



Shaping executive function in pre-school: The role of early educational practice

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ABSTRACT

Recent approaches to the development of Executive Function (EF) claim that it is trainable. Purpose-designed programs have proved successful in training EF skills in young children. If the EF is permeable to training from an early age, then the type of educational practice in the first years may as well have an effect. Despite the important implications of this thesis, there is limited evidence of the role of early educational practice in shaping the EF. Previous studies suggest that children in Montessori schools, which promote autonomy and self-regulation, often perform better on EF tasks than children in conventional schools. Evidence to date, however, is not unequivocal across the studies due to a number of factors, including the heterogeneity of the tasks used to assess EF and/or possible baseline differences in the groups that are compared. Here we compare the EF skills of fifty-eight, 4- to 6-year-olds of a similar socio-economic background who had been attending either a Montessori preschool or a conventional preschool for the same period of time. Their performance was assessed with different tasks involving a range of EF processes, such as working memory, cognitive flexibility, inhibitory control, and self-regulation. Results show an advantage of Montessori preschoolers in all EF tasks. More broadly, findings suggest that even when EF skills are not purposely trained, they can be enhanced by specific educational practices.

Executive function (EF) is an umbrella term involving a number of processes that regulate cognition and emotion to facilitate goal-oriented behavior (Nin et al., 2022). Traditionally, EF includes “a triad” of core processes involving working memory flexibility and inhibitory control (Carlson, 2005; Diamond, 2013; Miyake et al., 2000); from a broader perspective, however, self-regulation processes are also sheltered under the umbrella term of EF (Nesbitt & Farran, 2021; Rodríguez, 2022). Recent approaches to the development of EF propose that EF skills and processes are susceptible to training from an early age (Blair, 2017; Diamond et al., 2007; Diamond, 2014; Diamond & Lee, 2011), and claim that the earlier the training starts, the more beneficial the effect on children’s development (Thompson & Steinbeis, 2020; Wass et al., 2011; Wass et al., 2012). This claim is well-founded; for example, recent studies show relations between EF skills during infancy and later academic skills like reading (Blankenship et al., 2019). Moreover, EF difficulties in the preschool years predict both general cognitive development as well as academic performance in the school years (Diamond, 2013).

A wealth of evidence in the last 20 years indicate that EF skills in young children can be boosted through specific training in a wide

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range of executive control processes, including attentional control, cognitive flexibility, inhibitory control, working memory and self-regulation (Alloway et al., 2013; Diamond et al., 2007; Dunning et al., 2013; Holmes & Gathercole, 2014; Spencer-Smith & Klingberg, 2015). In the school context, some programs have proved to be particularly efficient in boosting EF skills (Blair & Diamond, 2008; Diamond et al., 2007; Schunk et al., 2022), even from the preschool years (Bodrova & Leong, 2018).

A recent series of meta-analyses confirmed that these skills can indeed be fostered during childhood (Kassai et al., 2019; Takacs & Kassai, 2019). However, the long-term effects (Takacs & Kassai, 2019) and the generalization of skills to untrained components of EF (Kassai et al., 2019) are limited in the explicit training programs, where the benefits on a wider range of developmental outcomes are also questioned (Nesbitt & Farran, 2021). Approaches that implicitly foster EF skills may have stronger, more beneficial long-term effects over those that focus on explicit training, (Takacs & Kassai, 2019; Niebaum & Munakata, 2023). In sum, evidence so far shows overall that (1) EF is permeable to training and (2) the longer-term effects may be stronger with practices that embed EF skills implicitly rather than explicitly within their program. If that is the case, then the type of educational practice that children receive at school can have an influence in the development of the EF, even when that is not their intended purpose (Diamond & Lee, 2011; Marshall, 2017; Takacs & Kassai, 2019). Despite the important implications of this possibility, there is limited evidence to date of the effect that different early educational practices may have on EF development.

Educational practice that promotes autonomy, one aspect that implicitly requires executive control, may particularly enhance EF development (Diamond, 2014; Takacs & Kassai, 2019). One example of such a practice is Montessori education; the child's autonomy is fundamental to this educational program (Lillard, 2012; Lillard, 2019). Montessori teachers' main role in the classroom is to guide children's learning. Children in this educational program must make decisions, which means they must control their behavior and thoughts and this provides them with ongoing opportunities for self-regulation (see Lillard & McHugh, 2019). Numerous aspects of the Montessori daily educational activities, such as the goal-oriented movement, the memorization of gesture sequences in novel contexts (Diamond, 2013; Diamond & Lee, 2011; Klingberg, 2010; Lillard, 2008) and educational materials that make errors self-evident so children can self-correct (Phillips-Silver & Daza, 2018) may demand EF skills (Lillard, 2012; Lillard & McHugh, 2019). By contrast conventional school practices, notwithstanding variability across programs, promote uniformity in order to fit a universal curriculum and assign a relatively unidirectional, directive role to the teacher (Dintersmith, 2018), creating fewer opportunities for children to make decisions and practice self-regulation.

Current evidence indicates that attending a Montessori school is often (although not always) related to good performance on EF tasks, relative to conventionally schooled and norming samples (e.g., Culclasure et al., 2018; Lillard & Else-Quest, 2006; Phillips-Silver & Daza, 2018). Findings are equivocal, however (Denervaud et al., 2019; Lillard et al., 2017), possibly due to a number of factors that make evidence from different studies difficult to compare. The present study attempts to address some of these factors; studies are reviewed in more detail below with reference to those factors.

1. Limitations in the assessment of the EF in preschoolers

One potential source of variation across the studies comes from the fact that different studies use different tasks to assess EF skills rather than a whole set covering a range of executive processes. In a few studies, Montessori preschoolers have shown an advantage over conventional preschoolers in different EF tasks, such as the Dimensional Change Card Sort (DCCS) (Lillard & Else-Quest, 2006), Head-Toes-Knees-Shoulders (HTKS) (Lillard, 2012), and Backwards Digit Span tasks (Denervaud et al., 2019). Other studies, however, show either no or only a marginal advantage in the Montessori students' EF skills. For example, Lillard et al. (2017) found no difference between the two groups in the development of EF skills across preschool, assessed by a composite of the HTKS task and the Design Copy task. Other studies have found no EF performance advantage by Montessori children, as compared to those in conventional schools, in a Flanker Fish task (Denervaud et al., 2019), HTKS (Culclasure et al., 2018), or in tests that assess children's ability to delay gratification (Lillard & Else-Quest, 2006). As Zelazo et al. (2016) argue, EF should be assessed with a range of tests rather than single tests; here, we are compiling a set of tasks used by separate studies to assess children in our sample. By using a set of tasks, we are more likely to tap into the latent characteristic that are shared across tasks. A systematic, complete assessment of EF processes with standard tasks applied to the same sample will allow a better assessment of whether Montessori (or any other educational practice) affects the development of EF.

1.1. Experience in the educational program: length of time in the program

Another obvious factor in the potential effect of an educational program on EF is the length of time that children have been enrolled in the program, and therefore the length of continuous experience in the program. This has not been systematically controlled in previous studies. Both longitudinal studies (e.g., Culclasure et al., 2018; Lillard et al., 2017) and cross-sectional studies (e.g., Denervaud et al., 2019) that report an EF advantage in Montessori students over those in conventional schools matched children by age but did not control for the length of continuous experience in each type of program. Phillips-Silver & Daza (2018) showed that continuous experience in the Montessori program may affect 3-year-olds' EF skills. In this study preschoolers attending a Montessori preschool for the first time were assessed at the beginning and the end of the academic year with two tasks from the NIH Toolbox (the Flanker test and the DCCS task). There was a significant improvement in children's performance in both tasks at the end of the year. This study, however, did not include their own control group. Since EF develops gradually, children could require more than one year of exposure to a given educational practice for benefit to accrue. In other developmental domains, the cumulative effect on children's early learning outcomes has been shown, especially after two consecutive years of the same educational practice (Cash et al., 2019; Wen et al., 2012). Thus, in the present study, in addition to comparing homogeneous groups in two different educational programs, the

effect of duration of exposure to each program on EF performance is controlled, and all participants had attended their school program for at least two years.

1.2. Baseline differences in related variables: semantic fluency

One further aspect that may explain the discrepancy in previous findings is potential baseline differences between the groups in capacities associated with the development of EF. Some previous studies have found links between language skills and EF during early years (Fuhs & Day, 2011; Kuhn et al., 2016; Schmitt et al., 2019). Except for the study by Denervaud et al. (2019), that matched children in the two groups for semantic fluency, most studies comparing Montessori and conventional preschool children have not specifically controlled for semantic fluency, which is often used as a proxy for general intelligence (Brydges et al., 2012) and has been shown to predict EF.

In the current study, we assessed participant semantic fluency to guard against a possible population difference between the levels of this EF predictor across the two school groups.

In sum, although some studies suggest Montessori schooling can enhance the development of the EF over more traditional methods results have not been consistent (Diamond & Lee, 2011; Diamond & Ling, 2020; Kayılı, 2018; Lillard, 2012; Lillard & Else-Quest, 2006; Lillard et al., 2017), and a number of limitations make this conclusion premature. Such limitations come mainly from three sources: (1) The tasks used to assess preschoolers EF skills vary across studies and no study has used a full set of tests; (2) The duration of students' experience of the program differs across studies; (3) there are, potentially, baseline sample differences in skills related to EF development, which can be indexed by semantic fluency.

The current study aims to better our understanding of the potential effect of a different type of early educational practice on the preschool EF by addressing these three limitations. Here we assess EF skills of 4- to 6-year-olds who had been continuously enrolled in their respective school program, either Montessori or conventional preschool, during a similar length of time with a whole set of tasks. This set of tasks aims to assess the executive function processes that fall under the wider definition of the term, including both the traditional core elements (working memory, inhibitory control, and cognitive flexibility) but also EF processes involved in self-regulation.

The Montessori school fully followed the Montessori educational program (full immersion) with teachers certified by the Association Montessori International (AMI), the organization Dr. Montessori founded to carry out her work. Children were assessed with an EF battery that was carefully chosen to assess a range of EF skills in preschoolers. If an early educational practice that promotes autonomy and self-regulation can have an effect in the development of EF, then Montessori preschoolers might show an advantage in EF skills as compared to preschoolers in a conventional school on this set of EF tasks.

2. Method

2.1. Participants

Fifty-eight 4- to 6-year-old children from two private preschools in a large city in Spain took part in the study. Thirty-two children attended a Montessori school ($M = 59.0$ months, age range 51–73, $SD = 0.71$, 56% boys), and 26 children attended a conventional school ($M = 58.0$ months, range = 51–67, $SD = 0.47$, 50% boys). An a priori power analyses for MANOVA (G*Power 3; Faul et al., 2007) indicated that we required at least 26 participants (Pillai $V = 0.4$, critical F value = 2.71, power = 0.80, $\alpha = 0.05$); thus, we had sufficient power to see an effect if it exists. All participants in both schools had been attending their respective school for at least 2 years, ($M = 2;4$ years of continued educational experience in the school).

Both schools were private and bilingual (Spanish-English). The families of the children in both schools were of medium-to-high socioeconomic status, as informed by the participant schools. Additional indicators of the medium-to-high SES in both groups were

Table 1
Summary of the EF set of tasks.

Main components assessed	Task	Coding
Working Memory	<i>Backwards Digit Span</i> Remember a series of digits in reverse	No. of inverse digit series correctly remembered 10 trials Range 1–4
Cognitive Flexibility	<i>Flanker Fish</i> Identify the direction of a “target” fish on a screen across standard and reverse trials	No. of correct responses 24 Trials Range 0–24
Inhibitory Control	<i>Head- Toes- Knees- Shoulders</i> Perform the opposite action to the one proposed by E	No. of correct responses (0–2 per trial) Two blocks of 10 trials Range 0–40
	<i>Peg Tapping</i> Perform the opposite action to the one proposed by E.	No. of Correct responses (0–2 per trial) 10 trials Range 0–20
Self- Regulation	<i>Gift Delay</i> Not to look while E is wrapping your surprise gift	No. of Looks

the similar enrollment fees of the two schools and the affluent neighborhood where they were located. The Montessori school met all the requirements of the AMI accreditation as follows: every teacher had an AMI diploma; a complete set of Montessori materials was available (and used) in each classroom; children had a 3-hour continuous work period; and there were at least 3 different age levels per class. The conventional school followed the official state program, which involves mostly frontal teaching, evaluations focused on academic outcomes, hourly changes in the subject being taught, and only one age-level per class.

Following the Helsinki protocol (1992), all parents or legal guardians gave informed consent to allow their children to participate, and children gave their oral assent prior to participating in the study.

2.2. Design

A one-factor (type of educational program: Montessori vs Conventional) multivariate group design was used. EF processes were assessed with 5 standard tasks, listed in Table 1 and described below.

2.3. Materials and procedure

Participants were individually tested by a female experimenter (E) in a quiet room in their preschool. After a warm-up period, where E talked to the child and made him/her feel at ease, the testing session began with the semantic fluency subtest of ENFEN (Portellano et al., 2009). Children are requested to utter as many words of a given semantic category as they can remember in a minute. The session continued with the set of EF tasks. Tasks were chosen as representative tests of core EF processes as they most frequently appear in the literature. As mentioned before, we also included a gift-delay task (as in Carlson, 2005) that is frequently used as a self-regulation task (e.g., Hughes et al., 2015) but also considered by other authors as a test of inhibitory control (Kochanska et al., 1996) or as a test of “effortful control” (Kochanska et al., 2000). All the tasks are standard in the assessment of preschoolers EF skills even if there are some discrepancies in the literature over the specific EF components that each involves; all fall under the broader “umbrella term” of EF. Table 1 indicates the main skills that each task aims to assess even if many are also tapping into other EF skills.

All tasks were presented following the standard original procedure or the relevant adaptation for preschoolers as described below. Although the schools were both bilingual, all tasks were administered in Spanish which was the native language of all children in the study.

2.3.1. Backwards digit span task

We used an updated version of the Backwards Digit Span test from the WISC-IV (2005), as in Denervaud et al. (2019). In this test, the child must remember and repeat (in a reverse order) a series of digits over up to 10 trials. The task finished after three consecutive mistakes, regardless of the length. The score is the longest series of digits correctly recalled.

2.3.2. Flanker fish task

This is an adapted, young-children friendly version of the original Eriksen & Eriksen (1974) flanker task. The flanker fish version replaces the original pointing arrows by fish “heading” into a direction. As in other preschooler studies with (see e.g., Denervaud et al., 2019) the task was presented on a computer screen. Children saw a row of fish heading in one direction, flanking a single fish heading in the opposite direction. The task required to indicate (by pressing buttons on the screen) the direction of the target-fish in each trial. Trials were distributed in three blocks of eight trials each. Each trial focused on a target fish. In the first block (standard flanker), the target fish is in the center of a 5-blue-fish row flanked by fish heading all in the same direction (the opposite of the target fish). In the second block (reverse trials) a 5-pink-fish row is shown, and the target fish now is fish 4, next to the central one who, as ever, is heading in the opposite direction. Finally, the third set (mixed trials) randomly mixed trials (standard and reverse) of the two other blocks. Performance was assessed only by the number of correct responses across the 24 trials. Response times were not considered because it has been proved that this measure is unreliable in preschoolers (Diamond et al., 2007). While the original task was used as a measure of interference control, the Flanker Fish task is often used as a task of cognitive flexibility (see e.g., Denervaud et al., 2019; Ding et al., 2014; Fu et al., 2018; Segers et al., 2016). The sequence of trials requires to keep in mind different rules and flexibly change from one rule to another (Schonert-Reichl et al., 2015).

2.3.3. HTKS test

We followed the protocol used in Lillard et al. (2017), who administered the same task when comparing children attending either Montessori and or conventional schools, in an age group similar to the current study. The task involved two sets of 10 trials each, where children had to follow a rule that indicated performing an action opposite to the one stated by the E as follows: (Set 1) “when I say touch your head, touch your toes” and (Set 2) “when I say touch your head, touch your toes”. In each set, children’s responses were coded as “0” (incorrect, e.g., the child touches her head in set 1), 1 (an initial mistake, immediately corrected, e.g., briefly touches her head but immediately goes on to touching her toes) and “2” (correct, i.e., follows the rule as indicated). Before each set of test trials, children completed four warm-up trials with feedback. The second set of ten trials, however, was administered only if the child had scored 10 or more in the first set (Lillard et al., 2017).

2.3.4. Peg tapping test

Children had to tap the table twice if the interviewer tapped the table once, and vice versa. Children’s responses were coded as “0” (incorrect), “1”, (an initial mistake immediately corrected), or “2” (correct) across 10 trials, for a total of 20 (Diamond & Taylor, 1996).

2.3.5. Gift delay task

We followed the protocol suggested by Carlson (2005) adapted from Kochanska et al. (1996). E told children that she had a surprise present but had forgotten to wrap it up. She then asked children to turn around and not look while she was wrapping the present. This process took 60 s. Children's performance was assessed by the number of times that they looked during the 60 s wrapping process.

The administration of the whole set of tasks took approximately 25 min. The tasks were presented in a fixed order as shown in Table 1.

2.4. Data analysis

Prior to group comparisons of the measures of interest, *t*-tests were run on the control variables (age in months, duration of school experience, and semantic fluency) to ensure group homogeneity.

The dependent measures were the scores in each task of the EF set. First, a correlational analysis between the test scores was performed. In order to determine whether there were differences between the two school groups (Montessori vs. Conventional) on children's EF performance, a one-way MANOVA including the scores of all the EF tasks was conducted. The MANOVA is a suitable analysis because it increases statistical power when the dependent variables are correlated, limits the joint error rate and, crucially, has proven to be robust to deviations from the normality assumptions in samples with $Ns > 30$ when the dependent variables are correlated (Bisquerra, 1989; Sheehan-Holt, 1998; Vallejo & Ato, 2012).

Finally, in order to gain further understanding on the performance of the individuals in each group across the tasks, we carried out descriptive analyses on the frequency distributions in quartiles.

3. Results

Preliminary analyses (using *t*-tests) indicated that the two groups (conventional and Montessori students) did not differ (all *ps* > 0.05) in either age (in months), or years in their respective schools, or semantic fluency scores (see Table 2).

3.1. Correlations between scores in the EF tasks

All correlations between the EF tasks were high and statistically significant (see Table 3). These results confirm that the dependent variables are related and, therefore, the tests adequately measure EF in preschool children.

Results from the one-way MANOVA revealed a significant multivariate effect of the school group (Pillai's Trace = 0.85, $F(5, 52) = 59.75$, $p < .001$, $\eta_p^2 = .85$). This analysis was followed by post-hoc univariate *F* tests on each of the EF variables. In all the tasks, except for the Flanker Fish task, performance of the Montessori school children was superior to performance of the conventional school children (see Table 4).

Further correlational analysis between EF tasks, semantic fluency and age (see Table 5) revealed that, as expected, these two variables are related to EF performance. In order to test whether the effect of the school program remains once we controlled for the effect of these variables, we proceeded to carry out a one-way MANCOVA.

Results from the one-way MANCOVA, controlling for age in months and verbal fluency, revealed a significant multivariate effect of the school group (Pillai's Trace = 0.88, $F(5, 50) = 69.88$, $p < .001$, $\eta_p^2 = .88$). Given the MANCOVA test results, ANCOVAs were then conducted on each of the 5 EF tasks. In all the tasks performance of the Montessori school children was superior to performance of the conventional school children (see Table 6).

3.2. Frequency distributions

In order to gain a more complete understanding of how participants performed, we provide a descriptive analysis of the frequency distributions in quartiles for each task in each school group (see Fig. 1). For this purpose, we divided the total score in each task into four sections along with the minimum and maximum scores for the whole sample, each section representing 25% of the total rating.

3.2.1. Backwards digit span

Inspection of distributions (Fig 1.1) showed differences in performance between children in the two schools; nine children in the Montessori school (less than one third, 28.1%) as compared to 16 conventional preschoolers (61.5%) scored in the lowest quartile (1st). Furthermore, only 1 child (3.8%) in the conventional school (as compared to 5 Montessori children, 15.6%) achieved the

Table 2
Study Participants.

Control variable	Montessori ($n = 32$)	Conventional ($n = 26$)
Gender, # of girls (%)	14 (43.8)	13 (50)
Age in months, M (SD)	59.00 (6.22)	57.92 (3.66)
Age range	51–73	51–67
Years at the school, M (SD)	2.25 (0.44)	2.26 (0.45)
Semantic fluency, M (SD)	8.75 (1.24)	8.62 (0.80)

Table 3
Correlations between the EF Tasks.

	<i>M</i>	<i>SD</i>	BD	FF	HTKS	PT	GD
1. Backwards Digits (BD)	2.64	0.72		0.74 ***	0.68 ***	0.69 ***	-0.63 ***
2. Flanker Fish (FF)	15.50	2.44			0.70 ***	0.62 ***	-0.60 ***
3. HTKS	11.41	3.92				0.81 ***	-0.62 ***
4. Peg Tapping (PT)	10.86	2.06					-0.54 **
5. Gift Delay (GD)	1.74	1.07					

** $p < .01$; *** $p < .001$. Note that gift wrapping is reversed: more looks indicate lower EF.

Table 4
Means, (SDs) for each Task and Statistical Values of the Post-hoc ANOVAs Comparisons between the Two School Groups.

EF tasks	Montessori	Conventional	F and p values	η_p^2
Backwards Digit Span	2.88 (0.66)	2.35 (0.69)	8.85, $p = .004$	0.136
Flanker Fish	15.97 (2.58)	14.92 (2.15)	2.72, $p = .105$	0.046
HTKS	14.16 (2.40)	8.04 (2.54)	88.64, $p < .001$	0.613
Peg Tapping	12.09 (1.80)	9.35 (1.13)	45.73, $p < .001$	0.450
Gift Delay	1.31 (0.93)	2.27 (1.00)	14.14, $p < .001$	0.202

Table 5
Correlations between Age in Months, Semantic Fluency and EF Tasks.

	<i>M</i>	<i>SD</i>	A	SF	BD	FF	HTKS	PT	GD
Age in months (A)	58.52	5.19		0.75 ***	0.63 ***	0.63 ***	0.47 ***	0.46 ***	-0.56 ***
Semantic Fluency (SF)	8.69	1.06			0.70 ***	0.81 ***	0.51 ***	0.54 ***	-0.63 ***

** $p < .01$; *** $p < .001$

Table 6
Means, (SDs) for each Task and Statistical Values of the Post-hoc ANCOVAs Comparisons between the Two School Groups.

EF tasks	Montessori	Conventional	F and p values	η_p^2
Backwards Digit Span	2.88 (0.66)	2.35 (0.69)	13.72, $p < .001$	0.203
Flanker Fish	15.97 (2.58)	14.92 (2.15)	4.55, $p = .037$	0.078
HTKS	14.16 (2.40)	8.04 (2.54)	173.86, $p < .001$	0.455
Peg Tapping	12.09 (1.80)	9.35 (1.13)	72.19, $p < .001$	0.572
Gift Delay	1.31 (0.93)	2.27 (1.00)	20.19, $p < .001$	0.272

maximum score.

3.2.2. Flanker fish task

The distribution in this task also showed differences in performance between participants in the two schools (fig. 1.2). Thirteen Montessori children (40.7%), as compared to 7 children (26.9%) in the conventional school, scored in the top two quartiles (3rd and 4th quartile); moreover, only 1 child (3.8%) in the conventional-school group -as compared to 7 children (21.9%) in the Montessori-school group- scored in the 4th quartile.

3.2.3. HTKS task

No Montessori child but 14 conventional children (53.8%) scored in the 1st quartile in this task; conversely, no child in the conventional program but 13 (40.6%) Montessori children scored in the 4th quartile (fig. 1.3). As this task required to score at least 10 points in the first part to move to the second, the result from the quartiles informs that all Montessori students passed to the second section of the task while only 7 (26.9%) conventional-school children did.

3.2.4. Peg tapping test

All children in the conventional school scored in this task within the 1st or the 2nd quartile, and no child scored above 10 (the Median value). Most Montessori children (22, 68.8%) scored in the higher ranges (from 12 to 15, 3rd and 4th quartiles) (fig. 1.4).

3.2.5. Gift delay task

Finally, most children in both educational programs looked at least once at the present (26 preschoolers (81.2%) in Montessori and 23 (88.5%) in conventional program. The pattern of response throughout this task, however, differed substantially between the two groups. Most conventional school children (14, 53.8%) looked 3 times (4th quartile), 8 children (30.7%) looked 2 times (3rd quartile)

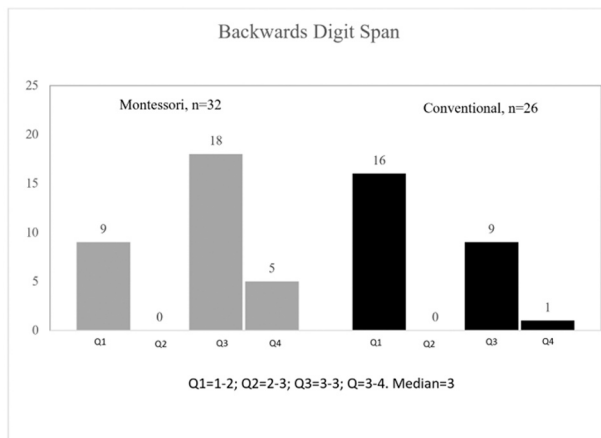


Figure 1.1

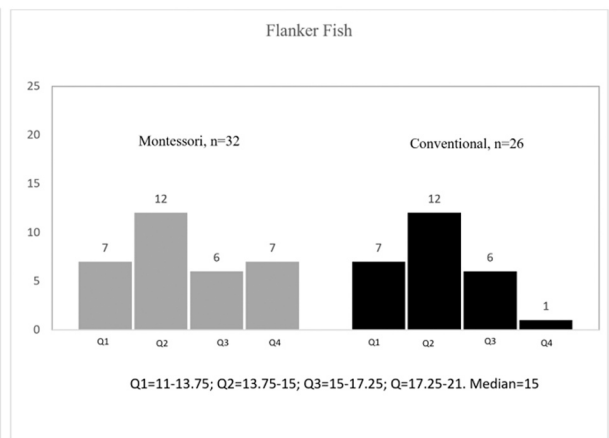


Figure 1.2

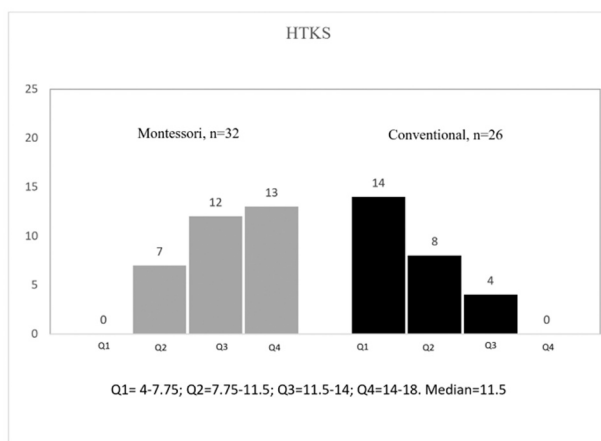


Figure 1.3

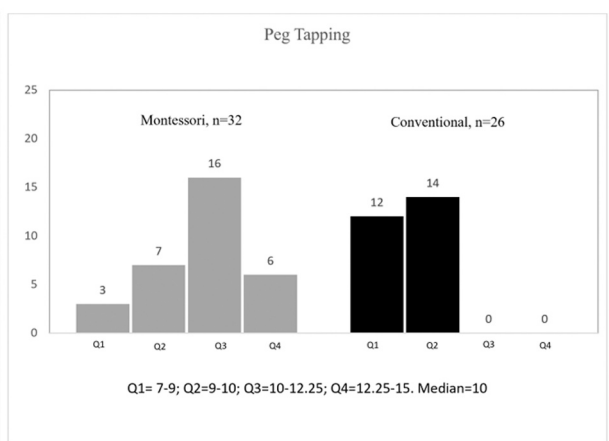


Figure 1.4

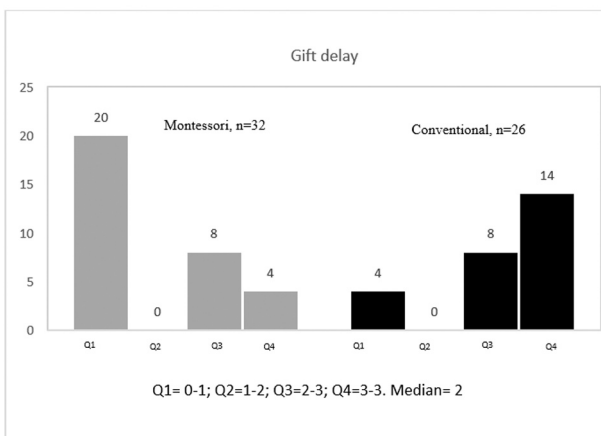


Figure 1.5

Fig. 1. Frequency Distributions (No. of children) in Quartiles for each EF Task by School Group.

and 4 (41.4%) were in the 1st quartile, where only 1 child looked just once; the distribution is reversed in the Montessori group; most children here were in the 1st quartile, i.e., either looked only once (14, 43.7%) or did not look at all (6, 18.7%) (fig. 1.5). Fig. 2 shows the percentage of children who turned around to look as a function of the school. Most children in the sample tended to look at least once but the two groups differed in how children behave after that first look. While most Montessori children turned around just once and stopped looking, most children in the conventional school continued to turn up and look up to three times.

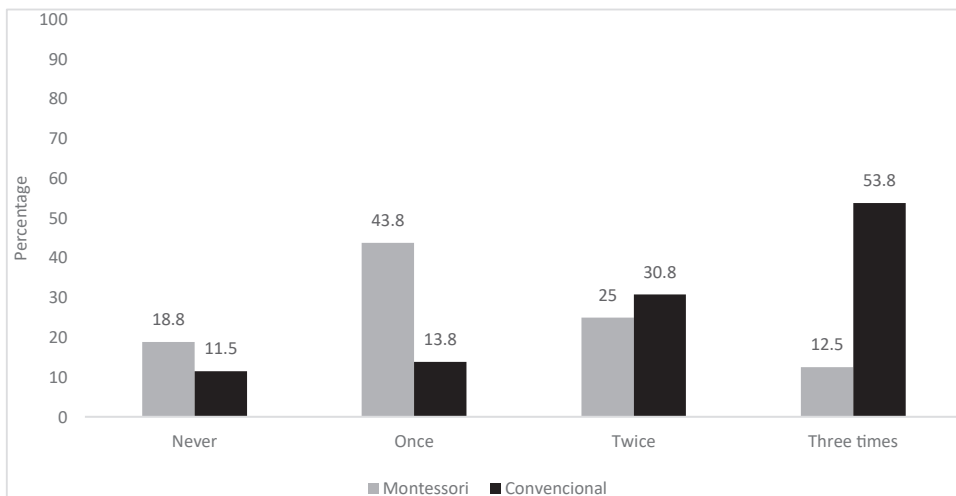


Fig. 2. Percentage of Children who Turned Around and Look by School Group.

To sum up, in all tasks, Montessori children mostly scored in the 3rd and 4th quartiles (except for the gift delay task, where higher performance implies lower scores) while most conventional preschoolers scored in the 1st and 2nd quartiles. Differences between the two school groups are more notable in the HTKS task and in the Gift Delay task, where the analysis of the distributions shows opposite clustering patterns; while most Montessori-children cluster in the scores of the upper quartiles, most conventional-school participants score in the two lower quartiles.

4. Discussion

The current study aimed to better understand the potential effect of early educational practice on the preschool EF skills by addressing three limitations of previous studies that compared a potentially EF enhancing educational program (Montessori) relative to the conventional school. First, unlike previous studies, children were assessed with a range of EF tasks covering a range of EF processes. Findings showed a strong association between all EF tasks indicating that the skills assessed are tapping into the processes under the umbrella of the EF, and potentially supporting a unitary EF structure in preschoolers (Karr et al., 2018). Secondly, the school program had a clear effect on preschoolers' EF performance. Students enrolled in a high-fidelity Montessori preschool program outperformed children in a conventional program. Such advantage cannot be attributed to baseline average differences between the groups in either chronological age or semantic fluency, or years of schooling. Moreover, the effect of the school program remains strong even when we control for a potential mediating effect of age and semantic fluency.

Below we proceed to discuss our findings in relation to those of previous studies by looking at each task and the main EF processes involved. We are aware of the general theoretical and methodological controversies regarding the processes involved in executive control and the optimal tasks to assess them (see e.g., Carlson, 2005; Garon et al., 2008; Karr et al., 2018; Nin et al., 2022); for the purposes of this study, however, we are focusing on the analysis of the tasks and processes as they have been used within the literature that compare the two educational programs at stake here.

In line with some previous findings (Denervaud et al., 2019; Lillard, 2012), results of this study show that preschoolers in the Montessori program have higher working memory skills and higher inhibitory control as compared to children in a conventional educational program. Findings of this study also show that the inhibitory-control strength showed by Montessori preschoolers is robust across different tasks; unlike previous studies, children were tested in two "inhibitory control tasks"; the Peg Tapping task as well as and the most frequently used HTKS task. Results from the children's performance in these two tasks provide evidence of consistency in inhibitory control across testing with different number of trials and across slightly different motor skills. More importantly, even if these tasks are often used to assess inhibitory control, both tap into similar processes that present added executive demands, such as the need to keep an arbitrary rule of action in the working memory ("if I say *head* you touch your *toe*") while inhibiting the prepotent response (touching her head). The combination of these two demands requires "complex executive control" (Russell, 1997); it can be argued, therefore, that the superior performance in these tasks also indicates a greater complex executive control in Montessori pupils.

Further evidence in favor of the higher complex executive control of the Montessori preschoolers comes from the results in the Gift Delay task. In order to show the self-regulation required by this task, children must also keep the experimenter's instruction ("you cannot look until the present is wrapped") in mind while inhibiting the pre-potent response of looking before they are allowed to do so. Proof of the difficulty in this task is that most participants looked at least once, contravening the experimenter's instruction. A comparison of the performance of the two groups shows, however, a clear advantage of Montessori preschoolers with a significantly lower mean number of anticipatory looks. Moreover, their pattern of responses shows higher behavioral control beyond the difference in the mean scores. When children in the Montessori program break the rule, they tend to do it only once, and then, quickly, they take control of their behavior. This contrasts with the behavior of children in the conventional school; once they have looked the first time, they

keep doing so up to the end of the test, unable to retake the inhibitory control on their behavior. To our knowledge, there are no comparable results in previous studies since this task has not been used to compare preschool children in these two types of educational practice. Findings of a previous study that assessed preschooler's self-regulation through a Delay Gratification task, rather than the gift delay task, found no significant differences between Montessori and Conventional preschoolers (Lillard & Else-Quest, 2006). The Delay Gratification task may, however, add demands that go beyond the competences at this young age, such as using a primary reward (more difficult to resist), that is also in the child's view all the time, and the need to process a rule that involves quantifying such reward. The Gift Delay task can be better suited to the still limited self-control of preschoolers and, therefore, may be more sensitive to any differences emerging at this stage.

Findings relative to cognitive flexibility are more intriguing. Results showed that Montessori students out-performed conventional school students in the Flanker Fish task only when the effects of semantic fluency and age are controlled for in the data analysis. The mediating effect of age and/or semantic fluency can explain why some previous studies did not find an advantage of Montessori students in cognitive flexibility as assessed either by the Flanker Fish task (Denervaud et al., 2019) or the DCCS task (Lillard & Else-Quest, 2006). Our results on the quartile distributions of the Flanker Fish task (i.e., the wider variability and the clustering of Montessori children on the higher scores of the distribution) reinforce the advantage of Montessori children; more interestingly, they indicate that a larger number of children in the Montessori group are ahead in their development of cognitive flexibility as compared to children in the conventional preschool. This goes in line with results by Philips-Silver and Daza, (2018) who showed that performance of Montessori preschoolers in a Flanker task improves at the end of their academic year; therefore, sustained experience in the Montessori program can enhance the development of cognitive flexibility. Although the current work is not a longitudinal study, unlike children in the study by Philips-Silver and Daza (2018), all children in our study already had at least two years of continuous experience in their respective programs. Our results indicate that children's cognitive flexibility in the Montessori program benefited more of their continuous educational experience than children in the conventional program. In fact, this can be applied to each of the competencies of the executive control that were tested in this study.

4.1. Limitations of this study

Although the findings of this research are clear, some limitations must be acknowledged. One concern is the lack of a long-term follow-up on the development of EF in children attending different educational programs. As noted in the introduction, a recent meta-analysis suggests that the gains achieved through EF explicit training may diminish over time (Takacs & Kassai, 2019); even if our study does not involve an explicit training programme, the EF advantaged showed by Montessori children in this study may also diminish over time. Therefore, it would be important for future studies to include medium- and long-term measures of EF development in order to elucidate the role of any the type of school program.

A second limitation is that, although children from both schools had similar levels of verbal fluency, a measure that correlates with EF and SES (Fernald et al., 2013), it is still possible that there were pre-existing differences in EF between the two groups before the enrollment in the program (i.e., that children with "more developed" EF might have enrolled the Montessori school). The fact that the differences in the EF performance between the two groups remain robust once we control for semantic fluency and age makes this starting baseline difference unlikely. This is, nevertheless, a difficult problem to overcome in any cross-sectional study but can be better addressed by longitudinal studies that follow the development of the EF from the early years in educational settings (see e.g., Rodríguez, 2022).

A third limitation is that this study established the SES of our participants indirectly, through the information provided by a third party (the schools) rather than the families of the participants themselves. Admittedly, this may have brought inaccuracies in the assessment of the SES; however, the fact that there were no baseline differences between the two groups in semantic fluency, a variable that strongly correlates with SES (Fernald et al., 2013) can be recruited as support that, even if the measure would have been inaccurate, it is unlikely that the two groups differed greatly in their SES. Finally, although the power analysis showed that the sample size was adequate, the sample was small.

5. Conclusion

In conclusion, beyond the limitations discussed above, findings of this study on the robust differences in preschooler performance across the whole set of EF tasks suggest that the early educational practice has an impact in the development of the EF. The Montessori program, in particular, seems to offer a type of educational practice with the power to enhance executive skills and facilitate the acquisition of complex executive control in preschoolers as compared to the conventional practice. What specific aspects of the Montessori practice may play this enhancing role is an open question for future research. Furthermore, whether such enhancing effect over the EF can be prolonged over time and whether it can be extended to other educational practices that also attribute an important value to self-directed learning, and autonomy (e.g., Waldorf, Reggio Emilia, or Active Learning Schools) is a question still to be answered. Nevertheless, our findings suggest that, even in the absence of any explicit training, the type of educational practice has a role to play in shaping the EF in the preschool years.

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CRedit authorship contribution statement

Silvia Guerrero: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Supervision. **María Núñez:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Funding acquisition. **Cristina Corbacho:** Investigation, Resources, Data curation.

Declaration of Competing Interest

None.

Data Availability

Data will be made available on request.

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