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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*

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

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4 Models of social behaviour, derived from social neuroscience literature, have
5 suggested that executive function (EF) is fundamental to children's social development
6 (Beauchamp & V. Anderson, 2010; Yeates et al., 2007). EF refers to the higher-order, cognitive
7 skills required for goal-directed behaviour (Goldstein, Naglieri, Princtotta, & Otero,
8 2014). These higher-order cognitive functions are mediated by the pre-frontal cortex and
9 provide control and direction to lower-order brain functions (Stuss & Levine, 2002). In the
10 literature, a conceptual distinction is commonly made between “cool” and “hot” executive
11 functions (Zelazo & Müller, 2002). Cool EF is associated with the dorsolateral pre-frontal
12 cortex and includes cognitive processes such as inhibition, working memory, and planning,
13 which are involved in abstract, emotionally neutral problems. Hot executive functions are
14 mediated by the ventromedial and orbito-frontal cortices which support affective processes
15 (e.g. ability to delay gratification, affective decision making), which are tapped by emotion
16 laden problems (Zelazo & Müller, 2002). The view posed by social neuroscience models and
17 held by many researchers is that children with poor EF abilities may be less able to inhibit
18 maladaptive behaviours and adapt to novel social situations and as a result these children may
19 mismanage social interactions leading to peer-directed aggression (Anderson, 2008; Astington,
20 2003). Therefore a persisting question over the last decade has been whether subtle cognitive
21 problems in early EF precede aggression and contribute to its onset and development.

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

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

10 EF is not a unitary construct, and hence different aspects of EF domains might relate
11 to different types of aggression. In line with this, emerging evidence has indicated that poor EF
12 is associated with physical aggression, but not relational, aggression in children between 6- and
13 17-years-of-age (Dane & Marini, 2014; Terranova, Morris, & Boxer, 2008). However, a study
14 of 9- to 12-year-olds reported that poor EF was related to both physical and relational
15 aggression (McQuade, Murray-Close, Shoulberg, & Hoza, 2013), although, only one cool EF
16 skill, working memory, was considered. Although it has been hypothesised that social problem
17 solving is likely to occur in motivationally and emotionally significant environments and
18 consequently may require hot EF (Zelazo & Müller, 2002), research into the role of hot EF in
19 aggression has not been adequately investigated. The few studies that have been carried out
20 have found mixed results, with some finding a negative relation between hot delay of
21 gratification and aggression in 2- to 5-years-old children (Di Norcia et al., 2015; Garner &
22 Waajid, 2012; Kim, Nordling, Yoon, Boldt, & Kochanska, 2014), and other research failing to
23 find a relationship beyond that of cool EF in children 3- to 6-years-of-age (Willoughby,
24 Kupersmidt, Voegler-Lee, & Bryant, 2011). However, these studies did not consider subtypes
25 of aggression. One study that did look at the role of hot EF across forms of aggression, however,

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

4 Understanding of the development of subtypes of aggression is further limited by the
5 fact that the majority of previous research looking at the relation between EF and aggression
6 in typical children (e.g. Garner & Waajid, 2012; Hughes, White, Sharpen, & Dunn, 2000;
7 Willoughby, Kupersmidt, Voegler-Lee, & Bryant, 2011) has been carried out at one time point
8 and longitudinal associations were not assessed. The only prospective longitudinal study to
9 date, followed children from 3- to 6-years-of-age and revealed that children's cool and hot
10 inhibition significantly predicted children's concurrent, but not later aggression (Olson et al.,
11 2011). However, this study did not take into account the other EF sub-domains or forms of
12 aggression. Forms of aggression have been found to follow varying trajectories. Children's use
13 of physical aggression tends to decline with age and rates of relational aggression typically
14 increase across early to middle childhood (Björkqvist, Österman, & Kaukiainen, 1992; Gray,
15 Carter, Briggs-Gowan, Jones, & Wagmiller, 2014; Monks, Smith, & Swettenham, 2003).
16 Exploring specific cognitive predictors of the development of forms of aggression may
17 therefore increase understanding of the underlying mechanisms for these varied pathways.

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

1 advances, consistent with the ongoing development of the prefrontal cortex (P. Anderson,
2 2008; V. Anderson et al., 2008). Thus, early childhood represents a sensitive period in the
3 evaluation of individual differences in EF and their contribution to social development. EFs
4 are thought to be necessary for adequate social development and as a result disruptions in early
5 EF development may influence the emergence and expression of social behaviours across
6 childhood (Beauchamp & V. Anderson, 2010). Deficits in children's EF have been found to
7 disrupt children's social skills development; reducing their repertoire of socially appropriate
8 behaviours for use in interactions with their peers (Eisenberg et al., 1995) and affecting their
9 standing with peers (Tseng & Gau, 2013). Poor EF abilities in early childhood may therefore
10 disrupt children's social development and have a lasting influence on social behaviour, such as
11 aggression, across childhood.

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

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

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

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1 **Method**

2 **Participants**

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

21 **Measures**

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

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

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

15 Children's planning skills were measured using the Tower of London (ToL) (Shallice,
16 1982). Children first completed two 2-move practice problems, before completing 12 test
17 problems ranging from 2- to 5-moves (Shallice, 1982). Each trial lasted a maximum of two
18 minutes and up to two attempts at each problem was allowed (Hughes, Dunn, & White, 1998;
19 Monks et al., 2005). The task ceased after the child completed the problem set or failed two
20 consecutive problems. Children were awarded 2 points if they completed the problem on the
21 first trial, 1 point if they took two attempts and 0 points if they failed to complete the problem
22 in two trials. Potential scores ranged from 0 to 24.

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

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

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

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

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

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

9 Teacher and teaching assistant scores were averaged to provide an overview of
10 children's aggression inside and outside the classroom and children had different informants
11 and a varying number of informants. Teacher and teaching assistant ratings were significantly
12 and positively correlations between these informants indicating adequate agreement
13 (correlations based on sample of 106 children: proactive physical aggression, $r = .51, p = <.001$;
14 reactive physical aggression, $r = .67, p = <.001$; proactive relational aggression, $r = .42, p =$
15 $<.001$; reactive relational aggression, $r = .39, p = <.001$). The PPRA has been found to have
16 good internal consistency (proactive physical aggression, $\alpha = .88$; reactive physical aggression,
17 $\alpha = .92$; proactive relational aggression, $\alpha = .88$; reactive relational aggression, $\alpha = .82$; Ostrov
18 & Crick, 2007). However, in the current study functions of aggression were positively and
19 significantly correlated (proactive and reactive physical aggression, $r = .90, p = <.001$;
20 proactive and reactive relational aggression, $r = .95, p = <.001$), indicating that in the present
21 sample the measure was not able to adequately distinguish between functions of aggression.
22 The scales were therefore collapsed into physical and relational forms of aggression in the
23 present study.

24

1 **Procedure**

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

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Results

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

1 skills were included to test for the effect of EF skills on changes in aggression over time.

2 Hierarchical modelling was implemented with SPSS MIXED MODELS, Version 24.

3

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

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

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

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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	-	-.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, * $p < .05$, ** $p < .01$, *** $p < .001$

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

8 ***Physical aggression:*** Time was associated with physical aggression, indicating
9 reductions in physical aggression between 5 and 6 years-of-age ($B=-1.45$, 95% CI: -2.26, -0.72;
10 $t(df) = -3.82 (155)$; $p < 0.001$). Gender was associated with physical aggression, with boys
11 being more physically aggressive than girls ($B=0.79$, 95% CI: 0.22, 1.36; $t(df) = 2.77 (79)$; p
12 $= 0.007$); however, age and verbal ability were not significantly associated with physical
13 aggression. Neither planning nor delay gratification were significant predictors of physical
14 aggression, and did not moderate the effect of time on the development of physical aggression.
15 Inhibitory control significantly predicted lower physical aggression ($B=-3.65$, 95% CI: -6.06,
16 -1.23; $t(df) = -2.98 (223)$; $p = 0.003$) and the interaction between time and inhibitory control
17 was significant ($B=1.64$, 95% CI: 0.62, 2.65; $t(df) = 3.18 (157)$; $p = 0.002$).

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

1 **Relational aggression:** Time was associated with relational aggression, indicating
2 reductions in relational aggression between 5 and 6 years of age ($B=-1.77$, 95% CI: -2.59, -
3 0.96; $t(df) = -4.30$ (151); $p < 0.001$). Neither gender, age, verbal ability, working memory nor
4 inhibitory control were significantly associated with relational aggression. Planning did predict
5 lower relational aggression ($B=-0.12$, 95% CI: -0.24, -0.01; $t(df) = -2.13$ (233); $p = 0.03$) but
6 did not predict changes in relational aggression over time. The interaction between time and
7 inhibitory control was significant ($B=0.99$, 95% CI: 0.01, 1.96; $t(df) = 2.00$ (151); $p = 0.047$).
8 To explore this interaction the relationship between inhibition and relational aggression was
9 plotted over time (see Figure 2). The figure indicates that similar to physical aggression,
10 inhibition appears to have a greater effect on relational aggression at 5 years-old than at 6 years-
11 old. At 5 years-old children with low inhibition demonstrated higher relational aggression than
12 children with high inhibition, but at 6 years-old low and high inhibition groups had similar
13 levels of relational aggression.

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

	Physical aggression				Relational aggression			
	<i>B (SE)</i>	<i>95% CIs</i>	<i>t (df)</i>	<i>p</i>	<i>B (SE)</i>	<i>95% CIs</i>	<i>t (df)</i>	<i>p</i>
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.

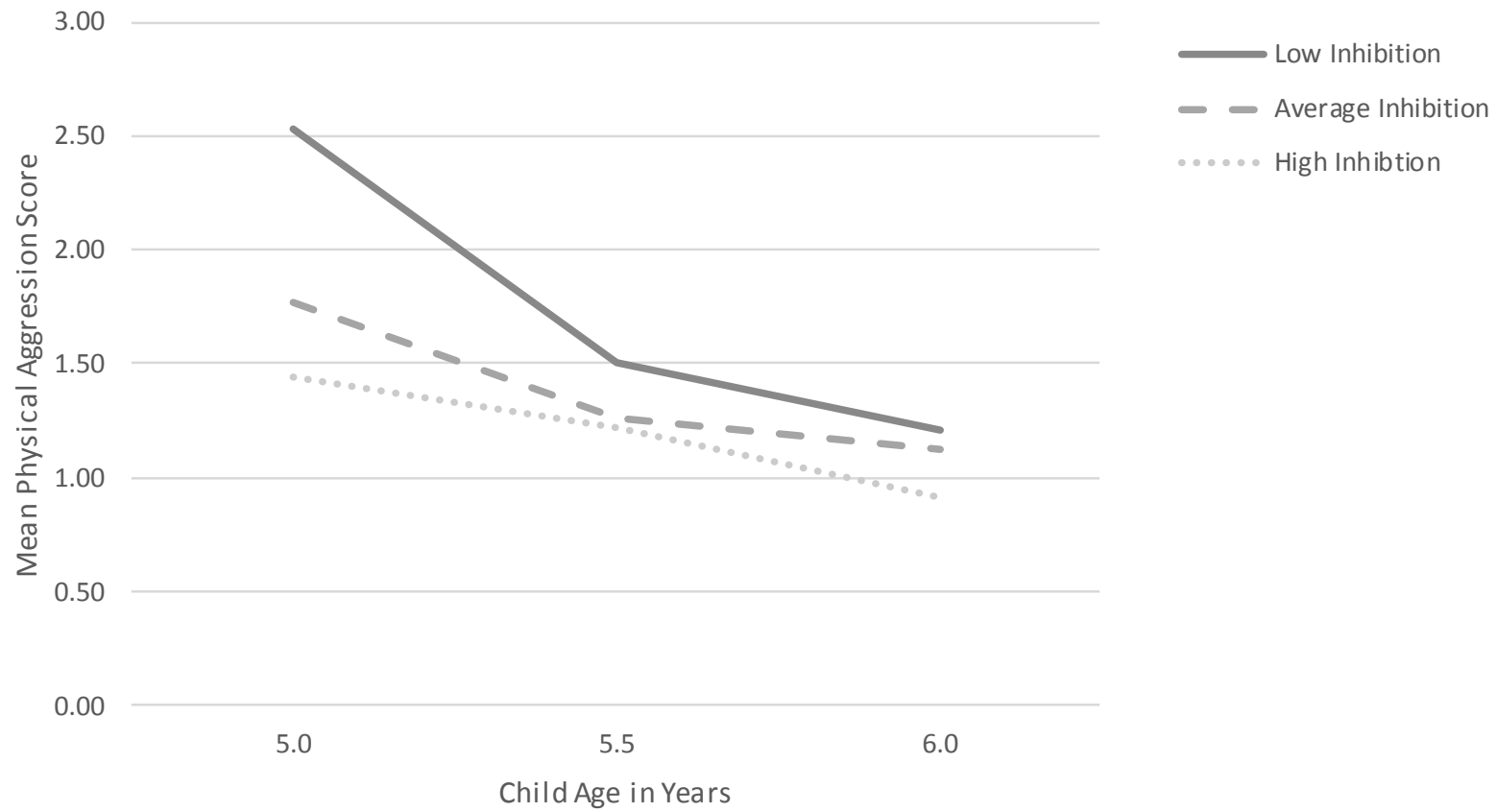


Figure 1. Mean physical aggression across time points for children categorised as low, average and high in inhibition

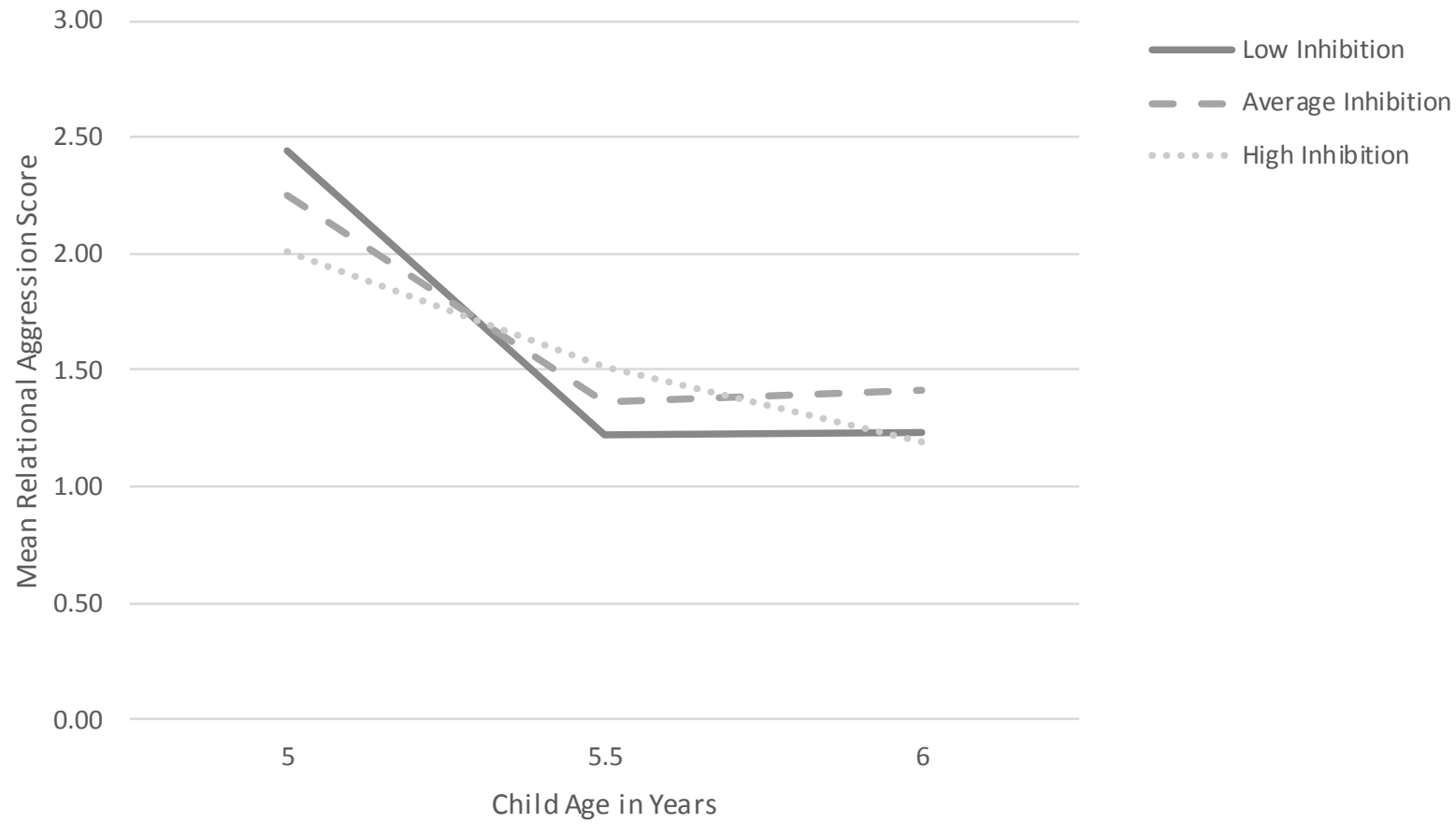


Figure 2. Mean relational aggression across time points for children categorised as low, average and high in inhibition

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Discussion

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

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

1 Boys demonstrated higher physical aggression than girls. This is line with the
2 extensive literature that has found that boys rely on physical aggression more than girls (Card,
3 Stucky, Sawalani, & Little, 2008; Crick & Grotpeter, 1995; Hay et al., 2011; Lussier, Corrado,
4 & Tzoumakis, 2012; Yuan et al., 2014). The present study, however, failed to find gender
5 differences in relational aggression. However, a study of children 9- to 15-years-of-age found
6 that gender difference in relational aggression are not apparent until around 10- to 11-years-of-
7 age, with girls being rated as higher in relational aggression (Smith, Rose, & Schwartz-Mette,
8 2009). Thus, gender difference in physical aggression may be apparent earlier on than in
9 relational aggression.

10 In line with prior studies (Poland et al., 2016; Utendale et al., 2011), cool inhibition at
11 5 years-old predicted physical aggression. Children with poor inhibition may be less able to
12 regulate their impulsive behaviour, frustration and anger (V. Anderson et al., 2008) and as a
13 result may be unable to withhold using a physically aggressive act. Added to this, poor cool
14 planning at 5 years-old was associated with higher relational aggression, expanding prior
15 research which has suggested planning is associated with social behaviour more broadly
16 (Jacobson et al., 2011). When confronted with situation that provoke relational aggression,
17 children with poor planning skills may be less able to generate non-aggressive strategies in
18 their interactions with peers. Relational aggression in early childhood is typically much more
19 direct in nature (Monks et al., 2003). This may be due to the fact indirect aggression is a more
20 cognitively sophisticated form of aggression (Björkqvist et al., 1992). Children with
21 particularly low planning ability may consequently rely on direct relational aggression to a
22 greater extent and therefore this may be more noticeable to teachers.

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

1 6 years-of-age. Children with low inhibition continued to show higher levels of physical
2 aggression than children with high inhibition between 5 and 6 years-old, though this effect
3 attenuated with time. This supports the view that early impulsive behaviour may influence the
4 development of physically aggressive behaviour (Farrington, 2005). EF undergoes rapid
5 development during early childhood (V. Anderson et al., 2008; Wellman et al., 2001), with
6 inhibition being one of the first EF abilities that children reach proficiency in (Smidts, Jacobs,
7 & Anderson, 2004; Tillman, Brocki, Sørensen, & Lundervold, 2015). This early development
8 in inhibition may set the foundation for children's emerging aggressive behaviour. Poor
9 inhibition may lead to limited or poor quality peer interactions, which serve to disrupt
10 children's social skills development; reducing their repertoire of socially appropriate
11 behaviours for use in interactions with their peers (Eisenberg et al., 1995). Indeed, children
12 who were highly aggressive demonstrated externalising personality patterns across childhood
13 and adulthood; that is, they reported more conflictual relationships with their mother and
14 partners, underachieved academically and occupationally, and engaged in higher delinquency
15 (Asendorpf, Denissen, & van Aken, 2008). Poor inhibition may therefore have a continued
16 effect on social development through its impact on children's social interactions. Poor
17 inhibition in early childhood may consequently represent a risk factor for poor social
18 development and may be a prime target for early intervention.

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

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

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

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

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

1 **Limitations**

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

22 **Conclusions and Directions for Future Research**

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

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

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