The association of infant crying, feeding and sleeping problems and inhibitory control with attention regulation at school-age

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Abstract

Regulatory problems in infancy and toddlerhood have previously been associated with an increased risk of developing attention problems in childhood. We hypothesized that early regulatory problems are associated with attention problems via reduced inhibitory control. This prospective study assessed 1,459 children from birth to 8 years. Crying, feeding and sleeping problems were assessed at 5 and 20 months via parent interviews and neurological examinations. At 20 months, inhibitory control was tested with a behavioral (snack delay) task. Attention regulation was assessed at 6 and 8 years using multiple instruments and informants. Detrimental effects of crying, feeding and sleeping problems on attention regulation were partly mediated by children's ability to inhibit unwanted behaviors (β=-0.04, p=.013). Accounting for cognition diminished this indirect effect (β=-0.01, p=.209). Instead, the effects of crying, feeding and sleeping problems on attention regulation were fully mediated by children's cognitive functioning (β=-0.10, p<.001). These results support that inhibitory control abilities partly mediate effects of crying, feeding and sleeping problems. However, these effects may be accounted for by children's general cognitive abilities. Early regulatory problems may set infants on a course of under control of behavior into school age, and such trajectories are highly associated with general cognitive development.

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In order to survive and adapt to the world outside the womb, the newborn is faced with multiple regulatory tasks. Early regulation of arousal and physiological states are important for the infant to be able to respond and adapt to external stimuli or demands from the environment. Infants have to accommodate and master sensory information from their surroundings and process internal sensations they receive from their body systems (Cesari et al., 2003; Degangi, Dipietro, Greenspan, & Porges, 1991; Johnson, 2013). Overall, during infancy and early childhood, children learn to regulate their behavior including physiological, sensory, motor, attentional, and emotional processes (Berger, Kofman, Livneh, & Henik, 2007). This process of early self-regulation combined with children's individual differences is an important aspect for the development of social behavior and cognition in later childhood (Kochanska, Murray, & Harlan, 2000; Olson, Bates, Sandy, & Schilling, 2002) and may even affect outcomes and success later in life (Althoff, Verhulst, Rettew, Hudziak, & van der Ende, 2010; Murray, Theakston, & Wells, 2016).

The regulation of crying, feeding and sleeping, also termed 'state regulation', plays a fundamental role in children's survival and early development (Berger et al., 2007; Schmid, Schreier, Meyer, & Wolke, 2010). During the first months of life infants need to adapt to the postnatal environment, ingest food and nutrition to grow and gain weight (within the first 3 to 6 months infants double their weight and triple it by the end of the first year of life), and learn to balance their sleep-wake-cycle and to self-sooth in response to arousal or stimulation. Infant crying, feeding and sleeping are intricate processes within the system of state regulation that is enabled and supported by the caregiver through dyadic interaction. For example, crying is a form of early verbal communication and signals the caregiver to sooth or feed the infant. Through soothing and feeding, a reciprocal relationship between infant and caregiver is facilitated (Bourvis et al., 2018; Feldman, 2015). Problems with crying, feeding and sleeping often cease with increasing age, i.e., maturity. However, if infants fail to achieve self-regulation of these behaviors, disturbances of crying, feeding or sleeping may persist or develop. These are often expressed by difficulties to stop crying or self-soothe, overcome neophobia to new food, or settle back to sleep (Popp et al., 2016). This means, infants do not cry or wake more frequently but they remain distressed for longer periods of time, i.e. are unable to regulate back to their equilibrium (Papoušek, Schieche, & Wurmser, 2007; St James-Roberts, 2012). Crying, feeding and sleeping problems are a common concern for parents, and as a result they frequently contact and seek help from health services (Hemmi, Wolke, & Schneider, 2011; Schmid et al., 2010). Although past research has often looked at crying, feeding or sleeping problems separately, there is evidence that these adaptation and maturational processes not only co-occur frequently but are interlinked (Gurevitz, Geva, Varon, & Leitner, 2014; Schmid et al., 2010; Wolke, 2003).

Crying, feeding and sleeping problems are characterized by difficulties of the infant to regulate or inhibit ongoing behavior. The Diagnostic Classification of Mental Health and Developmental Disorders of Infancy and Early Childhood (Zero to Three: National Center for Infants, 2005, 2016) describes infant and toddler behavior problems that relate to crying, feeding or sleeping problems as regulatory disorders. Regulatory disorders are defined as distinct behaviors that include difficulties with sensory, sensory-motor or organizational processing. These difficulties may manifest as fussiness, irritability or crying, eating problems, and poor regulation of sleep-wake cycles. According to guidelines of the German Association for Child and Youth Psychiatry (Deutsche Gesellschaft für Kinder- und Jugendpsychiatrie, 2015), symptoms of regulatory disorders include crying, feeding and sleeping difficulties, separation anxieties, temper tantrums and oppositional behavior. Indicators of persistent problems are if excessive crying persists beyond 3 months of age, food is refused, there are problems with sucking or swallowing, or neophobia to new food (which often occurs when infants are introduced to solid food), and problems with initiating and/or maintaining sleep.

Due to the lack of a standardized definitions and different assessment methods across studies, prevalence rates of infant crying, feeding and sleeping problems vary widely. Excessive crying persisting beyond 3 months of age has been reported in 6 to 13% of infants (Santos, Matijasevich, Capilheira, Anselmi, & Barros, 2015; Schmid et al., 2010; von Kries, Kalies, & Papousek, 2006; Wake et al., 2006). The prevalence of feeding and eating problems has been reported in 10 to 50% of children (Bilgin & Wolke, 2017a; Schmid et al., 2010; Wright, Parkinson, Shipton, & Drewett, 2007). Reports of prevalence rates of sleeping problems vary between 9 and 21% (Sadeh, Gruber, & Raviv, 2002; Schmid et al., 2010; Wake et al., 2006). The prevalence rate of multiple crying, feeding and sleeping problems varies between 2 and 17% (Wolke, Schmid, Schreier, & Meyer, 2009). Approximately 20% of infants are affected by crying, feeding or sleeping problems during the first year of life (Hemmi et al., 2011).

Most infants have crying, feeding or sleeping problems that are mild or transient and decrease with age without displaying any detrimental long-term behavioral consequences (DeGangi, Breinbauer, Roosevelt, Porges, & Greenspan, 2000; Wake et al., 2006). However, there is evidence that sleeping problems in infancy and toddlerhood are associated with self-regulation difficulties such as attention regulation and executive functioning (Bernier, Carlson, Bordeleau, & Carrier, 2010; Sadeh et al., 2015). Further, excessive crying persisting beyond 3 months of age and problems with feeding and sleeping in infancy have been associated with the development of behavior problems in childhood (Gurevitz et al., 2014; Hemmi et al., 2011; Hyde, O'Callaghan, Bor, Williams, & Najman, 2012; Korja et al., 2014; Sadeh et al., 2015; Santos et al., 2015; Schmid et al., 2010; Sivertsen et al., 2015; Williams & Sciberras, 2016), adolescence and into adulthood (Sadeh, Tikotzky, & Kahn, 2014). This relationship may be strongest in those children who have multiple crying, feeding and sleeping problems (Hemmi et al., 2011; Schmid et al., 2010; Wake et al., 2006; Winsper & Wolke, 2014). Furthermore, multiple crying, feeding and sleeping problems are moderately persistent across infancy into childhood (Bilgin & Wolke, 2016; Schmid et al., 2010; von Kries et al., 2006). Recent evidence suggests that multiple or persistent crying, feeding and sleeping problems are associated with a trajectory of attention problems from childhood to adulthood (Bilgin et al., 2018).

To conceptualize these developmental associations, a cascade model has been suggested in which early dysregulation, including persistent crying, feeding and sleeping problems, may represent the starting point of a developmental trajectory of dysregulation (Althoff et al., 2010; Holtmann et al., 2011; Sadeh et al., 2014; Schmid & Wolke, 2014; Winsper & Wolke, 2014). Accordingly, recent studies found that multiple crying, feeding and sleeping problems during infancy are associated with neurodevelopmental vulnerability, e. g. premature birth (Bilgin & Wolke, 2017b) and that this vulnerability may be characterized by persistent deficits (Reveillon, Huppi, & Barisnikov, 2017). Others have suggested that neurodevelopmental causes of dysregulation may have common genetic origins (Pettersson, Anckarsater, Gillberg, & Lichtenstein, 2013), but specific phenotypic trajectories have not been investigated.

Multiple or persistent crying, feeding and sleeping problems have been consistently found to be associated with attention problems in childhood up to the age of 10 years (Hemmi et al., 2011; Hyde et al., 2012; Schmid & Wolke, 2014; Wolke, Rizzo, & Woods, 2002). This association can be explained by similar attributes and risk factors. Similar to crying, feeding and sleeping problems, children who have attention problems have difficulties to inhibit stimuli and to regulate their attention in order to focus on a task at hand. Further, both crying, feeding and sleeping problems and attention problems are associated with the same environmental risk factors, such as family adversity and psychosocial stress (Gurevitz et al., 2014; Park et al., 2014; Schmid, Schreier, Meyer, & Wolke, 2011; Thunstrom, 2002). However, previous studies often had short follow-up periods, small sample sizes, or were retrospective in design (Becker, Holtmann, Laucht, & Schmidt, 2004; DeGangi et al., 2000; Desantis, Coster, Bigsby, & Lester, 2004; Neu & Robinson, 2003; O'Callaghan et al., 2010; Rao, Brenner, Schisterman, Vik, & Mills, 2004; Thunstrom, 2002), or only included parent-reported measures of behavior problems (Neu & Robinson, 2003; O'Callaghan et al., 2010; Thunstrom, 2002), which may be biased due to continued perception of the child as "difficult".

As children enter toddlerhood, they learn to be more autonomous and self-aware and to respond to external demands and requests to control their actions. Accordingly, self-regulation processes that demand emotional and cognitive control, such as inhibitory control, the ability to delay immediate gratification and inhibit impulsive responses, emerges in the second year of life (Kim, Nordling, Yoon, Boldt, & Kochanska, 2013; Kochanska, Coy, & Murray, 2001). Similar to infants with multiple crying, feeding and sleeping problems who have difficulties to inhibit an ongoing behavior, some children struggle to resist or delay an immediate impulse or desire. Inhibitory control abilities, often labelled 'delaying' (Kochanska et al., 2000), are subsumed under the construct 'effortful control' that is related to child temperament. Besides inhibitory control, effortful control includes skills such as motor inhibition, suppressing and initiating an activity when asked to and effortful attention (Kim et al., 2013; Kochanska et al., 2001; Poehlmann et al., 2010). Inhibitory control is associated with attentional control (Rothbart, Ahadi, & Evans, 2000) and an important precursor for the development of social competence and academic achievement (Casey et al., 2011; Mischel, Shoda, & Rodriguez, 1989; Moffitt et al., 2011; Olson et al., 2002), independent of general cognitive ability and socioeconomic status (Duckworth & Seligman, 2005; Freeney & O'Connell, 2010; Mischel et al., 2011).

Overall, self-regulation, including crying, feeding and sleeping problems, and inhibitory control in infancy and toddlerhood have been identified as precursors of impulsivity and inattention which in turn may lead to more severe problems such as attention deficit hyperactivity disorder (ADHD), conduct disorder, learning difficulties, and social exclusion (Campbell & von Stauffenberg, 2009; Olson et al., 2002; Sullivan et al., 2015). These associations have also been found in neurologically at-risk populations, i.e. preterm children, with inhibitory control predicting ADHD symptoms in childhood (Jaekel, Eryigit-Madzwamuse, & Wolke, 2016; Poehlmann-Tynan et al., 2015; Reveillon, Tolsa, Monnier, Huppi, & Barisnikov, 2016; Witt et al., 2014) and preadolescence (Reveillon et al., 2016). Accordingly, studies investigating the association between early self-regulation and later attention difficulties need to also control for effects of prematurity.

Thus, both naturally occurring difficulties with crying, feeding or sleeping assessed by observational studies and experimental tasks that assess inhibitory control predict later attention problems. However, it has not yet been investigated whether early crying, feeding and sleeping problems that indicate difficulties to inhibit an ongoing behavior may be directly associated with inhibitory control and whether this (in)ability to inhibit unwanted behaviors may be mediating the pathway from early crying, feeding and sleeping problems to attention regulation in childhood. This novel approach could confirm the notion of a cascade model of development which proposes that instead of one cluster of difficulties (i.e., early crying, feeding, and sleeping problems) directly predicting later outcomes (i.e. attention problems), these earlier difficulties may increase the likelihood of related constructs that require self-regulation, initiating a cascade of under-regulation affecting a later outcome (Bornstein, Hahn, & Wolke, 2013; Campbell & von Stauffenberg, 2009). Thus, early crying, feeding and sleeping problems may only represent a starting point of a developmental cascade of dysregulation that affects later attention. Such a model also implies that this developmental cascade may be identified, addressed and interrupted successfully by early intervention.

Given the ongoing debate whether attention is related to specific cognitive processes or rather to general cognitive function (Dennis et al., 2009; Gurevitz et al., 2014; Retzler et al., 2018; Thapar & Cooper, 2016), studies should take into account both concepts to help disentangle and clarify these associations.

The current large prospective longitudinal study assessed crying, feeding and sleeping problems at 5 and 20 months, children's inhibitory control abilities and cognition at 20 months, and attention regulation at 6 and 8 years. This made it possible to test a cascade model of dysregulation from early crying, feeding and sleeping problems to attention regulation via inhibitory control and general cognitive function abilities in early childhood.

We hypothesized that inhibitory control would mediate the association of multiple and/or persistent crying, feeding and sleeping problems with attention problems at school age. Further, we hypothesized that accounting for general cognitive abilities as a broader concept of cognitive function would diminish the effects of children's inhibitory control abilities. Instead, the association between crying, feeding and sleeping problems and later attention regulation may be mediated by children's general cognitive abilities.

METHODS

Design and Participants

Data were collected as part of the prospective Bavarian Longitudinal Study (BLS). The BLS is a geographically defined, whole population sample of neonatal at-risk children born in Southern Bavaria, Germany, between January 1985 and March 1986 who required admission to a children's hospital within the first 10 days after birth (*N*=7,505, 10.6% of all live births). In addition, 916 healthy infants born at term in the same obstetric hospitals were recruited as controls. Parents were approached within 48 hours of the infant's hospital admission and asked to participate.

The present study utilizes data collected from birth to 8 years. After the first phase of the study (birth to 56 months) the decision was made to reduce the sample to allow for more intensive psychological and neurological assessments while preserving sufficient statistical power. From the initial sample, 1,152 children hospitalized after birth (23-43 weeks gestational age (GA); survivors born <32 weeks GA and/or <1,500g birth weight and a subsample of children born >31 weeks GA (randomly drawn within the stratification factors child sex, socioeconomic background and degree of neonatal risk) and 343 healthy control children (*mean* GA 39.5, *SD*=1.41) who were assessed at corrected age 5 and 20 months were selected for assessment at age 6 and 8 years (*N*=1,495). Sampling criteria and dropout rates are provided elsewhere (Eryigit-Madzwamuse & Wolke, 2015; Jaekel, Baumann, & Wolke, 2013; Schmid & Wolke, 2014; Wolke & Meyer, 1999). The sample was further reduced due to missing data on crying, feeding and sleeping problems (*N*=36). Details of the final sample (*N*=1,459) are shown in Table 1.

At age 6 and 8 years, participating children and their parents were assessed by an interdisciplinary team for an entire day including neurological assessments (conducted by pediatricians), parent interviews (conducted by psychologists), cognitive assessments, and observations of behavior (administered by psychological assistants and the whole research team). All assessors were blind to children's characteristics and results of previous assessments. The present study was conducted according to guidelines laid down in the Declaration of Helsinki, with written informed consent obtained from a parent or guardian for each child before any assessment or data collection. All procedures involving human subjects in this study were approved by the ethics committee of the University of Munich Children's Hospital and the Bavarian Health Council (Landesärztekammer Bayern).

Measures

Multiple or persistent crying, feeding and sleeping problems from 5 to 20 months

As part of a neurodevelopmental assessment, pediatricians asked parents via a standardized interview about their child's crying, feeding and sleeping problems at age 5 months. At 20 months, sleeping and eating problems were assessed via standardized parental interview and results of a neurological examination of oral motor function both conducted by pediatricians. Pediatricians had been trained to achieve an inter-rater reliability > 90% and received three-monthly booster workshops in order to maintain reliability across the data collection period. Assessments at 5 (±0.41SD) and 20 (±0.41SD) months were carried out corrected for prematurity. The definitions for crying, feeding and sleeping problems at 5 months and sleeping and eating problems at 20 months are given in Supplementary Table 1 (Riegel, Ohrt, Wolke, & Österlund, 1995; Schmid et al., 2010).

Children with multiple crying, feeding and sleeping problems were those who had at least two problems at 5 or 20 months (N=81 (5.6%) and N=44 (3.0%), respectively). Persistent crying, feeding and sleeping problems were defined as having at least one problem at 5 and at 20 months of age (N=189 (13.0%)).

Subsequently, multiple and/or persistent crying, feeding and sleeping problems were combined and coded into a binary variable: 0 = no or single crying, feeding and sleeping problems (82.9%) versus 1 = multiple or persistent crying, feeding and sleeping problems (N=249 (17.1%)).

Inhibitory control at 20 months

Children's inhibitory control was measured with a standardized behavioral observation task (i.e., a snack delay task) at corrected age 20 months. The toddlers were presented with a raisin placed under a cup and asked to wait 60 seconds before touching and eating the raisin (Jaekel et al., 2016). The time until the toddlers touched the raisin was coded into two categories of inhibitory control ability: 0 = did not wait or waited up to 10 seconds (62.2%) and 1 = waited >10 seconds (37.8%). This categorization was chosen because the cut-off denoted a meaningful differentiation of emerging inhibitory control behavior, i.e. no waiting versus intermediate to excellent inhibitory control.

Cognitive function at 20 months

Children's cognitive function was assessed with the Griffiths Mental Development Scale (GMDS) (Brandt, 1983; Griffiths, 1979). The GMDS is a standardized developmental test and assesses five areas of development: locomotor, personal social development, hearing and speech, eye and hand coordination, and performance. A total developmental quotient, encompassing all five areas of development was computed according to German norms (Brandt, 1983). The GMDS has demonstrated satisfactory reliability and good construct validity across different studies and cultures (Luiz, Foxcroft, & Stewart, 2001).

Attention regulation at 6 and 8 years

Children's attention regulation skills were evaluated by examiners in two ways. First, child behavior during a challenging cognitive assessment was evaluated by trained psychological assistants with the Tester's Rating of Child Behavior (TRCB) (Jaekel, Wolke, & Bartmann, 2013). The TRCB encompassed 13 nine-point scale items (1 = very low to 9 = very high) of which 6 items (attention, robustness/endurance, demandingness (reverse coded), cooperativeness, compliance, difficulty (reverse recoded)) were combined into a Task Orientation scale based on factor analysis (see (Jaekel, Wolke, et al., 2013) (*Cronbach's alpha* = 0.90 at 6 years and 0.85 at 8 years). Second, child behavior across the whole assessment day was evaluated as a consensus rating by the whole research team (team rating of attention regulation of psychologist, assistant psychologist and pediatrician) (Jaekel, Wolke, et al., 2013). The TEAM rating consists of three dimensions from the TRCB: attention, robustness/endurance and demandingness (reverse coded). An index score of attention was computed (*Cronbach's alpha* = 0.88 at 6 years and 0.84 at 8 years). Higher scores on both the TRCB and the TEAM rating indicated better attention skills.

Additionally, mothers rated their children's attention problems with the Child Behavior Checklist (CBCL; (Achenbach, 1991)). Higher scores on this 11 items subscale indicate more attention problems.

Confounding variables

Three potential confounders previously shown to be associated with attention regulation, i.e. GA, child sex, and socioeconomic status (SES) were included in all analyses. GA at birth was determined from maternal reports of the last menstrual period and serial ultrasounds during pregnancy. Children were summarized into six GA groups (very preterm: < 32 weeks GA; moderately preterm: 32-33 weeks GA; late preterm: 34-36 weeks GA; early term: 37-38 weeks GA; full-term: 39-41 weeks GA; post term: 42-43). Information on family SES at birth was collected via structured parental interviews and computed as a weighted composite score derived from the occupation of the head of each family (usually the father) together with the highest educational qualification held by either parent into three categories of low, medium and high SES (Bauer, 1988).

Statistical Analyses

Group differences (multiple/persistent crying, feeding and sleeping problems versus no/single crying, feeding and sleeping problems) and sample descriptives were tested with t-tests for interval scaled variables or chi-square tests for dichotomous variables using SPSS Version 22 (IBM SPSS Statistics, IBM Corporation). The weighted least square estimation (WLSMV) in Mplus 7 (Muthén and Muthén, Los Angeles, California) was used for structural equation modelling (SEM). Fit of the models was tested using chi-square test of model fit, the Root Mean Squared Error of Approximation (RMSEA), and the Comparative Fit Index (CFI). Model fits were considered good with RMSEA below 0.06 and CFI above 0.95 (Hu & Bentler, 1999).

SEM was applied to test Hypothesis 1, i.e., direct and indirect effects of multiple/persistent crying, feeding and sleeping problems and inhibitory control on a latent attention regulation variable consisting of three measures: Tester's Rating of Child Behavior Task Orientation, TEAM rating of attention regulation, and parental rating of attention problems (CBCL, reverse coded). Child sex, family SES and GA group were included as potential confounders (Model 1, see Figure 1). The strength and significance of the indirect effect was tested with the delta method (Muthén & Muthén, 1998-2017; Preacher, Rucker, & Hayes, 2007).

Further, in a second SEM model (Model 2) Hypothesis 2 was tested, i.e., whether the associations between regulatory problems and later attention problems via inhibitory control disappeared once general cognitive ability assessed at 20 months of age was accounted for.

RESULTS

Children with multiple/persistent crying, feeding and sleeping problems were, on average, born at an earlier gestational age and showed poorer inhibitory control (i.e., could not wait at all or waited for less than 11 seconds before taking the raisin), cognitive functioning and attention regulation compared with children with no/single crying, feeding and sleeping problems (see Table 1). There were no differences in family SES or child sex.

Effects of crying, feeding and sleeping problems, and inhibitory control on attention regulation (Model 1)

SEM results (Model 1) showed that attention regulation in childhood was negatively affected by crying, feeding and sleeping problems (β=-0.10, p=.012) and positively affected by inhibitory control abilities (β=0.29, p<.001), controlling for SES, child sex and GA group (see Table 2 and Figure 1). Inhibitory control abilities were directly predicted by crying, feeding and sleeping problems (β=-0.12, p=.012). Moreover, effects of early crying, feeding and sleeping problems on children's attention regulation were partly mediated by inhibitory control abilities (β=-0.04, p=.013). Additionally, gestational age, family SES and child sex had a significant effect on inhibitory control abilities and later attention regulation. In contrast, crying, feeding and sleeping problems were not affected by gestational age, SES or child sex when all factors were considered in the model (see Table 2). All predictors explained 30% of the variance in children's attention regulation. Fit values indicated a good statistical model fit ($\chi 2$ (32) =65.157, p<.001; *CFI*=.989; *RMSEA*=.027).

Effects of crying, feeding and sleeping problems, inhibitory control and cognition on attention regulation (Model 2). SEM results of Model 2 showed that attention regulation in childhood was positively affected by early cognitive abilities (β=0.54, p<.001), controlling for SES, child sex and GA group (see Table 3 and Figure 2). In contrast, neither crying, feeding and sleeping problems nor inhibitory control abilities directly predicted attention regulation (β=0.07 and -0.02, respectively; both ps>.05). However, inhibitory control was directly predicted by crying, feeding and sleeping problems (β=-0.12, p=.012), and cognitive abilities were negatively predicted by crying, feeding and sleeping problems (β=-0.19, p<.001). In this model, effects of early crying, feeding and sleeping problems on children's attention regulation were fully mediated by cognitive abilities (β=-0.10, p<.001) but not by inhibitory control abilities (β=-0.01, p=.209). The covariance between inhibitory control and cognitive abilities was significant (r=0.42, p<.001).

Additionally, gestational age, family SES and child sex had a significant effect on inhibitory control abilities and later attention regulation. In contrast, cognitive abilities were only affected by gestational age and family SES, and crying, feeding and sleeping problems were not affected by any confounding variables, i.e. gestational age, SES or child sex when all factors were considered in the model (see Table 3). All predictors explained a considerable 48% of the variance in children's attention regulation. Again, fit values indicated a good statistical model fit ($\chi 2$ (37) =75.952, p<.001; CFI=.990; $RMSEA$=.027).

DISCUSSION

This study found that children with early multiple or persistent crying, feeding and sleeping problems had lower inhibitory control abilities and more attention problems than children without or with only transitory crying, feeding and sleeping problems. Crying, feeding and sleeping problems in infancy were associated with later attention regulation abilities even when controlled for child sex, SES, gestation at birth, and inhibitory control at 20 months. In addition, toddlers with better inhibitory control abilities had significantly better attention regulation at school-age.

Supporting our first hypothesis, results showed that children's inhibitory control abilities mediated negative effects of early crying, feeding and sleeping problems on later attention regulation after controlling for child sex, family SES and gestational age. This finding may help pinpoint the neurodevelopmental relationship between early indicators and later trajectories of dysregulation. The mechanism for this mediation may be explained by a shared neural basis. Among others, prefrontal, cingulate and striatal brain regions, mainly consolidated by dopamine pathways, have been shown to contribute to self-regulation and response inhibition which underpin basic executive, motivational and attentional control functions (Pauli-Pott & Becker, 2011; Posner, Rothbart, Sheese, & Tang, 2007). Deficits in these neural pathways shown via neuroimaging may function as candidate neural systems that link these causal associations (Castellanos & Proal, 2012). Nonetheless, this mediation effect was relatively small, indicating that other factors, such as maternal sensitivity, cognitive stimulation, or maternal depression may explain the associations between early crying, feeding and sleeping problems, inhibitory control and attention regulation (Lynn, Cuskelly, O'Callaghan, & Gray, 2011; Poehlmann et al., 2010). Indeed, the results of Model 2 suggest that children's general cognitive abilities may explain the effects of crying, feeding and sleeping problems and specific inhibitory control processes on later attention regulation. These results are in accordance with our second hypothesis and may be an indicator of the broader, more comprehensive concept represented by general cognitive function compared to inhibitory control as a single and specific cognitive process. Importantly, in both models, early crying, feeding and sleeping problems predicted inhibitory control which may suggest a general problem of under-control.

Consistent with past research, child sex, family SES, and gestational age at birth affected attention regulation and inhibitory control (Jaekel et al., 2016; Reveillon et al., 2016; Williams & Sciberras, 2016) whereas crying, feeding and sleeping problems were not affected by child sex, family SES, and gestational age. Previous studies reported mixed results, with some studies showing an association between crying, feeding and sleeping problems and gestational age (Bilgin & Wolke, 2016; Schmid et al., 2011), family SES (Hyde et al., 2012; Santos et al., 2015) or sex (Schmid & Wolke, 2014; Sidor, Fischer, Eickhorst, & Cierpka, 2013), whereas other studies found no effects for gestational age and birth weight (Hyde et al., 2012; Santos et al., 2015), family SES (Schmid et al., 2011) or sex (Santos et al., 2015; Schmid et al., 2011) on crying, feeding and sleeping problems. These inconsistent results may be explained by differences in sample size, study design and definition of crying, feeding and sleeping problems, and in particular, control for potential confounders, across studies.

The consistent finding across both models was that later childhood attention regulation difficulties were predicted by a cascade of early markers of dysregulation, i.e. multiple and persistent crying, feeding and sleeping problems and poorer cognitive and self-regulatory abilities. These results concur with previous findings linking both early crying, feeding and sleeping problems (Bernier et al., 2010; Hemmi et al., 2011; Sadeh et al., 2015; Schmid & Wolke, 2014; Sivertsen et al., 2015; Williams & Sciberras, 2016) and inhibitory control (Campbell & von Stauffenberg, 2009; Jaekel et al., 2016) with subsequent deficits in children's attention regulation abilities which may last into adulthood (Bilgin et al., 2018). Overall, the results suggest some validity of a previously proposed developmental cascade model, with crying, feeding and sleeping problems (Schmid & Wolke, 2014; Winsper & Wolke, 2014) and poor inhibitory control being early markers of a trajectory of dysregulated behavior for at least some children by the time they start school. As a result, in addition to attention deficits, these children may face further problems, e.g. conduct disorder, learning difficulties, lower academic achievement and social exclusion (Campbell & von Stauffenberg, 2009; Jaekel et al., 2016; Mischel et al., 1989; Olson et al., 2002). Nevertheless, our Model 2 strongly suggests that more general early cognitive abilities may explain most of the underlying individual variation and risk. Our findings may help inform the design of early screening to identify those children at highest risk who may profit from intervention before they start formal schooling.

STRENGTHS AND LIMITATIONS AND FUTURE DIRECTIONS

To our knowledge, this is the first study investigating the impact of both early crying, feeding and sleeping problems and inhibitory control abilities on children's attention regulation. The strengths of this study are its prospective longitudinal design, large sample size, the inclusion of children across the full spectrum of gestational age, the assessment of crying, feeding and sleeping problems with clinical parent interviews and neurological examinations, and the use of multi-informant child outcomes on attention regulation at two different ages in childhood.

There are also limitations. First, crying, feeding and sleeping problems were not assessed via structured diaries. However, due to high attrition in diary studies this may not be advisable in general population samples (Schmid & Wolke, 2014; St James-Roberts, Sleep, Morris, Owen, & Gillham, 2001; Wake et al., 2006). Second, although inhibitory control was tested with a standardized observational measure, the task was administered at a very young age (20 months), and, in order to help the children understand the concept of the task, two training runs were performed before the actual test. Although previous studies have applied up to four training runs (Poehlmann et al., 2010), this may have positively influenced children's subsequent inhibitory control abilities (Jaekel et al., 2016). Thus, adjusting the task to the children's age and abilities, and applying multiple tasks testing for different aspects of inhibitory control or delay of gratification would enhance interpretation and reliability of results (Campbell & von Stauffenberg, 2009; Jaekel et al., 2016).

Regarding practical implications, health practitioners should monitor multiple and persistent crying, feeding and sleeping problems as these may be early indicators of further dysregulation problems (Hemmi et al., 2011; Korja et al., 2014; Schmid & Wolke, 2014; Williams, Nicholson, Walker, & Berthelsen, 2016). However, as children develop, trajectories of self-regulation become more complex, and multiple crying, feeding, and sleeping problems alone may be less indicative of long-term risk than additional domains of emerging effortful control such as inhibitory control, as indicated by Model 1. Accordingly, early childhood education and specific attention training may help improve effortful control such as self-control and the ability to delay gratification (Berger et al., 2007; Diamond & Lee, 2011; Heckman, 2009; Murray et al., 2016) of children with crying, feeding and sleeping problems and those with poor inhibitory control alike. Nevertheless, considering the results of Model 2, screening for general cognitive problems around 2 years of age may be most recommended in order to identify those children who are at risk for later attention regulation difficulties, and to schedule early intervention.

CONCLUSION

Our results provide support that inhibitory control abilities mediate the negative effects of early crying, feeding and sleeping problems on attention regulation. However, the effects of crying, feeding and sleeping problems and inhibitory control may be accounted for by children's more general cognitive abilities. Thus, early crying, feeding and sleeping problems and poor inhibitory control abilities may represent one dimension of a developmental cascade of underachievement, with a trajectory of under control of behavior lasting into school age, being highly associated with general cognitive function. These findings contribute to our knowledge about the link between early crying, feeding and sleeping problems and attention regulation in middle childhood and thereby suggest new avenues for screening and intervention.

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Table 1. Sample characteristics by crying, feeding and sleeping problems groups

	Multiple/persistent crying, feeding and sleeping problems *N*=249 (17.1%)		No/single crying, feeding and sleeping problems *N*=1,210 (82.9%)		p-value
	N	% / Mean (SD)	N	% / Mean (SD)	
GA	249	35.94 (4.78)	1210	36.68 (3.99)	**.023**
GA groups					**.005**
Very preterm (<32 weeks)	63	25.3	200	16.5	
Moderately preterm (32-33 weeks)	11	4.4	87	7.2	
Late preterm (34-36 weeks)	29	11.6	192	15.9	
Early term (37-38 weeks)	38	15.3	166	13.7	
Full term (39-41 weeks)	98	39.4	535	44.2	
Post term (42-43 weeks)	10	4.0	30	2.5	
Sex (male)	128	51.4	611	50.5	.794
SES at birth					.686
Low	86	34.5	401	33.1	
Middle	88	35.3	463	38.3	
High	75	30.1	346	28.6	
Inhibitory control at age 20 months					**.009**
Did not wait/waited up to 10 sec	173	69.5	734	60.7	
Waited between11 to 60 sec	76	30.5	476	39.3	
Cognition at age 20 months					

GMDS total quotient	245	97.0 (23.2)	1208	103.6 (10.9)	<**.001**
Attention outcomes at age 6 years[a]					
CBCL subscale attention problems	241	4.3 (3.1)	1,201	3.3 (2.7)	<**.001**
TRCB index scale task orientation	228	6.6 (1.7)	1,190	6.7 (1.4)	.439
TEAM index scale attention	236	5.7 (2.0)	1,193	6.0 (1.6)	**.041**
Attention outcomes at age 8 years[a]					
CBCL subscale attention problems	227	2.8 (2.8)	1,129	2.2 (2.3)	**.006**
TRCB index scale task orientation	216	7.2 (1.2)	1,119	7.4 (1.0)	.093
TEAM index scale attention	219	6.6 (1.7)	1,120	6.8 (1.4)	.064

Note. SES = GA = gestational age; socioeconomic status; GMDS = Griffiths Mental Development Scale; CBCL = Child Behavior Checklist; TRCB = Tester's Ratings of Child Behavior; TEAM = Team Ratings of Child Behavior

[a] Before inclusion in structural equation models the CBCL subscale of attention problems was reverse coded and all attention outcome variables were standardized.

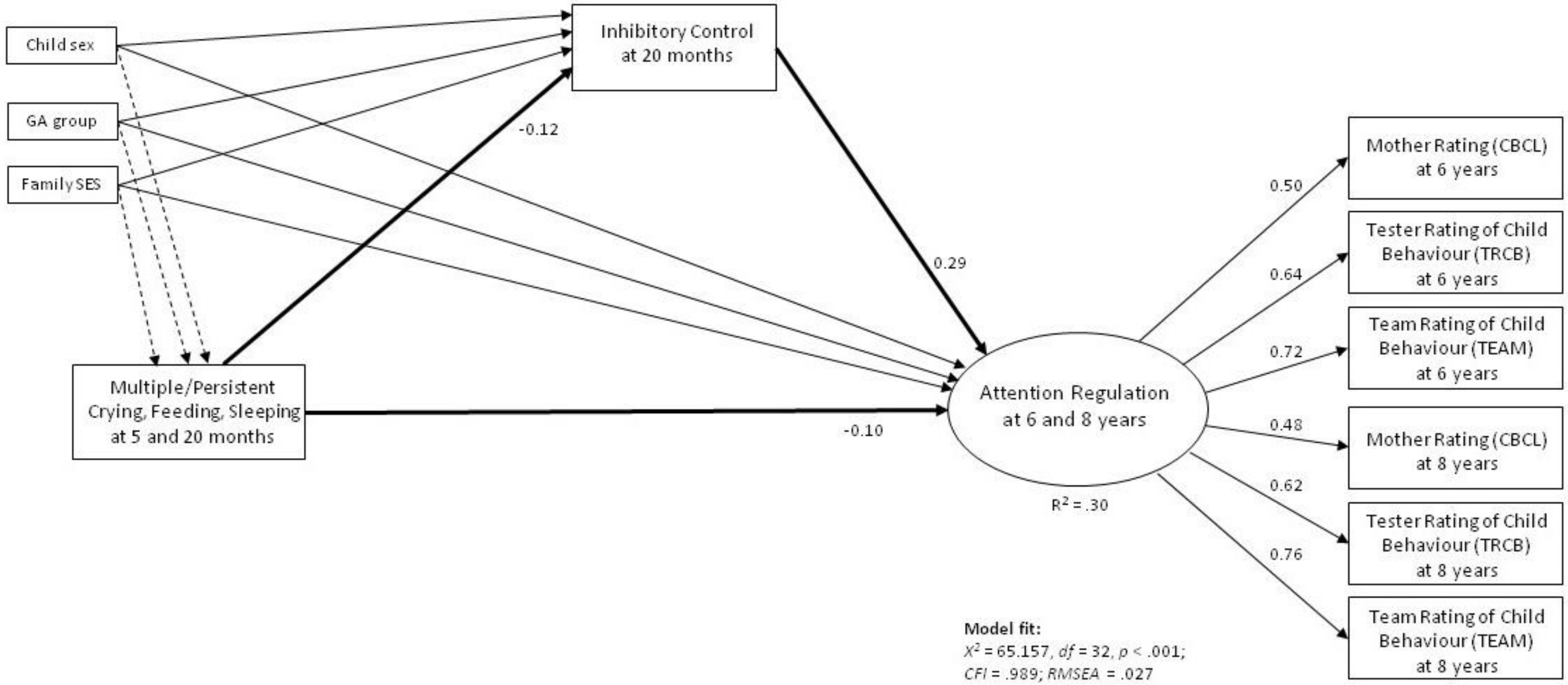
Table 2. Regression coefficients using Structural Equation Modelling (Model 1)

	Unstandardized			Standardized		
	B	*Standard Error*	*95% CI*	*β*	*p-value*	R^2
Direct effects						
Attention regulation						0.30
Inhibitory control	0.14	0.02	(0.10, 0.17)	0.29	**<.001**	
Crying, feeding and sleeping problems	-0.05	0.02	(-0.08, -0.02)	-0.10	**.012**	
SES low	-0.08	0.03	(-0.14, -0.02)	-0.07	**.019**	
SES high	0.17	0.04	(0.10, 0.23)	0.15	**<.001**	
Sex (male)	-0.15	0.03	(-0.21, -0.10)	-0.15	**<.001**	
GA group	0.08	0.01	(0.06, 0.10)	0.24	**<.001**	
Inhibitory control						0.12
Crying, feeding and sleeping problems	-0.13	0.05	(-0.21, -0.04)	-0.12	**.012**	
SES low	-0.02	0.08	(-0.16, 0.12)	-0.01	.792	
SES high	0.37	0.08	(0.23, 0.51)	0.16	**<.001**	
Sex (male)	-0.32	0.07	(-0.44, -0.21)	-0.15	**<.001**	
GA group	0.140	0.02	(0.10, 0.18)	0.21	**<.001**	
Crying, feeding and sleeping problems						0.01
SES low	0.06	0.09	(-0.09, 0.22)	0.03	.496	

	Unstandardized			Standardized		
	B	*Standard Error*	*95% CI*	*β*	*p-value*	R^2
SES high	0.08	0.10	(-0.08, 0.24)	0.04	.400	
Sex (male)	0.02	0.08	(-0.11, 0.15)	0.01	.824	
GA group	-0.04	0.02	(-0.08, -0.00)	-0.06	.086	
Indirect effects						
Attention via inhibitory control						
From crying, feeding and sleeping problems	-0.02	0.01	(-0.029, -0.006)	-0.04	**.013**	

Note. SES = socioeconomic status; GA = gestational age

Figure 1. Structural equation model (Model 1) showing associations between crying, feeding and sleeping problems, inhibitory control and attention regulation



Structural equation model showing direct and indirect effects of early crying, feeding and sleeping problems and inhibitory control on attention regulation at 6 and 8 years.

Please note: Bold lines represent hypothesized effects, solid lines represent significant effects, and dotted lines represent non-significant effects (standardized regression coefficients β). Error terms and covariations among control and indicator variables are not presented to enhance readability. Effects of interest are shown. For effects of confounders see Table 2.

Table 3. Regression coefficients using Structural Equation Modelling (Model 2)

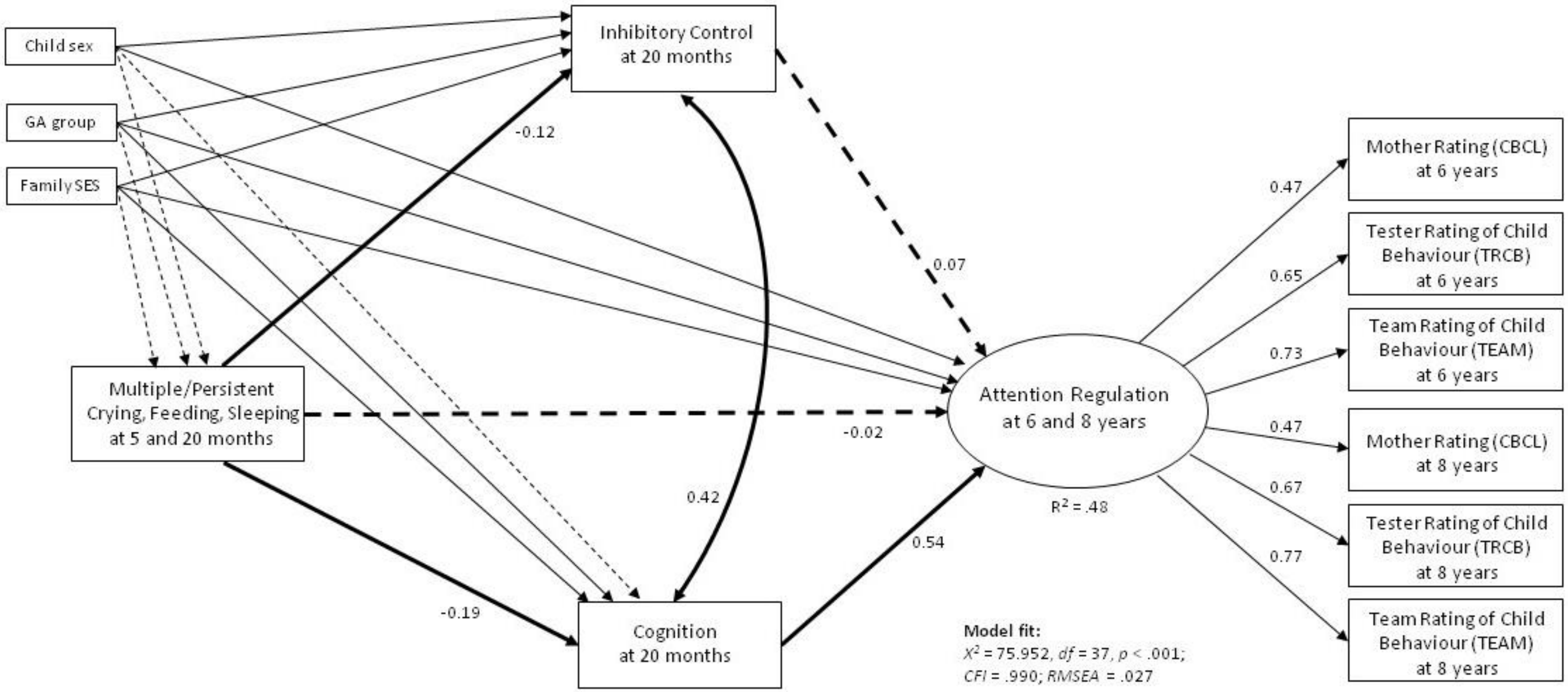
	Unstandardized			Standardized		
	B	*Standard Error*	*95% CI*	*β*	*p-value*	R^2
Direct effects						
Attention regulation						0.48
Cognition	0.25	0.02	(0.22, 0.29)	0.54	**<.001**	
Inhibitory control	0.03	0.02	(-0.01, 0.07)	0.07	.159	
Crying, feeding and sleeping problems	-0.01	0.02	(-0.04, 0.02)	-0.02	.594	
SES low	-0.05	0.03	(-0.10, -0.01)	-0.05	.066	
SES high	0.16	0.04	(0.10, 0.22)	0.15	**<.001**	
Sex (male)	-0.16	0.03	(-0.20, -0.11)	-0.17	**<.001**	
GA group	0.03	0.01	(0.01, 0.04)	0.09	**.002**	
Cognition						0.19
Crying, feeding and sleeping problems	-0.19	0.03	(-0.24, -0.14)	-0.19		
SES low	-0.09	0.05	(-0.18, 0.00)	-0.04	**<.001**	
SES high	0.14	0.07	(0.03, 0.24)	0.06	.101	
Sex (male)	-0.06	0.05	(-0.14, 0.02)	-0.03	**.041**	
GA group	0.23	0.02	(0.20, 0.26)	0.36	.228	
					<.001	

	Unstandardized			Standardized		
	B	*Standard Error*	*95% CI*	*β*	*p-value*	R^2
Inhibitory control						0.12
Crying, feeding and sleeping problems	-0.13	0.05	(-0.21, -0.04)	-0.12	**.012**	
SES low	-0.02	0.08	(-0.16, 0.12)	-0.01	.792	
SES high	0.37	0.08	(0.23, 0.51)	0.16	**<.001**	
Sex (male)	-0.32	0.07	(-0.44, -0.21)	-0.15	**<.001**	
GA group	0.14	0.02	(0.10, 0.18)	0.21	**<.001**	
Crying, feeding and sleeping problems						0.01
SES low	0.06	0.09	(-0.09, 0.22)	0.03	.496	
SES high	0.08	0.10	(-0.08, 0.24)	0.04	.401	
Sex (male)	0.02	0.08	(-0.11, 0.15)	0.01	.824	
GA group	-0.04	0.02	(-0.08, -0.00)	-0.06	.085	
Indirect effects						
Attention via inhibitory control						
From crying, feeding and sleeping problems	-0.00	0.00	(-0.01, 0.00)	-0.01	.209	
Attention via cognition						
	-0.05	0.01	(-0.06, -0.03)	-0.10	**<.001**	

	Unstandardized			Standardized		
	B	*Standard Error*	*95% CI*	*β*	*p-value*	R^2
From crying, feeding and sleeping problems						

Note. SES = socioeconomic status; GA = gestational age;

Figure 2. Structural equation model (Model 2) showing associations between crying, feeding and sleeping problems, inhibitory control, cognition and attention regulation



Structural equation model showing direct and indirect effects of early crying, feeding and sleeping problems, inhibitory control and cognition on attention regulation at 6 and 8 years.

Please note: Bold lines represent hypothesized effects, solid lines represent significant effects, and dotted lines represent non-significant effects (standardized regression coefficients β). Error terms and covariations among control and indicator variables are not presented to enhance readability. Effects of interest are shown. For effects of confounders see Table 3.