The Association between Parental Scaffolding and Children's Executive Function

by

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Abstract

The present study investigated the association between parental scaffolding during a shared puzzle task and young children's executive function (EF). Fifty-six children between the ages of 2 and 4 years were assessed on 3 different EF tasks, and completed a shared puzzle task with their primary caregivers. Higher rates of appropriate scaffolding were found to be positively correlated with child EF performance. In addition, regression analyses found scaffolding to be a significant predictor of child EF even after controlling for child age and verbal ability. These findings add to previous studies on parenting practices and early EF in suggesting that parental scaffolding may play an important role in young children's developing EF skills.

Preface

This thesis is an original work by Dorothea Hui. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name “Parent-Child Interactions and the Development of Children's Executive Function”, Pro 56915, 11th October 2016.

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The Association between Parental Scaffolding and Children's Executive Function

Executive functions (EFs) are the higher-order cognitive control abilities responsible for goal-directed behaviour (Best & Miller, 2010; Brocki & Tillman, 2014). EFs are particularly important for non-automatic novel and complex behaviours that require the usage of top-down control (Brocki & Tillman, 2014). Although sometimes described as a unitary construct, EFs encompass separable components that are correlated and share a general cognitive resource (Miyake et al., 2000). Two of the most frequently postulated components of EF in the literature are working memory (to update and monitor active information) and inhibition (to override and resist interference from an automatic but incorrect response; Miyake et al., 2000; Brocki & Tillman, 2014). EFs begin to emerge in the first years of life (Diamond, 1991) and continue to develop and advance through to adulthood (Huizinga, Dolan, van der Molen, 2006; Stievano & Valeri, 2013).

EFs are theorized to develop as a result of an interaction between the maturation of the brain and the external environment (Diamond, 1991). Research has examined the role of social factors on individual differences in child EF, ranging from the more distal aspect of family socioeconomic status (SES) to parent-child relationships (e.g., Hughes & Ensor, 2009; Mezzacappa, 2004). Parent-child relations arguably represent the central part of a young child's environment, especially in the early years of life (Bernier, Carlson, Deschênes, & Matte-Gagné, 2012). Early on in children's development, parents are primarily responsible for creating and maintaining these social interactions, and scaffolding is a prime way parents can facilitate children's cognitive abilities (Bibok, Carpendale, & Müller, 2009). However, parental scaffolding has received less attention in EF research. Addressing this gap, the present study examines the association between parental scaffolding and EF performance in early childhood.

Working Memory and Inhibition

Working memory involves a combination of monitoring and coding new incoming information for its relevance to the current task, and then appropriately revising the information active in mind by replacing previous information that is no longer relevant with the new, more relevant information (Miyake et al., 2000).

Inhibition refers to the ability to consciously and deliberately suppress automatic, prepotent, or dominant responses in favour of a more appropriate one when necessary (Miyake et al., 2000). This controlled inhibition has been described to also involve attention control (Nigg, 2000). Garon, Bryson, and Smith (2008) distinguished between two types of inhibition – simple and complex – based on whether working memory is also needed. Simple response inhibition only needs a small amount of working memory, as when a child delays eating a marshmallow (Cragg & Nation, 2008; Garon et al., 2008). Complex response inhibition, on the other hand, requires more working memory as it involves holding an arbitrary rule in mind or producing an alternate response in addition suppression (Garon et al., 2008). Simple inhibition of prepotent responses is generally assessed by performance on behavioural or cognitive tasks that require a conditioned or automatic response to be withheld or delayed in order to produce a less automatic response (Diamond, 2013; Macdonald, Beauchamp, Crigan, & Anderson, 2014).

While the prevailing view that working memory and inhibition are best conceptualized as separable components might hold true in adulthood, evidence for the interdependence of these functions in childhood has emerged (Macdonald et al., 2014). A unitary model of EF incorporating the two functions were reported by Wiebe et al. (2011) in their study of 3-year-olds using a Confirmatory Factor Analysis (CFA) model. Likewise, Willoughby, Blair, Wirth, and Greenberg (2010) tested the dimensionality of EF in a sample of 3-year-olds using CFA, and found their performance was adequately characterized by a single factor. The same finding was also discovered in a sample of children between 2.3 and 6 years of age, where the indexes of inhibitory control and working memory were found to load on a single latent factor despite differences among task characteristics (Wiebe, Espy, & Charak, 2008). Furthermore, Shing, Lindenberger, Diamond, Li, and Davidson (2010) also employed CFA and found no difference between working memory maintenance and inhibition until the age of 9.

Early Childhood EF Development

Children experience the emergence and rapid growth of their EFs during infancy and early childhood (Diamond & Taylor, 1996; Espy, Kaufmann, Glisky, & McDiarmid, 2001; Garon et al., 2008). This is, in part, due to the pronounced plasticity and maturation of the prefrontal cortex (PFC) between the ages of 2 and 5 years (Casey, Giedd, & Thomas, 2000; Huttenlocher & Dabholkar, 1997), which allows children to increasingly control their thoughts and actions (Conway & Stifter, 2012; Diamond, 2002; Lengua, Honorado, & Bush, 2007; Van Reet, 2015). This sensitive period of development provides a window of opportunity for contextual experiences – especially those embedded within parent-child relationships as young children are particularly dependent on parents – to influence the development of brain structures necessary for EFs (Conway & Stifter, 2012; Fay-Stammbach, Hawes, & Meredith, 2014; Lewis, Carpendale, Towse, & Maridaki-Kassotaki, 2010). In a similar way, this developmental period presents an ideal time for researchers to assess early predictors of EFs (Conway & Stifter, 2012).

Individual differences in the expression of working memory and inhibition may play an important role in the adaptive functioning of young children as they are now expected by parents to be able to remember certain rules and regulate their behaviour accordingly in common everyday situations, such as stopping play and cleaning up after play (Kochanska, Murray, & Coy, 1997; Morasch & Bell, 2011).

EFs are key for children's success in social interactions and learning, and early EF performance has also been linked to later positive developmental outcomes across cognitive, academic, emotional, and social domains (Herbers, Cutuli, Supkoff, Narayan, & Masten, 2014). Deficits in EF, on the other hand, have been implicated in various psychopathologies, including attention deficit hyperactivity disorder (ADHD; Berlin, Bohlin & Rydell, 2003).

Parental Scaffolding

Theorists have long emphasized the role of social interactions in the development of higher order cognitive skills (Conway & Stifter, 2012). According to Vygotsky (1930-1934/1978), social interaction and problem solving with adults is an avenue through which children's cognitive skills develop. Through the support of a more expert person during a joint activity, a context is created where opportunities for the development of higher forms of behaviour are cultivated (Vygotsky, 1930-1934/1978). This context is also otherwise known as the "zone of proximal development" or ZPD. The ZPD is described as the distance between the level of a child's performance that can be achieved under guidance from adults and the level of a child's performance when working independently (Vygotsky, 1930-1934/1978). This concept has been expanded upon by other theorists who have underscored the importance of social processes in the development of EFs, including parenting practices (Conway & Stifter, 2012; Kopp, 1982, 1989; Lewis et al., 2010).

The concept of "scaffolding" was originally coined and proposed by Wood, Bruner, and Ross (1976) as a model to account for the way certain types of social interactions facilitate children's cognitive development. Broadly defined, scaffolding involves the process of using verbal or nonverbal actions as intentional efforts to help plan and organize children's activity on a challenging task beyond their current level of ability (Bibok et al., 2009; Lewis & Carpendale, 2009). Scaffolding is not simply breaking a task down into simpler steps; it provides escalating assistance through both the quality and quantity of support (Greenfield, 1984; Griffin & Cole, 1984). Like the ZPD, which is not static and changes in accordance with the child's level of competency, effective scaffolding provides assistance sensitive to the child's current developmental level (Wood, 1980; Wood & Middleton, 1975). This also means that the scaffolding process may sometimes involve more help from the parent when the task is outside the child's grasp or following failure, and at other times, retreating from helping and observing when assistance is no longer needed as the child attains proficiency and success (Hammond, Müller, Carpendale, Bibok, & Liebermann-Finestone, 2012; Wood, 1980; Wood & Middleton, 1975). In other words, more is not always necessarily better. In fact, Tharp and Gallimore (1988) refer to assistance that is no longer required or too much assistance as a disruption and interference to children's learning. Therefore, the scaffolding process is relational by nature, its success determined by the reciprocity of interactions between a parent and a child during the task. In other words, even if parents' actions or suggestions may be helpful, if they failed to maintain their child's direction to the task at hand, then scaffolding was unsuccessful or failed to emerge appropriately. Central to the success of the scaffolding process is striking the balance between working with children at their present competency level and still challenging them at the same time (Bibok et al., 2009).

Wood and colleagues (1976) also identified six sub-processes or strategies in the scaffolding process by which the adult can facilitate children's emotional and cognitive development: (1) recruitment to the task at hand; (2) direction maintenance to complete the task; (3) frustration control to maintain engagement in task; (4) reduction in the degree of freedom; (5) marking of the task's critical features; and (6) demonstration. Building on these identified sub-processes, Hammond et al. (2012) provided an example of good scaffolding as allowing the child to confront errors, and starting with lower levels of assistance first before adjusting accordingly depending on the child and his/her responses (e.g. marking critical features before reducing the degrees of freedom, and only demonstrating directly if the other strategies were unsuccessful).

Parental Scaffolding and Childhood EF

The quality of parent-child interactions is recognized as an important predictor of individual differences in children's EF (Kochanska, Murray, Jaques, Koenig, & Vandegeest, 1996; Rochette & Bernier, 2016; Stievani & Valeri, 2013). The strategies parents offer to help children solve problems during scaffolding cultivate opportunities for high-quality parent-child interactions in challenging tasks (e.g. a difficult puzzle) that engage children's working memory and inhibitory capacities (Rosenqvist, Lahti-Nuuttila, Holdnack, Kemp, & Laasonen, 2016).

Associations between parental scaffolding and children's EF development have been found as early as 2 years of age (Bibok et al., 2009). Better parental scaffolding is related to higher child performance on EF tasks (Bernier, Carlson, & Whipple, 2010; Fay-Stammbach et al., 2014; Hammond et al., 2012; Hughes & Ensor, 2009). Bibok et al. (2009) found that parental verbal scaffolding during a puzzle task was linked to child concurrent EF performance at age 2. In addition, maternal verbal scaffolding during play at the age of 2 was found to be a stronger predictor for children's EF when they turned 4 than EF performance at age 2 (Hughes & Ensor, 2009). A study looking at parent-child interactions during problem-solving tasks also found greater scaffolding behaviours that kept and redirected children's focus on the task at hand, to be associated with higher levels of working memory in children (Fay-Stammbach et al., 2014). These results closely match the view of Wood and colleagues (1976) that scaffolding is not limited to verbal factors, and that scaffolding processes simultaneously target regulating children's motivation (frustration control, recruitment) and cognition (marking critical features, reduction in degrees of freedom, demonstration).

A possible explanation is that parental scaffolding behaviours serve as an auxiliary cognitive resource that children can use to regulate their own behaviour (Bibok et al., 2009). That is, the scaffolding process may be functionally similar to EFs as they are both providing children with the cognitive resources to organize and plan their goal-directed actions (Bibok et al., 2009). In this case, parents may be performing on children's behalf the many functional roles that are associated with EFs by initially acting as external regulators of children's affect and behaviour (Bibok et al., 2009; Grossmann & Grossmann, 1991; Spangler, Schieche, Ilg, Maier, & Ackerman, 1994). This is in line with Rogoff and Gardener's (1984) rendition of the ZPD concept as that developmental phase in the development of a cognitive skill where children have only partially acquired the skill but can successfully master and internalize it with the supervision and assistance of adults. Therefore, by creating this ZPD in the context of a joint activity where parents can help children practice, strengthen, and gradually engage in those EF skills on their own successfully, scaffolding may facilitate the development of EFs.

The Present Study

The present study examined parental scaffolding during a puzzle task and its association with child EF during the early childhood years. Few studies to date have investigated EF development in young children from this more proximal social relationship between a parent and child (Hammond et al., 2012). The main goal of the study was to better understand the contributions of appropriate scaffolding behaviours and the role parents could play in young children's EF development. I hypothesized that a greater amount of appropriate scaffolding provided to children when required would be related with higher EF performance.

Method

Participants

The sample included 56 children (30 boys and 26 girls), between the ages of 2 years 7 months and 4 years old (M = 3.21 years, SD = .46), and their respective primary caregivers (50 mothers, 5 fathers, and 1 grandmother). Participants were recruited through flyers and posters in schools and childcare facilities, social media, and by word of mouth throughout the city of Edmonton, Alberta, Canada. Interested parents completed a telephone screening to determine eligibility to participate. To be eligible, children must have been born full-term (within 3 weeks of due date), not be diagnosed with behavioural disorders or developmental delays, and have at least 50% English exposure at home. The sample included 69.64% Caucasian/European-Canadian, 12.5% mixed, 10.71% Asian/Pacific Islander, 3.57% Hispanic/Latina/Latino, 1.79% African-Canadian, and 1.79% Arabic.

Procedure

Testing took place in a child development laboratory at the University of Alberta. After the study was explained to parents and any questions were answered, each parent-child dyad completed the shared ring puzzle task and a shared book reading task that was unrelated to the present analyses. Next, a short battery of EF tasks was administered to the child, including the Nebraska Barnyard, Go/No-go, and Gift Delay tasks (see below for task descriptions). Parents remained in the same room while children carried out the battery of EF tasks – except for the Gift Delay task – and completed a packet of questionnaires about their family background and parenting styles. Lastly, the Peabody Picture Vocabulary Test-4th edition (PPVT-IV; Dunn & Dunn, 2007) was used to assess child verbal ability. The entire session was recorded by two video cameras from two corners of the room. Parents were reimbursed for any travel expenses to the lab, and the parent and child received a gift card and small toy, respectively, in appreciation for their time and participation.

Measures

Parental Scaffolding.

Shared ring puzzle task. A ring puzzle task (Carpendale, 1999; Schmid-Schönbein & Thiel, 2010) was used to measure scaffolding. The stimuli for this task consisted of four white concentric rings grouped around a middle circle that had been cut into equally sized pieces (see Figure 1). Children had to put the pieces together and form the concentric circles correctly. Parents were instructed to help their children solve it the way they do at home, and children were told their parents would help them solve it. Following the protocol from Hammond et al. (2012), the experimenter completed the first (innermost) ring as a demonstration and the fourth (outermost) ring was taped down, so children were only required to solve the second and third rings with their parents. The experimenter left the room after providing the demonstration and instructions, and returned after the two rings were completed successfully. Parent-child dyads typically took around 3 to 6 min to complete.

As mentioned by Hammond and colleagues (2012), the principles that constituted this puzzle task were: (1) although the pieces looked similar (all white), they had different curvatures that determined which ring they fit in the puzzle, and (2) incorrectly positioned pieces could create gaps in the puzzle. The possible errors and challenges faced by children while working on this task was recognizing and mastering the two principles, and also controlling their frustration when committing errors.

Scaffolding coding. Parental scaffolding from the joint puzzle solving interaction was given an overall score based on the percentage of time, measured in seconds, the parent was appropriately scaffolding. The formula for the scaffolding score is as follows:

$$\frac{time\ parent\ appropriately\ scaffolded}{total\ time\ child\ encountered\ errors\ and\ required\ help} \times 100 \qquad (1)$$

The coding scheme used was adapted from the one employed by Hammond and colleagues (2012; see Appendix for our coding manual). During periods when children made errors or required help (e.g. placed a piece in the incorrect ring, did not understand there were two rings to fit, or had trouble pushing a piece in), parent scaffolding behaviours (or the lack thereof) were coded. Due to the relational nature of scaffolding, the main guiding questions when evaluating its appropriateness were whether the parent was sensitive to the child's requirements of help and level of ability, whether the parent's behaviours helped the child understand and master the principles of the puzzle, and whether the parent managed to successfully assist the child in learning how to manage those possible challenges. The role of parents in the scaffolding process should ideally be following the child's lead and demonstrating the task with an escalating level of assistance when required, instead of inserting the highest level of assistance first or not even letting the child confront the error.

This task was coded and scored using Datavyu (Lingeman, Freeman & Adolph, 2014). Temporal resolution of the video coding was 30 frames per second, therefore the maximum degree of precision was 33.3 milliseconds. In addition, 20% of the videos were double coded by a secondary rater who was trained using the coding manual attached (see Appendix). Onsets and offsets within 2 seconds were counted as an agreement. Interrater reliability ranged from 82% to 100% agreement (M = .89) for the error intervals and from 40% to 100% agreement (M = .87) for the scaffolding judgements. The Cohen's Kappa for scaffolding judgements was .74. In instances of disagreement, the primary coder's score was used. Out of the 56 parent-child dyads, only one did not complete the puzzle task and had no scaffolding score calculated.

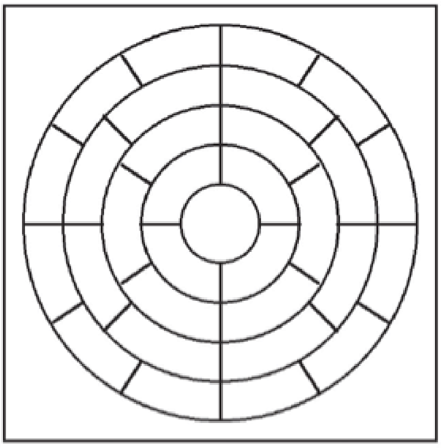

Figure 1. Diagram of ring puzzle. Four rings around the centre circle were cut as shown by the lines. The four innermost ring pieces were demonstrated by the experimenter, while the last ring of 12 pieces were taped down. Parent-child dyads completed the second and third rings together.

Executive Function battery.

Nebraska Barnyard task. A preschool version of the Nebraska Barnyard task was used to assess working memory (Wiebe et al., 2011; adapted from Hughes, Dunn, & White, 1998). This task required children to learn the animal names corresponding to four colourful buttons arranged in a 2 x 2 grid on a touch screen computer (Figure 2). Each button produced a corresponding animal sound when pressed, and the task began with the animal pictures on their respective buttons. The experimenter first demonstrated pushing the buttons on the touch screen computer and got the child to press the buttons so s/he got familiar with where each animal was. Following that, the animal pictures were removed and the blank button colours matched the colour of the animal pictures first shown on each of them (the "pig" button was pink, the "frog" button was green, the "cat" button was orange, and the "horse" button was black). They then had to remember a sequence of animals spoken aloud by the experimenter and press the corresponding buttons on the touch screen in the right order. The task gradually increased in difficulty as the sequences increased in length, and each sequence length had a maximum of three trials. The third trial for a given sequence length was not administered if the first two were correct, and the task was discontinued when the child responded incorrectly to all trials at a given sequence length.

The dependent variable for this task was a summary score calculated by dividing the number of correct trials by the total trials administered for each sequence length, and then summing up these proportion scores across all the administered sequence lengths (including the 1-item trials). Four participants had missing data in the Nebraska Barnyard task due to experimenter error (n = 2), computer error (n = 1), and child fussiness (n = 1).

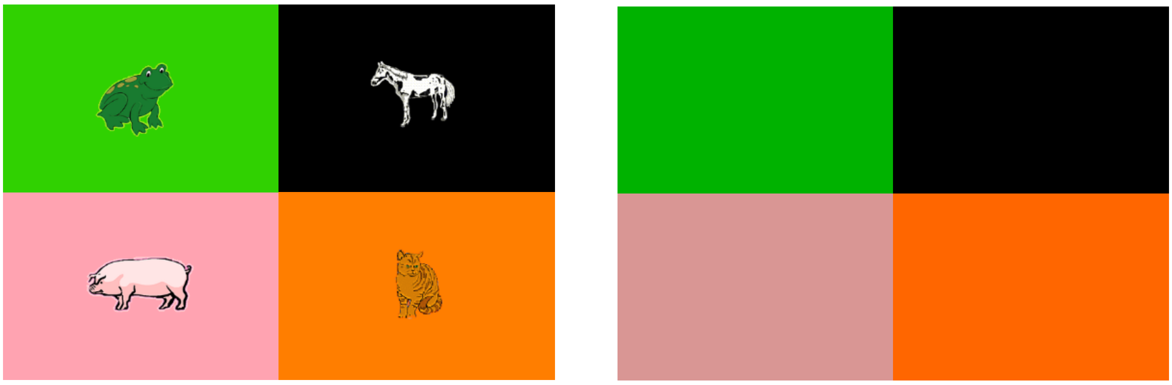

Figure 2. Nebraska Barnyard practice trial (left) where animal pictures are present for child to learn the animal-button mappings, and test trial (right) where only coloured buttons remain as the experimenter reads out sequence of animal name for child to push correspondingly.

Fish go/no-go task. In this computerized task assessing response inhibition, children were asked to "catch" a fish ("go" stimulus) by pressing a button, and refrain from pressing the button in response to a shark ("no-go" stimulus) (Wiebe, Sheffield, & Espy, 2012). Feedback was provided for correct "go" and incorrect "no-go" responses, a net catching the fish plus a bubbling sound or a shark breaking the net together with a buzzer sound respectively (see Figure 3). Children first completed a training phase where the rules of the game were introduced, and to expose them to the stimuli and various forms of feedback. Then they moved on to the test phase where the less frequent "no-go" stimuli appeared 25% of the time. On test trials, children had either 2500 ms (2-year-olds) or 2000 ms (3-year-olds) to respond, consistent with previous usage of the task with this age range.

The dependent variable for this task was d-prime, the standardized difference between the rate of correct catches (hits) and incorrect catches (false alarms). This is often used in the literature especially with young children as it not only reflects better discrimination of 2 types of stimuli, but also combines accuracy of both the "go" and "no-go" trials which is very advantageous for young children who may not have good attentional deployment (e.g. missed many "go" trials; Wiebe et al., 2011).

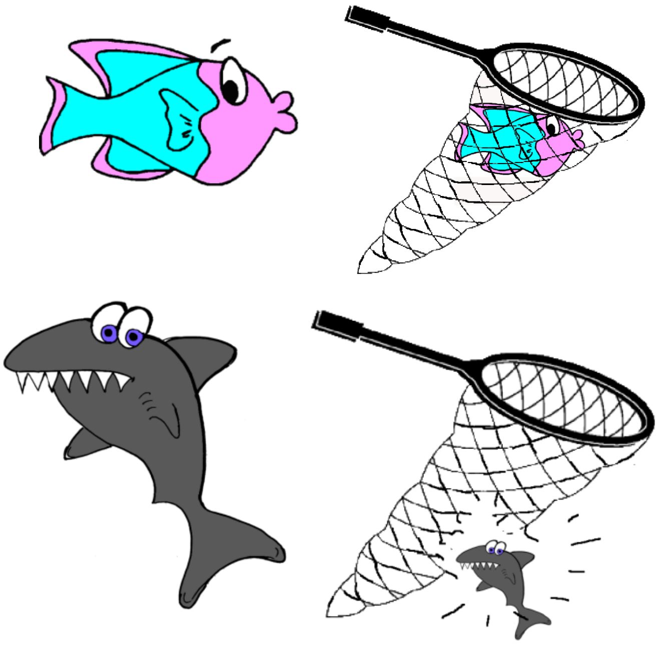

Figure 3. An example of the feedback for a correct "go" response (top panel with fish) and an incorrect "no-go" response (bottom panel with shark).

Gift Delay task. The Gift Delay task, a measure of delayed gratification and inhibitory control, was also used (Kochanska et al., 1996). In the first part of this task, the experimenter told the child that s/he was getting a present. Once the parent left the room to wait to be surprised by the child's gift, the experimenter said she forgot to wrap the present and would have to wrap it behind the child. The child was then instructed to face away and not peek while the experimenter noisily wrapped the present for 1 min (part 1). The child was given a score from 1 to 3 (1 = *turns around to look or gets out of chair*, 2 = *peeks over the shoulder*, 3 = *no attempt to peek*).

Following this, the experimenter closed the gift box and told the child, "Uh oh! I forgot a bow for your gift box! I am going to go to the other room to get it, but I am going to leave your present here. Stay in your chair, face the wall, and no peeking at your present, okay? I'll be right back." The experimenter then left the room for 3 min (part 2). The child received a score from 1 to 5 for this second part (1 = *opens and/or takes toy out of gift box*, 2 = *touches gift box but does not open it*, 3 = *gets out of chair but does not touch gift box*, 4 = *turns around but does not get out of chair*, 5 = *does not turn around and stays in chair*).

The dependent variable for this task was a composite score reflecting the given scores for each part and latency to do any of the aforementioned behaviours (e.g. turning around, getting out of the chair). The latter was calculated in seconds; therefore, if the child remained in the chair without turning around, the maximum value of 60 s (part 1) or 180 s (part 2) was assigned. Better inhibitory control was indicated by a higher value. This task was not administered to one participant due to child distress, and another participant's data was excluded due to experimenter error. Twenty per cent of the gift delay tasks were double coded. Interrater reliability for Part 1 latency was 91%, and 100% for Part 2 latency and Part 1 and 2 assigned scores.

EF Composite score. Individual EF tasks are typically low in reliability, and combining them results in a more stable and reliable measure (Rushton, Brainerd, & Pressley, 1983). Therefore, a composite score of EF was used in the analyses for this study. The EF composite scores were calculated by first transforming the three EF task scores into z-scores. This was done by subtracting the means from the scores and then dividing them by their standard deviations. These z-scores were then averaged to create a composite score. Higher scores indicated higher EF performance. Participants had to have complete data on at least two of the three EF tasks to be included in the composite score; therefore, two participants with missing data on all three EF tasks were excluded.

Control variables. There is evidence that child age, child verbal ability, and socioeconomic status (SES; a broad measure of family social and material resources) are associated with EF. Therefore I included child age, child verbal ability, and maternal education (a correlate of verbal intelligence and SES) as potential covariates in the regression analyses (Bernier et al., 2012; Cuevas et al., 2014; Kaler & Kopp, 1990).

The Peabody Picture Vocabulary Test-4th edition (PPVT-IV), a standardized measure, was used to assess children's receptive vocabulary. Children were instructed to respond to single words spoken aloud by the experimenter by pointing to the appropriate picture out of four coloured drawings. PPVT-IV standard criteria for starting (children's PPVT-IV age) and stopping (when children identify eight or more items in a set incorrectly) were followed. The dependent variable for this measure was the standardized score calculated using the PPVT–IV ASSIST scoring software. Maternal education was assessed by the parent's report of the highest level of education completed by the child's mother (7.14% had completed high school, 5.36% had completed some university, 10.71% had a college diploma, 50.00% had a Bachelor's degree, and 26.79% had a professional degree).

Results

Mean scores for the PPVT-IV, Nebraska Barnyard, Go/No-go, Gift Delay, and EF composite score are summarized in Table 1. Correlation and regression analyses were carried out to answer the research question. All analyses were conducted in R (version 3.4.1), using the "stats" package cor() and cor.test() functions for correlations, and lm() and anova() functions for multiple regression (R Core Team, 2013).

Table 1

Descriptive statistics for language, EF, and scaffolding measures.

Variables	N	Mean	*SD*	Range
PPVT-IV (standard score)	55	117.60	12.78	97–144
NB	52	1.53	.54	.25–3
GNG	51	.99	1.39	-2.03–3.34
Gift delay	54	-.005	3.31	-6.09–3.48
EF Composite score	54	.08	1.63	-3.72–4.06
Scaffolding	55	74.86	23.39	0–100

Note. PPVT-IV = Peabody Picture Vocabulary Test-4th edition; NB = Nebraska Barnyard task; GNG = Go/No-Go task; EF = Executive function

Correlations

Correlations among the scaffolding scores, EF performance indices, and control variables are shown in Table 2. Higher rates of appropriate scaffolding by parents was related to better child performances on the Nebraska Barnyard task, Gift Delay task, and EF composite score. There was also a strong positive association between parental scaffolding and child age. Contrary to my predictions, although there was a strong positive relation between the composite score for EF and vocabulary, the correlations between EF, age, and maternal education were not statistically significant. Nebraska Barnyard performance was consistently positively associated with the three control variables, whereas better performance on the Go/No-go was only associated with a higher vocabulary.

Table 2

Correlations among study variables.

Variables	Age	Maternal Education	PPVT-IV	NB	GNG	Gift delay	EF Composite
Maternal Education	.008						
PPVT-IV	.14	.13					
NB	.36**	.32*	.36*				
GNG	-.05	-.06	.29*	.25^{t}			
Gift delay	.26^{t}	.13	.13	.21	.10		
EF Composite	.27^{t}	.20	.32*	.71**	.68**	.67**	
Scaffolding	.39**	.25^{t}	.15	.41**	.07	.32*	.37**

Note. PPVT-IV = Peabody Picture Vocabulary Test-4th edition; NB = Nebraska Barnyard; GNG = Go/No-go; EF = Executive function. $^{t}p < .10$. $*p < .05$. $**p < .01$.

Regression Analyses

Stepwise regression analyses with backward selection were run to further investigate scaffolding as a predictor for children's EF. The dependent variable (DV) in the regression models was the EF composite score, and a summary of the results are presented in Table 3. The first model entered all candidate variables – age, verbal ability, SES, and scaffolding. The initial model was statistically significant, $F(4,47) = 4.14$, $p < .01$; with only verbal ability as a significant predictor of EF. The second and final model showed the best fit, as indicated by its smaller AIC value (Gelman & Hill, 2007). This model included age, verbal ability, and scaffolding as predictors, $F(3,48) = 5.48$, $p < .01$; verbal ability and scaffolding were both significant predictors of EF. Therefore, in addition to the significant positive correlation between parental scaffolding and child EF, parental scaffolding was a significant predictor of children's EF after controlling for child age and verbal ability.

Table 3

Summary of Backward Stepwise Regression analysis for variables predicting EF composite score (N =52)

Independent Variables	Adj. R^2	β	p	AIC
Model 1	.20		.006	-44.43
Age		.19	.16	
PPVT-IV		.26*	.048	
Maternal Education		.08	.55	
Scaffolding		$.27^t$	.064	
Model 2	.21		.003	-46.04
Age		.18	.17	
PPVT-IV		.27*	.04	
Scaffolding		.29*	.04	

Note. PPVT-IV = Peabody Picture Vocabulary Test-4th edition.

$^t p < .10$. $^* p < .05$.

Discussion

The purpose of this study was to investigate the association between parental scaffolding in a problem-solving context and children’s EF. It was expected that better performances in EF would be related to a greater proportion of appropriate or good scaffolding. The results from the analyses lend general support to this hypothesis. It was found that there was a strong correlation between parents who engaged in higher proportions of appropriate scaffolding and better EF performance in young children. This relation held up over the age and verbal ability controls as shown in the subsequent regression analyses.

These results are consistent with the contention that caregiving plays an important role in children’s developing EF abilities (Bernier et al., 2010; Kopp, 1982). The findings suggest that between the ages of 2.5 and 4 years of age is a developmental period when scaffolding is particularly supportive of children’s EFs. This developmental period coincides with age-related changes in frontal lobe connectivity and maturation (Conway & Stifter, 2012; Diamond, 2002; Lengua et al., 2007). What is the mechanism for this relationship? One possibility is that parents who provide appropriate scaffolding may continually challenge young children's nascent EF skills. In the context of the puzzle task, scaffolding behaviours that successfully help children stay focused and master the task's critical features may help improve children's abilities to inhibit irrelevant behaviours (e.g. forming train tracks with the curved puzzle pieces), and select as well as maintain relevant information active in their minds (e.g. remembering that small curved pieces fit in the inner ring while wider curved pieces fit in the outer ring). Since the scaffolding process encourages children to eventually learn how to solve problems on their own, parental scaffolding may foster young children's developing EFs over time by giving them practice when engaging in challenging activities that require those skills (Bibok et al., 2009).

In contrast with previous studies that have found an indirect effect of scaffolding on children's EF through verbal ability (Hammond et al., 2012; Landry, Miller-Loncar, Smith, & Swank, 2002), there was no significant correlation between scaffolding and children's verbal ability in this study. It has been contended that language is central to the development of higher cognitive functions, and the verbal aspect of scaffolding may promote self-directed speech, which in turn helps children organize their abilities into more purposeful behaviour (Fernyhough & Fradley, 2005; Hammond et al., 2012; Wood et al., 1976). The usefulness of self-directed speech in EF development is evident in the developmental changes observed in young children as they move from voicing expectations but failing to implement behaviours (e.g. saying "no" but still pushing the button for a shark during the Go/No-go task), to voicing and carrying out the behaviours simultaneously (e.g., saying "no" and refraining from pushing the button for a shark during the Go/No-go task), and finally performing the behaviours with expectations held mentally only (e.g. simply refraining from pushing the button for a shark during the Go/No-go task). One explanation for the discrepancy in results may relate to the design of the studies: the present study looked at the association between scaffolding and child EF at only one point in time, while Hammond et al. (2012; scaffolding at ages 2 and 3 on child EF at 4 years of age) and Landry et al. (2002; scaffolding at ages 3 and 4 on EF from ages of 6 to 8) both examined the effect of scaffolding at different time points on later EF. Parental scaffolding could have longitudinal associations but not concurrent associations with child verbal ability, and scaffolding helps promote language over time. For example, in Hammond et al.'s (2012) study, the only significant correlations found between parental scaffolding and child verbal ability were between parental scaffolding at the age of 2 years and child language at the ages of 3 and 4 years. Moreover, Hayes (2009) stated that there need not be a significant association between predictor and outcome for mediation, as a total effect includes multiple paths of influence, and not all may be part of the formal model.

It is also important to note that out of the three EF tasks, scaffolding was not found to be associated with children's performance on the Go/No-go task. A possible explanation for the lack of a significant correlation between scaffolding and response inhibition may be due to the decreased requirements for using higher processing in simple response inhibition. As pointed out by both Carlson (2009) and Hughes and Ensor (2009), the scaffolding process is intentionally targeting children's problem solving skills, which may not be captured in the response inhibition construct individually. However, Barkley (1997) contends that the other executive functions, including working memory, are perched hierarchically atop inhibition, suggesting that it is a necessary precursor to the rest. It is also important to mention that in 3-year-olds, the age of participants in this study, research using CFA does not find reliable evidence for differentiated EF subcomponents (e.g., Wiebe et al., 2008; Willoughby et al., 2010). Nelson et al. (2016) found that at the age of 3, all measures of EF and other foundational cognitive skills loaded together on a unitary and undifferentiated factor, indicating that observed task performance at this young age was driven by a common set of abilities. The most popular explanation for why EFs may be organized differently in young children compared to adults is that EF skills become more differentiated and specialized with advancing development (Nelson et al., 2016; Shing et al., 2010). Another plausible explanation is that young children may employ a qualitatively different approach to EF tasks due to the immaturity of their prefrontal and nervous systems in particular (Chevalier, Huber, Wiebe, & Espy, 2013).

In addition, although EFs have been found to differ by age, verbal ability, and maternal education (e.g., Hughes & Ensor, 2009; Wiebe et al., 2012), the present study found no direct relation (i.e. insignificant zero-order correlation) between EF and maternal education. The lack of association found between EF and maternal education from the correlation and regression analyses might have been due to the restricted range of SES in the sample, as the majority of the mothers were college-and university-educated. Some studies that were conducted with predominantly highly educated parents have also found no significant associations between EF and SES (e.g., Bindman, Hindman, Bowles, & Morrison, 2013; Hammond et al., 2012). Studies that have observed a relation between EF and SES, on the other hand, generally had samples with a broader range of SES (e.g., Mezzacappa, 2004; Noble, Norman, & Farah, 2005). One reason for this is that various environmental measures, including ratings of family chaos, may only show significant variance if low SES participants are included in the sample as they are the group most at risk of being exposed to multiple environmental stressors (Hughes & Ensor, 2009). An alternative plausible explanation for the lack of association between EF and maternal education in the present study is that similar to the concept of “good enough parenting”, it may be that over a certain threshold or level of education, variation is less important for children’s outcomes (Hoghughi & Speight, 1998;

Taylor, Spencer, & Baldwin, 2000). Just as “good enough” parenting adequately meets children’s needs to grow up into healthy and competent adults, having at least a certain level of SES may be enough to observe benefits in children’s cognition. For example, in the study conducted by Noble et al. (2005) that found low SES children performed worse than middle SES children on various cognitive tasks, the middle SES group had no upper limits imposed on the levels of parental education, parental occupational status and family income that constituted their measure of SES. Furthermore, the present study used maternal education as a single indicator of SES, and including additional components (e.g., family income and parental occupational status) would establish a more reliable and stable measure of SES (Cuevas et al., 2014; McCloyd, 1998).

This study is characterized by a number of limitations. First and foremost, no causal inferences can be drawn from this study, as it is purely correlational and cannot rule out the possibility of another variable explaining the relation between scaffolding and EF. For example, parental scaffolding and child EF could be involved in a reciprocal or transaction process, where appropriate scaffolding enhances EF development and children with better EF skills provide greater opportunities for or elicit more appropriate parental scaffolding behaviours (Tucker-Drob & Harden, 2012). However, the results do open up future directions for longitudinal designs that allow causal conclusions, as they suggest further exploration of parental scaffolding is likely to be a valuable path for research on EF development in early childhood. The sample was also predominantly European-Canadian/Caucasian, which does not allow our findings to be generalizable to other, more diverse populations. An additional limitation is that the small number of fathers in the current sample did not allow for comparisons between maternal and paternal scaffolding to be made. However, regression models were run with only the mothers in the sample to verify if the overall pattern was the same, and both scaffolding and child verbal ability remained significant predictors of EF.

This is in line with previous studies that found little differences between mothers' and fathers' scaffolding during problem-solving contexts with children in the age group the present study investigated (Conner, Knight, & Cross, 1997; Pratt, Kerig, Cowan, & Cowan, 1988).

In summary, the findings from the present study add to a growing body of literature that suggest parental scaffolding is involved in young children's developing EF and may be an important source of individual difference in children's EF. Future research will be needed to determine the precise mechanism by which the scaffolding process influences EF. Nonetheless, this study provides further support for the importance of tailored assistance to maximize children's cognitive potential, and an important direction for future home interventions to facilitate EF development.

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Appendix

Coding Manual (Ring Puzzle Task)

OVERALL CODING STRATEGY:
1) Watch video in real time.
2) Code <id>, <task>, and <child_error>.
3) Watch the child error segments in real time without coding.
4) Watch the child error segments again and code the scaffolding strategies.
5) Code <outcome> and <scaffolding>.

Task Duration & Child Error Segment Durations

- After you have watched straight through the video in real time once, begin by first entering the participant information in <id>.

<id>
Fill in the participant information.
id = child ID number.
tdate = test date (ddmmyyyy)
bdate = child's birthdate (ddmmyyyy)
sex = m (male) or f (female)
agegrp = 1 (2.5 – 2.99) or 2 (≥3.0)

- When you see the child and parent begin the task, go to jog and find the frame. Enter a new cell in the <task> column to set the onset.
- At the end of the video, when the puzzle is completed, jog to find the offset.

<task>
This is meant to capture the duration of the entire puzzle task – the whole time the parent and child are working on the puzzle.

Onset
The first frame when the child and parent begin the puzzle task (i.e. grabbing of the first piece – either by the child/parent).

Offset
The first frame when the puzzle is completed (i.e. all pieces fitted into the square base).

- When you see an error made by the child, go to jog and find the frames (within 1-2 frames is fine, don't agonize). Enter a new cell in the <child_error> column. Keep watching until the error ends and then go to jog to find offset. Repeat this until you've identified all the times the child encountered an error during the task.

<child_error>
This code is meant to capture the scaffolding behaviour observed by the parent when the child encounters an error or requires help on the task.

Onset

The first frame when the child makes an error or requires help (e.g. putting a piece in the wrong circle, not being able to fit piece in the right ring, placing pieces in the wrong direction).

Parents can also initiate an error interval if they direct their child towards an abandoned, incorrectly placed piece or interfere with their child's activities (e.g. hands getting in the way, taking pieces from child's hand when child is persevering without issues).

EXCEPTIONS:

1. When the child places a piece but is still moving it around/still has it in their hand(s):
   - If parent scaffolds with some verbal statement, code onset when the parent begins speaking
   - If parent scaffolds with some non-verbal behaviour, code onset when the parent begins the behaviour
   - If parent does not do anything, code onset when child shows signs of requiring help/frustration (e.g. sighs, pushing hard with both hands)

Offset

Code the first frame when the error was resolved (either by the child or parent) and the child continues with the task or when the child continues with the task and ignored the error/parent's strategies (if any).

***NOTE:**

Coding when 2 or more errors occur simultaneously (e.g. child places one piece incorrectly, and then grabs another piece and makes another error with the 2nd piece whilst the 1st piece is still placed incorrectly on the puzzle)

- Error intervals should not overlap. Anytime that a child abandons one puzzle piece in favour of a new piece, the error interval for the first piece *stops* when the new piece is selected (i.e. picked up), and a new error interval for the second piece begins if that piece is also placed incorrectly.

EXCEPTIONS:

1. If the child's attention is still maintained by a parent's scaffolding, while simultaneously grabbing another piece, the parent's scaffolding OVERIDES the contact with the new piece for setting the offset.

Scaffolding strategies

- From this point on, you will only be looking at the **<child_error>** segments. Watch the entire error in real time and keep track of the “yes” behaviours. Then fill in the “yes” arguments.
- If you’re not sure if a particular behaviour happened, watch the trial again in real time but look at a different camera view. If you’re still not sure, do not code “yes” for the behaviours in question.

<leading_qns>
At any point when the child encountered the error, did the parent ever try to ask leading questions?

Leading questions mean that the parent asked a question that prompted or encouraged the desired behaviour. (Marks critical features of the task)
e.g. “Does it fit somewhere else?”
y = yes

<marks_features>
At any point during the error interval, did the parent say anything to mark features of the puzzle pieces or puzzle task?

Marking critical features mean that the parent mentioned something about the features of the puzzle pieces (i.e. the curve, size etc).
e.g. “It looks wobbly.”; “The curve is really round.”; “There are gaps here.”; “It’s not very snug.”
y = yes

<suggestions>
At any point when the child encountered the error, did the parent ever try making suggestions to the child?

Suggestions refer to hints or recommendations parents give the child to consider or try. (Reduces degree of freedom)
e.g. “Why don’t you try over there?”
y = yes

<arranging>
At any point when the child encountered the error, did the parent ever try to arrange the puzzle pieces for the child?

Arranging the puzzle pieces means that the parent tried to group similar sized pieces together or moved already placed pieces around to make the task easier for the child. (Reduces degree of freedom)
e.g. Arranging the large and small pieces, sliding the puzzle pieces around the rings to make room for the child’s placement of a piece
y = yes

<inserts_piece>
At any point when the child encountered the error, did the parent ever insert a puzzle piece into the puzzle him/herself?

Inserts piece means the parent used his/her hand to fit a puzzle piece in a ring. (Demonstrating)
y = yes

<other>
This code is meant to capture any other scaffolding behaviours observed by the parent, that do not fall under the previous 4 types.

***NOTE:**
Any associated scaffolding behaviour should be attributed to the corresponding error interval.

- For instance, if the parent is redirecting the child to the *first* incorrectly placed piece, the parental scaffolding behaviors should be attributed to the error interval that corresponds to the *first piece*

Coding when parent and child are both making physical contact with the same puzzle piece at the same time

- Use other cues to judge whether the parent's behaviour was intrusive.
  - Eye gaze (e.g. is the child looking towards the correct location where the piece should be and was going to be placed)
  - Verbal cues
  - Parent behaviour during the previous/subsequent error intervals

Scaffolding Judgement

<outcome>
Did the parent's scaffolding strategies result in the child's error being resolved?

s = success
Child's error was resolved (either by child or parent) and the child could continue with the puzzle.

f = failure
Child continues with the puzzle without resolving the error successfully or ignoring parent's strategies.

<scaffolding>
Was the parent's scaffolding strategy/strategies appropriate?

a = appropriate
When the child encountered an error, the parent demonstrated task with escalating level of assistance (marking critical features before reducing child's degree of freedom and lastly demonstrating).

<u>Appropriate scaffolding can include:</u>
- Parent inserting a piece if the child asks specifically for help with inserting a piece (includes verbal and nonverbal requests).

NOTE: If a child says something like, "it's your turn, Mom/Dad, DO NOT code this at all (i.e., turn-taking is not an error)

x = not appropriate
When the child encountered an error, the parent did not let child confront the error (e.g. moving piece to correct spot when child isn't looking), or interfered with the child's activities (e.g. hands getting in the way), or inserted the highest level of assistance (e.g inserting piece) before trying other strategies.

<u>Some examples of inappropriate scaffolding:</u>
- Not enough help:
  - Parent asked a question, child looked confused, parent paused and did not attempt any other strategies with higher assistance, and child grabbed another piece
  - Parent attempted to draw child's attention to an error, child did not respond or responded to parent's comment but was incorrect, and parent let it go (i.e., did not successfully alert child to error)
- Too much help:
  - USUALLY when parent inserts a piece whilst the child is looking away (i.e. preventing child from confronting error/inserting highest level of assistance before trying other strategies)
    - Take note of where the child's attention is directed when a parent is inserting a piece. This can help determine whether inserting the piece was appropriate or not.
  - Parent is busy inserting a piece(s) whilst the child is encountering an error/needs help (i.e. parent ignored or failed to notice child needing help)
  - Hands in the way (i.e., interfering with the child's activities)