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Quality of classroom interactions in kindergarten and executive functions among five year-old children

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Abstract: The goal of this study was to examine the relationship between the quality of classroom interactions in kindergarten and executive functions (EFs) among 5-year-old children. The sample consisted of 118 children, with a mean age of 73.34 months (SD = 4.22), from 12 kindergarten classes. The quality of classroom interactions was measured using the Classroom Assessment Scoring System (CLASS), while the children's EFs (working memory (WM), inhibition, cognitive flexibility, and planning) were measured using various tests conducted on the children (e.g. Forward and Backward Digit Span). The results show that emotional support in the classroom was positively correlated with EF skills among the children, in particular, those related to WM and cognitive inhibition. Moreover, the results indicate that instructional support was negatively correlated with the children's WM. Further analyses demonstrated that gross family income reduced the association between instructional support and WM. These findings attest to the importance of emotional

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Stephanie Duval is a professor in the Département des sciences de l'éducation (Department of Educational Sciences) at Université du Québec à Chicoutimi (Chicoutimi, Canada). Her doctoral thesis in educational psychology led her to develop expertise on the quality of classroom interactions and executive functions among children, the cornerstones of children's educational success.

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PUBLIC INTEREST STATEMENT

This article examines the effect of the quality of teacher–child interactions in the kindergarten classroom on executive functions (EFs) among 5-year-old children. As early as kindergarten, the quality of classroom interactions is known to be a key component of teaching quality. Indeed, quality interactions, measured in terms of (1) emotional support (e.g. positive climate, teacher sensitivity), (2) classroom organization (e.g. behaviour management, productivity) and (3) instructional support (e.g. concept development, language modelling), have a positive effect on academic achievement, which involves EFs. EFs refer more specifically to the high-level cognitive processes (e.g. cognitive flexibility, inhibitory control, working memory and planning) involved in the coordination of new and complex behaviours. This article brings out the kinds of interventions that teachers can implement in the kindergarten classroom to support EFs among 5-year-old children.

support for the development of EFs, particularly WM, and bring out the potential moderating effect of family characteristics (e.g. gross family income) on executive functioning.

Subjects: Classroom Practice; Early Years; Education; Education - Social Sciences

Keywords: quality of classroom interactions; executive functions; early childhood education

1. Introduction

Researchers have increasingly stressed the importance of examining executive functions (EFs) among children, with a view to fostering academic achievement from the very start of schooling (Carlson, Zelazo, & Faja, 2013; Raver & Blair, 2014). This is because EFs, which refer to a set of cognitive processes such as working memory (WM), inhibitory control, cognitive flexibility and planning, are responsible for motor, social, emotional, language and cognitive control among children (Barral, De Pretto, Debû, & Hauert, 2010; Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Miyake et al., 2000; Welsh, Nix, Blair, Bierman, & Nelson, 2010), which, in turn, play a role in academic achievement.

The abilities associated with executive functioning[1] can first be explained by factors related to the child, such as the child's age, sex or intelligence quotient (IQ) (Wiebe, Espy, & Charak, 2008; Zelazo, 2013). For example, Wiebe et al. (2008) showed that preschool-aged girls displayed a higher level of inhibitory control than boys. However, since the child's brain presents considerable plasticity during early childhood, environmental factors also play an important role in brain development during this period (Obradović, Portilla, & Boyce, 2012).

For example, some studies have shown that socio-economic status and the quality of parental practices have an effect on early executive functioning (Bernier, Carlson, Deschênes, & Matte-Gagné, 2012; Hammond, Müller, Carpendale, Bibok, and Liebermann-Finestone, 2012) showed a relationship between parental scaffolding and executive functions among preschoolers. Thus, beyond individual characteristics (e.g. age, sex, IQ), environmental factors also have an effect on executive functioning during childhood (Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005).

2. Executive functions (EFs)

Executive functions refer to a set of interdependent cognitive processes. According to Best, Miller, and Jones (2009), there are approximately 15 components of executive functioning, the main ones being working memory, inhibitory control, cognitive flexibility and planning (or problem solving) (Lezak, Howieson, Bigler, & Tranel, 2012). More specifically, WM refers to the ability to retain information from one context and apply it appropriately in another context (Roberts & Pennington, 1996). Inhibition refers to the ability to delay or suppress prepotent responses, that is, usual, automatic or overlearned responses that are not relevant to the task at hand (Barkley, 1997). Cognitive flexibility is defined as the ability to change tasks or strategies and move from one cognitive operation to another (Chevalier, 2010), while planning involves predicting and assessing one's behaviours as well as constructing and coordinating a set of actions aimed at accomplishing a specific goal (Kaller, Unterrainer, Rahm, & Halsband, 2004).

The period from age 3 to 7 is critical for the development of executive functioning (Chevalier, 2010). Based on standardized tests involving young children (e.g. Self-Ordered Pointing task), Hongwanishkul et al. (2005) showed that WM develops significantly between the ages of 3 and 5. Similarly, both behavioural and cognitive inhibition show considerable progress between the ages of 1 and 3 (Chevalier, 2010), while a gradual improvement in inhibition can be observed up to the age of 5 (Garon, Bryson, & Smith, 2008). Cognitive flexibility and planning also develop very quickly during early childhood, particularly between the ages of 3 and 5 (Zelazo, Müller, Frye, & Marcovitch, 2003). For example, 5-year-olds succeed better than 3-year-olds at the Tower of Hanoi task

(planning) (Zelazo, Carter, Reznick, & Frye, 1997), reflecting the rapid development of this EF, which can be explained by the maturing of the prefrontal cortex.

The significant development of EFs between the ages of 3 and 7 speaks to the importance of examining the factors that are likely to foster this process during early childhood, with a view to supporting academic achievement in kindergarten. Various factors that influence EFs have been reported in the literature, such as the characteristics of the child, which are genetic and biological in nature.

2.1. Factors related to the child

Inter-individual differences in EF skills are primarily attributed to the child's age, which can be explained by brain development (Carlson et al., 2013; Garon et al., 2008). Studies have also shown inter-individual differences in EFs related to the child's sex (Wiebe et al., 2008). Moreover, Polderman et al. (2006) showed a significant association between EF skills and the child's IQ. While these different individual characteristics (age, sex and IQ) influence EFs, environmental factors, such as those related to the family, have also been shown to have an effect on executive functioning (Rueda et al., 2005).

2.2. Factors related to the family

Studies have brought out a relationship between socio-economic status (SES) during childhood and EFs (Hook, Gwendolyn, Lawson, & Farah, 2013; Rueda & Paz-Alonso, 2013). More specifically, children from families of higher SES present better EFs than children from families of lower SES (Blair & Razza, 2007; Carlson et al., 2013).

In addition to family income, parental education also appears to be a determining factor for EF skills (Ardila, Rosselli, Matute, & Guajardo, 2005; Noble et al., 2015). For example, Ardila et al. (2005) brought out a significant correlation between the parents' educational level and EFs among 5- to 13-year-olds. Compared to parents with lower levels of education, parents with higher levels of education tend more to create a stimulating environment for their children, which, in turn, appears to foster EFs among these children (Ardila et al., 2005).

Moreover, studies have indicated that parental practices also have an effect on EFs among children. More specifically, researchers have examined the link between the quality of parent–child interactions and children's executive functioning (Bibok, Carpendale, & Müller, 2009; Hammond et al., 2012). Hammond et al. (2012) reported that parental scaffolding at age 3 was found to have a direct effect on EFs at age 4, whereas scaffolding at age 2 had an indirect effect on EFs at age 4 through the child's verbal ability at age 3. These studies show the potential effect of social interactions on executive functioning among children, denoting, in particular, the importance of the quality of parent–child interactions—parental scaffolding and parental responsiveness—for the development of EFs. While these studies are not numerous, they indicate an association between the quality of interactions in the family environment and executive functioning among children.

By extension, it is plausible that the quality of classroom interactions might also have an effect on executive functioning among children, at least until proven otherwise. Indeed, it is known that the quality of the learning environment has a considerable impact on academic achievement among children (Curby, Rimm-Kaufman, & Abry, 2013), and that academic achievement is supported by executive functioning. In this regard, Obradović et al. (2012) note that one of the major challenges currently facing researchers is to explain how executive functioning might be affected by the context in which children grow and learn, particularly the classroom environment. However, to our knowledge, few if any studies have examined the link between the quality of classroom interactions and EFs among kindergarten children. We thus hypothesized that high-quality classroom interactions might foster the development of EFs among 5-year-old children.

2.3. Factors related to the learning environment: quality of classroom interactions

High-quality classroom interactions, wherein the teacher provides rich and diverse learning situations that are well suited to the children's needs, allow the children to develop the ability to reason and build strategies (Pianta, La Paro, & Hamre, 2008). A positive teacher–child relationship, that is, a relationship characterized by sensitivity and warmth, leads children to actively engage in learning (Pianta, 1999). Children who have a positive relationship with their teacher thus appear to perform better at school, show better social skills and display greater motivation (Booren, Truett, & Cash, 2011; Hughes & Kwok, 2007).

Similarly, when teachers meet the needs of the children in their class and take the latter's ideas into account, the children tend to engage more in the classroom activities proposed (Hatfield, Hestenes, Kintner-Duffy, & O'Brien, 2013). This attests to the importance of teacher support, through interactions with the children, for the latter's development—a phenomenon that can be explained by the positive effects of high-quality adult–child interactions on the development of a child's brain. Indeed, social interactions have a direct effect on the brain's ability to learn and are essential for children's cognitive development (Blakemore, Winston, & Frith, 2004).

There is thus a need to further explore the influence of the quality of classroom interactions on EFs, given that the latter undergo rapid development during early childhood (Welsh et al., 2010). Since EFs are known to be a predictor of academic achievement among children (Diamond, 2009; Zelazo, 2013) and academic achievement is associated with the quality of interactions in the classroom, EFs are likely to be associated with the quality of classroom interactions in kindergarten. Investigating this link thus constitutes a promising avenue of research, with a view to fostering EFs among kindergarten children. However, how can the relationship between the quality of classroom interactions and executive functioning among children best be explored?

A meta-analysis by Sabol, Soliday Hong, Pianta, and Burchinal (2013) examined several indicators of the quality of early childhood education programmes (e.g. group size, quality of interactions in the classroom) and several of the instruments used to measure them (e.g. Early Childhood Education Rating System–Revised (ECERS–R), Classroom Assessment Scoring System (CLASS)). According to their data analysis, the quality of classroom interactions, as measured by the CLASS, was the strongest predictor of children's learning (Sabol et al., 2013). The CLASS, which measures the quality of interactions in the classroom, covers three main areas: emotional support, classroom organization and instructional support (Pianta et al., 2008). This model of classroom interactions is based on the results of theoretical (Hamre & Pianta, 2007) and empirical studies (Hamre, Pianta, Mashburn, & Downer, 2007), and has been strongly supported by various researchers (e.g. Curby et al., 2013; Hamre, Downer, & Pianta, 2013).

In the United States, the CLASS has been used and validated in thousands of classrooms, from pre-kindergarten to high school (Hamre et al., 2007). In Quebec, it was used by Cantin, Bouchard, Lemire, and Charron (2011) to assess the quality of classroom interactions during the transition to pre-kindergarten, and by Pagé et al. (2014) to assess the same in kindergarten (N = 6 classes). Like the American studies, those in Quebec showed that the quality of interactions in the classroom generally tended to be quite low (Cantin et al., 2011; Pagé et al., 2014).

To our knowledge, no study to date has examined the relationship between the quality of classroom interactions and EFs among 5-year-old children, even though academic achievement is known to be supported by EFs. Observing the quality of classroom interactions in kindergarten will make it possible to determine which pedagogical practices best support EFs among children at age 5. The goals of this study were thus threefold: (1) to measure EFs among 5-year-old children; (2) to measure the quality of classroom interactions in kindergarten and (3) to examine the relationship between the quality of classroom interactions in kindergarten and EFs among 5-year-old children.

3. Method

3.1. Participants

The sample consisted of 118 children (70 girls and 48 boys), with a mean age of 73.34 months (SD = 4.22), from 12 kindergarten classes across seven schools, with socio-economic environment indices[2] ranging from 1 to 9 (M = 6.86). As for the children's families, 34.7% of parents held a college diploma or vocational certificate. The majority of parent respondents were mothers (n = 85.5%), with a mean age of 35.09 years (SD = 5.23). Most worked full time (n = 70.1%) and were married or had a common law partner (n = 66.8%). A quarter of families (n = 27.1%) had a gross family income of $100,000 or more a year, while 12.7% of families were living on less than $15,000 a year.

3.2. Instruments

3.2.1. Measures of EFs

The Forward and Backward Digit Span (Carlson, 2005) was used to assess WM. Each child was asked to repeat 2- to 4-item series of digits in reverse order, with each test becoming slightly more difficult than the last. The children were assigned a raw score out of 5. The Forward and Backward Digit Span is age-sensitive, and correlates well with other measures of WM (Monette & Bigras, 2008). The Dimensional Change Card Sort (Zelazo, 2006) was used to assess cognitive flexibility. In this task, which involves a set of cards showing either a boat or a rabbit, in red or blue, the child is asked to sort the cards, first according to colour and then according to shape. A raw score out of 24 was assigned to each child at the end of the task. This test, designed for children between the ages of 3 and 5, has demonstrated excellent test–retest reliability (Beck, Schaefer, Pang, & Carlson, 2011), and is age-sensitive (Monette & Bigras, 2008).

The Day–Night task was used to assess cognitive inhibition (Gerstadt, Hong, & Diamond, 1994). In this task, cards showing a sun or moon are presented to the child. The child is asked to say *night* when the sun card is presented and *day* when the moon card is presented. The children are assigned a raw score out of 16 based on the number of times they succeed at the task. The Day–Night task correlates well with the child's age (Gerstadt et al., 1994) and has been used in several other studies (e.g. Carlson, Davis, & Leach, 2005; Diamond, 2009). Behavioural inhibition was assessed using the NEPSY-II Statue subtest. In this test, the child must stand completely still and resist the impulse to respond to distracting behaviours on the part of the examiner. The children were assigned a total score from 0 to 30 (Korkman, Kirk, & Kemp, 1998).

The Tower of Hanoi (Welsh, 1991) was used to assess planning. Two boards, a sample board and a play board, each containing three vertical rods bearing discs of varying sizes, were presented to the child. The child was asked to reproduce, on the play board, the pattern of discs on rods presented on the sample board, in the fewest number of moves possible (raw score out of 36) (Monette & Bigras, 2008). The Tower of Hanoi is a standard test that has demonstrated good reliability (Gnys & Willis, 1991) and is one of the most useful from a psychometric perspective (Monette & Bigras, 2008).

3.2.2. Control measures related to EFs

In order to specifically bring out the effect of classroom interactions on executive functioning, in line with main goal of this study, control measures were used to isolate the factors related to the child and the family. With regard to the factors related to the child, the Block Design subtest (WPPSI-III, Wechsler, 2005) was administered to the participants to control for the often documented effect of IQ on EFs (Ardila, Ostrosky-Solis, Rosselli, & Gomez, 2000; Mahone et al., 2002). In this test, which measures the child's non-verbal cognitive ability, the child must analyse models and reproduce them using wooden blocks within a specified time limit (raw score out of 40). The WPPSI-III has been shown to have good psychometric properties, with reliability coefficients ranging from .88 to .96 (Wechsler, 2005).

To control for the potential effect on EFs of the child's age and sex, data on these individual characteristics were collected by means of a socio-demographic questionnaire distributed to parents. The same questionnaire was also used to collect information on family characteristics (i.e. gross family income and parental education) so as to control for their effects on the children's EFs.

3.2.3. Quality of classroom interactions

The quality of classroom interactions in kindergarten was measured using the CLASS (Pianta et al., 2008), assessing three domains: emotional support, classroom organization and instructional support. During four 30-min cycles, an observer examined the quality of classroom interactions (total duration = 120 min/class). A 7-point Likert scale was used and scores were then grouped into three levels: low (1 and 2), average (3–5), or high (6 and 7). Each domain showed an acceptable level of internal consistency: α = .83 (emotional support); α = .97 (classroom organization) and α = .82 (instructional support).

3.3. Procedure

In January 2014, a parental consent form and socio-demographic questionnaire were sent home with the child, filled out by the parent respondent, and returned to the school in the child's school bag. Once these forms had been filled out and collected, the quality of classroom interactions was measured and the data related to EFs were collected among the children (duration = 30 min/child).

4. Results

The results will be presented in three sections, reflecting the three goals of our study, namely, to measure: (1) the children's EF skills; (2) the quality of classroom interactions in kindergarten and (3) the relationship between the quality of classroom interactions in kindergarten and EFs among 5-year-old children.

4.1. EF skills

To examine EFs according to the child's IQ, age and sex, bivariate correlations were conducted between these variables. Before presenting these correlations, it is interesting to note the associations between the EFs themselves. Thus, as shown in Table 1, WM was significantly correlated with the other four EFs under study, namely, cognitive inhibition (r = .351, p < .01), behavioural inhibition (r = .196, p < .05), cognitive flexibility (r = .380, p < .01) and planning (r = .229, p < .05). The results also illustrate that behavioural inhibition was significantly and positively correlated with both cognitive flexibility (r = .450, p < .01) and planning (r = .191, p < .05).

Moreover, the results shown in Table 1 indicate that the child's estimated IQ was significantly and positively correlated with planning (r = .272, p < .05) and that the child's age was positively correlated with behavioural inhibition (r = .231, p < .05)—thus, the older the child, the better his/her behavioural inhibition skills. Lastly, Table 1 shows that the child's sex was negatively and significantly associated with planning (r = −.208, p < .05), indicating that girls had better planning skills than boys.

Table 1. Correlations between IQ, age and sex

Variables	1	2	3	4	5	6	7	8
1. Estimated IQ	–							
2. Age	.132	–						
3. Sex	.009	−.109	–					
4. WM	.100	−.070	−.006	–				
5. Cognitive inhibition	−.008	.065	−.163	.351**	–			
6. Behavioural inhibition	.049	.231*	−.139	.196*	.112	–		
7. Cognitive flexibility	.137	.117	−.155	.380**	.450**	.080	–	
8. Planning	.272**	.135	−.208*	.229*	.155	.191*	.079	–

*$p \leq .05$.
**$p \leq .01$.

Table 2. Mean scores and standard deviations—EF skills according to sex

Variables	Girls		Boys		Total	ANOVA	
	M	SD	*M*	SD	Range	*F*	Sig.
WM	59.25	.77	59.00	.79	25.25.00–100.00	.00	.95
Cognitive inhibition	93.50	2.43	87.88	2.99	.00.00–100.00	3.16	.79
Behavioural inhibition	82.37	6.61	75.60	7.91	6.66.67–100.00	2.25	.14
Cognitive flexibility	79.71	4.29	84.75	3.01	25.25.00–100.00	2.82	.09
Planning	85.47*	4.10	78.78*	7.32	.00–100.00	5.19	.02

*$p \leq .05$.

Descriptive analyses were conducted to bring out the level of EF skills according to the child's sex. For the purposes of comparison, the scores are reported as a value out of 100. Table 2 presents the means and standard deviations for the scores on each of the tests used to measure EFs, for girls and boys, respectively. Overall, the means ranged from 59.00 to 93.50 (out of 100), and the scores ranged from 0 to 100 (see Table 2).

More specifically, as shown in Table 2, the mean score for WM was 59.25 for girls (SD = .77) and 59.00 for boys (SD = .79). Table 2 shows a low standard deviation for the WM scores, indicating a narrow distribution of scores around the mean. Moreover, the mean score for cognitive inhibition was 93.50 for girls (SD = 2.43) and 87.88 for boys (SD = 2.99). As for behavioural inhibition, the mean scores were 82.37 for girls (SD = 6.61) and 75.60 for boys (SD = 7.91).

As can be observed in Table 2, of the five EF tests, the standard deviation was the highest for behavioural inhibition, reflecting a wider distribution of scores around the mean. As for cognitive flexibility, the mean score was 79.71 for girls (SD = 4.29) and 84.75 for boys (SD = 3.01). Lastly, the mean score for planning was 85.47 for girls (SD = 4.10) and 78.78 for boys (SD = 7.32). Overall, the mean scores were the highest for cognitive inhibition, and the lowest for WM, regardless of the child's sex (see Table 2).

In addition to the factors related to the child, those related to the family were also examined in order to control for their effects on EFs among 5-year-old children. As shown in Table 3, gross family income was positively correlated with planning ($r = .224$, $p < .05$). Moreover, the results show that parental education was positively associated with both cognitive flexibility ($r = .191$, $p < .05$) and planning ($r = .198$, $p < .05$). These findings were considered in the data analysis and interpretation of the results. More specifically, these factors were controlled for in order to bring out the real effect of the quality of classroom interactions in kindergarten on executive functioning.

Table 3. Correlations between EFs according to family characteristics

Variables	1	2	3	4	5	6	7
1. Gross family income	–						
2. Educational level	.546**	–					
3. WM	.133	.159	–				
4. Cognitive inhibition	.078	.096	.351**	–			
5. Behavioural inhibition	−.051	−.022	.196*	.112	–		
6. Cognitive flexibility	.082	.195*	.380**	.450**	.080	–	
7. Planning	.224*	.198*	.229*	.155	.191*	.079	–

*$p \leq .05$.
**$p \leq .01$.

4.2. Quality of classroom interactions in kindergarten

Descriptive statistical analyses were conducted to bring out the means and standard deviations for the three domains of the CLASS. The results indicate an average level of emotional support, with a score of 4.92 (SD = .50). Moreover, of the three domains of the CLASS, classroom organization presented the highest score (M = 5.12, SD = .63) while instructional support presented the lowest score (M = 3.27, SD = .5).

A bivariate correlation analysis was conducted to examine the correlations between these three domains. The results show that they were significantly correlated among themselves. Specifically, emotional support was significantly and positively correlated with both classroom organization (r = .712, p < .01) and instructional support (r = .531, p < .01). Thus, the higher the level of emotional support, the higher the level of classroom organization and instructional support. Moreover, classroom organization was significantly and positively correlated with instructional support (r = .686, p < .01).

4.3. Relationship between EFs and quality of classroom interactions in kindergarten

Bivariate correlations, presented in Table 4, brought out associations between the EFs under study and the quality of interactions in the classroom. As can be observed, emotional support was significantly correlated with both WM (r = .222, p < .05) and cognitive inhibition (r = .216, p < .05). Thus, the higher the level of emotional support, the better the child's WM and cognitive inhibition.

Hierarchical regression analyses were conducted to clarify the associations between these dependent variables (i.e. WM and cognitive inhibition) and independent variables (i.e. emotional support, classroom organization and instructional support). The assumptions of linearity, homogeneity and normality were tested and met (Field, 2012). Each regression analysis consisted of two blocks of variables: "estimated IQ", "age", "sex" and "gross family income/parental education" were entered in the first block, while the three domains of the CLASS, namely, emotional support, classroom organization and instructional support, were entered in the second block.

4.3.1. Relationship between WM and quality of classroom interactions

Table 5 presents the results of the hierarchical regression analysis for WM and the quality of classroom interactions. The results indicate that Block 1 did not contribute significantly to explaining the WM score. The results for Block 2, however, show that the quality of classroom interactions contributed significantly to WM (F (6, 116), 2.58, p = .026), explaining 8.4% of the variance in the WM score (see Table 5). The β coefficients suggest that a higher level of emotional support in the classroom was associated with higher WM scores (β = .258, p < .05), whereas a lower level of instructional support was associated with higher WM scores (β = −.293, p < .05).

Since the negative relationship between instructional support and WM was an unexpected result, further analyses were performed. According to Hayes (2013), a moderating variable may effectively

Table 4. Correlations between EFs and quality of classroom interactions

Variables	1	2	3	4	5	6	7	8
1. Emotional support	–							
2. Classroom organization	.712*	–						
3. Instructional support	.531**	.686*	–					
4. WM	.222*	.136	−.037	–				
5. Cognitive inhibition	.216*	.133	.033	.351**	–			
6. Behavioural inhibition	.075	.068	.020	.196*	.112	–		
7. Cognitive flexibility	.155	.102	.037	.380**	450**	.080		
8. Planning	−.024	.025	−.059	.229*	.155	.191*	.079	–

*$p \leq .05$.
**$p \leq .01$.

be brought out in studies where a result appears to be contradictory. Based on studies showing the effect on children's EFs of family characteristics, in particular gross family income (Noble, Norman, & Farah, 2005) and parental education (Ardila et al., 2005), an additional regression analysis was conducted to test whether our combined family characteristics variable moderated the relationship between instructional support and WM.

Thus, to test for this moderating effect, an interaction term (predictor X moderator) was created and entered in the multiple regression (Block 3). As in the preceding regression analysis (see Table 5), the results presented in Table 6 show that Block 1 did not contribute significantly to explaining the WM score. Here again, the results for Block 2 (F (7,113), 2.430, p = .024) indicate that emotional support, on its own, helped to explain WM (β = .258, p = .034). The results for Block 2 also bring out a significant and negative relationship between instructional support and WM. However, when Block 3 was added, instructional support no longer helped to explain the WM score (F (8,113), 2.114, p = .041) (see Table 6). Thus the "instructional support X gross family income/parental education" interaction reduced the negative association initially found between instructional support and WM.

Pursuing these analyses further, cross-tabulation tables were then created to more thoroughly explore the potential influence of family characteristics on the children's EFs. These cross-tabulations explained the unexpected result brought out in the regression analysis (i.e. the negative relationship between instructional support and WM), using categorical variables (Field, 2012). In this step, the variable "gross family income/parental education" was split into two variables, namely, "gross family income" and "parental education" in order to examine the results separately.

Table 7 presents the results for quality of instructional support[3] according to gross family income. As can be seen, the children in classes where the level of instructional support was low tended to come from families with high gross incomes. More specifically, almost half of the children from more affluent families were in classes in which instructional support was low (n = 47.8%). Among the children in these classes, most came from families in which the parents earned over $75,000/year ($n$ = 56.4%), whereas only 4 out of 55 children (.07%) came from families with an income of less than $15,000/year (see Table 7). It should be noted that the chi-square value for Table 7 was significant (χ^2 = 57.99, p = .03); gross family income had a significant effect on EFs among these 5-year-old children, which helped reduce the association between instructional support and WM.

Table 5. WM among 5-year-old children and quality of classroom interactions

Variables	*B*	SE *B*	*β*	R^2	ΔR^2	s R^2
Block 1						
Estim. IQ (block design)	.010	.010	.101	.041	.005	.304
Child's age	−.017	.018	−.093			.391
Child's sex	−.061	.147	−.039			.678
Income/parental education	.125	.099	.126			.209
Block 2						
Estim. IQ (block design)	.017	.010	.167	.141	.084	.482
Child's age	−.014	.018	−.075			.086
Child's sex	−.040	.142	.026			.442
Income/parental education	.116	.030	.129			.779
Emotional support	.401	.209	.258*			.045
Classroom organization	.242	.191	.198			.235
Instructional support	−.447	.197	−.293*			.023

*$p \leq .05$.

Table 6. Addition of 3rd block—WM among 5-year-old children and quality of classroom interactions

Variables	*B*	SE *B*	*β*	R^2	ΔR^2	s R^2
Block 1						
Estimated IQ (block design)	.011	.010	.093	.030	−.005	.311
Child's age	−.017	.018	−.062			.388
Child's sex	−.054	.149	−.035			.716
Income/parental education	.139	.031	.110			.216
Block 2						
Estimated IQ (block design)	.016	.010	.157	.126	.069	.486
Child's age	−.015	.018	−.049			.088
Child's sex	−.040	.144	−.026			.444
Income/parental education	.146	.030	.105			.781
Emotional support	.401	.209	.258*			.034
Classroom organization	.242	.191	.150			.332
Instructional support	−.447	.197	−.293*			.036
Block 3						
Child's sex	−.041	.145	.000	.127	.061	.998
Child's age	−.015	.018	−.049			.611
Estimated IQ (block design)	.017	.010	.157			.107
Income/parental education	.145	.030	.105			.281
Emotional support	.409	.209	.263*			.034
Classroom organization	.236	.191	.150			.332
Instructional support	−.446	.509	−.317			.339
"Instructional support X income/parental education" interaction	.010	.064	.104			.823

*$p \leq .05$.

Table 7. Cross-tabulation table for "quality of instructional support" and "gross family income"

Gross family income		Quality of instructional support		
		Low	Medium	Total
(1) Less than $15,000	No. of children	4	9	13
	% of children in each quality level	7.3	15	11.3
(2) From $15,000 to $30,000	No. of children	4	9	13
	% of children in each quality level	7.3	15	11.3
(3) From $30,000 to $50,000	No. of children	6	10	16
	% of children in each quality level	10.9	16.7	13.9
(4) From $50,000 to $75,000	No. of children	10	18	28
	% of children in each quality level	18.1	30	24.4
(5) $75,000 and over	No. of children	31	14	45
	% of children in each quality level	56.4	23.3	39.1
Total	No. of children	55	60	115
	% of children in each quality level	100	100	100

To sum up, the results demonstrate that gross family income reduced the negative association found between instructional support and WM.

Table 8. Quality of classroom interactions and cognitive inhibition among 5-year-old children

Variables	*B*	SE *B*	β	R^2	ΔR^2	s R^2
Block 1						
Estim. IQ (block design)	−.017	.034	.050	.037	.002	.629
Child's age	.041	.061	.065			.583
Child's sex	−1.054	.510	−.194			.141
Income/parental education	.117	.105	.110			.127
Block 2						
Estim. IQ (block design)	−.003	.035	−.008	.090	.030	.972
Child's age	.050	.0628	.079			.509
Child's sex	−.975	.504	−.179			.145
Income/parental education	.119	.106	.112			.125
Emotional support	1.425	.733	.263*			.050
Classroom organization	.107	.670	.025			.683
Instructional support	−.710	.693	−.134			.231

*$p \leq .05$.

4.3.2. Relationship between cognitive inhibition and quality of classroom interactions

To clarify the correlation between cognitive inhibition and the quality of classroom interactions (see Section 4.3), an additional regression analysis was conducted, as was done for WM. Table 8 presents the results of the hierarchical regression analyses pertaining to cognitive inhibition. The results for Block 1 reveal that the level of cognitive inhibition was influenced neither by the child's individual characteristics, nor by factors related to the family. However, Block 2 shows that emotional support on its own helped explain cognitive inhibition (F (7, 114) = .263, p = .050), explaining 3% of the variance in this score. The β coefficient for emotional support suggests that better emotional support was associated with higher cognitive inhibition scores.

5. Discussion

This study set out to accomplish three goals: (1) to measure EFs among 5-year-old children; (2) to measure the quality of classroom interactions in kindergarten and (3) to examine the relationship between the quality of classroom interactions in kindergarten and EFs among 5-year-old children.

First, the results show fairly high levels of cognitive inhibition among the children in the sample, as measured using the Day–Night task (Gerstadt et al., 1994). This finding is consistent with other studies (e.g. Simpson & Riggs, 2007) reporting similar levels of cognitive inhibition towards the end of the preschool period. Working memory, on the other hand, presented the lowest scores. Moreover, as measured using the Forward and Backward Digit Span, the WM scores showed the lowest variability. According to Zelazo et al. (2003), this test, in which the child must repeat, in reverse order, series of digits that are 2–4 items long, represents a complex test for preschool-aged children.

As for the effect of individual characteristics on the children's EFs, our results, in line with other studies (e.g. Ardila et al., 2000; Mahone et al., 2002), show that the child's IQ was significantly and positively associated with planning. Similarly, the child's age was significantly and positively associated with behavioural inhibition. This finding is consistent with that reported by Heikamp, Trommsdorff, Druey, Hübner, and von Suchodoetz (2013) where the child's age was associated with inhibitory control.

Moreover, the correlation analyses showed that cognitive inhibition and cognitive flexibility were correlated. Although these two executive functions are distinct, Deville and Meynier (2014) asserted

that the processes underlying flexibility and inhibition are inter-dependent. Miyake et al. (2000) also asserted that cognitive flexibility and inhibitory control cannot be considered to be completely independent. Inhibition consists in maintaining one's focus on a single type of stimuli by blocking out any non-pertinent information presented, whereas cognitive flexibility allows the child to adjust to new situations when learned and familiar procedures no longer constitute a relevant response (Deville & Meynier, 2014).

Furthermore, our results show that WM was correlated with the other EFs, which means that higher WM scores were associated with higher scores for inhibition, cognitive flexibility and planning. However, it is difficult to make sense of these associations: Is WM associated with the other EFs, or are the other EFs associated with WM? Future research could clarify these results, in particular, by using path analysis.

Case (1992) asserted that improvements in WM allow children to make progress in their overall executive functioning. More recently, Kaufman (2010) asserted that WM has to do with the region in the child's brain that corresponds to cognitive tasks, that is, the area of the brain in which the child can retain information which is then used to think and act. Using their WM skills enables children to organize the information retained and make use of it in various tasks (e.g. making a plan, building comprehension) (Kaufman, 2010). Thus, WM allows children to participate in activities that call upon other elements of executive functioning.

Moreover, Carlson et al. (2013) asserted that WM contributes to executive functioning performance during early childhood, hence the importance of fostering WM during kindergarten. More recently, Fitzpatrick, Archambault, Janosz, and Pagani (2015) showed that the WM skills of preschoolers (aged 2–3½) were associated with the latter's future academic achievement, and were considered to be a good indicator of their risk for school dropout. These different studies bring out the importance of focusing on WM, with a view to supporting other EFs among children and, ultimately, fostering academic achievement.

Furthermore, our results showed that the quality of emotional support provided in the kindergarten classroom was correlated with both WM and cognitive inhibition. This finding is consistent with other studies (e.g. Hatfield et al., 2013; Raver & Blair, 2014) showing that EF skills develop through social interactions. For example, Haden, Ornstein, Rudek, and Cameron (2009) reported that parent–child interactions can improve a child's memory. When the mother reminisces out loud (e.g. about things that happened during the day), this helps children construct representations of and organize their own personal experiences. The ability to coherently organize information in one's brain is essential for most improvements in memory made during childhood, and is closely related to the emergence of inhibition (Howes et al., 2008).

In the classroom, as shown by Ornstein, Haden, and San Souci (2008) and Ornstein, Coffman, Grammer, San Souci, and McCall (2010), the teacher's language during instruction has an effect on the children's memory development. For example, teachers who use mnemonic strategies, that is, procedures that enhance memory, in turn foster the development of memory strategies among the children in their classrooms (Ornstein et al., 2008, 2010).

With regard to inhibition, Barkley (1997) showed an association between inhibitory control and the regulation of emotions among children. More recently, Penela, Walker, Degnan, Fox, and Henderson (2015) brought out a relationship between emotion regulation, inhibition skills and social competence among children. These researchers, moreover, suggest targeting emotion regulation strategies with a view to improving inhibition skills among young children, which, in turn, have an effect on the quality of classroom interactions (Penela et al., 2015). On the other hand, negative emotions, such as stress and anxiety, have a negative effect on children's EFs, including memory skills (Raver & Blair, 2014; Schoofs, Preuss, & Wolf, 2008).

In the classroom, a high level of emotional support, characterized by a warm and receptive teacher who takes the children's points of view into account and creates an environment that is conducive to learning, can lessen the children's stress. Indeed, Hatfield et al. (2013) showed that children in classrooms characterized by higher levels of emotional support show lower levels of cortisol than children in classrooms characterized by lower levels of emotional support. Teachers who take the children's ideas into account help the latter to feel comfortable in the classroom environment, which reduces their level of stress and fosters the development of their EFs (Hatfield et al., 2013).

To further clarify the results of the correlation analyses, regression analyses were conducted for WM and cognitive inhibition. In both cases, the results still showed the influence of emotional support on these EF skills. However, a surprising finding emerged from these analyses, namely, the negative association between instructional support and WM. To explain this association, non-parametric analyses were performed to test for the presence of a moderating variable (i.e. family characteristics) on the relationship between instructional support and WM.

The results showed that gross family income reduced the association between the quality of instructional support and WM among the 5-year-old children in our study. This finding is in line with other studies showing an association between family income and children's EFs. For example, studies have shown that children from more advantaged backgrounds perform better than children from less advantaged backgrounds on tests measuring cognitive flexibility and inhibition (Ardila et al., 2005; Noble, McCandliss, & Farah, 2007).

This association between socio-economic background and children's EFs is consistent with many empirical and theoretical studies on the effects of family characteristics on cognitive development among children (Conger & Donnellan, 2007; DiPietro, Costigan, Hilton, & Pressman, 1999). More specifically, studies have shown that poorer socio-economic backgrounds (e.g. economically disadvantaged, low levels of education) are associated with a developmental risk in terms of general health outcomes and cognitive and socio-emotional outcomes, which can begin as early as in the womb and continue through to adulthood (Conger & Donnellan, 2007; Duncan, Ziol-Guest, & Kalil, 2010).

In our study, most of the children in the classrooms characterized by lower levels of instructional support came from the families in which the gross family income and educational level of the parent respondent were higher, which gave more weight to the means obtained. This could explain the negative association between instructional support and WM. Indeed, it is plausible that the parents of the families with higher income levels tended to provide more instructional support to their children, which thus compensated for the low level of instructional support provided in the classroom. Following the same line of reasoning, it is likely that the children from the less affluent families needed more instructional support. Therefore, even if the children from the families with higher gross family incomes were in a classroom characterized by low instructional support, they nevertheless obtained good scores on the EF tests on account of these family characteristics. Future research should examine more specifically the potential moderating role of the family in the association between the quality of classroom interactions and EFs.

High-quality instructional support does not, in itself, foster the development of EFs among 5-year-old children, particularly among children from more affluent families. The question thus arises as to how the classroom environment can effectively foster the development of EFs, beyond the influence of family characteristics? It should nevertheless be noted that, in our study, of the three domains of the CLASS, instructional support obtained the lowest scores. It is therefore plausible that improving the quality of instructional support, especially in disadvantaged neighbourhoods, might help support EFs among kindergarten children.

Indeed, the disadvantages related to the characteristics of the family environment and their effects on children's EFs might be compensated by a high-quality learning environment (Chevalier, 2010). Our study thus suggests that this avenue of research should be pursued in order to determine

whether or not there is a relationship between instructional support and EFs among children from disadvantaged backgrounds.

When it comes to fostering the development of executive functions in the classroom (pedagogical implications), researchers (e.g. Bodrova, 2008; Diamond, 2013; Elkonin, 1978) have shown that play and scaffolding are promising avenues to explore. According to Diamond (2013), symbolic play acts as an essential pedagogical tool in the classroom because it leads children to use several strategies related to EFs: playing a role while keeping the roles of others in mind (WM), inhibiting behaviours that would run contrary to the attributes of the characters they are playing (inhibitory control), flexibly adapting to twists and turns in the storyline (cognitive flexibility) and planning for the development of events as the story unfolds (planning) (Diamond, 2013).

Similarly, in symbolic play, scaffolding by an adult, a sub-dimension of instructional support, allows the child's play to become more complex, helping the child to develop both the ability to reason and the cognitive strategies related to executive functioning. Indeed, Bodrova (2008) maintained that scaffolding in the context of symbolic play has a positive impact not only on the development of such play itself, but also on the development of the child's cognitive skills. In the light of the advantages of symbolic play for child development, Bodrova and Leong (2011) created the Tools of the Mind program based on the work of Vygotsky and Luria. This programme specifically aims to develop EFs among young children through social interactions (Diamond, 2009), in particular by using make-believe play (playing house, cops and robbers, etc.). Tools of the Mind also encourages children to use inner dialogue and visual reminders to develop inhibitory control, which is a component of executive functioning.

Use of the Tools of the Mind program in kindergarten classrooms has shown that interactions during periods of play help children to develop the abilities associated with executive functioning (Diamond, 2009). In the current study, our observations took place in the morning, during more highly structured activities involving the entire group. Consequently, very few interactions took place in the context of play, which might explain the low levels of instructional support found in this study, as well as the negative association with WM. It would be useful, in future studies, to observe the quality of interactions between the teacher and child during symbolic play and examine the effects of these interactions on the child's EFs.

6. Limitations

Our sample consisted of only 118 children from 12 kindergarten classes. Consequently, our results cannot be generalized. Moreover, although the schools were in neighbourhoods with a wide range of socio-economic environment indices, most of the children came from schools in disadvantaged neighbourhoods (rank 8 or 9). On the other hand, most of the children came from families in which the parent respondent held a college diploma or university degree, with a gross family income of $75,000 or higher. There was thus not a wide variability in the socio-economic status of the families, which may have reduced the effect of the quality of classroom interactions on EFs.

7. Conclusion

This study examined the relationship between the quality of classroom interactions and EFs among 5-year-old children. Many questions are currently being raised regarding the pedagogical practices that best promote EFs among children, with a view to fostering academic achievement from the very start of schooling. Our results help shed light on this issue, confirming the need to focus on the quality of interactions in the classroom. However, despite the correlations found between the three domains of the CLASS, only emotional support appeared to influence the children's EF skills, in particular, WM and cognitive inhibition. In this regard, researchers have shown that positive adult–child interactions play a crucial role in the development of EFs (Bernier, Carlson, & Whipple, 2010; Rueda & Paz-Alonso, 2013).

Moreover, our results show that factors related to the family reduced the association between instructional support and WM among the 5-year-old children. In fact, gross family income first predicted WM scores among these kindergarten children, which explained the negative association between instructional support and WM found in our study. It thus appears that instructional support was not associated with the EFs of the children from the more advantaged families. It is plausible that these children benefit from instructional support at home, through interactions with their parents. However, it is also plausible that high-quality instructional support might foster EFs to a greater extent among children from more disadvantaged families, and thus compensate for the challenges stemming from their family environment.

To sum up, this study showed that the quality of interactions in the classrooms observed was only average, in all three domains of the CLASS. Among the three domains, the quality of classroom organization was found to be the highest, whereas the quality of instructional support was found to be the lowest. Considering that emotional support influences both WM and cognitive inhibition, it is possible that improving the level of emotional support would help to better support EFs among children, especially those from poorer socio-economic backgrounds.

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Notes
1. The term "executive functioning" is used here synonymously for executive functions.
2. The socio-economic environment index (*les indices de milieu socioéconomique*, IMSE) presents 10 ranks of deprivation: a rank of 1 corresponds to schools at which the majority of pupils come from the most advantaged backgrounds, whereas a rank of 10 corresponds to schools at which the majority of pupils come from the most disadvantaged backgrounds (ministère de l'éducation, du loisir et du sport [MELS], [MELS], [MELS], 2015).
3. The "high" level (scores of 6 and 7 in the CLASS) was not considered in the cross-tabulation tables because this level of quality was not found in the participating classes.

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