing EF skills at this development stage.

Executive Functions: Relations to Family SES, Residential Areas, and Contact with Nature

In explaining EF's development, scientifics have been focused on a wide range of factors, such as different aspects of socioeconomic and educational level (Hackman et al., 2015; Sarsour et al., 2011), residential area (Freitas et al., 2022; Gouin et al., 2015; Hermida et al., 2019; Linnell et al., 2013) and contact with nature (Madzia et al., 2019; Taylor et al., 2002). A huge body of research has demonstrated the associations between family socioeconomic status (SES) and specific cognitive functions (for a review, see Duncan & Magnuson, 2012). As Duncan and Magnuson (2012) pointed out, although correlations between parental schooling levels, and children's achievement “are among the most replicated results (Bornstein et al., 2003) from developmental studies. Yet, surprisingly, little is known about the causal nature of these associations (Sobel, 1998)”. In the case of family incomes effects, a meta-analysis concluded that household income has a positive causal effect on children's outcomes, including their cognitive and social-behavioral development and their health (Cooper & Stewart, 2021). In the same line, a recent study shows that infants in families who receive more support from child-related tax improved math and reading test scores and achieved a higher likelihood of high-school graduation (Barr et al., 2022).

The residential areas (rural *versus* urban areas) is another contextual factor that may influence children's EF, yet the studies have yield mixed results (Freitas et al., 2022; Gouin et al., 2015; Hermida et al., 2019; Linnell et al., 2013). On one hand, studies have reported that children from rural areas achieved a worse performance than those from urban areas (Hermida et al., 2019; Wang et al., 2019). On the other hand, researchers have also found that children living in rural areas outperformed peers from urban contexts in WM tasks (Freitas et al., 2022), and behavior in the classroom (respect of classroom rules,

attention, independence when confronted with a task, speed of task execution, work organization, self-confidence, the ability to keep up with classroom rhythm, and tiredness; Boussicault et al., 2013). Given the mixed results, more research is required to clarify the potential differential EF development in children from rural/urban areas.

A different contextual factor related to children's EF is contact with nature. Although much less explored, studies indicated that children's contact with natural areas is associated with EF and self-regulation skills (Madzia et al., 2019; Taylor et al., 2002). Specifically, children's exposure to nature has been related to better cognitive skills, such as better recovery in attention (Amicone et al., 2018; Schutte et al., 2017), perceived restorativeness (Amicone et al., 2018; Schutte et al., 2017), and WM (Schutte et al., 2017; Torquati et al., 2017), as well as higher delay of gratification (Jenkin et al., 2018). This connection between exposure to nature and children's cognitive development has been also supported by a recent meta-analysis (Weeland et al., 2019). This study concluded that children who lived in greener neighborhoods or who are more frequently exposed to nature display better self-regulation, stating that natural environments have a positive impact on children's cognitive and affective development. However, the exposure to nature seems not to be equally beneficial across EF domains neither to all EF measures. For instance, the expected positive changes for inhibitory skills after playing outdoors were only found in one of three inhibitory computerized tasks in a new study (Rosiek et al., 2022). In this sense, more research is needed to clarify the effects of nature on specific EF components, as well as the different types of natural elements (including natural areas, green urban spaces, breaks on green areas, and watching natural elements on computers).

Present Study

The present research was focused on preschooler years because the scientific community recognizes that Executive Functions develop dramatically between 3-6 years of age (Carlson et al., 2004; Chevalier & Blaye, 2009; Wright et al., 2003; Zelazo & Müller, 2002), underlining the relevance of these ages in subsequent social and cognitive development (Carlson, 2005). However, most of the aforementioned studies were focused on school ages (Amicone et al., 2018; Freitas et al., 2022; Linnell et al., 2013; Madzia et al., 2019; Taylor et al., 2002), leaving a gap in the study of EF during preschooler ages. Another key point to consider is that the literature about the differences between urban and rural areas has been centered on children's academic achievement (Graham & Provost, 2012; Williams & Mann, 2006; Young, 1998) instead of studying the psychological mechanism underlying those preschoolers' academic outcomes, such as Executive Functions. In relation to sociodemographic characteristics, a review from Rosa and Collado (2019) already pointed out the relevance to consider these factors in the contact with nature links; unfortunately, only a few studies have included them in their studies (Duron-Ramos et al., 2020; Gifford & Nilsson, 2014; Hinds & Sparks, 2008). Moreover, the present study collected children's EF data from urban and rural populations, which is crucial to achieve a representative sample, especially in the case of Aragón (Spain), where 92 % of the areas are considered rural (Aragonese Institute of Statistics, 2019).

With those gaps in mind, the present research proposed to analyze the relationship between contextual factors and EF in a sample of typically developing preschoolers in both rural and urban areas in the province of Teruel (Aragón, Spain). Specifically, our objectives were:

1. To investigate the possible differences in Executive Functions of preschoolers from rural *versus* urban environments.
2. To analyze the possible association between contact with nature and preschoolers' Executive Functions.
3. To examine whether contact with nature was moderating the relation between SES and preschoolers' Executive Functions.

Method

Participants

The initial sample was composed of 61 preschoolers but, given the aims of the study, two children were excluded because they were 3 years-old, two because they had a neurodevelopmental disorder, and

one because the family did not complete the EF questionnaire. Consequently, the final number of participants were 56 preschoolers (30 boys and 26 girls) aged 4-6 years ($M = 4.86$, $SD = 0.82$). Among the participating families, 26.8% lived in urban areas, and 73.2% in rural areas in the province of Teruel (Aragón, Spain).

Related to the parents' education level, 21.8% of the mothers were educated at the elementary school, 25.5% at the high school level, and 52.7% at the university level. In the case of the fathers, the percentage were 38.5% studied until elementary school, 40.4% until high school and 21.2% until the university level. In terms of monthly income, 1.9% of the families reported to earn less than 750€ (lower extreme compared to the average family income), 17.3% reported to earn from 751 to 1200 (well below average), 7.7% from 1201 to 1600 (below average), 15.4% from 1601 to 2000 (in average), 28.8% from 2001 to 3000€ (above average), and 28.8% families reported more than 3000€ (well above average).

Measures

Contact with nature: the frequency of contact with nature was measured using a 4-item questionnaire (Gotch & Hall, 2004; Larson et al., 2011) translated to Spanish (Collado et al., 2015). Families were asked to fill it with the following questions that refer to the last 12 months: "How frequently your child has spent time in natural places such as the countryside, the beach, the mountains, etc.?", "How frequently your child has visited places such as zoos or aquariums?"; and another two questions about daily activities related to nature: "Does your child play in natural places after school time?", and "Does your child play in natural places during the weekends?". The 5-likert scale to reply ranged from "never" (1) to "more than 10 times" (5; for the first two questions), and from "never" (1) to "always" (5; for the last two questions). The final internal consistency was $\alpha = .76$. The total score of the scale was calculated by adding the scores from the 4 items.

Executive Functions: Behavior Rating Inventory of Executive Function, Preschool Version (BRIEF-P; Gioia et al., 2000; Spanish version adapted by Bausela & Luque, 2006) is a parents' report questionnaire to evaluate the daily, behavioral and observable aspects of Executive Functions. According the objectives of the study, three scales were selected: Working memory (WM; ability to hold information when completing a task, when encoding information, or when generating goals/plans in a sequential manner; $\alpha = .76$; $n = 8$ items; e.g.: "his/her capacity to pay attention has a brief duration"); Flexibility (ability to move freely from one activity or situation to another, to tolerate change; to switch or alternate attention, $\alpha = .60$, $n = 8$ items, e.g.: "the new situations can disturb him/her or make him/her uncomfortable"), and Inhibition (ability to control impulses and to stop engaging in a behavior, $\alpha = .81$, $n = 8$ items, e.g.: "s/he acts without thinking before"). The responses followed a 3-likert scale: "never" (0), "sometimes" (1) and "frequently" (2). The higher score the child obtained, the more difficulties in EF the child exhibited.

Rural and urban area: it was considered as urban area the place where the population was higher than 30.000 residents and the density was higher than 100 residents per km², following the description of rural area: "geographical space formed by the addition of towns or local entities [...] with a lower population than 30.000 inhabitants and a density lower than 100 inhabitants per km²" (Law 45/2007, 13 of December, law for the sustainable development of the countryside, BOE 299, of December 14th, 2007).

Socioeconomic and educational status: children's caregivers informed about their educational level (Primary education, Secondary education, and Postsecondary education) and monthly family incomes. For the analyses, three measures were considered: mother's, and father's education, and a composite score of SES (composed as the average of the standardized score of the three variables).

Procedure

The study was approved by the Research Ethics Committee of the Aragón (PI21-136), following Helsinki's guidelines. There were three forms to invite families to participate: (1) through public schools of Teruel province (Spain), (2) advertised in local journals, (3) publicized in social networks. A total of three schools agreed to participate and 23 families contacted the principal researcher by email/social network. The collection data took place at the end of the course (May-June 2021). In the case of schools, family's

consent, project information and the questionnaires were sent to the families through the teachers. Families had one/two weeks to fill them out and return the documents to the school (if they wanted to participate), or to give them back not complied (if they did not want to participate). The time required to complete the questionnaires was, approximately, 15-20 minutes.

Results

Descriptive statistics

According to the goals of the study, means and standard deviations for preschooler's EF distinguishing between their place of residence (urban *versus* rural) and their frequency of nature contact (higher *versus* lower contact) were calculated (see Table 1). To create the two latter groups, the total score of Contact with nature scale was split by the mean.

The normality of the distribution of each variable was evaluated based on the skewness and kurtosis values, considering distributions with values of ± 1 to be normal, with values up to ± 2 being acceptable (Field, 2013; George & Mallery, 2016). The skewness and kurtosis values allow us to assume that the distributions of the variables present a normal distribution. Assumptions for regression analyses was also verified (i.e., linearity, homoscedasticity, absence of multicollinearity, independence and normality of the standardized residuals; Field, 2013). All analyses were conducted in SPSS (IBM Corp, 2019).

Gender, age and SES differences

A series of preliminary analyses were run to test for potential gender, age, and SES' family effects on children's EF. Gender effect on EF was tested using *t*-test analysis for independent groups. The results showed that gender was not related to WM ($t(54)=.54, p=.595$), Flexibility ($t(54)=1.37, p=.176$), neither Inhibition ($t(54)=.60, p=.552$) difficulties. For testing potential age effects, analyses of variance (ANOVA) were run taking age as independent variable and EF scores as dependent variables. ANOVAs indicated that children at 5-year-olds ($M=7.00, SD=3.66$) tended to exhibit less inhibition skills than children at 4-year-old ($M=4.34, SD=2.42$) ($F(2,53)=4.07, p=.023, \eta_p^2=.133$). However, no significant result was found for WM ($F(2,53)=1.35, p=.268, \eta_p^2=.048$), neither for Flexibility scores ($F(2,53)=1.67, p=.198, \eta_p^2=.059$). Finally, zero-order correlations were conducted to test whether family' SES, mothers', and fathers' education correlated to EF scores, but analyses yield no significant results for SES composite score (WM: $r=-.16, p=.256$, Flexibility: $r=-.01, p=.936$; Inhibition: $r=-.02, p=.893$), and fathers' education (WM: $r=-.10, p=.505$, Flexibility: $r=-.05, p=.732$; Inhibition: $r=.11, p=.447$), whereas mothers' education was associated with WM ($r=-.28, p=.038$), but not related to the rest of child's EF (Flexibility: $r=.09, p=.517$; Inhibition: $r=-.23, p=.101$). Given the results, age and mothers' education were included in further analyses for Inhibition and Working memory scales, respectively.

Table 1. Descriptive statistics for variables under study

	Skewness	Kurtosis						Residential area		Contact with nature		Total sample
			Boys (<i>n</i> =30)	Girls (<i>n</i> =26)	4 years- old (<i>n</i> =23)	5 years- old (<i>n</i> =18)	6 years- old (<i>n</i> =15)	Urban area	Rural area	Higher contact with nature	Lower contact with nature	
Diff. WM	.86	.82	4.03 (3.24)	3.62 (2.48)	3.09 (2.94)	4.44 (2.97)	4.26 (2.65)	3.00 (2.24)	4.18 (3.09)	3.11 (2.45)	4.54 (3.08)	3.83 (2.90)
Diff. Flexibility	.49	-.39	3.60 (2.62)	2.77 (1.75)	2.57 (1.97)	3.78 (2.34)	3.53 (2.53)	3.33 (2.32)	3.15 (2.32)	2.93 (2.32)	3.46 (2.32)	3.21 (2.27)
Dif. Inhibition	.42	.04	5.73 (3.17)	5.23 (3.09)	4.35 (2.42)	7.00 (3.66)	5.47 (2.49)	5.40 (2.61)	5.31 (3.16)	5.56 (2.78)	5.11 (3.23)	5.50 (3.12)
Contact with nature	-.96	.63	7.33 (2.01)	7.84 (2.73)	7.43 (2.55)	7.43 (2.55)	7.88 (2.39)	6.80 (2.11)	7.88 (2.39)	9.32 (.86)	5.74 (1.99)	7.56 (2.35)

Objective 1: Are there differences between rural/urban areas and preschoolers' Executive Functions?

Independent *t*-Student analysis was run to explore the potential differences in preschoolers' difficulties in Flexibility based on their residential area (rural or urban). The results indicated that the place where children lived was not related to their difficulties in Flexibility skills ($t(54)=-.23, p=.815$). In the case

of WM and Inhibition scores, ANOVA analysis also indicated that the residential area was not related to Inhibition ($F(1,52)=.00$, $p=.997$, $\eta_p^2=.000$), even controlling by child's age ($F(1,52)=2.26$, $p=.139$, $\eta_p^2=.042$), neither to WM scores ($F(1,51)=.05$, $p=.819$, $\eta_p^2=.001$), even controlling by mothers' education ($F(1,51)=.07$, $p=.065$, $\eta_p^2=.065$). Means and standard deviations were shown in Table 1.

Objective 2: Is there any association between contact with nature and preschoolers' Executive Functions?

Zero-order correlations were calculated to investigate the associations between the frequency in contact with nature and children's difficulties in EF. As shown in Table 2, the analyses revealed that contact with nature was significant and negatively associated with preschoolers' Working memory, with a moderate effect (following Cohen's effect size recommendations). These results indicated that the more contact with nature preschoolers had, the less difficulties in holding information when completing a task, encoding information, or generating goals/plans in a sequential manner parents' observed in their children. Given the significant correlations between WM and contact with nature, WM was the EF variable considered in further analyses. The other two EF scales yield non-significant results, although the correlation between contact with nature and Flexibility scale was marginally significant ($p=.054$), suggesting that children with more contact with nature tended also to express less difficulties in moving from one activity or situation to another, to tolerate change, or to switch or alternate attention.

Table 2. Zero-order correlations between preschoolers' difficulties in Executive Functions and their contact with nature frequency

	Difficulties in EF scales		
	Working Memory	Flexibility	Inhibition
Contact with nature	-.34**	-.26 [†]	-.05

** = $p < .01$; [†] = $p < .10$

In order to reply to the second objective of the present study, linear regression was conducted considering difficulties in Working memory as a dependent variable, contact with nature as independent variable. The results confirmed that preschoolers' contact with nature was a significant predictor of their difficulties in Working memory ($F(4.11)=.022$; $\beta = -.31$, $p=.026$), even controlling by mothers' education ($\beta = -.18$, $p=.194$).

Objective 3: is family SES related to contact with nature and preschoolers' Executive Functions?

As mentioned before, mothers' education was associated with WM ($r = -.28$, $p = .038$), but not related to the rest of child's EF (Flexibility: $r = .09$, $p = .517$; Inhibition: $r = -.23$, $p = .101$), whereas WM was the only EF component correlated to contact with nature ($r = -.34$). Given these results, an analysis of variance (ANOVA) was computed to test whether the contact with nature interacted with mothers' education in explaining children's Working memory skills. With that aim, mothers' schooling (levels: elementary school, high school or university) and preschoolers' contact with nature (levels: high/low) were considered. The analysis revealed significant results for the interaction between mothers' education and children's contact with nature ($F(2,47)=2.97$, $p=.061$, $\eta_p^2=.112$). As shown in Figure 1, mothers' elementary education tended to be associated with preschoolers experiencing more difficulties in Working memory skills when they have less contact with nature, but not when they were more frequently in contact with nature.

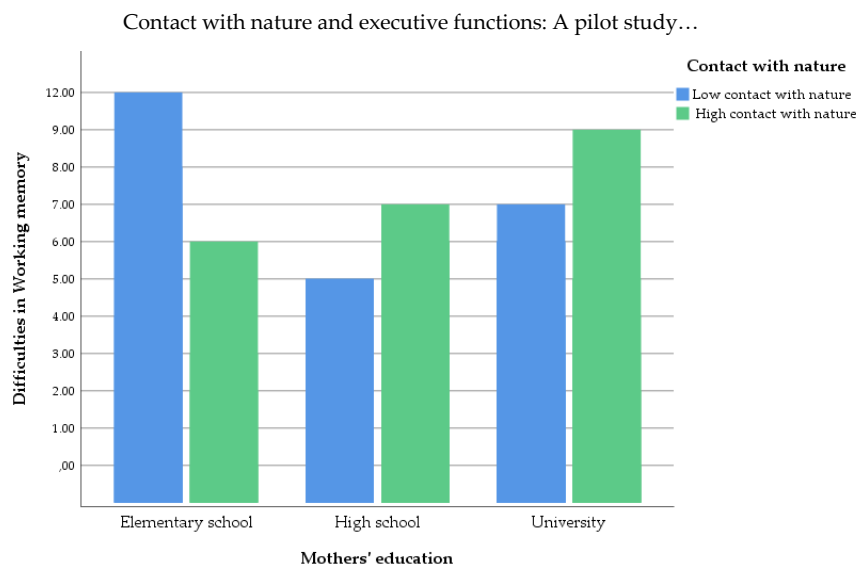


Figure 1. Bar-chart representation of the interaction effect contact with nature and mothers' education in children's Working memory.

Discussion

The present study pretends to approach to a booming line of research: the importance of the natural environment for preschoolers' cognitive development. Our results suggested that the rural/urban environment seems not to be a relevant factor for children's EF, but contact with nature is associated with Working memory skills. Specifically, those preschoolers who had more contact with nature by playing on it or spending more time in natural surroundings in the last 12 months were scored as exhibiting less difficulties in Working memory, as parents reported. Furthermore, mothers' lower education was related to more difficulties in preschoolers' Working memory when they have less contact with nature, but spending more time in natural surroundings seems to buffer that negative relation between poorer maternal education and children's EF skills.

The first objective argued that children living in urban and rural areas might exhibit differences in their performance in Executive Functions. Our results indicated that the place where children lived was not related to their difficulties in Working memory, neither Flexibility, nor Inhibition, which is in line with previous literature (Okur, 2020; Rojas-Barahona et al., 2015). However, there are also studies pointing to differences in EF performance in favor of children living in rural areas (Freitas et al., 2022), or in urban areas (Hermida et al., 2019). These mixed results might indicate that children's EF might not be directly associated with the residential area, but related to poverty and amount of resources (Hermida et al., 2019), specific parenting behaviors and daily routines. In this line, a bunch of research has repeatedly pointed the importance of household chaos disorganization and parenting environment on early EF skills (Lucassen et al., 2015; Valcan et al., 2018; Vernon-Feagans et al., 2016). Therefore, it seems that in studying the contextual factors contributing to preschoolers' EF skills the residential area might not be a key factor, but that the potential differences in EF would emerge from the family' social and material conditions and parenting behaviors.

The second objective of this study was to analyze the possible association between contact with nature and preschoolers' Executive Functions. The results confirmed that there is an association between contact with nature and Working memory, while Inhibition and Flexibility scores did not yield significant results. Moreover, preschoolers' contact with nature in the last 12 months was a significant predictor of their Working memory skills. This association is coherent with previous findings in scholars' samples (Dadvand et al., 2015; Taylor et al., 2002), although it remains unclear the mechanism underlying these benefits (Schutte et al., 2017). The majority of the studies (for instance, Dadvand et al., 2015; Mårtensson et al., 2009; Schutte et al., 2017; Taylor et al., 2002) explain the benefits of nature on children's development based on Attention Restoration Theory (ART; Kaplan, 1995). Following this theory, the decrease in

cognitive resources developing over time on sustained cognitive demands might be better overcome by spending time in natural settings, as these spaces –unlike built and urban environments– would facilitate the default mode network or mind-wandering. In this condition the occurrence of thoughts is not tied to the immediate environment –thoughts that are not related to a given task at hand (Murray et al., 2020)–, but to a range widely and spontaneously across other topics that do not require sustained attention (American Psychological Association, 2015). Another explanation for the connection between cognitive skills and contact with nature may be the relation between exposure to nature and physical activity, which is related to cognitive improvement (Fedewa & Ahn, 2011). However, a recent meta-analysis has questioned the causal evidence supporting the link between regular physical exercise and an overall enhancement of cognitive function (Ciria et al., 2023). Taking into account the possible explanation, it is possible that, by spending more time in natural spaces, children’s cognitive resources might better recover than in urban settings, as Amicone et al. (2018) already confirmed with school-age students in school environments.

The non-significant results between the other two EF and contact with nature would be explained by different reasons. In the case of Inhibition, the lack of significant findings is coherent with previous studies (Koepp et al., 2022; Schutte et al., 2017), suggesting that playing and spending time outside may not have the same relation with inhibitory skills as have with WM skills. However, our results contrast with the study of Taylor et al. (2002), who found that girls with greener views from their home performed better on tasks involving inhibitory control. There are several differences between the studies that may account for this difference in results. First, the tasks differ: Taylor et al. (2002) used a battery to evaluate inhibition of initial impulses administered to the child (Matching Familiar Figures Test, Stroop Color-Word Test, and Category Matching), whereas our parents’ reports (BRIEF-P) may not be as sensitive to capture individual differences in children’s inhibitory skills. There is also possible that the developmental stage (preschoolers *versus* scholars) and our small sample size might have affected the results. As Schutte (2017) proposed, future research should replicate the influence of nature on inhibitory control in preschoolers and schoolchildren using different inhibitory control measures. Finally, although no studies relating contact with nature and Flexibility were found, the small sample sizes would be a limitation, as the magnitude of the correlation was low-moderated ($r=-.26$, $p=.054$), but with larger sample size may reach significant levels.

The final objective of this research was testing the relation between contact with nature and family’ SES in connection to preschoolers’ EFs. Our results showed that mothers’ elementary education was related to more difficulties in preschoolers’ Working memory when children spend less time in contact with nature, whereas spending more time in natural surroundings seems to buffer that negative relation between lower maternal education and children’s EF skills. This finding brings interesting aspects in the discussion. First, mothers’ education was the only SES variable related to children’s EF (not fathers’ education, nor the composite SES score considering parental education and family incomes). This result might be explained because Spanish mothers are the principal caregiver at home (Spanish Statistics National Institute, 2016), which means that they spend more time caring for their children and have responsibility for the everyday care of their child and the decisions that affect that care. In the same line, the manuscript published by González et al. (2020) revealed that maternal education was the strongest factor contributing to children’s cognitive development among diverse socioeconomic factors, such as social class, fathers’ education level and employment. However, it is not only the time spent, but also the child-mother dyad characteristics. As Rivero et al. (2022) showed, Spanish mothers exhibits more affection, responsiveness, encouragement, and teaching attitudes to their child than Spanish fathers do, which might affect the child-father dyad and their effects. Secondly, the significant relation between mothers’ education and children’s cognitive skills has been consistently found in previous literature (Andrade et al., 2005; Greenwood et al., 2021; Hackman et al., 2015; Stevens et al., 2009). In this sense, it has been suggested that attending a higher education helps mothers to provide a more intellectually stimulating environment to their child, resulting in a higher performance in executive functioning tests (Ardila et al., 2005). However, our study suggests that the relation maternal education-child’s EF is not the same across different EF domains, as only WM was found to be correlated to mothers’ education. The positive result for WM is in line with Hackman et al. (2015), who showed that lower maternal education predicted children’s worse

performance in Working memory skills. Moreover, the null result for Inhibition scale is coherent with previous research showing that maternal education level was neither related to children's inhibitory control scores measured by computerized tasks (Pauli-Pott et al., 2010) nor by face-to-face battery tasks (Montroy et al., 2019). Given the mixed results, more studies are needed to address the influence of mothers' education on preschoolers' EF specific skills by using multiple approaches to catch the potential differences at multiple levels, such as brain imaging techniques (EEG, fMRI), teachers' and parents' reports, and observational measures. Lastly, maternal education seems to interact with contact with nature in relation to children's WM. As mentioned before, mothers with lower education tend to have children with higher WM difficulties; however, when these preschoolers spend more time in contact with nature, the negative relation between lower maternal education and children's EF skills seems to be mitigated. As far as authors know, the present research is the first study addressing this issue, but results might be explained based on the ART (Kaplan, 1995). According to this theory, although preschoolers from mothers with lower education tend to exhibit more difficulties in WM skills, this negative effect might be buffered by spending more time in natural spaces, as natural environments would help children with better recovery of their cognitive resources than in urban contexts.

Conclusion

Bearing in mind that this research is a pilot study, our findings still provide meaningful evidence to reinforce the importance of spending time in natural areas for public health, education services, and clinical practice. Meaningful, because 82% of Spanish children up to 12 years old play outdoors for less time than recommended (Technological Institute of Children's Products and Leisure, 2019), but also because the benefits of nature contact (Weeland et al., 2019) are comparable to school-based prevention programs for child depression and anxiety (e.g., Werner-Seidler et al., 2017). In this line, our findings add more empirical evidence for nature exposure as a promising tool for stimulating cognitive development and self-regulation skills (Weeland et al., 2019), promoting pro-environmental attitudes (Collado et al., 2015), and preventing child psychopathology (Werner-Seidler et al., 2017). The implications of these data include the encouragement of green areas and natural environments from public policies, as well as the enrichment of school areas with green schoolyards to promote children's Executive Functions development.

Limitations and Future Research

The current study presents a set of limitations, such as the nature of measures, the cross-sectional design, the sample size, and the potential consequences of lockdowns due to COVID. First, the instruments to measure children's EF and contact with nature were reported by parents, whereas a multi-informant variable (e.g., also considering teachers' perceptions about child's EF or administering a battery of EF tasks) would have provided a more comprehensive vision about children's executive functioning. As mentioned in the discussion section, more research with multiple measure levels and approaches is needed to better understand the connection between family context, contact with nature, and executive functioning development. Second, although parents were asked about the frequency of their contact with nature in the last year, and the hypotheses were drawn based on previous studies and theoretical frameworks, the cross-sectional design of the study makes it not possible to establish causal relations between the variables. Thirdly, as our sample size is limited, the size effects and statistical power might be lower than expected from a larger sample. Lastly, the data collection took place during the sanitary restrictions derived from COVID and, although preschoolers were not required to wear a mask, the specific situation might have affected the results.

Regarding future research, one potential line would address the potential benefits of being in contact with nature for families with lower education; for example, studying the effect of nature exposure on parents and the possible contribution to the parent-child dyad. This line of research would have an important impact in designing new educational and social intervention programmes for these preschoolers based on empirical evidence. Furthermore, it would be also interesting to address the effect of spending

time in urban green areas *versus* in nature to test the potential differences as well as the applications for prevention and intervention programmes.

Declarations

Authors' Declarations

Acknowledgements: We thank the participating children, their parents, teachers, and the administrative authorities of the schools for their cooperation.

Authors' contributions: NSP: Conceptualization, Investigation, Methodology, Formal analysis, Writing-Original draft preparation, Writing-Reviewing and Editing, Funding acquisition. MGE: Writing-Original draft preparation, Writing-Reviewing and Editing. RSG: Writing-Original draft preparation, Writing-Reviewing and Editing. GLC: Conceptualization, Methodology, Writing-Reviewing and Editing, Funding acquisition.

Competing interests: The authors declare that they have no competing interests.

Funding: This research was supported by a grant by Antonio Gargallo University Foundation (2020/B009) and PID2019-107857GA-I00 (FEDER funds) from the Spanish Ministry of Science and Innovation.

Ethics approval and consent to participate: The study was approved by the Research Ethics Committee of the Aragon (PI21-136), following the Helsinki's guidelines.

Publisher's Declarations

Editorial Acknowledgement: The editorial process of this article was carried out by Dr. Mehmet Mart, Dr. Helen Little, Dr. Helen Bilton & Dr. Michaela Kadury-Slezak.

Publisher's Note: Journal of Childhood, Education & Society remains neutral with regard to jurisdictional claims in published maps and institutional affiliation.

References

- Ahmed, S., Tang, S., Waters, N., & Davis-Kean, P. (2018). Executive function and academic achievement: longitudinal relations from early childhood to adolescence. *Journal of Educational Psychology, 111*(3), 446–458. <https://doi.org/10.1037/edu0000296>
- Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology, 106*(1), 20–29. <https://doi.org/10.1016/j.jecp.2009.11.003>
- Alloway, T. P., & Copello, E. (2013). Working memory: the what, the why, and the how. *The Educational and Developmental Psychologist, 30*(2), 105–118. <https://doi.org/10.1017/edp.2013.13>
- American Psychological Association. (2015). *APA Dictionary of Psychology* (2nd ed.). American Psychological Association.
- Amicone, G., Petruccelli, I., De Dominicis, S., Gherardini, A., Costantino, V., Perucchini, P., & Bonaiuto, M. (2018). Green breaks: The restorative effect of the school environment's green areas on children's cognitive performance. *Frontiers in Psychology, 9*, 1579. <https://doi.org/10.3389/fpsyg.2018.01579>
- Anderson, P. (2002). Assessment and development of Executive Function (EF) during childhood. *Child Neuropsychology, 8*(2), 71–82. <https://doi.org/10.1076/chin.8.2.71.8724>
- Anderson, P. J., & Reidy, N. (2012). Assessing executive function in preschoolers. *Neuropsychology Review, 22*(4), 345–360. <https://doi.org/10.1007/s11065-012-9220-3>
- Andrade, S. A., Santos, D. N., Bastos, A. C., Pedromônico, M. R. M., Almeida-Filho, N. de, & Barreto, M. L. (2005). Ambiente familiar e desenvolvimento cognitivo infantil: Uma abordagem epidemiológica [Family environment and child's cognitive development: an epidemiological approach]. *Revista de Saúde Pública, 39*(4), 606–611. <https://doi.org/10.1590/S0034-89102005000400014>
- Aragonese Institute of Statistics. (2019). Portal de Aragon. <https://www.aragon.es/organismos/departamento-de-economia-planificacion-y-empleo/direccion-general-de-economia/instituto-aragones-de-estadistica-iaest->
- Ardila, A., Rosselli, M., Matute, E., & Guajardo, S. (2005). The influence of the parents' educational level on the development of executive functions. *Developmental Neuropsychology, 28*(1), 539–560. https://doi.org/10.1207/s15326942dn2801_5
- Barr, A., Eggleston, J., & Smith, A. A. (2022). Investing in infants: The lasting effects of cash transfers to new families. *The Quarterly Journal of Economics, 137*(4), 2539–2583. <https://doi.org/10.1093/qje/qjac023>
- Bausela, E., & Luque, T. (2006). *Evaluación conductual de la función ejecutiva—versión infantil*. TEA Ediciones.
- Becker, D. R., Miao, A., Duncan, R., & McClelland, M. M. (2014). Behavioral self-regulation and executive function both predict visuospatial skills and early academic achievement. *Early Childhood Research Quarterly, 29*(4), 411–424.

<https://doi.org/10.1016/j.ecresq.2014.04.014>

- Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development, 81*(6), 1641–1660. <https://doi.org/10.1111/j.1467-8624.2010.01499.x>
- Blair, C. (2016). Executive function and early childhood education. *Current Opinion in Behavioral Sciences, 10*, 102–107. <https://doi.org/10.1016/j.cobeha.2016.05.009>
- Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*(2), 647–663. <https://doi.org/10.1111/j.1467-8624.2007.01019.x>
- Bornstein, M. H., Hahn, C.-S., Suwalsky, J. T., & Haynes, O. M. (2003). *Socioeconomic status, parenting, and child development: The Hollingshead Four-Factor Index of Social Status and The Socioeconomic Index of Occupations*. Lawrence Erlbaum Associates Publishers.
- Boussicault, G., Nguyen the Tich, S., Branger, B., Guimard, P., Florin, A., Rozé, J. C., & Flamant, C. (2013). The Global School Adaptation Score: a new neurodevelopmental assessment tool for very preterm children at five years of age. *The Journal of Pediatrics, 163*(2), 460–464. <https://doi.org/10.1016/j.jpeds.2013.01.052>
- Brown, T. E., & Landgraf, J. M. (2010). Improvements in executive function correlate with enhanced performance and functioning and health-related quality of life: Evidence from 2 large, double-blind, randomized, placebo-controlled trials in ADHD. *Postgraduate Medicine, 122*(5), 42–51. <https://doi.org/10.3810/pgm.2010.09.2200>
- Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children’s mathematics ability: Inhibition, Switching, and Working Memory. *Developmental Neuropsychology, 19*(3), 273–293. https://doi.org/10.1207/S15326942DN1903_3
- Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology, 28*(2), 595–616. https://doi.org/10.1207/s15326942dn2802_3
- Carlson, S. M., Mandell, D. J., & Williams, L. (2004). Executive Function and Theory of Mind: stability and prediction from ages 2 to 3. *Developmental Psychology, 40*(6), 1105–1122. <https://doi.org/10.1037/0012-1649.40.6.1105>
- Carlson, S. M., Zelazo, P. D., & Faja, S. (2013). Executive function. In *The Oxford handbook of developmental psychology (Vol 1): Body and mind* (pp. 706–743). Oxford University Press.
- Casey, B. J., Giedd, J. N., & Thomas, K. M. (2000). Structural and functional brain development and its relation to cognitive development. *Biological Psychology, 54*(1), 241–257. [https://doi.org/10.1016/S0301-0511\(00\)00058-2](https://doi.org/10.1016/S0301-0511(00)00058-2)
- Chevalier, N., & Blaye, A. (2009). Setting goals to switch between tasks: Effect of cue transparency on children’s cognitive flexibility. *Developmental Psychology, 45*(3), 782–797. <https://doi.org/10.1037/a0015409>
- Ciria, L. F., Román-Caballero, R., Vadillo, M. A., Holgado, D., Luque-Casado, A., Perakakis, P., & Sanabria, D. (2023). An umbrella review of randomized control trials on the effects of physical exercise on cognition. *Nature Human Behaviour, 1*–14. <https://doi.org/10.1038/s41562-023-01554-4>
- Clark, C. A. C., Pritchard, V. E., & Woodward, L. J. (2010). Preschool executive functioning abilities predict early mathematics achievement. *Developmental Psychology, 46*(5), 1176–1191. <https://doi.org/10.1037/a0019672>
- Clark, C., Prior, M., & Kinsella, G. (2002). The relationship between executive function abilities, adaptive behaviour, and academic achievement in children with externalising behaviour problems. *Journal of Child Psychology and Psychiatry, 43*(6), 785–796. <https://doi.org/10.1111/1469-7610.00084>
- Collado, S., Corraliza, J. A., Staats, H., & Ruiz, M. (2015). Effect of frequency and mode of contact with nature on children’s self-reported ecological behaviors. *Journal of Environmental Psychology, 41*, 65–73. <https://doi.org/10.1016/j.jenvp.2014.11.001>
- Conway, A., & Stifter, C. A. (2012). Longitudinal Antecedents of Executive Function in preschoolers. *Child Development, 83*(3), 1022–1036. <https://doi.org/10.1111/j.1467-8624.2012.01756.x>
- Cooper, K., & Stewart, K. (2021). Does household income affect children’s outcomes? A systematic review of the evidence. *Child Indicators Research, 14*(3), 981–1005. <https://doi.org/10.1007/s12187-020-09782-0>
- Cortés Pascual, A., Moyano Muñoz, N., & Quílez Robres, A. (2019). The relationship between executive functions and academic performance in primary education: review and meta-analysis. *Frontiers in Psychology, 10*, 1582. <https://doi.org/10.3389/fpsyg.2019.01582>
- Cowan, N., Fristoe, N. M., Elliott, E. M., Brunner, R. P., & Sauls, J. S. (2006). Scope of attention, control of attention, and intelligence in children and adults. *Memory & Cognition, 34*(8), 1754–1768. <https://doi.org/10.3758/BF03195936>
- Crisci, G., Caviola, S., Cardillo, R., & Mammarella, I. C. (2021). Executive Functions in neurodevelopmental disorders: comorbidity overlaps between attention deficit and hyperactivity disorder and specific learning disorders. *Frontiers in Human Neuroscience, 15*. <https://doi.org/10.3389/fnhum.2021.594234>
- Dadvand, P., Nieuwenhuijsen, M. J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., Rivas, I., López-Vicente, M., De Castro Pascual, M., Su, J., Jerrett, M., Querol, X., & Sunyer, J. (2015). Green spaces and cognitive development in primary

- schoolchildren. *Proceedings of the National Academy of Sciences of the United States of America*, 112(26), 7937–7942. <https://doi.org/10.1073/pnas.1503402112>
- Diamond, A. (2013). Executive Functions. *Annual Review of Psychology*, 64, 135–168. <https://doi.org/10.1146/annurev-psych-113011-143750>
- Diamond, A. (2016). Why improving and assessing executive functions early in life is critical. In J. A. Griffin, P. McCardle, & L. S. Freund (Eds.), *Executive function in preschool-age children: Integrating measurement, neurodevelopment, and translational research* (pp. 11–43). American Psychological Association. <https://doi.org/10.1037/14797-002>
- Duncan, G. J., & Magnuson, K. (2012). Socioeconomic status and cognitive functioning: Moving from correlation to causation. *Wiley Interdisciplinary Reviews: Cognitive Science*, 3(3), 377–386. <https://doi.org/10.1002/wcs.1176>
- Duron-Ramos, M. F., Collado, S., García-Vázquez, F. I., & Bello-Echeverría, M. (2020). The role of urban/rural environments on Mexican children's connection to nature and pro-environmental behavior. *Frontiers in Psychology*, 11, 514. <https://doi.org/10.3389/fpsyg.2020.00514>
- Fedewa, A. L., & Ahn, S. (2011). The effects of physical activity and physical fitness on children's achievement and cognitive outcomes: A meta-analysis. *Research Quarterly for Exercise and Sport*, 82(3), 521–535. <https://doi.org/10.1080/02701367.2011.10599785>
- Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. SAGE.
- Freitas, L. L., Cardoso, T. S. G., Argollo, N., & Mello, C. B. (2022). Socioeconomic status, urbanization and executive functions development: Differences between urban and rural children. *Psicologia: Teoria e Pesquisa*, 38. <https://doi.org/10.1590/0102.3772e38220.en>
- Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin*, 134(1), 31–60. <https://doi.org/10.1037/0033-2909.134.1.31>
- Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from national curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology*, 18(1), 1–16. <https://doi.org/10.1002/acp.934>
- George, D., & Mallery, P. (2016). *IBM SPSS statistics 23 step by step* (14th ed.). Routledge.
- Gifford, R., & Nilsson, A. (2014). Personal and social factors that influence pro-environmental concern and behaviour: A review. *International Journal of Psychology*, 49(3), 141–157. <https://doi.org/10.1002/ijop.12034>
- Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). *Behavior rating inventory of executive function: BRIEF*. Psychological Assessment Resources Odessa.
- González, L., Cortés-Sancho, R., Murcia, M., Ballester, F., Rebagliato, M., & Rodríguez-Bernal, C. L. (2020). El rol de la clase social, la educación y el desempleo parentales en el desarrollo cognitivo infantil [The role of parental social class, education and unemployment on child cognitive development]. *Gaceta Sanitaria*, 34(1), 51–60. <https://doi.org/10.1016/j.gaceta.2018.07.014>
- Gotch, C., & Hall, T. (2004). Understanding nature-related behaviors among children through a theory of reasoned action approach. *Environmental Education Research*, 10(2), 157–177. <https://doi.org/10.1080/13504620242000198159>
- Gouin, M., Flamant, C., Gascoin, G., Rouger, V., Florin, A., Guimard, P., Rozé, J.-C., & Hanf, M. (2015). The association of urbanicity with cognitive development at five years of age in preterm children. *PLOS ONE*, 10(7), e0131749. <https://doi.org/10.1371/journal.pone.0131749>
- Graham, S., & Provost, L. (2012). *Mathematics achievement gaps between suburban students and their rural and urban peers increase over time*. Issue Brief N 52. Carsey Institute. <https://doi.org/10.34051/p/2020.172>
- Greenwood, P., Dudley, J., Hutton, J., DiFrancesco, M., Farah, R., & Horowitz-Kraus, T. (2021). Higher maternal education is related to negative functional connectivity between attention system networks and reading-related regions in children with reading difficulties compared to typical readers. *Brain Research*, 1766, 147532. <https://doi.org/10.1016/j.brainres.2021.147532>
- Hackman, D. A., Gallop, R., Evans, G. W., & Farah, M. J. (2015). Socioeconomic status and executive function: Developmental trajectories and mediation. *Developmental Science*, 18(5), 686–702. <https://doi.org/10.1111/desc.12246>
- Hermida, M. J., Shalom, D. E., Segretin, M. S., Goldin, A. P., Abril, M. C., Lipina, S. J., & Sigman, M. (2019). Risks for child cognitive development in rural contexts. *Frontiers in Psychology*, 9, 2697. <https://doi.org/10.3389/fpsyg.2018.02735>
- Hinds, J., & Sparks, P. (2008). Engaging with the natural environment: The role of affective connection and identity. *Journal of Environmental Psychology*, 28(2), 109–120. <https://doi.org/10.1016/j.jenvp.2007.11.001>
- Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences*, 16(3), 174–180. <https://doi.org/10.1016/j.tics.2012.01.006>
- Hughes, C., White, A., Sharpen, J., & Dunn, J. (2000). Antisocial, angry, and unsympathetic: "hard-to-manage" preschoolers' peer problems and possible cognitive influences. *The Journal of Child Psychology and Psychiatry and Allied Disciplines*, 41(2), 169–179. <https://doi.org/10.1017/S0021963099005193>

- IBM Corp. (2019). *IBM SPSS Statistics for Windows* (Version 26). IBM Corp.
- Jacobson, L. A., Williford, A. P., & Pianta, R. C. (2011). The role of executive function in children's competent adjustment to middle school. *Child Neuropsychology*, *17*(3), 255–280. <https://doi.org/10.1080/09297049.2010.535654>
- Jenkin, R., Frampton, I., White, M. P., & Pahl, S. (2018). The relationship between exposure to natural and urban environments and children's self-regulation. *Landscape Research*, *43*(3), 315–328. <https://doi.org/10.1080/01426397.2017.1316365>
- Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169–182. [https://doi.org/10.1016/0272-4944\(95\)90001-2](https://doi.org/10.1016/0272-4944(95)90001-2)
- Kibbe, M. M., & Leslie, A. M. (2013). What's the object of object working memory in infancy? Unraveling 'what' and 'how many'. *Cognitive Psychology*, *66*(4), 380–404. <https://doi.org/10.1016/j.cogpsych.2013.05.001>
- Koepp, A. E., Gershoff, E. T., Castelli, D. M., & Bryan, A. E. (2022). Preschoolers' executive functions following indoor and outdoor free play. *Trends in Neuroscience and Education*, *28*, 100182. <https://doi.org/10.1016/j.tine.2022.100182>
- Larson, L. R., Green, G. T., & Castleberry, S. B. (2011). Construction and Validation of an Instrument to Measure Environmental Orientations in a Diverse Group of Children. *Environment and Behavior*, *43*(1), 72–89. <https://doi.org/10.1177/0013916509345212>
- Latzman. (2009). *Interrelations among youth temperament, executive functions, and externalizing behaviors*. The University of Iowa.
- Sustainable development of the countryside, Publ. L. No 45/2007 (2007) <https://www.boe.es/boe/dias/2007/12/14/pdfs/A51339-51349.pdf>
- Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology*, *21*(1), 59–80. <https://doi.org/10.1348/026151003321164627>
- Linnell, K. J., Caparos, S., de Fockert, J. W., & Davidoff, J. (2013). Urbanization decreases attentional engagement. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(5), 1232–1247. <https://doi.org/10.1037/a0031139>
- Lucassen, N., Kok, R., Bakermans-Kranenburg, M. J., Van Ijzendoorn, M. H., Jaddoe, V. W. V., Hofman, A., Verhulst, F. C., Lambregtse-Van den Berg, M. P., & Tiemeier, H. (2015). Executive functions in early childhood: The role of maternal and paternal parenting practices. *British Journal of Developmental Psychology*, *33*(4), 489–505. <https://doi.org/10.1111/bjdp.12112>
- Madzia, J., Ryan, P., Yolton, K., Percy, Z., Newman, N., LeMasters, G., & Brokamp, C. (2019). Residential greenspace association with childhood behavioral outcomes. *The Journal of Pediatrics*, *207*, 233–240. <https://doi.org/10.1016/j.jpeds.2018.10.061>
- Mårtensson, F., Boldemann, C., Söderström, M., Blennow, M., Englund, J.-E., & Grahn, P. (2009). Outdoor environmental assessment of attention promoting settings for preschool children. *Health & Place*, *15*(4), 1149–1157. <https://doi.org/10.1016/j.healthplace.2009.07.002>
- Miller, M., & Hinshaw, S. P. (2010). Does childhood executive function predict adolescent functional outcomes in girls with ADHD?. *Journal of Abnormal Child Psychology*, *38*(3), 315–326. <https://doi.org/10.1007/s10802-009-9369-2>
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. <https://doi.org/10.1006/cogp.1999.0734>
- Montroy, J. J., Merz, E. C., Williams, J. M., Landry, S. H., Johnson, U. Y., Zucker, T. A., Assel, M., Taylor, H. B., Lonigan, C. J., Phillips, B. M., Clancy-Menchetti, J., Barnes, M. A., Eisenberg, N., Spinrad, T., Valiente, C., de Villiers, J., & de Villiers, P. (2019). Hot and cool dimensionality of executive function: Model invariance across age and maternal education in preschool children. *Early Childhood Research Quarterly*, *49*, 188–201. <https://doi.org/10.1016/j.ecresq.2019.06.011>
- Morgan, P. L., Farkas, G., Wang, Y., Hillemeier, M. M., Oh, Y., & Maczuga, S. (2019). Executive function deficits in kindergarten predict repeated academic difficulties across elementary school. *Early Childhood Research Quarterly*, *46*, 20–32. <https://doi.org/10.1016/j.ecresq.2018.06.009>
- Müller, U., & Kerns, K. (2015). The development of executive function. In *Handbook of child psychology and developmental science: Cognitive processes* (Vol. 2, 7th ed., pp. 571–623). John Wiley & Sons, Inc. <https://doi.org/10.1002/9781118963418.childpsy214>
- Murray, S., Krasich, K., Schooler, J. W., & Seli, P. (2020). What's in a task? Complications in the study of the task-unrelated-thought variety of mind wandering. *Perspectives on Psychological Science*, *15*(3), 572–588. <https://doi.org/10.1177/1745691619897966>
- Okur, Ş. (2020). *Predictors of executive function in early childhood: Urban and rural poverty*. [Doctoral dissertation]. Middle East Technical University.
- Otterman, D. L., Koopman-Verhoeff, M. E., White, T. J., Tiemeier, H., Bolhuis, K., & Jansen, P. W. (2019). Executive functioning and neurodevelopmental disorders in early childhood: A prospective population-based study. *Child and Adolescent Psychiatry and Mental Health*, *13*, 38. <https://doi.org/10.1186/s13034-019-0299-7>
- Pauli-Pott, U., Albayrak, Ö., Hebebrand, J., & Pott, W. (2010). Association between inhibitory control capacity and body weight in overweight and obese children and adolescents: Dependence on age and inhibitory control component. *Child Neuropsychology*, *16*(6), 592–603. <https://doi.org/10.1080/09297049.2010.485980>

- Riggs, N. R., Jahromi, L. B., Razza, R. P., Dillworth-Bart, J. E., & Mueller, U. (2006). Executive function and the promotion of social-emotional competence. *Journal of Applied Developmental Psychology, 27*(4), 300–309. <https://doi.org/10.1016/j.appdev.2006.04.002>
- Rivero, M., Vilaseca, R., Cantero, M.-J., Navarro-Pardo, E., Ferrer, F., Valls-Vidal, C., & Bersabé, R. M. (2022). Parenting of Spanish mothers and fathers playing with their children at home. *Plos One, 17*(6), e0266762. <https://doi.org/10.1371/journal.pone.0266762>
- Rojas-Barahona, C. A., Förster, C. E., Moreno-Ríos, S., & McClelland, M. M. (2015). Improvement of working memory in preschoolers and its impact on early literacy skills: a study in deprived communities of rural and urban areas. *Early Education and Development, 26*(5–6), 871–892. <https://doi.org/10.1080/10409289.2015.1036346>
- Rosa, C. D., & Collado, S. (2019). Experiences in nature and environmental attitudes and behaviors: setting the ground for future research. *Frontiers in Psychology, 10*, 763. <https://doi.org/10.3389/fpsyg.2019.00763>
- Rosiek, M. A., Etnier, J. L., & Willoughby, M. T. (2022). A comparison of the effects of outdoor physical activity and indoor classroom-based activities on measures of executive function in preschoolers. *International Journal of Early Childhood, 54*(2), 203–215. <https://doi.org/10.1007/s13158-022-00318-x>
- Samuels, W. E., Tournaki, N., Blackman, S., & Zilinski, C. (2016). Executive functioning predicts academic achievement in middle school: A four-year longitudinal study. *The Journal of Educational Research, 109*(5), 478–490. <https://doi.org/10.1080/00220671.2014.979913>
- Sarsour, K., Sheridan, M., Jutte, D., Nuru-Jeter, A., Hinshaw, S., & Boyce, W. T. (2011). Family socioeconomic status and child executive functions: The roles of language, home environment, and single parenthood. *Journal of the International Neuropsychological Society, 17*(1), 120–132. <https://doi.org/10.1017/S1355617710001335>
- Schoemaker, K., Bunte, T., Wiebe, S. A., Espy, K. A., Deković, M., & Matthys, W. (2012). Executive function deficits in preschool children with ADHD and DBD. *Journal of Child Psychology and Psychiatry, 53*(2), 111–119. <https://doi.org/10.1111/j.1469-7610.2011.02468.x>
- Schutte, A. R., Torquati, J. C., & Beattie, H. L. (2017). Impact of urban nature on executive functioning in early and middle childhood. *Environment and Behavior, 49*(1), 3–30. <https://doi.org/10.1177/0013916515603095>
- Sobel, M. E. (1998). Causal inference in statistical models of the process of socioeconomic achievement: A case study. *Sociological Methods & Research, 27*(2), 318–348. <https://doi.org/10.1177/0049124198027002006>
- Spanish Statistics National Institute. (2016). *Total personas (de 18 y más años). Actividades de cuidados y tareas del hogar. Niños que asisten a centros educativos y de cuidados. Hogares con personas dependientes*. INE. <https://www.ine.es/dynt3/inebase/es/index.htm?padre=8495&capsel=8539> - if here is english please add. It's only in Spanish, but the name in English would be: "Spanish Statistics National Institute. (2016). *Total people (18 years and over). Care activities and household chores. Children attending educational and care centers. Households with dependent people*. INE. <https://www.ine.es/dynt3/inebase/es/index.htm?padre=8495&capsel=8539>"
- Stevens, C., Lauinger, B., & Neville, H. (2009). Differences in the neural mechanisms of selective attention in children from different socioeconomic backgrounds: An event-related brain potential study. *Developmental Science, 12*(4), 634–646. <https://doi.org/10.1111/j.1467-7687.2009.00807.x>
- Taylor, A. F., Kuo, F. E., & Sullivan, W. C. (2002). Views of nature and self-discipline: evidence from inner city children. *Journal of Environmental Psychology, 22*(1), 49–63. <https://doi.org/10.1006/jevp.2001.0241>
- Technological Institute of Children's Products and Leisure. (2019). *Guía AIJU 3.0*. <https://www.infocoponline.es/pdf/Guia-AIJU-2019-20.pdf>
- Torquati, J., Schutte, A., & Kiat, J. (2017). Attentional demands of executive function tasks in indoor and outdoor settings: behavioral and neuroelectrical evidence. *Children, Youth and Environments, 27*(2), 70–92. <https://doi.org/10.7721/chilyoutenvi.27.2.0070>
- Unsworth, N., Fukuda, K., Awh, E., & Vogel, E. K. (2014). Working memory and fluid intelligence: capacity, attention control, and secondary memory retrieval. *Cognitive Psychology, 71*, 1–26. <https://doi.org/10.1016/j.cogpsych.2014.01.003>
- Valcan, D. S., Davis, H., & Pino-Pasternak, D. (2018). Parental behaviours predicting early childhood executive functions: A meta-analysis. *Educational Psychology Review, 30*, 607–649. <https://doi.org/10.1007/s10648-017-9411-9>
- Vernon-Feagans, L., Willoughby, M., & Garrett-Peters, P. (2016). Predictors of behavioral regulation in kindergarten: Household chaos, parenting, and early executive functions. *Developmental Psychology, 52*(3), 430–441. <https://doi.org/10.1037/dev0000087>
- Wang, K. Y. R., Su, Y., Xu, X., Richards, B. D., & Rao, N. (2019). *Executive function development in urban and rural areas in China*. In Society for Research in Child Development (SRCD) Biennial Meeting. All Academic, Inc.
- Weeland, J., Moens, M. A., Beute, F., Assink, M., Staaks, J. P. C., & Overbeek, G. (2019). A dose of nature: Two three-level meta-analyses of the beneficial effects of exposure to nature on children's self-regulation. *Journal of Environmental Psychology, 65*, 101326. c
- Werner-Seidler, A., Perry, Y., Callear, A. L., Newby, J. M., & Christensen, H. (2017). School-based depression and anxiety prevention

Contact with nature and executive functions: A pilot study...

- programs for young people: A systematic review and meta-analysis. *Clinical Psychology Review*, 51, 30–47. <https://doi.org/10.1016/j.cpr.2016.10.005>
- Williams, E. D. T., & Mann, T. L. (2006). *Early childhood education in rural communities: access and quality issues*. Frederick D. Patterson Research Institute.
- Wilson, J., Hogan, C., Wang, S., Andrews, G., & Shum, D. (2022). Executive function moderates the relationship between temperament and psychological difficulties in middle childhood. *Child Neuropsychology*, 28(6), 831–852. <https://doi.org/10.1080/09297049.2021.2023121>
- Wright, I., Waterman, M., Prescott, H., & Murdoch-Eaton, D. (2003). A new Stroop-like measure of inhibitory function development: Typical developmental trends. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 44(4), 561–575. <https://doi.org/10.1111/1469-7610.00145>
- Young, D. J. (1998). Rural and urban differences in student achievement in science and mathematics: A multilevel analysis. *School Effectiveness and School Improvement*, 9(4), 386–418. <https://doi.org/10.1080/0924345980090403>
- Zelazo, P. D., Blair, C. B., & Willoughby, M. T. (2016). *Executive function: Implications for education*. U. S. Department of Education (pp. 1–148). <https://ies.ed.gov/ncer/pubs/20172000/pdf/20172000.pdf>
- Zelazo, P. D., & Miller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Blackwell Handbook of Childhood Cognitive Development* (pp. 445–469). Blackwell Publishers Ltd. <https://doi.org/10.1002/9780470996652.ch20>