Journal of Experimental Child Psychology 142 (2016) 158–170

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Does executive function mediate the path from mothers' depressive symptoms to young children's problem behaviors?

Gabriela D. Roman [a,b,*], Rosie Ensor [a], Claire Hughes [a]

[a] Centre for Family Research, University of Cambridge, Cambridge CB2 3RQ, UK
[b] Institute of Criminology, University of Cambridge, Cambridge CB3 9DA, UK

ARTICLE INFO

Article history:
Received 4 December 2014
Revised 23 September 2015

Keywords:
Executive function (EF)
Maternal depression
Externalizing problems
Internalizing problems
Mediation
Longitudinal analysis

ABSTRACT

This study investigated the mediation role played by children's executive function in the relationship between exposure to mild maternal depressive symptoms and problem behaviors. At ages 2, 3, and 6 years, 143 children completed executive function tasks and a verbal ability test. Mothers completed the Beck Depression Inventory at each time-point, and teachers completed the Strengths and Difficulties Questionnaire at child age 6. Longitudinal autoregressive mediation models showed a mediation effect that was significant and quite specific; executive function (and not verbal ability) at age 3 mediated the path between mothers' depressive symptoms (but not general social disadvantage) at the first time-point and children's externalizing and internalizing problems at age 6. Improving children's executive functioning might protect them against the adverse effects of exposure to maternal depressive symptoms.

Introduction

Among parents of young children, symptoms of depression are common and often chronic (Field, 2011), such that McLennan, Kotelchuck, and Cho (2001) found that nearly a quarter (24%) of

* Corresponding author at: Institute of Criminology, University of Cambridge, Cambridge CB3 9DA, UK.
E-mail address: gdp27@cam.ac.uk (G.D. Roman).

http://dx.doi.org/10.1016/j.jecp.2015.09.022
0022-0965/

17-month-olds were exposed to maternal depression, with a third of these children still exposed to depression a year later. This early exposure to maternal depressive symptoms predicts a plethora of negative child outcomes. Compared with children of nondepressed mothers, children of depressed mothers show elevated rates of both externalizing problems, such as hyperactivity (Ashman, Dawson, & Panagiotides, 2008), conduct disorder (Leschied, Chiodo, Whitehead, & Hurley, 2005), and violence (Hay, Pawlby, Waters, Perra, & Sharp, 2010), and internalizing problems, such as depression (Hammen & Brennan, 2003; Murray et al., 2011), anxiety (Gartstein et al., 2010), and social phobia (Biederman et al., 2001). Studies of the mechanisms underpinning these associations have, to date, focused on aspects of maternal functioning such as maternal regulatory processes (Dix & Meunier, 2009). Child functioning has received much less attention, which is surprising given that exposure to maternal depressive symptoms is related to cognitive abilities that are relevant for behavioral adjustment such as executive functions (Hughes, Roman, Hart, & Ensor, 2013) and language development (e.g., Quevedo et al., 2012).

Research into the cognitive and neural mechanisms that may underlie childhood antisocial behaviors has highlighted the higher order processes associated with the prefrontal cortex that underpin flexible goal-directed action, collectively known as executive function (EF) (Hughes, 2011). The protracted development of the prefrontal cortex has led theorists to posit that EF might be particularly susceptible to environmental factors (e.g., Mezzacappa, 2004; Noble, Norman, & Farah, 2005). Studies of risk factors indicate that exposure to extreme adversity (i.e., maltreatment or neglect) has profound consequences for the functioning of the prefrontal cortex (for a review, see Belsky & De Haan, 2011). Until recently, however, few studies considered less extreme adversity such as exposure to mild maternal depressive symptoms (Odgers & Jaffee, 2013). The current study addressed this gap by focusing on children's exposure to maternal depressive symptoms in a normative sample and by examining the relationship between exposure to maternal depressive symptoms and child EF over the course of early childhood (ages 2–6 years).

The development of the prefrontal cortex is marked by growth spurts, with the first 3 years of life representing a time when the majority of myelination occurs and is paralleled by peaks in synaptic formation and dendritic growth (e.g., Spencer-Smith & Anderson, 2009). This heightened brain development translates into important EF developments through both refinements of acquired skills (e.g., Alloway, Gathercole, Willis, & Adams, 2004) and initial attempts to integrate and coordinate multiple functions (Garon, Bryson, & Smith, 2008). The emergence of toddlerhood as a critical period is further supported by research highlighting that individual differences in EF appear remarkably stable over time (Carlson, Mandell, & Williams, 2004; Fuhs & Day, 2011; Hughes & Ensor, 2007; Hughes, Ensor, Wilson, & Graham, 2010), with the implication that effects observed in preschoolers and school-aged children might simply reflect carry-on effects of early delays. Indeed, the complexity of EF development, whereby at each point emergent skills are reliant on the mastery of simpler abilities, lends support to the idea that EF development follows a cascading pathway model (e.g., Cummings, Davies, & Campbell, 2000). As such, this study focused on whether exposure to maternal depressive symptoms might translate into behavior problems specifically through delays in EF skills acquisition at a very early stage (i.e., age 3 years).

The current article represents a secondary data analysis. To examine whether poor early EF is a mechanism through which exposure to maternal depressive symptoms translates into problem behaviors, the current study builds on several studies involving overlapping samples. Regarding the first path in this proposed mediation model, these earlier studies showed that children of mothers who had fewer depressive symptoms at child age 2 years or who displayed steeper recoveries from depressive symptoms over 4 years typically showed better EF at age 6 years (Hughes et al., 2013). This was true even when individual differences in children's working memory at age 2 and maternal education and positive control at child ages 2 and 6 were accounted for (Hughes et al., 2013). In contrast, no relationship between maternal depression and child EF was found by two separate studies of older children in which maternal depression scores were dichotomized (Klimes-Dougan, Ronsaville, Wiggs, & Martinez, 2006; Micco et al., 2009). As discussed by Hughes and colleagues (2013), the most likely explanations for these discrepant findings relate to differences during the developmental period under focus (adolescence vs. early or middle childhood) and the sensitivity of the measures used. Regarding the latter, the previous studies that reported a relationship between maternal depression and child EF

used self-reported continuous measures of depression that differentiated between mothers' depression severity at all levels, whereas the studies that found no relationship used rigorous clinical diagnoses such that mothers with subclinical depression were placed in the "control" group together with nondepressed mothers.

Regarding the second path of the mediation model, longitudinal analyses of data from the current sample have documented predictive relations between (a) poor EF at age 3 years and multi-informant ratings of problem behaviors at age 4 years (Hughes & Ensor, 2008) and (b) poor EF at age 4 years and low gains in EF from ages 4 to 6 years and teacher-rated problem behaviors at age 6 years (Hughes & Ensor, 2011). Importantly, even though these earlier studies demonstrated each of the two paths of the mediation model, they did not examine whether EF is a mechanism through which exposure to maternal depression transforms into problem behaviors. Indeed, significant relationships for different segments of a theoretical model of mediation do not conclusively establish a mediated effect (Kenny, 2012). In this case, elevated maternal depressive symptoms may independently predict both poor EF and child problem behaviors (i.e., multifinality of causes; Cicchetti & Toth, 1998). The only study to have investigated a mediation effect was an analysis of data from an enlarged sample of 235 4-year-olds comprising the study children and their best friends; although this analysis did show a mediation effect of child EF in the relationship between exposure to maternal depressive symptoms and child behavior difficulties (sample overlap: 66%; Hughes & Ensor, 2009a), the cross-sectional nature of the data limits the strength of conclusions that can be reached. To address this gap, the current study aimed to examine whether children's EF at age 3 years mediates the relationship between mothers' depressive symptoms at child age 2 years and children's externalizing and internalizing problems at age 6 years.

Method

Participants

At study entry, the sample comprised 143 families (out of a total of 192 eligible families), with a child aged between 24 and 36 months at the first visit and English as a home language, recruited in Cambridgeshire, United Kingdom. Starting with age 4 years, the sample was enlarged to include the study children's best friends, yielding a new sample of 235 children. This implied that analyses focused on toddlerhood involved the core sample, whereas analyses focused only on preschool and later development involved the enlarged sample, with a sample overlap of approximately 66%. The current study focused on toddlerhood; therefore, data analysis was applied to members of the core sample for whom data were available at ages 2 and 3 years.

Face-to-face recruitment was carried out at support groups for young mothers and at every mother–toddler group in wards within the highest quartile nationally of deprivation (Noble et al., 2008), thereby resulting in a socially diverse sample. Informed consent and ethical approval were obtained for all assessments. As a token of thanks for their participation, families received £20 (i.e., 20 British pounds) for each visit to the home. A copy of the video footage recorded in the lab and taxi/travel costs were also provided. More than 95% of the children were White/Caucasian and 56 (39%) were girls. At the study entry, 25% of women were single parents and 53% of mothers had no education qualifications or had education qualifications only up to GCSE (general certificate of secondary education) level (usually obtained at age 16 years). Regarding family size, 12% of children had no siblings, 53% had one sibling, 22% had two siblings, and the remaining 13% had three or more siblings. This study focused on data collected when children were 2 years old (Time 1; $SD_{\text{age 2}}$ = 4 months), 3 years old (Time 2; $SD_{\text{age 3}}$ = 4 months), and 6 years old (Time 3; $SD_{\text{age 6}}$ = 4 months).

Measures

Deprivation

Following the example of Moffitt et al. (2002), deprivation at study entry was evaluated using eight markers: maximum education level per family was GCSE (usually obtained at age 16 years), head of household occupation in elementary or machine operation occupation, annual household income

under £10,000, receipt of public benefits, council house as the home, home reported as crowded by the mother, single-parent family, and no access to a car. Of the 127 (89%) families without missing data, 31% of families showed no deprivation (zero markers), 32% of families showed moderate deprivation (one or two markers), and 37% of families showed high deprivation (three or more markers).

Mothers' depressive symptoms

Maternal depressive symptoms were self-reported using the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) at all time-points. The BDI includes 21 questions about affective, somatic, and cognitive symptoms. Item response categories range from 0 (*minimal*) to 3 (*extreme*). Item intraclass correlation was high at all time-points, with a Cronbach's alpha $\geqslant .82$. Two-parameter logistic item response theory models applied at each time-point revealed that the BDI was especially successful in identifying mothers who experienced mild to moderate depressive symptoms. Some of the items that showed lowest power to discriminate between different levels of depressive symptoms were those about "weight loss," "loss of interest in sex," and "somatic preoccupation." Some of the items with consistently high discrimination across assessments were those about "concentration difficulty," "past failure," or "loss of pleasure." The most "difficult" items (i.e., items endorsed only by very depressed mothers) were "punishment feelings," "suicidal ideation," "somatic preoccupation," and "past failure," whereas the "easiest" items (i.e., items also endorsed by nondepressed mothers) were "tiredness or fatigue," "irritability," and "changes in sleeping patterns."

Children's problem behaviors

At child age 6 years, 74 teachers completed the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) for 120 of the children. The SDQ response categories range between 0 (*not true*) and 2 (*certainly true*), and the 25 items are divided into 5-item subscales: a positive subscale (prosocial behavior) and four problem subscales (conduct problems, hyperactivity, emotional problems, and peer problems). This study focused on the problem subscales. Item intraclass correlation was high for the total problem behavior score (Cronbach's alpha = .82) and for the items comprising the externalizing (Cronbach's alpha = .84) and internalizing (Cronbach's alpha = .74) problems subscales.

Verbal ability

At ages 2 and 3 years, children's verbal ability was assessed using the Naming and Comprehension subtests of the British Abilities Scales (BAS; Elliott, Murray, & Pearson, 1983), which tap expressive and receptive language skills. Scores ranged between 0 and 20 for the Naming subtest and between 0 and 27 for the Comprehension subtest. At age 6 years, verbal ability was measured using the Revised British Picture Vocabulary Scale (BPVS; Dunn, 1997), which taps receptive language. Total scores were computed as a sum.

Executive function

At ages 2 and 3 years, children completed four tasks: Beads, Trucks, Baby Stroop, and Spin the Pots. At age 6 years, children completed three tasks: Beads, Day–Night, and Tower of London. The tasks were delivered by researchers (PhD students and research assistants) trained by the task developer.

The Beads task, a part of the Stanford–Binet Intelligence Scales (Thorndike, Hagen, & Sattler, 1986), taps working memory. Four warm-up trials are followed by 10 trials where children are shown 1 or 2 beads (for 2 or 5 s, respectively) and must identify them in an image of 12 beads sorted by color and shape. In a further 16 trials, children are presented with a photographic representation of a bead pattern for 5 s, which they must reproduce with real beads arranged on a stick. Scores represent the number of correct trials and range between 0 and 26 points.

The Trucks task taps rule learning and switching (Hughes & Ensor, 2005), each tested with an 8-trial phase. Children must guess which of two pictures of trucks will lead to a reward. The first truck chosen by children gives the rule in the first phase; the opposite truck gives the rule in the second phase. Scores represent the number of correct trials and range between 0 and 16 points.

The Spin the Pots task (Hughes & Ensor, 2005) assesses working memory. Children are shown eight distinct "pots" (e.g., jewelry boxes, candy tins, wooden boxes) placed on a Lazy Susan tray and are invited to help the researcher place attractive stickers in six of the eight pots. Then, the tray is covered

with a cloth and spun, after which the cloth is removed and children must choose a pot. The test is discontinued when children find all of the stickers or after 16 attempts. The score is 16 minus the number of errors made.

The Baby Stroop task taps inhibitory control (Hughes & Ensor, 2005). Children are presented with a normal-sized cup and spoon and a baby-sized cup and spoon. In the control phase, children must name the large cup/spoon "mommy" and the small cup/spoon "baby." In the second phase, children must use the labels incongruously. The Day–Night task is a Stroop task designed for older children (Gerstadt, Hong, & Diamond, 1994). This task is identical to the Baby Stroop task except for the props; the cup and spoon are replaced by two abstract patterns representing "Day" and "Night." The 12 trials are presented in a pseudo-random order, with scores ranging from 0 to 12.

The Tower of London task (Shallice, 1982), taps planning abilities. The props include a wooden board with three pegs of unequal size and three large spongy balls. The large peg can carry three balls, the middle peg can carry two balls, and the small peg can carry only one ball. Children must reproduce arrangements presented in an image by moving only one ball at a time and using the minimum number of moves needed. Warm-up trials with one-move problems are followed by two-, three-, and four-move problems (three problems each). Children achieve 2 points for success using the minimum number of moves, 1 point for success with the use of extra moves, and 0 points for failure to complete the problem or when more than $2n + 1$ extra moves are necessary. Total scores range between 0 and 18 points.

Results

Analyses were conducted using Mplus Version 7.11 (Muthén & Muthén, 1998–2010). Power analyses were performed using the macro developed by Preacher and Coffman (2006). Little's (1998) MCAR tests applied to missing data patterns revealed that data were missing completely at random for all variables. Specifically, data were missing completely at random in relation to maternal depressive symptoms, such that depressed mothers were not more likely to drop out of the study than non-depressed mothers. Maternal depression scores were based on longitudinal factor analysis; as such, scores were estimated in instances with missing data. Therefore, factor scores of maternal depressive symptoms were available for all mothers and at all time-points. The same was true for child EF. Data were also missing completely at random in relation to child problem behaviors, and further missing value analysis revealed that missing information about problem behaviors was not more likely to come from boys than girls or from children of mothers with low education than other children. Missing data were avoided with regard to problem behaviors for those cases with data on some of the items through the use of factor analysis in the creation of final scores.

To account for data missingness and skewness, we used robust estimators: WLSMV to obtain factor scores of depressive symptoms and child problem behaviors (here indicators were categorical) and MLR to specify factors of EF and mediation models (here all measures were continuous). Model fit was evaluated using the comparative fit index (CFI), the Tucker–Lewis index (TLI), and the root mean square error of approximation (RMSEA). Adequate fit was achieved for CFI and TLI values $\geqslant .90$ and for RMSEA values $\leqslant .08$ (Hu & Bentler, 1999). Good fit was achieved for CFI and TLI values $\geqslant .95$ and for RMSEA values $\leqslant .06$ (Bentler, 1990). The chi-square is also reported for all models but was not used in the evaluation of model fit due to the tendency of the chi-square to over-reject true models for large samples and/or models with many degrees of freedom (Bentler, 1990). Fully standardized coefficients are presented.

Descriptive statistics

Across time-points, 65% to 73% of mothers exhibited no or minimal depression (i.e., scores < 10), 19% to 24% exhibited mild to moderate depression (i.e., scores of 10–18), and 7% to 12% exhibited moderate to severe levels of depressive symptoms (i.e., scores $\geqslant$ 19). Mean levels of child problem behaviors ($M = 8.07$) fell within the normal range (i.e., scores of 0–11), but elevated problem behaviors were also noted ($Max = 25$), and on average scores were slightly higher (on all dimensions except peer

problems) than a nationally representative sample of 5- to 10-year-old children in Great Britain (youthinmind, 2012). Specifically, borderline or abnormal levels of problem behaviors were exhibited by 13.8% of the children in relation to conduct problems, 34.7% of the children in relation to hyperactivity, 11% of the children in relation to emotional problems, 14.5% of the children in relation to peer problems, and 26.1% of the children in relation to total behavior difficulties. Table 1 summarizes children's mean levels of EF and verbal abilities. As expected, children improved in their mean levels of verbal abilities and EF across time.

Data reduction

We created factor scores from the questionnaire-based variables to index mothers' depressive symptoms at each time-point and child problem behaviors at the final time-point. We used the procedure described by Ensor, Roman, Hart, and Hughes (2012) to create factor scores of mothers' depressive symptoms by dichotomizing BDI items due to low selection rates of the higher categories and applying single-factor confirmatory factor analysis with scalar invariance (i.e., equal structure, loadings, and thresholds) to factors obtained at each time-point. The model achieved good power ($\alpha = 1.00$) and adequate fit, $\chi^2(1967) = 2184.025$, $p < .01$, RMSEA = 0.03, 90% confidence interval (CI) [0.02, 0.04], CFI = .92, TLI = 0.92.

We used the procedure described by Goodman, Lamping, and Ploubidis (2010) to create factor scores of child problem behaviors by applying confirmatory factor analysis with four first-order factors (conduct problems, hyperactivity, emotional problems, and peer problems) and two second-order factors (externalizing problems [conduct problems and hyperactivity] and internalizing problems [emotional problems and peer problems]). The model achieved good power ($\alpha = .91$) and adequate fit, $\chi^2(166) = 291.74$, $p < .01$, RMSEA = 0.08, 90% CI [0.06, 0.09], CFI = .91 TLI = 0.90. All item loadings onto first-order factors ($\beta \geqslant .57$, $p < .01$) and all first-order factor loadings onto second-order factors were significant ($\beta \geqslant .45$, $p < .01$).

In addition, we used the findings of exploratory factor analyses previously reported by Hughes and Ensor (2008) at ages 3 and 4 years to specify a single factor of EF at each time-point. At ages 2 and 3 years, we specified a factor based on children's scores on the Beads, Trucks, Baby Stroop, and Pots tasks. At age 6 years, we specified a factor based on children's scores on the Beads, Stroop, and Tower of London tasks. To examine stability in EF over time, we specified regression paths between EF factors at consecutive time-points. To account for the known association between EF and verbal ability, we

Table 1
Descriptive statistics: Children's scores on each of the four EF tasks at ages 2, 3, and 6 years

Scale	*N*	Mean	*SD*	Range	Skewness
Age 2					
Beads	121	2.95	2.90	0–11	0.52
Trucks	117	7.25	3.71	3–16	0.94
Stroop	130	8.24	3.47	0–12	−0.82
Pots	142	11.82	2.87	5–16	−0.51
Verbal ability	140	20.44	9.80	0–39	−0.30
Age 3					
Beads	133	9.27	3.96	0–20	−0.16
Trucks	134	9.29	4.94	2–18	0.30
Stroop	133	10.24	2.27	1–12	−1.59
Pots	134	12.66	3.06	1–16	−1.24
Verbal ability	134	32.55	6.04	18–44	−0.44
Age 6					
Beads	127	13.81	4.21	5–25	0.30
Trucks	128	16.69	2.39	8–18	−2.30
Stroop	128	10.96	1.86	4–12	−2.24
Tower of London	128	13.58	3.12	1.5–18	−1.04
Verbal ability	128	53.10	14.57	18–98	0.39

included indicators of verbal ability as time-varying covariates of EF and specified regression paths between verbal ability indicators at consecutive time-points. The model achieved adequate power ($\alpha = .73$) and adequate fit, $\chi^2(73) = 106.54$, $p < .01$, RMSEA = 0.06, 90% CI [0.03,0.08], CFI = .93, TLI = 0.91. The range of factor loadings obtained here ($\beta_{range} = .24–.65$, $p < .01$) was similar to that reported by studies where EF was constructed using slightly different tasks (e.g., .17–.63; Espy, Kaufmann, Glisky, & McDiarmid, 2001). Fully standardized parameter estimates indicated that inter-individual differences in EF ($\beta_{2-3} = .91$ and $\beta_{3-6} = .80$, $p < .01$) and verbal ability ($\beta_{2-3} = .79$ and $\beta_{3-6} = .60$, $p < .01$) were stable over time. In addition, EF and verbal ability were significantly positively related at each time-point ($r_{age\ 2} = .84$, $p < .01$, $r_{age\ 3} = .56$, $p < .01$, and $r_{age\ 6} = .78$, $p < .01$).

Mediation analyses

To test mediation effects, we specified the autoregressive longitudinal mediation model presented in Fig. 1. The model showed good fit to the data, $\chi^2(160) = 203.215$, $p = .01$, RMSEA = 0.04, 90% CI [0.02,0.06], CFI = .95, TLI = 0.94. The model achieved good power ($\alpha = .95$). The power of the model was enhanced by the large number of degrees of freedom of the model ($df = 160$ in the mediation model), which offset any power issues related to a small sample size (143 participants). Relative to girls, boys had poorer EF at age 2 years ($\beta = -.21$, $p = .01$) and higher externalizing problems at age 6 years ($\beta = .13$, $p < .05$). Net of these effects, higher maternal depressive symptoms at child age 2 predicted poorer child EF at age 3 ($\beta = -.20$, $p < .01$) even when accounting for stability in EF from age 2 to age 3 ($\beta = .90$, $p < .01$) and the significant association between EF and verbal ability at age 3 ($\beta = .71$, $p < .05$). In turn, poorer EF at age 3 predicted higher externalizing problems at age 6 ($\beta = -.32$, $p < .01$) and higher internalizing problems at age 6 ($\beta = -.32$, $p < .01$). This was true even given the significant concurrent relationship between child EF and externalizing problems ($\beta = -.48$, $p < .01$) and between child EF and internalizing problems ($\beta = -.43$, $p < .05$). Regarding externalizing problems, the indirect effect was significant ($\beta_{ind} = .07$, $p < .05$, 95% CI [0.001,0.130]). Regarding internalizing problems, the indirect effect was marginally significant ($\beta_{ind} = .06$, $p = .059$, 95% CI [−0.002,0.134]).

To further probe the robustness of our findings, we tested two alternative models. The first model (Fig. 2) showed that verbal ability did not act as an alternative mediator, although higher maternal

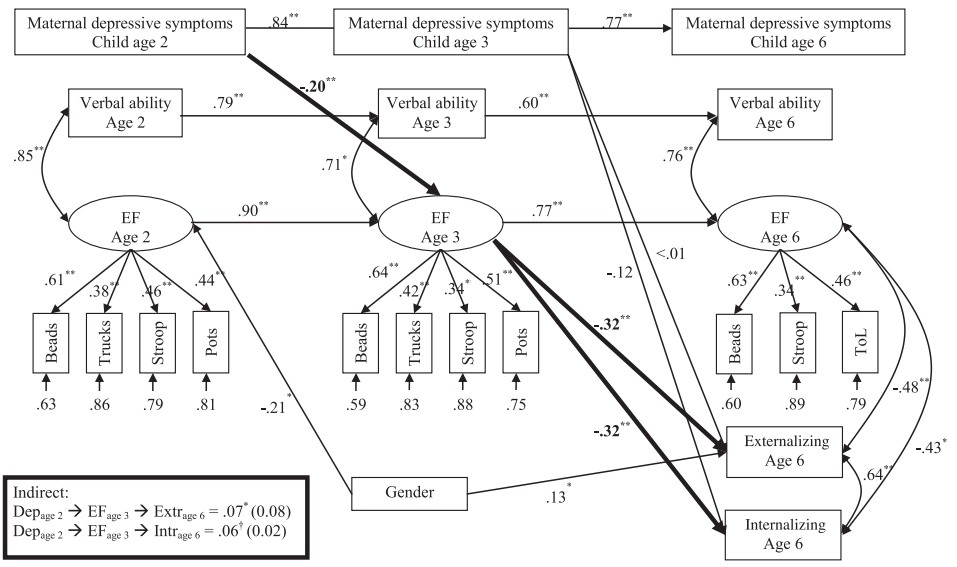

Fig. 1. Autoregressive longitudinal mediation model of child EF in the relationship between mothers' depressive symptoms and children's externalizing and internalizing problems. $^{\dagger}p \leqslant .10$; $^{*}p \leqslant .05$; $^{**}p \leqslant .01$.

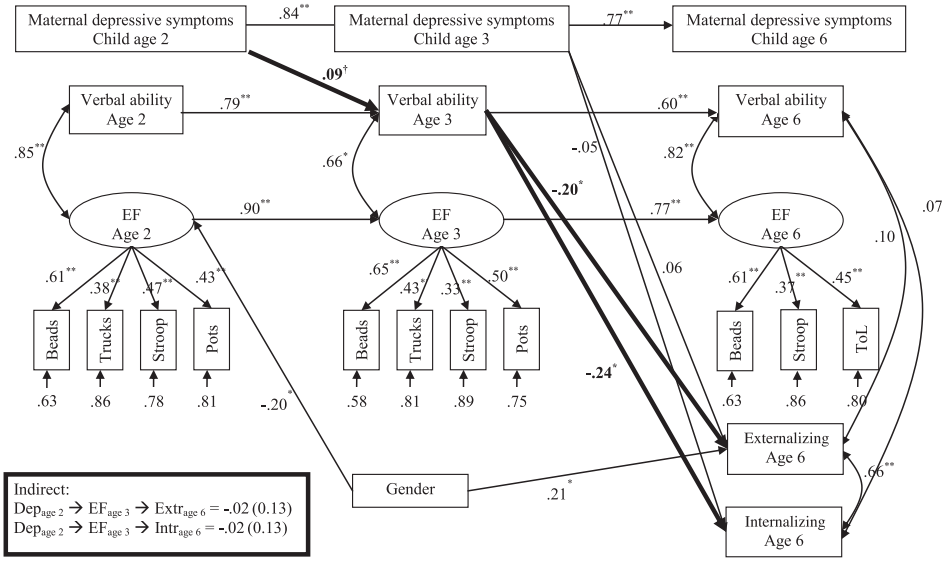

Fig. 2. Autoregressive longitudinal mediation model of child verbal ability in the relationship between mothers' depressive symptoms and children's externalizing and internalizing problems. $^{\dagger}p \leqslant .10$; $^{*}p \leqslant .05$; $^{**}p \leqslant .01$.

depressive symptoms at child age 2 years predicted marginally significantly lower child verbal ability at age 3 years, which in turn predicted higher externalizing and internalizing problems at age 6 years. The second model (Fig. 3) showed that the observed effects of depressive symptoms on behavior adjustment via poor EF did not simply reflect effects of deprivation more generally because, although exposure to higher levels of deprivation at age 2 directly predicted higher externalizing problems at

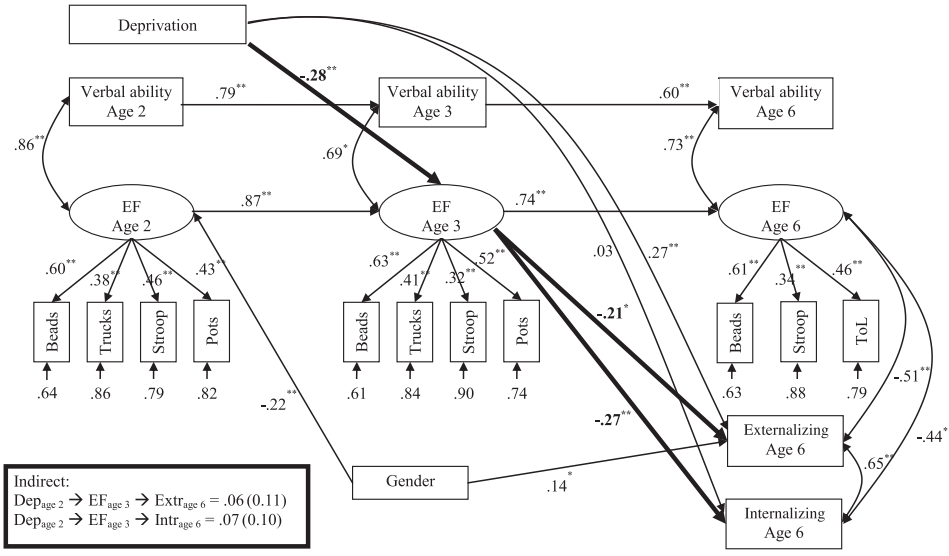

Fig. 3. Autoregressive longitudinal mediation model of child EF in the relationship between deprivation and children's externalizing and internalizing problems. $^{\dagger}p \leqslant .10$; $^{*}p \leqslant .05$; $^{**}p \leqslant .01$.

age 6 and poorer EF at age 3, and poorer EF at age 3 predicted higher externalizing and internalizing problems at age 6, the indirect effects were not significant.

Discussion

This study investigated whether the path from maternal depressive symptoms to young children's problem behaviors operates, at least in part, through impairments in children's EF. Building on a previous model, which tested the long-term associations between children's exposure to maternal depressive symptoms during toddlerhood and EF at age 6 years (Hughes et al., 2013), the current findings support Cummings et al. (2000) cascading pathway model of development in that they demonstrate more immediate associations between exposure to maternal depressive symptoms and poor EF, which are then carried over time.

Regarding the second path, our findings were consistent with those from a recent meta-analytic review (Schoemaker, Mulder, Deković, & Matthys, 2013), which showed a weak to moderate association between preschool children's externalizing problems and their overall EF, inhibitory control, working memory, and attention shifting (Schoemaker et al., 2013). Our findings are also consistent with previous reports of associations between internalizing problems and overall EF (Riggs, Blair, & Greenberg, 2003), working memory (Brocki & Bohlin, 2004), and inhibitory control (e.g., Rhoades, Greenberg, & Domitrovich, 2009).

Our main study finding was that individual differences in EF at age 3 years significantly mediated the relationship between mothers' depressive symptoms at child age 2 years and children's externalizing problems at age 6 years. To our knowledge, this is the first study to test such mediation effects within a rigorous autoregressive longitudinal design, whereby measures (all except child problem behaviors) were assessed repeatedly at each of the three time-points. The prospective longitudinal design and the selected time intervals add to the significance of findings; ages 2 and 3 are key periods when children improve on their EF skills and acquire more advanced types of EF, whereas age 6 follows the transition to school.

Importantly, the current findings indicate that the mediation role of EF is unlikely merely to reflect associations with other cognitive abilities that underlie behavior adjustment such as verbal fluency. Verbal ability is highly related to EF (e.g., Hughes & Ensor, 2007), and until recently tasks measuring various EF components tended to be verbal in nature (e.g., the backward word span task, tapping working memory) (Carlson, Moses, & Breton, 2002). It is noteworthy, therefore, that verbal ability was not a mediator, probably because heightened maternal symptoms only predicted marginally significantly lower verbal ability. Although conclusions are limited by the inclusion of a single indicator of verbal fluency, this finding suggests that different cognitive domains might not be equally important in the relation between exposure to maternal depressive symptoms and problem behaviors and calls for future studies of child mediators.

Along the same lines, it is also important to note that child EF did not mediate the relationship between general deprivation and problem behaviors. Depressive symptoms occur more often in the context of deprivation (Stansfeld, Clark, Rodgers, Caldwell, & Power, 2011), and previous studies have dealt with this convoluted relationship by showing that maternal depression mediates the relationship between deprivation and child problem behaviors (Rijlaarsdam et al., 2013) and that reduced economic resources mediate the relationship between depressive symptoms and child behavior (Turney, 2012). Alternatively, measures of deprivation and depressive symptoms have been combined into a single measure of family risk (e.g., Halligan et al., 2013). Not surprisingly, we found that greater deprivation at age 2 years predicted poorer EF at age 3 years and heightened externalizing problems at age 6 years. However, the indirect effect was not significant; this null finding is important because it suggests that the mediatory role of poor EF is specific to the effects of exposure to maternal depressive symptoms.

Establishing the specificity of risk factors implicated in an EF-mediated pathway to problem behaviors is theoretically significant. In particular, a significant mediation effect of EF in the relationship between exposure to deprivation and problem behaviors would have been consistent with the suggestion that those variations in problem behaviors that are due to impairments in EF are mostly created

by inadequate levels of overall stimulation and environmental inconsistency, supporting theoretical conceptualizations of EF as a regulatory process dependent on "optimal" stimulation. In contrast, our findings of a significant mediation effect of EF in the relationship between exposure to maternal depressive symptoms and problem behaviors is consistent with the suggestion that variations in problem behaviors due to impairments in EF might be caused by poor-quality interpersonal relationships, supporting models of EF development through modeling of adult behavior and observational learning (Hughes & Ensor, 2009b).

Maternal depression has been associated with impairments in mothers' own EF skills (e.g., Barrett & Fleming, 2011; Johnston, Mash, Miller, & Ninowski, 2012). Children are keen observers of adults' everyday behaviors (Dunn, 1993) and so may internalize problem-solving strategies that do not rely on the use of high EF skills. For example, depressed mothers are less likely to use planning in order to optimize repetitive tasks (Hughes & Ensor, 2009b), which might translate into fewer opportunities for their children to observe and internalize such strategies. In addition, depression is known to deplete emotional resources by activating an oversensitized distress response system and reducing the threshold for what is considered aversive (for a review, see Dix & Meunier, 2009). Both deficits in maternal EF (Psychogiou & Parry, 2014) and deficits in emotion processing and emotion regulation (Dix & Meunier, 2009) have been hypothesized as mechanisms through which depression translates into low maternal cognitive flexibility. A reduced ability to respond contingently would adversely affect parental scaffolding of children's goal-directed activities, which has been shown to predict EF development (Bernier, Carlson, & Whipple, 2010; Hughes & Ensor, 2009b; Schroeder & Kelley, 2010). Scaffolding also involves *showing* children how to solve (a part of) the next step, which children immediately imitate, internalize, and then apply to further steps in the process until the next stage of difficulty is achieved and the scaffolding process is repeated. In other words, to a large extent, scaffolding can be seen as a form of concentrated and focused observational learning. Future studies that take a close look at how scaffolding unfolds in interactions between children and mothers in the context of depression could greatly enhance our understanding of the processes that relate exposure to maternal depressive symptoms and child EF development.

Other factors that might be expected to distort the mediation effect reported here include parenting and maternal functioning. These have been omitted from the current study due to a focus on child mediators. However, the inclusion of measures of parenting and the parent–child relationship is unlikely to have altered the results because previous analyses of data from this sample showed that including maternal positive control at ages 2 and 6 years did not weaken the negative effects of mothers' depressive symptoms at child age 2 on child EF at age 6 (Hughes et al., 2013); likewise, there was no interaction between observed mother–child mutuality (at both ages 2 and 6) and mothers' depressive symptoms at age 2 as predictors of child problem behaviors at age 6 (Ensor et al., 2012). Another important environmental factor not included here is the father, an omission largely caused by the absence of fathers in more deprived families (25% of the mothers were single parents at study entry).

A key strength of this study is the use of independent assessments for each variable. Mothers' depressive symptoms were self-reported, children's EF abilities were tested through age-appropriate experimental tasks, and children's externalizing and internalizing problems were reported by teachers. On the flipside, a limitation of this study is the use of a single measurement method for each variable. For example, mothers' self-reported depressive symptoms were not corroborated by clinical interviews. Children's EF abilities were measured by multiple measures, but each subcomponent (i.e., working memory, inhibitory control, or attention shifting) was measured by a single task. This said, all main constructs were factor analyzed and used either as latent variables or as resulting factor scores in all analyses, thereby reducing measurement error. The small sample size and the presence of relatively few mothers with depressive symptoms indicate that results are preliminary in nature and warrant further validation with larger samples.

The current study has several implications for interventions aimed at reducing children's externalizing problems. Combined "two-generation" interventions aimed at improving both mothers' depressive symptoms and children's externalizing problems are a potential avenue given that improvements in maternal depressive symptoms have been associated with more successful treatment of child externalizing problems (Van Loon, Granic, & Engels, 2011). On the downside, such interventions might be more susceptible to failure if the component aimed at reducing maternal depressive symptoms is not

successful, as has been indicated by research showing that heightened maternal depressive symptoms interfere with the positive effects of interventions aimed at child adjustment (Beauchaine, Webster-Stratton, & Reid, 2005; Van Loon et al., 2011; but see Rishel et al., 2006, for null findings). From this point of view, the current study's implication that interventions that improve children's EF could help to reduce externalizing problems in children exposed to maternal depression (as indicated by the significant longitudinal mediation effect) is particularly noteworthy. Previous research has shown that children's EF is improved by a variety of interventions, some of which can easily be implemented in schools (for a review, see Diamond & Lee, 2011). In addition, it may be possible to promote children's EF through interventions aimed at improving the home environment such as by reducing chaos (e.g., Evans, Gonnella, Marcynyszyn, Gentile, & Salpekar, 2005) and encouraging parents to limit children's exposure to fast-paced cartoons (Lillard & Peterson, 2011).

In sum, despite the omissions identified above, and within the limitations imposed by the study design, by demonstrating that individual differences in child EF at age 3 years mediate the relationship between exposure to maternal depressive symptoms at age 2 years and teacher ratings of externalizing and internalizing problems at age 6 years, this study adds to our understanding of the self-regulatory mechanisms through which exposure to maternal depressive symptoms might translate into child problem behaviors. Moreover, our findings provide a potential avenue in the quest for factors that may buffer young children from the adverse effects of exposure to mothers' depressive symptoms.

Acknowledgements

This research was funded by a grant to Claire Hughes from the Economic and Social Research Council (ref: ES/D00554X/1). We thank the families who participated in the Toddlers Up study.

References

Alloway, T. P., Gathercole, S. E., Willis, C., & Adams, A. M. (2004). A structural analysis of working memory and related cognitive skills in young children. *Journal of Experimental Child Psychology, 87*, 85–106.

Ashman, S. B., Dawson, G., & Panagiotides, H. (2008). Trajectories of maternal depression over 7 years: Relations with child psychophysiology and behavior and role of contextual risks. *Development and Psychopathology, 20*, 55–77.

Barrett, J., & Fleming, A. S. (2011). Annual research review: All mothers are not created equal: Neural and psychobiological perspectives on mothering and the importance of individual differences. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 52*, 368–397.

Beauchaine, T. P., Webster-Stratton, C., & Reid, M. J. (2005). Mediators, moderators, and predictors of 1-year outcomes among children treated for early-onset conduct problems: A latent growth curve analysis. *Journal of Consulting and Clinical Psychology, 73*, 371–388.

Beck, A. T., Ward, C. H., Mendelson, M., Mock, J., & Erbaugh, J. (1961). An inventory for measuring depression. *Archives of General Psychiatry, 4*, 561–571.

Belsky, J., & De Haan, M. (2011). Annual research review: Parenting and children's brain development: The end of the beginning. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 52*, 409–428.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*, 238–246.

Bernier, A., Carlson, S. M., & Whipple, N. (2010). From external regulation to self-regulation: Early parenting precursors of young children's executive functioning. *Child Development, 81*, 326–339.

Biederman, J., Faraone, S. V., Hirshfeld-Becker, D. R., Friedman, D., Robin, J. A., & Rosenbaum, J. F. (2001). Patterns of psychopathology and dysfunction in high-risk children of parents with panic disorder and major depression. *American Journal of Psychiatry, 158*, 49–57.

Brocki, K. C., & Bohlin, G. (2004). Executive functions in children aged 6 to 13: A dimensional and developmental study. *Developmental Neuropsychology, 26*, 571–593.

Carlson, S. M., Mandell, D. J., & Williams, L. (2004). Executive function and theory of mind: Stability and prediction from ages 2 to 3. *Developmental Psychology, 40*, 1105–1122.

Carlson, S. M., Moses, L. J., & Breton, C. (2002). How specific is the relation between executive function and theory of mind? Contributions of inhibitory control and working memory. *Infant and Child Development, 11*, 73–92.

Cicchetti, D., & Toth, S. L. (1998). The development of depression in children and adolescents. *American Psychologist, 53*, 221–241.

Cummings, E. M., Davies, P. T., & Campbell, S. B. (2000). *Developmental psychopathology and family process: Theory, research, and clinical implications*. New York: Guilford.

Diamond, A., & Lee, K. (2011). Intervention shown to aid executive function development in children 4–12 years old. *Science, 333*, 959–964.

Dix, T., & Meunier, L. N. (2009). Depressive symptoms and parenting competence: An analysis of 13 regulatory processes. *Developmental Review, 29*, 45–68.

Dunn, J. (1993). *Young children's close relationships: Beyond attachment*. Newbury Park, CA: Sage Publications.

Dunn, L. (1997). *British picture vocabulary scale-revised*. Windsor, UK: NFER–Nelson.
Elliott, C., Murray, D., & Pearson, L. (1983). *British abilities scales*. Windsor, UK: NFER–Nelson.
Ensor, R., Roman, G. D., Hart, M., & Hughes, C. (2012). Mothers' depressive symptoms and low mother–toddler mutuality both predict children's maladjustment. *Infant and Child Development, 21*, 52–66.
Espy, K. A., Kaufmann, P. M., Glisky, M. L., & McDiarmid, M. D. (2001). New procedures to assess executive functions in preschool children. *Clinical Neuropsychologist, 15*, 46–58.
Evans, G., Gonnella, C., Marcynyszyn, L., Gentile, L., & Salpekar, N. (2005). The role of chaos in poverty and children's socioemotional adjustment. *Psychological Science, 16*, 560–565.
Field, T. (2011). Prenatal depression effects on early development: A review. *Infant Behavior and Development, 34*, 1–14.
Fuhs, M. W., & Day, J. D. (2011). Verbal ability and executive functioning development in preschoolers at Head Start. *Developmental Psychology, 47*, 404–416.
Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134*, 31–60.
Gartstein, M. A., Bridgett, D. J., Rothbart, M. K., Robertson, C., Iddins, E., Ramsay, K., et al (2010). A latent growth examination of fear development in infancy: Contributions of maternal depression and the risk for toddler anxiety. *Developmental Psychology, 46*, 651–668.
Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: Performance of children 31/2–7 years old on a Stroop-like Day–Night test. *Cognition, 53*, 129–153.
Goodman, R. (1997). The Strengths and Difficulties Questionnaire: A research note. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 38*, 581–586.
Goodman, A., Lamping, D. L., & Ploubidis, G. B. (2010). When to use broader internalising and externalising subscales instead of the hypothesised five subscales on the Strengths and Difficulties Questionnaire (SDQ): Data from British parents, teachers, and children. *Journal of Abnormal Child Psychology, 38*, 1179–1191.
Halligan, S. L., Cooper, P., Fearon, P., Wheeler, S., Crosby, M., & Murray, L. (2013). The longitudinal development of emotion regulation capacities in children at risk for externalising disorders. *Development and Psychopathology, 25*, 391–406.
Hammen, C., & Brennan, P. A. (2003). Severity, chronicity, and timing of maternal depression and risk for adolescent offspring diagnoses in a community sample. *Archives of General Psychiatry, 60*, 253–258.
Hay, D. F., Pawlby, S., Waters, C. S., Perra, O., & Sharp, D. (2010). Mothers' antenatal depression and their children's antisocial outcomes. *Child Development, 81*, 149–165.
Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*, 1–55.
Hughes, C. (2011). Changes and challenges in 20 years of research into the development of executive functions. *Infant and Child Development, 20*, 251–271.
Hughes, C., & Ensor, R. (2005). Executive function and theory of mind in 2 year olds: A family affair? *Developmental Neuropsychology, 28*, 645–668.
Hughes, C., & Ensor, R. (2007). Executive function and theory of mind: Predictive relations from ages 2 to 4. *Developmental Psychology, 43*, 1447–1459.
Hughes, C., & Ensor, R. (2008). Does executive function matter for preschoolers' problem behaviors? *Journal of Abnormal Child Psychology, 36*, 1–14.
Hughes, C., & Ensor, R. (2009a). Independence and interplay between maternal and child risk factors for preschool problem behaviors? *International Journal of Behavioral Development, 33*, 312–322.
Hughes, C., & Ensor, R. (2009b). How do families help or hinder the emergence of early executive function? *New Directions for Child and Adolescent Development, 123*, 35–50.
Hughes, C., & Ensor, R. (2011). Individual differences in growth in executive function across the transition to school predict externalizing and internalizing behaviors and self-perceived academic success at 6 years of age. *Journal of Experimental Child Psychology, 108*, 663–676.
Hughes, C., Ensor, R., Wilson, A., & Graham, A. (2010). Tracking executive function across the transition to school: A latent variable approach. *Developmental Neuropsychology, 35*, 20–36.
Hughes, C., Roman, G., Hart, M. J., & Ensor, R. (2013). Does maternal depression predict young children's executive function? A 4-year longitudinal study. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 5*, 169–177.
Johnston, C., Mash, E. J., Miller, N., & Ninowski, J. E. (2012). Parenting in adults with attention-deficit/hyperactivity disorder (ADHD). *Clinical Psychology Review, 32*, 215–228.
Kenny, D. A. (2012). *Mediation.* From: <http://davidakenny.net/cm/mediate.htm> Retrieved 16.11.12.
Klimes-Dougan, B., Ronsaville, D., Wiggs, E. A., & Martinez, P. E. (2006). Neuropsychological functioning in adolescent children of mothers with a history of bipolar or major depressive disorders. *Biological Psychiatry, 60*, 957–965.
Leschied, A. W., Chiodo, D., Whitehead, P. C., & Hurley, D. (2005). The relationship between maternal depression and child outcomes in a child welfare sample: Implications for treatment and policy. *Child and Family Social Work, 10*, 281–291.
Lillard, A., & Peterson, J. (2011). The immediate impact of different types of television on young children's executive function. *Pediatrics, 128*, 644–649.
Little, R. J. A. (1998). A test of missing completely at random for multivariate data with missing values. *Journal of the American Statistical Association, 83*, 1198–1202.
McLennan, J. D., Kotelchuck, M., & Cho, H. (2001). Prevalence, persistence, and correlates of depressive symptoms in a national sample of mothers of toddlers. *Journal of the American Academy of Child and Adolescent Psychiatry, 40*, 1316–1323.
Mezzacappa, E. (2004). Alerting, orienting, and executive attention: Developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. *Child Development, 75*, 1373–1386.
Micco, J. A., Henin, A., Biederman, J., Rosenbaum, J. F., Petty, C., Rindlaub, L. A., ... Hirshfeld-Becker, D. R. (2009). Executive functioning in offspring at risk for depression and anxiety. *Depression and Anxiety, 26*, 780–790.
Moffitt, T. E., Adlam, A., Affleck, G., Andreou, P., Aquan-Assee, J., Arseneault, L., ... Young, J. (2002). Teen-aged mothers in contemporary Britain. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 43*, 727–742.

Murray, L., Arteche, A., Fearon, P., Halligan, S., Goodyer, I., & Cooper, P. (2011). Maternal postnatal depression and the development of depression in offspring up to 16 years of age. *Journal of the American Academy of Child and Adolescent Psychiatry, 50*, 460–470.

Muthén, L. K., & Muthén, B. O. (1998–2010). *Mplus user's guide* (6th ed.). Los Angeles: Muthén & Muthén.

Noble, M., McLennan, D., Wilkinson, K., Whitworth, A., Barnes, H., & Dibben, C. (2008). *The English indices of deprivation 2007*. From <http://www.communities.gov.uk/documents/regeneration/pdf/131290.pdf> Retrieved 30.09.10.

Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science, 8*, 74–87.

Odgers, C. L., & Jaffee, S. R. (2013). Routine versus catastrophic influences on the developing child. *Annual Review of Public Health, 34*, 29–48.

Preacher, K. J., & Coffman, D. L. (2006). *Computing power and minimum sample size for RMSEA (computer software)*. Available from: <http://quantpsy.org>.

Psychogiou, L., & Parry, E. (2014). Why do depressed individuals have difficulties in their parenting role? *Psychological Medicine, 44*, 1345–1347.

Quevedo, L. A., Silva, R. A., Godoy, R., Jansen, K., Matos, M. B., Tavares Pinheiro, K. A., et al (2012). The impact of maternal post-partum depression on the language development of children at 12 months. *Child: Care, Health, and Development, 38*, 420–424.

Rhoades, B. L., Greenberg, M. T., & Domitrovich, C. E. (2009). The contribution of inhibitory control to preschoolers' social–emotional competence. *Journal of Applied Developmental Psychology, 30*, 310–320.

Riggs, N. R., Blair, C. B., & Greenberg, M. T. (2003). Concurrent and 2-year longitudinal relations between executive function and the behavior of 1st and 2nd grade children. *Child Neuropsychology, 9*, 267–276.

Rijlaarsdam, J., Stevens, G. W. J. M., Van der Ende, J., Hofman, A., Jaddoe, V. W. V., MacKenbach, J. P., ... Tiemeier, H. (2013). Economic disadvantage and young children's emotional and behavioral problems: Mechanisms of risk. *Journal of Abnormal Child Psychology, 41*, 125–137.

Rishel, C. W., Greeno, C. G., Marcus, S. C., Sales, E., Shear, M. K., Swartz, H. A., et al (2006). Impact of maternal mental health status on child mental health treatment outcome. *Community Mental Health Journal, 42*, 1–12.

Schoemaker, K., Mulder, H., Deković, M., & Matthys, W. (2013). Executive functions in preschool children with externalizing behavior problems: A meta-analysis. *Journal of Abnormal Child Psychology, 41*, 457–471.

Schroeder, V. M., & Kelley, M. L. (2010). Family environment and parent–child relationships as related to executive functioning in children. *Early Child Development and Care, 180*, 1285–1298.

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 298*, 199–209.

Spencer-Smith, M., & Anderson, V. (2009). Healthy and abnormal development of the prefrontal cortex. *Developmental Neurorehabilitation, 12*, 279–297.

Stansfeld, S. A., Clark, C., Rodgers, B., Caldwell, T., & Power, C. (2011). Repeated exposure to socioeconomic disadvantage and health selection as life course pathways to mid-life depressive and anxiety disorders. *Social Psychiatry and Psychiatric Epidemiology, 46*, 549–558.

Thorndike, R. L., Hagen, E. P., & Sattler, J. M. (1986). *Stanford–Binet Intelligence Scale* (4th ed.). Chicago: Riverside.

Turney, K. (2012). Pathways of disadvantage: Explaining the relationship between maternal depression and children's problem behaviors. *Social Science Research, 41*, 1546–1564.

Van Loon, L. M. A., Granic, I., & Engels, R. C. M. E. (2011). The role of maternal depression on treatment outcome for children with externalizing behavior problems. *Journal of Psychopathology and Behavioral Assessment, 33*, 178–186.

youth*in*mind (2012). *Norms*. From: <http://www.sdqinfo.com/norms/UKNorm3.pdf> Retrieved 28.09.12.