Abstract

To study the role of executive function (EF) in the early development of aggression, the role of cool and hot EF skills at 5 years-old in the development of physical and relational aggression between 5 and 6 years-old was explored. Typically-developing children (N = 80) completed tasks assessing their cool (inhibition, working memory, planning) and hot EF (affective decision making, delay of gratification) skills at 5-years-old. Longitudinal data were collected from teachers that rated children's aggression when they were 5-, 5.5- and 6-years-old. Inhibition at 5-years-old predicted changes in physical and relational aggression between 5- and 6-years old. Early cool EF, but not hot EF, may therefore be associated with aggression and inhibitory control specifically with changes in aggression during early childhood.

Key Words: *Aggression, Executive Function, Early Childhood*

Cool and hot executive functions at 5-years-old as predictors of physical and relational aggression between 5- and 6-years-old

Models of social behaviour, derived from social neuroscience literature, have suggested that executive function (EF) is fundamental to children's social development (Beauchamp & V. Anderson, 2010; Yeates et al., 2007). EF refers to the higher-order, cognitive skills required for goal-directed behaviour (Goldstein, Naglieri, Princoptta, & Otero, 2014). These higher-order cognitive functions are mediated by the pre-frontal cortex and provide control and direction to lower-order brain functions (Stuss & Levine, 2002). In the literature, a conceptual distinction is commonly made between “cool” and “hot” executive functions (Zelazo & Müller, 2002). Cool EF is associated with the dorsolateral pre-frontal cortex and includes cognitive processes such as inhibition, working memory, and planning, which are involved in abstract, emotionally neutral problems. Hot executive functions are mediated by the ventromedial and orbito-frontal cortices which support affective processes (e.g. ability to delay gratification, affective decision making), which are tapped by emotion laden problems (Zelazo & Müller, 2002). The view posed by social neuroscience models and held by many researchers is that children with poor EF abilities may be less able to inhibit maladaptive behaviours and adapt to novel social situations and as a result these children may mismanage social interactions leading to peer-directed aggression (Anderson, 2008; Astington, 2003). Therefore a persisting question over the last decade has been whether subtle cognitive problems in early EF precede aggression and contribute to its onset and development.

There is a substantial body of evidence that poor cool EF, particularly inhibition, is related to increased aggression during childhood (Masten et al., 2012; Poland, Monks, Tsermentseli, 2016; Utendale, Hubert, Saint-Pierre, & Hastings, 2011). However, this research often fails to consider the varied nature of aggression. Aggression is argued to comprise

distinct subtypes (Dodge, 1991; Dodge & Coie, 1987; Grotpeter & Crick, 1996). Aggression can be physical (e.g. hitting), verbal (e.g. name calling) or relational (e.g. social exclusion; Crick, Casas, & Ku, 1999; Ostrov & Crick, 2007) and these forms of aggression can be used to achieve reactive or proactive functions (Dodge & Coie, 1987). Though, the utility of this distinction between functions has been called into question as aggression may serve both a reactive and proactive function (Bushman & Anderson, 2001). In contrast, distinct forms of physical and relational aggression have been widely supported in the literature and these forms of aggression have been associated with varying underlying cognitive factors, such as deception (Ostrov, 2006; Ostrov &Godleski, 2010).

EF is not a unitary construct, and hence different aspects of EF domains might relate to different types of aggression. In line with this, emerging evidence has indicated that poor EF is associated with physical aggression, but not relational, aggression in children between 6- and 17-years-of-age (Dane & Marini, 2014; Terranova, Morris, & Boxer, 2008). However, a study of 9- to 12-year-olds reported that poor EF was related to both physical and relational aggression (McQuade, Murray-Close, Shoulberg, & Hoza, 2013), although, only one cool EF skill, working memory, was considered. Although it has been hypothesised that social problem solving is likely to occur in motivationally and emotionally significant environments and consequently may require hot EF (Zelazo & Müller, 2002), research into the role of hot EF in aggression has not been adequately investigated. The few studies that have been carried out have found mixed results, with some finding a negative relation between hot delay of gratification and aggression in 2- to 5-years-old children (Di Norcia et al., 2015; Garner & Waajid, 2012; Kim, Nordling, Yoon, Boldt, & Kochanska, 2014), and other research failing to find a relationship beyond that of cool EF in children 3- to 6-years-of-age (Willoughby, Kupersmidt, Voegler-Lee, & Bryant, 2011). However, these studies did not consider subtypes of aggression. One study that did look at the role of hot EF across forms of aggression, however,

failed to find a relation (Poland et al., 2016). Further investigation of the relation between EF domains and subtypes of aggression is therefore crusial as it may provide a greater insight into the varied nature of aggression.

Understanding of the development of subtypes of aggression is further limited by the fact that the majority of previous research looking at the relation between EF and aggression in typical children (e.g. Garner & Waajid, 2012; Hughes, White, Sharpen, & Dunn, 2000; Willoughby, Kupersmidt, Voegler-Lee, & Bryant, 2011) has been carried out at one time point and longitudinal associations were not assessed. The only prospective longitudinal study to date, followed children from 3- to 6-years-of-age and revealed that children's cool and hot inhibition significantly predicted children's concurrent, but not later aggression (Olson et al., 2011). However, this study did not take into account the other EF sub-domains or forms of aggression. Forms of aggression have been found to follow varying trajectories. Children's use of physical aggression tends to decline with age and rates of relational aggression typically increase across early to middle childhood (Björkqvist, Ősterman, & Kaukiainen, 1992; Gray, Carter, Briggs-Gowan, Jones, & Wagmiller, 2014; Monks, Smith, & Swettenham, 2003). Exploring specific cognitive predictors of the development of forms of aggression may therefore increase understanding of the underlying mechanisms for these varied pathways.

If EF contributes to aggression, then from a developmental perspective identifying whether EF is an underlying mechanism for change in aggression across childhood is not just beneficial for understanding the development of aggression but also for intervening. Criminology literature has suggested that impulsivity (a concept related to poor inhibition) in childhood is associated with later aggressive criminal behaviour in adolescence and adulthood (Farrington, 2005; Murray, Irving, Farrington, Colman, & Bloxsom, 2010), suggesting that cognitive development in childhood may have lasting developmental effects. Early childhood is an important period in the development of EF. It is in this period EF abilities undergo rapid

advances, consistent with the ongoing development of the prefrontal cortex (P. Anderson, 2008; V. Anderson et al., 2008). Thus, early childhood represents a sensitive period in the evaluation of individual differences in EF and their contribution to social development. EFs are thought to be necessary for adequate social development and as a result disruptions in early EF development may influence the emergence and expression of social behaviours across childhood (Beauchamp & V. Anderson, 2010). Deficits in children's EF have been found to disrupt children's social skills development; reducing their repertoire of socially appropriate behaviours for use in interactions with their peers (Eisenberg et al., 1995) and affecting their standing with peers (Tseng & Gau, 2013). Poor EF abilities in early childhood may therefore disrupt children's social development and have a lasting influence on social behaviour, such as aggression, across childhood.

Examining gender differences in the development of social behaviours, such as aggression, is also important in order to identify patterns of development specific to each gender (Ostrov & Godleski, 2010). According to the results of a meta-analysis, physical aggression is more common in boys whereas relational aggression is more typical of girls (Card et al., 2008). Though, gender differences in relational aggression may be more prominent during adolescence (Archer, 2004). This may be reflective of differences in the organization of girls' and boys' peer groups. Girls tend to form smaller more exclusive peer groups than boys (Lagerspetz, Bjorkqvist, & Peltonen, 1988). The development of aggressive behaviour may consequently vary for boys and girls. Added to this, girls have also been found to exhibit greater EF skills (Gur et al., 2012). The role of cognitive abilities in aggression may therefore vary across genders, especially in early childhood when EF is rapidly developing.

Given that early childhood is a period of rapid growth in EF and that existing findings suggest that EF may play a role in the development of different types of aggression, the current study examined the role of early cool and hot EF skills at 5 years-old in the development of

physical and relational aggression between 5 and 6 years-old in order to identify whether early EF represents an underlying mechanism for change in aggression. Children's EF at 5 years-old was measured as this is at the end of the rapid period of EF development in early childhood (P. Anderson, 2008; V. Anderson et al., 2008). This study therefore aimed to build upon current research that has found an association between EF and aggression concurrently (Masten et al., 2012; Poland et al., 2016) and research that has found early cognitive abilities influence pathways of aggressive behaviour (Farrington, 2005; Murray et al., 2010) by examining whether early cool and hot EF skills differentially influence the developmental trajectories of subtypes of aggression across early childhood. Early childhood is period where children are old enough to have a high probability of demonstrating individual differences in EF and aggression, but young enough so that any detected differences could not be attributed to prolonged aggression. The age span adopted in this study therefore enables a short-term longitudinal evaluation of the predictive value of any cognitive risks identified to be explored. Further, children at this age are able to participate in the relatively lengthy and difficult assessment batteries required to evaluate a range of EF abilities. It was tentatively hypothesised that poorer cool EF, especially inhibition, would be associated with increasing physical aggression during early childhood due to the link between impulsive behaviour and aggression in young children (Dane & Marini, 2014; Poland et al., 2016). Further, it was tentatively hypothesised that poorer hot EF would predict relational aggression due to its more affective nature.

Method

Participants

Eighty children (40 boys and 40 girls) from two mainstream primary schools in the United Kingdom were recruited to participate in the current study from a larger sample of 106 children between 3 and 6 years-of-age. The subsample was selected based on child age (5 years-old) and having an aggression measure at all three time points. The schools from which children were recruited were comparable on the percentage of pupils receiving free school meals: 26.6% and 24.7%. At initial recruitment, children were 5-years-old (M = 58.8 months, SD = 6.66 months). At initial recruitment children were selected from four nursery classes and two reception classes. Exclusionary criteria included a mental health diagnosis (e.g. ADHD, ASD, conduct disorders) or a learning disability. The children were assessed at three time points during the course of 12 months: initial recruitment, 6 months later and 12 months after the initial time point. At the second time point 73 children were followed up (9% attrition) and at the third time point 72 children were followed up (1% attrition). Attrition was due to children no longer attending the school. At the second time point children had a mean age of 64.65 months (SD = 7.20 months) and at the third time point children's mean age was 71.36 months (SD = 7.17 months). The Class Teachers (N = 16) and Teaching Assistants (N = 23) of the children involved in the study were also recruited to participate. All children were evaluated by one teacher and at least one teaching assistant. The maximum number of teaching assistants providing score for one child was 3.

Measures

EF. Three cool EF skills were assessed at the first time point: inhibition, working memory and planning. Children completed a computerised Fish and Shark Go/No-Go task to measure their inhibitory control (Simpson & Riggs, 2006). Children were required to catch the

fish by pressing a button on the response pad (Go trials), but to avoid catching the sharks by withholding pressing the button (No-Go trials). Feedback was provided for correct and incorrect responses. Each child first completed 6 practice trials (3 Go and 3 No-Go trials) and then 40 test trials (30 Go and 10 No-Go trials). The proportion of correct No-Go trials was measured.

To assess children's working memory the Digit Span forward and backwards subtests (WISC-III; Wechsler, 1991) were used. The forward subtest involves recalling a series of number sequences (increasing from two to nine digits) in the same order as spoken. The backward subtest involves recalling a series of number sequences (increasing from two to eight digits) in reverse order. Although the Digit Span was initially designed for use with children between six and 16 years of age, it has been successfully used with children five years old and below (Alloway, Gathercole, Kirkwood, & Elliott, 2008; Bull, Espy, & Wiebe, 2008). Children were awarded 1 point for each correct trial. Scores from the forward and backward subtest were summed and potential scores ranged from 0 to 30.

Children's planning skills were measured using the Tower of London (ToL) (Shallice, 1982). Children first completed two 2-move practice problems, before completing 12 test problems ranging from 2- to 5-moves (Shallice, 1982). Each trial lasted a maximum of two minutes and up to two attempts at each problem was allowed (Hughes, Dunn, & White, 1998; Monks et al., 2005). The task ceased after the child completed the problem set or failed two consecutive problems. Children were awarded 2 points if they completed the problem on the first trial, 1 point if they took two attempts and 0 points if they failed to complete the problem in two trials. Potential scores ranged from 0 to 24.

Two hot EF skills were assessed at the first time point: affective decision making and delay of gratification. A modified version of the Children's Gambling Task (CGT) developed

by Kerr and Zelazo (2004) was used to measure children's affective decision making (Poland et al., 2016). Children were instructed to select cards from one of two decks. When turned the cards revealed happy faces, corresponding to the number of beads won, and sad faces, representing the number of beads lost. There was an advantageous deck which resulted in a net win of five beads per 10 cards and a disadvantageous deck which resulted in a net loss of 5 beads per 10 cards. There were 6 demonstration trials and 50 test trials. At the end of the task, children could trade their beads for stickers. Affective decision making was assessed on whether predominately advantageous or disadvantageous decisions were made across the last three trial blocks (Poland et al., 2016).

To assess children's ability to delay gratification the Gift Delay task was used (Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996). Each child was instructed not to peek while the researcher pretended to wrap them a gift. The researcher wrapped the gift in a standardised manner: rifling through a plastic bag, cutting wrapping paper with scissors, folding the paper and tearing off the tape for 60 seconds. Children scored 2 points if they did not turn around, 1 point if they peeked over their shoulder and 0 points if they turned around completely. At each time point the range of gifts was altered in order to maintain task novelty.

Verbal Ability. At Time 1 the short version of the British Picture Vocabulary Scale (BPVS; Dunn, Whetton, & Pintilie, 1982) was used to assess children's receptive vocabulary. The BPVS requires the child to select the picture (from four options) that best matches a word. Standardized scores according to age were used.

Aggression. Teacher reports of children's aggression were gathered at each of the time points. Class teachers and teaching assistants completed the 12 item Preschool Proactive and Reactive Aggression Scale (PPRA) for each child in their class participating in the study (Ostrov & Crick, 2007). The PPRA has 4 subscales, with 3 items for each: proactive physical

aggression (e.g. this child often threatens others physically to get what s/he wants), reactive physical aggression (e.g. if other children make this child mad, s/he will often physically hurt them), proactive relational aggression (e.g. to get what this child wants, s/he often tells others that s/he won't be their friend anymore), and reactive relational aggression (e.g. if other children hurt this child, s/he often keeps them from being in their group of friends). Teaching staff rated how true each statement was of the child on a 5-point likert scale, ranging from '1' meaning 'never or almost never true' to '5' meaning 'always or almost always true'. Teacher and teaching assistant ratings for each subscale were averaged.

Teacher and teaching assistant scores were averaged to provide an overview of children's aggression inside and outside the classroom and children had different informants and a varying number of informants. Teacher and teaching assistant ratings were significantly and positively correlations between these informants indicating adequate agreement (correlations based on sample of 106 children: proactive physical aggression, $r = .51$, $p = <.001$; reactive physical aggression, $r = .67$, $p = <.001$; proactive relational aggression, $r = .42$, $p = <.001$; reactive relational aggression, $r = .39$, $p = <.001$). The PPRA has been found to have good internal consistency (proactive physical aggression, $\alpha = .88$; reactive physical aggression, $\alpha = .92$; proactive relational aggression, $\alpha = .88$; reactive relational aggression, $\alpha = .82$; Ostrov & Crick, 2007). However, in the current study functions of aggression were positively and significantly correlated (proactive and reactive physical aggression, $r = .90$, $p = <.001$; proactive and reactive relational aggression, $r = .95$, $p = <.001$), indicating that in the present sample the measure was not able to adequately distinguish between functions of aggression. The scales were therefore collapsed into physical and relational forms of aggression in the present study.

Procedure

The current study received ethical approval from the University's Research Ethics Committee. Informed consent was obtained from teaching staff and primary caregivers of children participating in the research. This was a longitudinal study which began in April 2014 and finished in July 2015. There were three time points, approximately 6 months apart. At the first time point, when children were aged 5-years-old, cool and hot EF skills were assessed. Children completed the tasks individually with the researcher in a quiet room at their school. The tasks were spread over three sessions that each lasted between 20 to 45 minutes. Children completed the tasks in a fixed order at each time point. Session 1: BPVS and CGT; Session 2: ToL, digit span, and Go/No-Go; Session 3: gift wrap. At each time point teacher reports of children's aggressive behaviour were obtained.

Results

Descriptive statistics for EF and aggression are reported in Table 1 and correlations between variables are reported in Table 2. Two two-level hierarchical linear mixed model analyses were undertaken to test for the effect of EF at 5 years of age on physical and relational aggression and on changes in physical and relational aggression between 5 and 6 years of age. The models contained either physical or relational aggression as the dependent variable and selected cool and hot EF variables (see below), age, gender and verbal ability as explanatory variables. The models allowed repeated measures for each child to be correlated by fitting random intercepts that varied at the level of each individual. Residual plots were used to check normality assumptions and the final generalised linear mixed models were fitted by maximum likelihood. Time was entered as a continuous predictor and interactions between time and EF

skills were included to test for the effect of EF skills on changes in aggression over time. Hierarchical modelling was implemented with SPSS MIXED MODELS, Version 24.

Table 1. Mean and standard deviation for executive function and aggression variables

	Time 1		*Time 2*		*Time 3*	
	M	*SD*	*M*	*SD*	*M*	*SD*
PA	1.78	.83	1.29	.74	1.06	.63
RA	2.19	.79	1.40	.69	1.30	.63
Inhibition	.82	.22	-	-	-	-
Working Memory	6.45	2.78	-	-	-	-
Planning	4.56	4.35	-	-	-	-
Decision Making	-.03	.44	-	-	-	-
Delay of Gratification-	1.43	.80	-	-	-	-
Verbal Ability	96.64	16.95	-	-	-	-

Note. *RPA = PA = physical aggression, RA = relational aggression, M* = mean, *SD* = standard deviation, *N* = 80.

Table 2. Correlations between executive function skills and physical and relational aggression

	1	2	3	4	5	6	7	8	9	10	11	12
1. Gender	-	.22*	.05	.10	.05	.25*	-.30**	-.36**	-.33**	.13	-.10	-.003
2.Inhibition		-	.33**	.14	.11	.43***	-.46***	-.12	-.11	-.23*	.16	.05
3. Working Memory			-	.26**	-.04	.16	-.15	.02	.08	-.08	.18	.14
4. Planning				-	.12	.23*	-.30**	-.22*	-.15	-.32**	-.08	-.05
5. Decision Making					-	-.04	.09	.07	-.023	-.01	.06	.07
6. Delay of Gratification						-	-.36**	-.11	-.14	-.19	.05	.09
7. T1 PA							-	.33**	.32**	.65***	.10	.11
8. T2 PA								-	.79**	.05	.70***	.56***
9. T3 PA									-	.03	.63***	.77***
10. T1 RA										-	.11	.07
11. T2 RA											-	.66***
12. T3 RA												-

Note. *RPA = Reactive Physical Aggression, PPA = Proactive Physical Aggression, RRA = Reactive Relational Aggression, PRA = Proactive Relational Aggression,* ***p* < .05, ***p* < .01, ****p* < .001

To test whether EF skills at 5 years of age predicted changes in physical or relational aggression between 5 and 6 years-of-age, we included all EF skills that correlated with either physical or relational aggression at 5 years of age in hierarchical linear mixed models. For physical aggression these were inhibition, planning and delay gratification. For relational aggression these were inhibition, planning and working memory. Gender and verbal ability were also included as covariates. The results of the hierarchical linear mixed models are reported in Table 3.

Physical aggression: Time was associated with physical aggression, indicating reductions in physical aggression between 5 and 6 years-of-age (*B*=-1.45, 95% CI: -2.26, -0.72; *t (df)* = -3.82 (155); $p < 0.001$). Gender was associated with physical aggression, with boys being more physically aggressive than girls (*B*=0.79, 95% CI: 0.22, 1.36; *t (df)* = 2.77 (79); $p = 0.007$); however, age and verbal ability were not significantly associated with physical aggression. Neither planning nor delay gratification were significant predictors of physical aggression, and did not moderate the effect of time on the development of physical aggression. Inhibitory control significantly predicted lower physical aggression (*B*=-3.65, 95% CI: --6.06, -1.23; *t (df)* = -2.98 (223); $p = 0.003$) and the interaction between time and inhibitory control was significant (*B*=1.64, 95% CI: 0.62, 2.65; *t (df)* = 3.18 (157); $p = 0.002$).

To explore the interaction between inhibition and physical aggression this relation over time was plotted (see Figure 1). Children at least one standard deviation below the mean for inhibition were categorised as being low in inhibition and children at least one standard deviation above the mean were categorised as being high in inhibition. The remaining children were classed as average in inhibition. The figure indicates that the lower a child's inhibition the greater their physical aggression between 5 and 6 years-old. However, the effect of inhibition on physical aggression appears to reduce between 5 and 6 years of age.

Relational aggression: Time was associated with relational aggression, indicating reductions in relational aggression between 5 and 6 years of age (*B*=-1.77, 95% CI: -2.59, -0.96; *t (df)* = -4.30 (151); $p < 0.001$). Neither gender, age, verbal ability, working memory nor inhibitory control were significantly associated with relational aggression. Planning did predict lower relational aggression (*B*=-0.12, 95% CI: -0.24, -0.01; *t (df)* = -2.13 (233); $p = 0.03$) but did not predict changes in relational aggression over time. The interaction between time and inhibitory control was significant (*B*=0.99, 95% CI: 0.01, 1.96; *t (df)* = 2.00 (151); $p = 0.047$). To explore this interaction the relationship between inhibition and relational aggression was plotted over time (see Figure 2). The figure indicates that similar to physical aggression, inhibition appears to have a greater effect on relational aggression at 5 years-old than at 6 years-old. At 5 years-old children with low inhibition demonstrated higher relational aggression than children with high inhibition, but at 6 years-old low and high inhibition groups had similar levels of relational aggression.

Table 3. Estimated effects of EF skills and covariates on changes in physical and relational aggression

	Physical aggression				Relational aggression			
	B (SE)	*95% CIs*	*t (df)*	*p*	*B (SE)*	*95% CIs*	*t (df)*	*p*
Time	-1.49 (.39)	-2.26, -.72	-3.82 (155)	<.001	-1.77 (.41)	-2.59, -.96	-4.30 (151)	<.001
Gender	.79 (.29)	.22, 1.36	2.77 (79)	.007	.02 (.28)	-.53, .57	.08 (78)	.937
Age	.04 (.02)	-.01, .08	1.71 (78)	.092	.04 (.02)	-.01, .09	1.66 (77)	.101
Verbal ability	-.00 (.00)	-.02, .02	-.13 (82)	.894	.00 (.01)	-.01, .02	.57 (80)	.567
Planning	-.09 (.05)	-.20, .02	-1.62 (223)	.107	-.12 (.06)	-.24, -.01	-2.13 (233)	.034
Delay	-.10 (.33)	-.74, .55	-.31 (224)	.754	-	-	-	-
Memory	-	-	-	-	-.07 (.08)	-.26, .12	-.72 (233)	.469
Inhibition	-3.65 (1.22)	-6.06, -1.23	-2.98 (223)	.003	-2.01 (1.21)	-4.39, .38	-1.65 (233)	.099
Time*Planning	.00 (.02)	-.04, .05	.07 (154)	.944	.01 (.03)	-.04, .06	.445 (151)	.657
Time*Delay	-.06 (.14)	-.33, .20	-.48 (151)	.632	-	-	-	-
Time*Memory	-	-	-	-	.07 (.04)	-.01, .15	1.78 (151)	.077
Time*Inhibition	1.64 (.51)	.62, 2.65	3.18 (157)	.002	.99 (.49)	.01, 1.96	2.00 (151)	.047

Note.

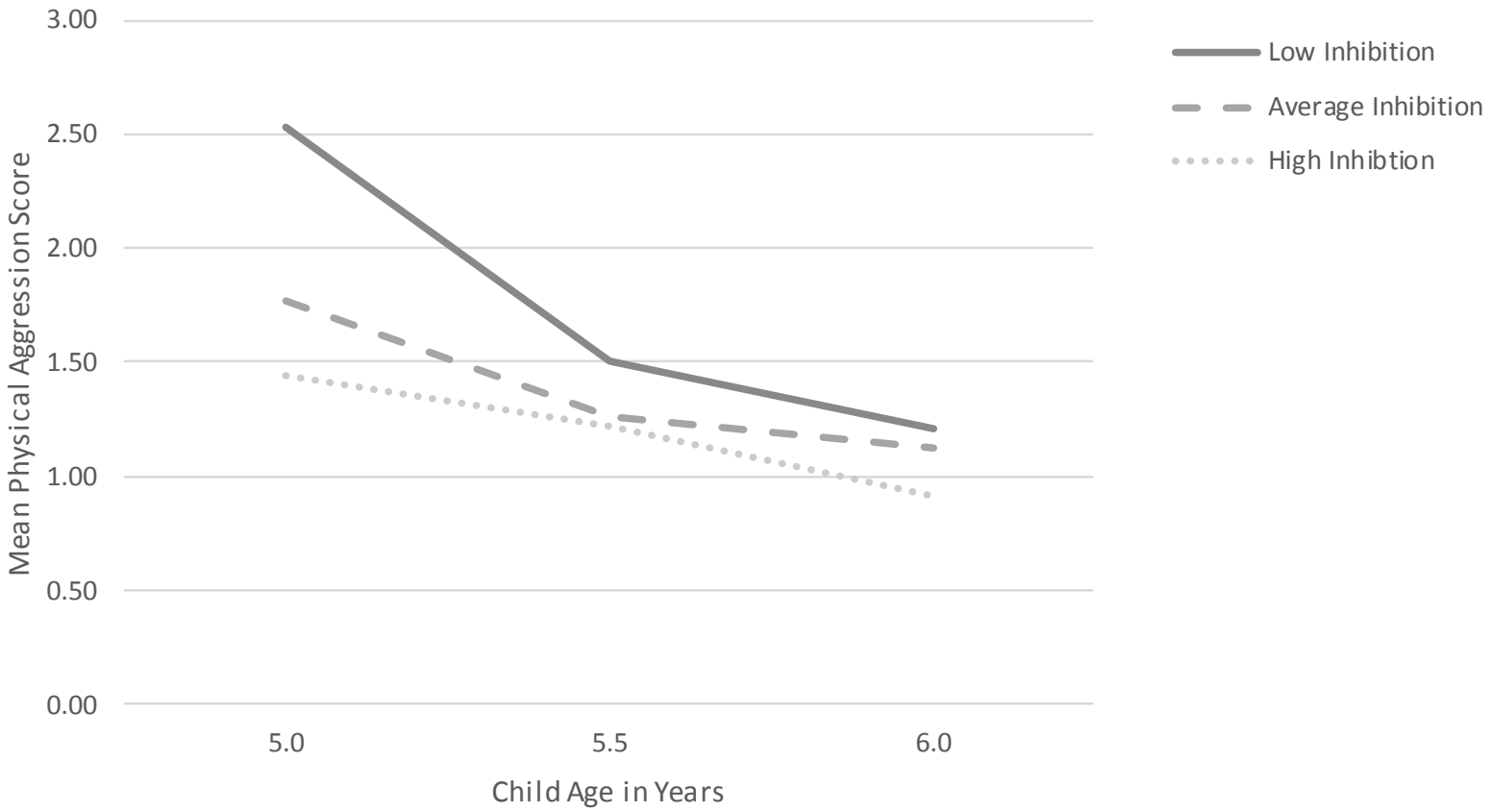

Figure 1. Mean physical aggression across time points for children categorised as low, average and high in inhibition

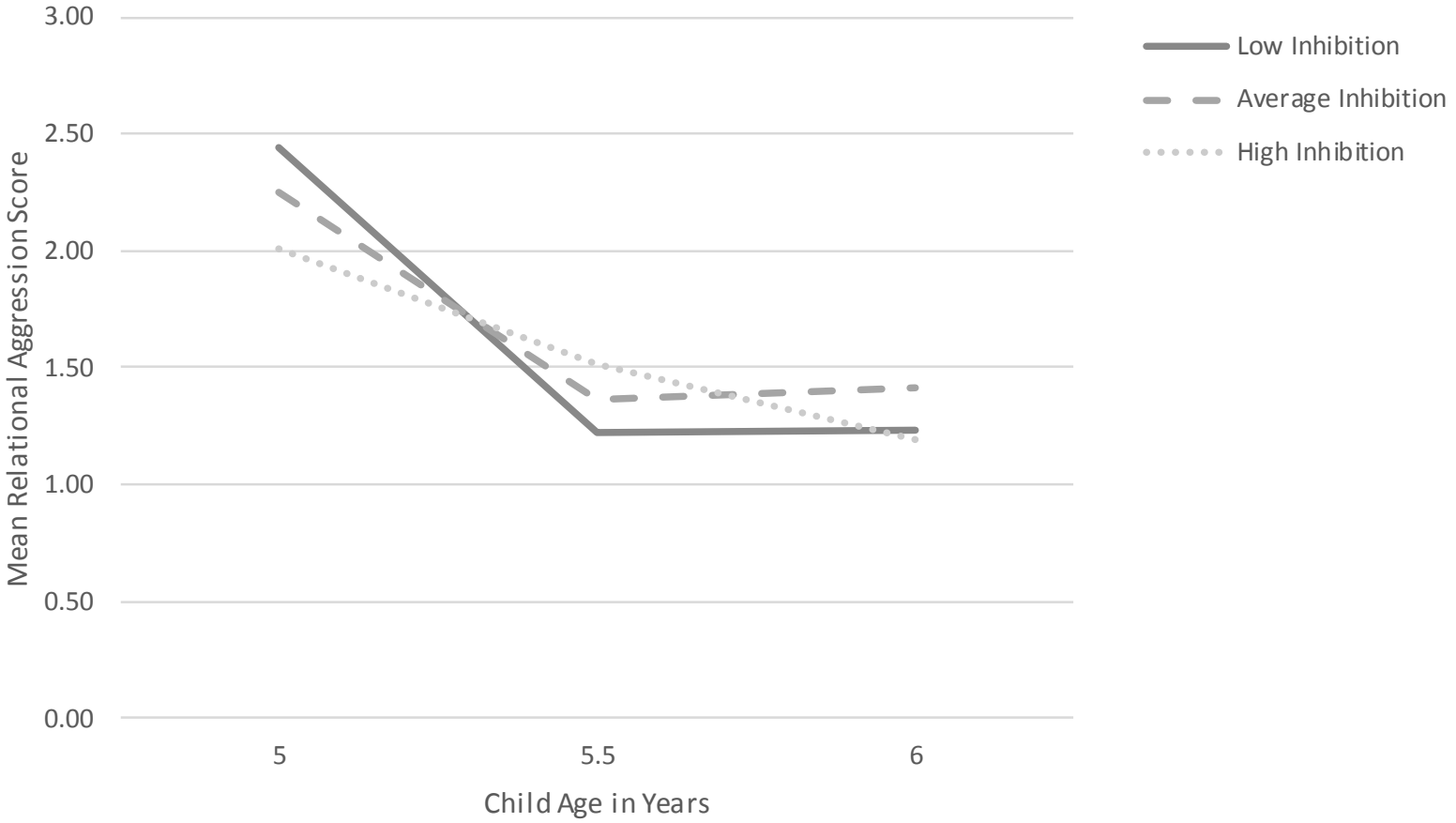

Figure 2. Mean relational aggression across time points for children categorised as low, average and high in inhibition

Discussion

This study examined the role of cool and hot EF skills in changes in physical and relational aggression between 5 and 6 years-old in order to increase understanding of individual differences in the development of aggression. The present research revealed three main findings: 1) Poorer cool inhibition at 5-years-old predicted higher physical and relational aggression between 5 and 6-years-old; 2) Planning at 5 years-old was negatively associated with relational aggression; 3) Gender was associated with physical aggression, with boys being higher in physical aggression compared to girls. The current study therefore indicated that early cool inhibition may be influence the development of subtypes of aggression between 5 and 6 years-old. Hot EF skills, in contrast, were not associated with the development of physical or relational aggression between 5 and 6 years-old.

In accordance with the findings of prior research (Alink et al., 2006; Nærde, Ogden, Janson, & Zachrisson, 2014), physical aggression to showed age related declines between 5- and 6-years-old. This decline in physical aggression may reflect the fact that during this age period most children learn to control their behaviour and regulate their anger, develop a theory of mind, and become empathic (e.g. Hoffman, 2000; Srouge, 1995; Wellman, 1992). As a result, children learn to respond in a socially acceptable way instead of acting aggressively. In addition, the exponential growth in children's language skills that takes place in early childhood may contribute to the decline in prevalence of physical aggression (Tsao, Liu, & Kuhl, 2004). Relational aggression also showed age related declines between 5- and 6-years-old, which may similarly reflect children's developing behavioural and emotional control (Hoffman, 2000; Housman, 2017). However, with children's developing understanding of the mind and language skills they may move from using direct relational aggression (as assessed in this study) to more indirect, covert relational aggression (Björkqvist et al., 1992).

Boys demonstrated higher physical aggression than girls. This is line with the extensive literature that has found that boys rely on physical aggression more than girls (Card, Stucky, Sawalani, & Little, 2008; Crick & Grotpeter, 1995; Hay et al., 2011; Lussier, Corrado, & Tzoumakis, 2012; Yuan et al., 2014). The present study, however, failed to find gender differences in relational aggression. However, a study of children 9- to 15-years-of-age found that gender difference in relational aggression are not apparent until around 10- to 11-years-of-age, with girls being rated as higher in relational aggression (Smith, Rose, & Schwartz-Mette, 2009). Thus, gender difference in physical aggression may be apparent earlier on than in relational aggression.

In line with prior studies (Poland et al., 2016; Utendale et al., 2011), cool inhibition at 5 years-old predicted physical aggression. Children with poor inhibition may be less able to regulate their impulsive behaviour, frustration and anger (V. Anderson et al., 2008) and as a result may be unable to withhold using a physically aggressive act. Added to this, poor cool planning at 5 years-old was associated with higher relational aggression, expanding prior research which has suggested planning is associated with social behaviour more broadly (Jacobson et al., 2011). When confronted with situation that provoke relational aggression, children with poor planning skills may be less able to generate non-aggressive strategies in their interactions with peers. Relational aggression in early childhood is typically much more direct in nature (Monks et al., 2003). This may be due to the fact indirect aggression is a more cognitively sophisticated form of aggression (Björkqvist et al., 1992). Children with particularly low planning ability may consequently rely on direct relational aggression to a greater extent and therefore this may be more noticeable to teachers.

This research extends prior studies which have highlighted the central role of inhibition(Poland et al., 2016a; Utendale et al., 2011). The current results suggest that inhibition at 5 years-old predicts changes in physical and relational aggression between 5 and

6 years-of-age. Children with low inhibition continued to show higher levels of physical aggression than children with high inhibition between 5 and 6 years-old, though this effect attenuated with time. This supports the view that early impulsive behaviour may influence the development of physically aggressive behaviour (Farrington, 2005). EF undergoes rapid development during early childhood (V. Anderson et al., 2008; Wellman et al., 2001), with inhibition being one of the first EF abilities that children reach proficiency in (Smidts, Jacobs, & Anderson, 2004; Tillman, Brocki, Sørensen, & Lundervold, 2015). This early development in inhibition may set the foundation for children's emerging aggressive behaviour. Poor inhibition may lead to limited or poor quality peer interactions, which serve to disrupt children's social skills development; reducing their repertoire of socially appropriate behaviours for use in interactions with their peers (Eisenberg et al., 1995). Indeed, children who were highly aggressive demonstrated externalising personality patterns across childhood and adulthood; that is, they reported more conflictual relationships with their mother and partners, underachieved academically and occupationally, and engaged in higher delinquency (Asendorpf, Denissen, & van Aken, 2008). Poor inhibition may therefore have a continued effect on social development through its impact on children's social interactions. Poor inhibition in early childhood may consequently represent a risk factor for poor social development and may be a prime target for early intervention.

Inhibition was also associated with changes in relation aggression. Children with low inhibition. Children with low inhibition showed higher relational aggression than children with high inhibition at 5 years-old, but showed a much steeper decline in physical aggression between 5 and 5.5 years-old. By 6 years-old there appeared to be little difference in relational aggression levels across low, average, and high inhibition groups. In typically developing children, EF may be more strongly related to relational aggression during the transition to school. With the transition to school (which occurs around 4-years-of-age in the UK) children

begin to interact with their peers and their verbal skills increase as well as their social understanding (Hughes, 2011), which may allow children to understand how to use aggression to manipulate relationships. Children who therefore have the necessary social understanding to use proactive aggression and lack the planning abilities to generate alternative strategies, or the impulse control to withhold aggression may consequently engage in higher proactive aggression. In early childhood, relational aggression is likely to be more direct and unsophisticated (e.g. telling a peer you won't play with them) (Crick et al., 1999) and may consequently be associated with negative consequences, such as punishment by teachers or peer rejection (McNeily, 1996 – Nelson). This may result in children who lack the inhibition to withhold aggression to switch to more indirectly aggressive behaviours as they gain the cognitive and verbal abilities to do so (Björkqvist et al., 1992). This hypothesis, though, needs to be further investigated.

The finding that inhibition predicts the development of aggression is in agreement with research conducted with adult samples. Research with adults has suggested that individuals with load inhibition are unable to inhibit aggression due to their failure to use inhibition feedback cue to regulate their behaviour (Hoaken et al., 1998). Consequently, it may be that individuals with poor inhibition, who demonstrate poor social information processing, and an inability to cope with overwhelming response options, fail to access more socially appropriate response options and instead make default aggressive responses. From a neuropsychological theoretical perspective, the inhibitory control model suggests that violence and aggression in frontally impaired patients results from to their inability to inhibit their aggressive impulses (Barratt, 1994; Séguin, 2009). In support of the inhibitory control model, there is evidence that individuals who engage in antisocial, aggressive, and criminal behaviour demonstrate impaired inhibition (Farrington, 2005). Further, more recently there has been a move in research focus to identifying the factors underlying the joint development of

neuropsychological function (such as impulsivity) and aggression (Séguin, 2009). This work has suggested that the link between physical aggression and hyperactivity problems and neuropsychological function can be identified early in childhood (Séguin & Zelazo, 2005). The present study indicates this may also be the case for relational aggression. Added to this, maternal prenatal smoking predicts both increased physical aggression and hyperactivity in young children (Huijbregts, Séguin, Zoccolillo, Boivin, & Tremblay, 2007). Poor inhibition and aggressive behaviour may therefore go hand in hand and this relationship may be evidence early on in a child's life.

In contrast to prior studies which have indicated hot EF is related to disruptive and aggressive behaviour (Garner & Waajid, 2012; Kim et al., 2014), hot EF skills at 5-years-old did not predict changes in physical or relational aggression between 5 and 6 years-old. The lack of a significant relation between hot EF and aggression may reflect the fact that the present study focused on early childhood, whereas previous research has focused on middle childhood to adolescence. EF skills follow varying trajectories of development, with inhibition being one of the first EF abilities that children reach proficiency in (Smidts, Jacobs, & Anderson, 2004; Tillman, Brocki, Sørensen, & Lundervold, 2015). Due to its early development inhibition may therefore influence aggression during early childhood. Hot EF has been posited to follow a more protracted developmental course than cool EF, with more marked changes occuring around 14- to 15-years-old (Prencipe et al., 2011). During early childhood, children show limited advancement in hot EF abilities (O'Toole, Monks, & Tsermentseli, 2017) and as a result hot skills have not been formed yet and therefore may not be related to aggression. Indeed, Willoughby et al. (2011) also failed to find an association between hot EF and aggression in young children. Hot EF may therefore play a more central role in aggression in later childhood and adolescence.

Limitations

This study made novel contributions to current understanding of the development of the different forms of aggression across early childhood. The findings of this study, though, should be considered in light of the following limitations. EF was assessed at 5-years-old only. EF undergoes rapid development during early childhood (V. Anderson et al., 2008) and therefore understanding the links between the developmental advances in EF skills and changes in aggression would further add to current understanding of the development of aggression. The relatively small sample size may have reduced the power of the models and as a result relations between some EF abilities and aggression may not have been detected. This research provides a first exploratory look at the role of early EF in the development of forms and aggression and findings therefore need to be corroborated with larger samples. Further, the fact EF was assessed at time one only and the sample size was relatively small meant that indirect and bidirectional relations between EF and aggressive subtypes could not be examined. Future studies that explore the relation between developmental trajectories of EF and aggression would therefore be beneficial. The study relied on Teacher reports of children's aggression. Lastly, the study included forms but not functions of aggression. The underlying cognitive factors of physical and relational aggression may vary depending on their function (Poland et al., 2016). However, as found in the present study, differentiating between functions of aggression is challenging. Research directed towards both developing methods of distinguishing between functions of aggression in young children as well as exploring the development of functions and forms of aggression is needed.

Conclusions and Directions for Future Research

This study suggests that early cool inhibition plays a central role in the development of both physical and relational aggression between 5 and 6 years-old, suggesting children’s

early inhibition may have a lasting influence on their social development. Targeting inhibition in interventions, especially during early childhood, at a time when there is particular growth in EF may be beneficial in reducing later aggressive behaviour. The present study included a relatively short follow-up period of one year. Future research examining the influence of early inhibition on aggression across a broader age range will therefore increase understanding of its underlying role in changes in aggression. The present study revealed that hot EF was not associated with the development of physical or relational aggression. There is much debate around whether distinct cool and hot EF domains are evident (O'Toole et al., 2017) and few assessments of hot EF skills are currently available. An important aim for research going forward is therefore to elucidate models of cool and hot EF and develop more developmentally-appropriate measures of hot EF to assess its links to behaviour. Studying the developmental trends of hot and cool EF and their longitudinal associations to other cognitive abilities, such as theory of mind, may aid in gaining a greater understanding of the link between cognition and behaviour in typical and atypical development.

References

Alink, L. R. a, Mesman, J., Van Zeijl, J., Stolk, M. N., Juffer, F., Koot, H. M., … Van Ijzendoorn, M. H. (2006). The early childhood aggression curve: Development of physical aggression in 10- To 50-month-old children. *Child Development*, *77*, 954–966. doi: 10.1111/j.1467-8624.2006.00912.x

Alloway, T. P., Gathercole, S. E., Kirkwood, H., & Elliott, J. (2008). Evaluating the validity of the Automated Working Memory Assessment. *Educational Psychology*, *28*, 725–734. doi: 10.1080/01443410802243828

Anderson, P. J. (2008). Towards a developmental model of executive function. In V. Anderson, R. Jacobs, & P. J. Anderson (Eds.), *Executive Functions and the Frontal Lobes: A Lifespan Perspective* (pp. 3–23). New York, USA: Psychology Press.

Anderson, V., Anderson, P. J., Jacobs, R., & Spencer-Smith, M. (2008). Development and assessment of executive function: From preschool to adolescence. In P. Anderson, Vicki; Jacobs, Rani; Anderson (Ed.), *Executive functions and the frontal lobes: A lifespan perspective* (pp. 123–155). New York, USA: Psychology Press.

Asendorpf, J. B., Denissen, J. J., & van Aken, M. A. (2008). Inhibited and aggressive preschool children at 23 years of age: personality and social transitions into adulthood. *Developmental psychology*, *44*, 997 - 1011. doi: 10.1037/0012-1649.44.4.997

Astington, J. W. (2003). Sometimes necessary, never sufficient: False-belief understanding and social competence. In B. Repacholi & V. Slaughter (Eds.), *Individual Differences in Theory of Mind: Implications for Typical and Atypical Development* (pp. 13–29). New York, USA: Psychology Press.

Barratt, E. S. (1994). Impulsiveness and aggression. In J. Monahan, & H. Steadman (Eds.), *Violence and mental disorder: Developments in risk assessment* (pp. 61–79). Chicago: University of Chicago Press.

Beauchamp, M. H., & Anderson, V. (2010). SOCIAL: an integrative framework for the development of social skills. *Psychological Bulletin*, *136*, 39–64. doi: 10.1037/a0017768

Björkqvist, K., Ősterman, K., & Kaukiainen, A. (1992). The development of direct and indirect aggressive strategies in males and females. In K. Björkqvist & P. Niemelä (Eds.), *Of Mice and Women: Aspects of Female Aggression* (pp. 51–64). San Diego, CA: Academic Press.

Blair, R. J. R. (2001). ADVANCES IN NEUROPSYCHIATRY: Neurocognitive models of aggression, the antisocial personality disorders, and psychopathy. Journal of Neurology, Neurosurgery & Psychiatry, 71(6), 727–731. doi:10.1136/jnnp.71.6.727

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology, 33*, 205–228. doi: 10.1080/87565640801982312

Bushman, B. J., & Anderson, C. A. (2001). Is it time to pull the plug on hostile versus instrumental aggression dichotomy? Psychological Review, 108(1), 273–279. doi:10.1037/0033-295x.108.1.273

Card, N. A., Stucky, B. D., Sawalani, G. M., & Little, T. D. (2008). Direct and indirect aggression during childhood and adolescence: A meta-analytic review of gender differences, intercorrelations , and relations to maladjustment. *Child Development, 79*, 1185–1229. doi: 10.1111/j.1467-8624.2008.01184.x

Crick, N. R., Casas, J. F., & Ku, H. C. (1999). Relational and physical forms of peer

victimization in preschool. *Developmental Psychology*, *35*, 376–385. doi: 10.1037/0012-1649.35.2.376

Crick, N. R., & Grotpeter, J. K. (1995). Relational aggression, gender, and social-psychological adjustment. *Child Development*, *66*, 710–722. doi: 10.1111/j.1467-8624.1995.tb00900.x.

Dane, A. V., & Marini, Z. A. (2014). Overt and relational forms of reactive aggression in adolescents: Relations with temperamental reactivity and self-regulation. *Personality and Individual Differences*, *60*, 60–66. doi: 10.1016/j.paid.2013.12.021

Di Norcia, A., Pecora, G., Bombi, A. S., Baumgartner, E., & Laghi, F. (2015). Hot and cool inhibitory control in Italian toddlers: Associations with social competence and behavioral problems. *Journal of Child and Family Studies*, *24*, 909–914. doi: 10.1007/s10826-014-9901-z

Dodge, K. A. (1991). The structure and function of reactive and proactive aggression. In D. J. Pepler & K. H. Rubin (Eds.), *The Development and Treatment of Childhood Aggression* (pp. 201–215). Hillsdale, New Jersey: Lawrence Erlbaum Associates Inc.

Dodge, K. A., & Coie, J. D. (1987). Social-information-processing factors in reactive and proactive aggression in children's peer groups. *Journal of Personality and Social Psychology*, *53*, 1146–1158. doi: 10.1037//0022-3514.53.6.1146

Dunn, L. M., Whetton, C., & Pintilie, D. (1982). *British Picture Vocabulary Scale*. Windsor, UK: NFER-Nelson.

Eisenberg, N., Fabes, R. A., Murphy, B. C., Maszk, P., Smith, M., & Karbon, M. (1995). The role of emotionality and regulation in children's social functioning: A longitudinal study. *Child Development*, *66*, 1360–1384. doi: 10.2307/1131652

Farrington, D. P. (2005). Childhood origins of antisocial behavior. Clinical Psychology & Psychotherapy, 12(3), 177–190. doi:10.1002/cpp.448

Garner, P. W., & Waajid, B. (2012). Emotion knowledge and self-regulation as predictors of preschoolers' cognitive ability, classroom behavior, and social competence. *Journal of Psychoeducational Assessment, 30*, 330–343. doi: 10.1177/0734282912449441

Goldstein, S. E., & Tisak, M. S. (2006). Early adolescents' conceptions of parental and friend authority over relational aggression. *The Journal of Early Adolescence*, *26*, 344–364. doi: 10.1177/0272431606288552

Goldstein, S., Naglieri, J. A., Princoptta, D., & Otero, T. M. (2014). Introduction: A history of executive functioning as a theoretical and clinical construct. In S. Goldstein & J. A. Naglieri (Eds.), *Handbook of Executive Functioning* (pp. 3–13). New York, USA: Springer.

Gray, S. A. O., Carter, A. S., Briggs-gowan, M. J., Jones, S. M., & Wagmiller, R. L. (2014). Growth trajectories of early aggression, overactivity, and inattention: Relations to second-grade reading. *Developmental Psychology*, *50*, 2255–2263. doi: 10.1037/a0037367

Grotpeter, J. K., & Crick, N. R. (1996). Relational aggression, overt aggression, and friendship. *Child Development, 67*, 2328–2338. doi: 10.2307/1131626

Hay, D. F., Nash, A., Caplan, M., Swartzentruber, J., Ishikawa, F., & Vespo, J. E. (2011). The emergence of gender differences in physical aggression in the context of conflict between young peers. *British Journal of Developmental Psychology*, *29*, 158–175. doi: 10.1111/j.2044-835X.2011.02028.x

Hoaken, P. N. S., Shaughnessy, V. K., & Pihl, R. O. (2003). Executive cognitive functioning and aggression: Is it an issue of impulsivity? Aggressive Behavior, 29(1), 15–30. doi:10.1002/ab.10023

Housman, D. K. (2017). The importance of emotional competence and self-regulation from birth: A case for the evidence-based emotional cognitive social early learning approach. *International Journal of Child Care and Education Policy*, *11*, 1 - 19. doi: 10.1186/s40723-017-0038-6

Huijbregts, S. C. J., Séguin, J. R., Zoccolillo, M., Boivin, M., & Tremblay, R. E (2007). Maternal prenatal smoking and externalizing behavior during early childhood: Are associations specific to hyperactivity, physical aggression or their co-occurrence? *Journal of Abnormal Child Psychologym*, 35:203– 215.

Hughes, C. (2011). *Social Understanding and Social lives: From Toddlerhood through to the Transition to School*. Hove, UK: Psychology Press.

Hughes, C., Dunn, J., & White, A. (1998). Trick or treat?: Uneven understanding of mind and emotion and executive dysfunction in " hard-to-manage" preschoolers. *Journal of Child Psychology and Psychiatry*, *39*, 981–994. doi: 10.1111/1469-7610.00401

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. doi: 10.1016/j.jecp.2010.06.005

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. doi: 10.1080/87565640903325691

Hughes, C., White, A., Sharpen, J., & Dunn, J. (2000). Antisocial, angry, and unsympathetic:

"hard-to-manage" preschoolers' peer problems and possible cognitive influences. *Journal of Child Psychology and Psychiatry*, *41*, 169–179. doi: 10.1017/S0021963099005193

Jacobson, L. A., Williford, A. P., & Pianta, R. C. (2011). The role of executive function in children's competent adjustment to middle school. *Child Neuropsychology*, *17*, 255–280. doi: 10.1080/09297049.2010.535654

Kerr, A., & Zelazo, P. D. (2004). Development of "hot" executive function: The children's gambling task. *Brain and Cognition*, *55*, 148–157. doi: 10.1016/S0278-2626(03)00275-6

Kim, S., Nordling, J. K., Yoon, J. E., Boldt, L. J., & Kochanska, G. (2014). Effortful control in "hot" and "cool" tasks differentially predicts children's behaviour problems and academic performance. *Journal of Abnormal Child Psychology*, *41*, 43–56. doi: 10.1007/s10802-012-9661-4

Kochanska, G., Murray, K., Jacques, T. Y., Koenig, A. L., & Vandegeest, K. A. (1996). Inhibitory control in young children and its role in emerging internalization. *Child Development*, *67*, 490–507. doi: 10.2307/1131828

Lagerspetz, K. M., Björkqvist, K. and Peltonen, T. (1988), Is indirect aggression typical of females? gender differences in aggressiveness in 11- to 12-year-old children. Aggr. Behav., 14: 403-414. doi:10.1002/1098-2337

Lussier, P., Corrado, R., & Tzoumakis, S. (2012). Gender differences in physical aggression and associated developmental correlates in a sample of Canadian preschoolers. *Behavioural Sciences and Law*, *30*, 643–671. doi: 10.1002/bsl.2035

Masten, A. S., Herbers, J. E., Desjardins, C. D., Cutuli, J. J., McCormick, C. M., Sapienza, J. K., … Zelazo, P. D. (2012). Executive function skills and school success in young

children experiencing homelessness. *Educational Researcher, 41*, 375–384. doi: 10.3102/0013189X12459883

McNeilly-Choque, M. K., Hart, C. H., Robinson, C. C., Nelson, L. J., & Olsen, S. F. (1996). Overt and Relational Aggression on the Playground: Correspondence Among Different Informants. Journal of Research in Childhood Education, 11(1), 47–67. doi:10.1080/02568549609594695

McQuade, J. D., Murray-Close, D., Shoulberg, E. K., & Hoza, B. (2013). Working memory and social functioning in children. *Journal of Experimental Child Psychology*, *115*, 422–435. doi: 10.1016/j.jecp.2013.03.002

Monks, C. P., Palermiti, A., Ortega, R., & Costabile, A. (2011). A cross-national comparison of aggressors, victims and defenders in preschools in England, Spain and Italy. *The Spanish Journal of Psychology*, *14*, 133–144. doi: 10.5209/rev

Monks, C. P., Smith, P. K., & Swettenham, J. (2003). Aggressors, victims, and defenders in preschool: Peer, self, and teacher reports. *Merrill-Palmer Quarterly*, *49*, 453–469. doi: 10.1353/mpq.2003.0024

Monks, C. P., Smith, P. K., & Swettenham, J. (2005). Psychological correlates of peer victimisation in preschool: Social cognitive skills, executive function and attachment profiles. *Aggressive Behavior*, *31*, 571–588. doi: 10.1002/ab.20099

Murray, J., Irving, B., Farrington, D. P., Colman, I., & Bloxsom, C. A. J. (2010). Very early predictors of conduct problems and crime: results from a national cohort study. Journal of Child Psychology and Psychiatry, 51, 1198–1207. doi:10.1111/j.1469-7610.2010.02287.x

Murray-Close, D., & Crick, N. R. (2006). Children's moral reasoning regarding physical and relational aggression. *The Journal of Early Adolescence*, *26*, 344–364. doi:

10.1177/0272431606288552

Nærde, A., Ogden, T., Janson, H., & Zachrisson, H. D. (2014). Normative development of physical aggression from 8 to 26 months. *Developmental Psychology, 50*, 1710–1720. doi: 10.1037/a0036324

Ostrov, J. M. (2006). Deception and subtypes of aggression during early childhood. Journal of Experimental Child Psychology, 93, 322–336. doi:10.1016/j.jecp.2005.10.004

Olson, S. L., Lopez-Duran, N., Lunkenheimer, E. S., Chang, H., & Sameroff, A. J. (2011). Individual differences in the development of early peer aggression: Integrating contributions of self-regulation, theory of mind, and parenting. *Development and Psychopathology*, *23*, 253–266. doi: 10.1017/S0954579410000775

Ostrov, J. M., & Crick, N. R. (2007). Forms and functions of aggression during early childhood: A short-term longitudinal study. *School Psychology Review*, *36*, 22–43. doi: 10.1007/s10802-007-9179-3

Ostrov, J. M., & Godleski, S. A. (2010). Toward an integrated gender-linked model of aggression subtypes in early and middle childhood. Psychological Review, 117, 233–242. doi:10.1037/a0018070

Ostrov, J. M., Murray-Close, D., Godleski, S. A., & Hart, E. J. (2013). Prospective associations between forms and functions of aggression and social and affective processes during early childhood. *Journal of Experimental Child Psychology*, *116*, 19–36. doi: 10.1016/j.jecp.2012.12.009

O'Toole, S. E., Monks, C. P., & Tsermentseli, S. (2017). Associations between and development of cool and hot executive functions across early childhood. *British Journal of Developmental Psychology,(2017).* doi: 10.1111/bjdp.12226.

Poland, S. E., Monks, C. P., & Tsermentseli, S. (2016). Cool and hot executive function as predictors of aggression in early childhood: Differentiating between the function and form of aggression. *British Journal of Developmental Psychology, 34*, 181–197. doi: 10.1111/bjdp.12122

Poulin, F., & Boivin, M. (2000). Reactive and proactive aggression: Evidence of a two-factor model. *Psychological Assessment, 12*, 115–122. doi: 10.1037//1040-3590.12.2.115

Prencipe, A., Kesek, A., Cohen, J., Lamm, C., Lewis, M. D., & Zelazo, P. D. (2011). Development of hot and cool executive function during the transition to adolescence. *Journal of Experimental Child Psychology*, *108*, 621–637. doi: 10.1016/j.jecp.2010.09.008

Séguin, J. R. (2009). The frontal lobe and aggression. *The European Journal of Developmental Psychology*, *6*(1), 100–119. http://doi.org/10.1080/17405620701669871

Séguin, J. R., & Zelazo, P. D. Executive function in early physical aggression. In: Tremblay RE, Hartup WW, Archer J, editors. *Developmental origins of aggression*. New York: Guilford Press; 2005. pp. 307–329.

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London, B, 298*, 199–209. doi: 10.1098/rstb.1982.0082.

Simpson, A., & Riggs, K. J. (2006). Conditions under which children experience inhibitory difficulty with a "'button-press'" go/no-go task. *Journal of Experimental Child Psychology*, *94*, 18–26. doi: 10.1016/j.jecp.2005.10.003

Smidts, D. P., Jacobs, R., & Anderson, V. (2004). The object classification task for children (OCTC): A measure of concept generation and mental flexibility in early childhood. *Development and Psychopathology*, *26*, 385–401. doi: 10.1207/s15326942dn2601_2

Smith, R. L., Rose, A. J., & Schwartz-Mette, R. A. (2009). Relational and overt aggression in

childhood and adolescence: Clarifying mean-level gender differences and associations with peer acceptance. *Social Development, 19,* 243–269. doi: 10.1111/j.1467-9507.2009.00541.x

Stuss, D. T., & Levine, B. (2002). Adult clinical neuropsychology: Lessons from studies of the frontal lobes. *Annual Review of Psychology, 53,* 401–433. doi: 10.1146/annurev.psych.53.100901.135220

Terranova, A. M., Morris, A. S., & Boxer, P. (2008). Fear reactivity and effortful control in overt and relational bullying: A six-month longitudinal study. *Aggressive Behavior, 34,* 104–115. doi: 10.1002/ab.20232

Tillman, C., Brocki, K. C., Sørensen, L., & Lundervold, A. J. (2015). A longitudinal examination of the developmental executive function hierarchy in children with externalizing behavior problems. *Journal of Attention Disorders, 19,* 496–506. doi: 10.1177/1087054713488439

Tremblay, R. E. (2000). The development of agressive behaviour during childhood: What have we learned in the past century? *International Journal of Behavioral Development, 24,* 129–141. doi: 10.1080/016502500383232

Tsao, F.-M., Liu, H.-M., & Kuhl, P. K. (2004). Speech Perception in Infancy Predicts Language Development in the Second Year of Life: A Longitudinal Study. Child Development, 75(4), 1067–1084. doi:10.1111/j.1467-8624.2004.00726.x

Tseng, W. L., & Gau, S. S. F. (2013). Executive function as a mediator in the link between attention-deficit/hyperactivity disorder and social problems. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 54,* 996–1004. doi: 10.1111/jcpp.12072

Utendale, W. T., Hubert, M., Saint-Pierre, A. B., & Hastings, P. D. (2011). Neurocognitive

development and externalizing problems: The role of inhibitory control deficits from 4 to 6 Years. *Aggressive Behavior*, *37*, 476–488. doi: 10.1002/ab.20403

Vaillancourt, T., Miller, J. L., Fagbemi, J., Côtè, S., & Tremblay, R. E. (2007). Trajectories and predictors of indirect aggression : Results from a nationally representative longitudinal study of Canadian children aged 2 – 10. *Aggressive Behavior*, *33*, 314–326. doi: 10.1002/ab

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children—Third Edition*. San Antonio, TX: Psychological Corporation.

Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory-of-mind development: The truth about false belief. *Child Development*, *72*, 655–684. doi: 10.1111/1467-8624.00304

White, B. A., Jarrett, M. A., & Ollendick, T. H. (2012). Self-regulation deficits explain the link between reactive aggression and internalizing and externalizing behavior problems in children. *Journal of Psychopathology and Behavioral Assessment*, *35*, 1–9. doi: 10.1007/s10862-012-9310-9

Willoughby, M., Kupersmidt, J., Voegler-Lee, M., & Bryant, D. (2011). Contributions of hot and cool self-regulation to preschool disruptive behavior and academic achievement. *Developmental Neuropsychology*, *36*, 162–180. doi: 10.1080/87565641.2010.549980

Yeates, K. O., Bigler, E. D., Dennis, M., Gerhardt, C. A., Rubin, K. H., Stancin, T., … Vannatta, K. (2007). Social outcomes in childhood brain disorder: A heuristic integration of social neuroscience and developmental psychology. *Psychological Bulletin*, *133*, 535–556. doi: 10.1037/0033-2909.133.3.535

Yuan, C., Shao, A., Chen, X., Xin, T., Wang, L., & Bian, Y. (2014). Developmental trajectory and gender differences in Chinese adolescents' physical and relational

aggression: An analysis using the latent class growth model. *Journal of Aggression, Conflict and Peace Research, 6*, 44–55. doi: 10.1108/JACPR-11-2012-0013

Zelazo, P. D., & Müller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Handbook of Childhood Cognitive Development* (pp. 445–470). Oxford: Blackwell Publising Ltd.

Zsolnai, A., Lesznyák, M., & Kasik, L. (2012). Pre-school children's aggressive and pro-social behaviours in stressful situations. *Early Child Development and Care*, *182*, 1503–1522. doi: 10.1080/03004430.2011.623779