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Self-Regulation in Childhood

Developmental Mechanisms and Relations to ADHD Symptoms

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Abstract
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Self-regulation is a multi-faceted construct that concerns goal-directed behaviors, which aid individuals in everyday life and in achieving long-term goals. Self-regulation in believed to progress in a hierarchical fashion, in that simple cognitive functions are integrated into more complex functions across development. Attention-deficit/hyperactivity disorder (ADHD) is a heterogeneous childhood-onset disorder, characterized by deficits in various aspects of self-regulation, including core symptoms of inattention and hyperactivity/impulsivity, and comorbidity with externalizing disorders such as oppositional defiant disorder (ODD). The last decade has seen a shift from simple etiological models towards more complex ones, which stress multiple pathways to the disorder. In addition, there is an ongoing search for early markers of the condition, which will increase our understanding, enable early detection, intervention, and perhaps even prevention of the full disorder. Cognitive regulation, aspects of temperament (i.e. negative affect, surgency, and effortful control), and parenting are three areas of importance for self-regulation in general and of ADHD symptoms in particular. Grounded in these three constructs, informed by the hierarchical model of self-regulation development, and a multiple pathway perspective on ADHD, the present thesis aimed to map development of self-regulation, with a special focus on inattention and hyperactivity/impulsivity. Four studies were conducted based on three samples, ranging from infancy to 12 years, including both typically developing children and children diagnosed with ADHD. **Study I** found that early sustained attention predicted later cognitive regulation, providing support for the hierarchical model of self-regulation development. In addition, maternal sensitivity contributed to higher levels of emotion regulation whereas surgency contributed to lower levels of emotion regulation. **Study II** gained support for a multiple pathway perspective on ADHD, in that higher temperamental regulation and maternal sensitivity contributed to lower levels of inattention and hyperactivity/impulsivity, and higher surgency contributed to higher levels of hyperactivity/impulsivity. **Study III** replicated findings from Study II and confirmed early temperament markers of later inattention and hyperactivity/impulsivity, and that early cognitive regulation was a poor predictor of later symptoms. **Study IV** proposed contributions of multiple regulatory functions to ADHD symptoms and elevated negative affect in ODD. The latter was moderated by parental support, which seemed to be a protective factor for children with high levels of negative affect. In all, the findings point to the importance of both intrinsic and extrinsic factors in the development of self-regulation, which seems to progress in a hierarchical fashion. Aspects of temperament rather than cognitive regulation seem to be valid early markers of later inattention and hyperactivity/impulsivity. Multiple pathways to ADHD symptoms are proposed, with contributions of maternal sensitivity and temperament early in development and different regulatory functions in school-aged children. In addition, elevated negative affect in combination with low parental support seem to be characteristic of ODD rather than of core symptoms of ADHD. The thesis contributes to the complexity and heterogeneity of ADHD and that ADHD is best viewed as a developmental disorder, in that the influence of various regulatory factors change over time.

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For Vera and Melker
Andreas

List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

I Frick, M. A., Forslund, T., Fransson, M., Johansson, M., Bohlin, G., & Brocki, K. C. (2018). The role of sustained attention, maternal sensitivity, and infant temperament in the development of early self-regulation. *British Journal of Psychology*, *109*(2), 277-298.

II Frick, M. A., Forslund, T., & Brocki, K. C. (2018). Can reactivity and regulation in infancy predict inattentive and hyperactive/impulsive behavior in 3-year-olds? *Development and Psychopathology*, 1-11.

III Frick, M. A., Bohlin, G., Hedqvist, M., & Brocki, K. C. (2018). Temperament and cognitive regulation during the first 3 years of life as predictors of inattention and hyperactivity/impulsivity at 6 years. *Journal of Attention Disorders*, 1087054718804342.

IV Frick, M. A. & Brocki, K. C. (2019). A multi-factorial perspective on ADHD and ODD in school-aged children: What is the role of cognitive regulation, temperament, and parental support? *Under revision.*

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The contribution of Matilda A. Frick to the studies were as follows:
Study I and II: Co-planned and co-designed the study, collected 2/3 of the data, coded maternal sensitivity, analyzed the data, and wrote the manuscript with contributions from the co-authors.
Study III: Co-planned, co-designed, and collected data at follow-up at 6 years, analyzed the data, and wrote the manuscript with contributions from the co-authors.
Study IV: Co-planned and co-designed the study, collected ½ of the data, analyzed the data, and wrote the manuscript with contributions from the co-author.

Contents

Abbreviations

ADHD	Attention-Deficit/Hyperactivity Disorder
CCTI	Colorado Childhood Temperament Inventory
CD	Conduct Disorder
EATQ-R	Early Adolescent Temperament Questionnaire Revised
EF	Executive Functioning
EFs	Executive Functions
GxE	Gene-Environment Interactions
IBQ-R VSF	Infant Behavior Questionnaire Revised Very Short Form
ICC	Intra-Class Correlation
ODD	Oppositional Defiant Disorder
PEQ	Parent Environment Questionnaire
rGE	Gene-Environment Correlation
SES	Socio-Economic Status
SD	Standard Deviation
SNAP-IV	Swanson, Nolan, and Pelham Scale – IV
WISC-IV	Wechsler Intelligence Scale for Children – 4th ed

Introduction

Imagine the long-term goal of finishing high school. Which psychological skills do a child need to achieve such a complex aim? We know that, apart from basic cognitive abilities and a social context that makes schooling possible, a set of interrelated yet separable functions referred to as self-regulation are of great importance (Best, Miller, & Naglieri, 2011). Self-regulation concerns abilities that aid the child in regulating negative emotions ("I'm never going to make it!"), positive emotions ("I don't care about school, I just want to have fun with my friends!"), and contribute to problem solving and structuring of tasks that need to be accomplished (Nigg, 2017). In addition, self-regulation is of importance not only for academic achievement, but also for peer-relationships and general well-being (Moffitt et al., 2011). Relatedly, attention-deficit/hyperactivity disorder (ADHD) is a childhood onset disorder characterized by inattention and hyperactivity/impulsivity, deficits in self-regulation, and commonly accompanied by comorbid conditions such as oppositional defiant disorder (ODD; APA, 2013). As such, ADHD is also associated with detrimental outcomes regarding academic achievement, relationships, and health (Hoza, 2007; Ingram, Hechtman, & Morgenstern, 1999; Loe & Feldman, 2007). Further examination of early markers of later poor self-regulation, including ADHD symptoms, are needed. Increased understanding of these associations across development, will elucidate the knowledge of progression of self-regulation in general, and of ADHD specifically, and enable early detection and intervention. Three areas that are known to be of importance for development of self-regulation and ADHD symptoms, but that rarely have been assessed together are cognitive regulation, temperament, and parenting. The present thesis aimed to characterize development of self-regulation over time, with a special focus on inattentive and hyperactive/impulsive behavior, by examining common and independent contributions of cognitive regulation, temperament, and parenting. In addition, interactive effects between the intrinsic (cognitive regulation and temperament) and extrinsic (parenting) factors were examined. Three different samples are included in the thesis, spanning the ages 10 months to 12 years, including typically developing children and children with a diagnosis of ADHD. In the introduction, I will first describe the typical development of cognitive regulation and temperament and the effect of parenting on self-regulation. I will then move on to ADHD and describe how cognitive regulation, temperament, and parenting relate to symptoms of inattention, hyperactivity/impulsivity and ODD.

Self-Regulation

The broad concept of self-regulation refers to goal-directed behaviors and encompasses regulation of cognition, emotion, and behavior (Karoly, 1993). The construct has been described in many ways with varying terminology, such as executive functioning (EF), cognitive self-regulation, effortful control, emotion regulation, behavioral inhibition, and delay of gratification (Nigg, 2017). Several of these constructs will be examined in the current thesis. During the recent years, successful attempts has been made to present a general construct which incorporates regulation of cognition, action, and emotion as regulated in a bottom-up or top-down fashion (see Figure 1; Bridgett, Burt, Edwards, & Deater-Deckard, 2015; Nigg, 2017). Top-down refers to deliberate, volitional regulation, whereas bottom-up refers to automatic, spontaneous regulation, and the two are best viewed on a continuum. In addition, top-down and bottom-up processes are fundamentally connected in many ways, such as that bottom-up responses can be modulated by top-down regulation (Nigg, 2017). As the term *self*-regulation implies, it is an intrinsic process within the individual. However, extrinsic factors such as parenting are believed to influence development of self-regulation over time (Bernier, Carlson, & Whipple, 2010). In the current thesis I use the term self-regulation as an umbrella term, comprising cognitive regulation, aspects of temperament such as effortful control and emotion regulation, inattention, hyperactivity/impulsivity, and ODD. All of these constructs concern features of self-regulation, in that some are psychological constructs and some (i.e., inattention, hyperactivity/impulsivity, and ODD) reflect behavioral manifestations of deficient self-regulation (see Figure 1).

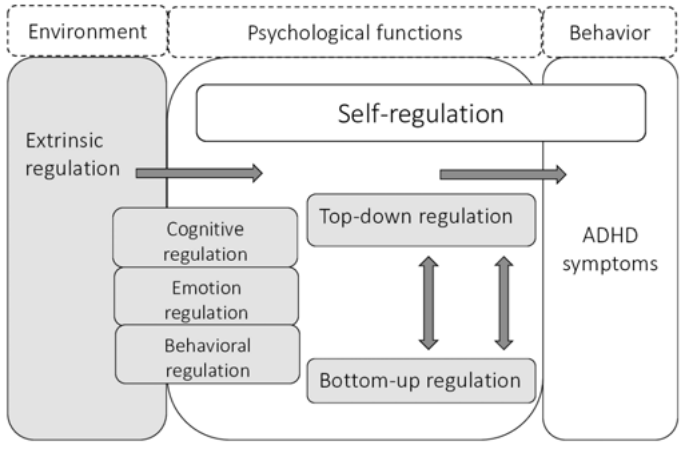

Figure 1. Model of self-regulation, adapted from Nigg, 2017. ADHD symptoms are viewed as behavioral manifestations of deficits in psychological functions. Due to the heterogeneous nature of the condition, the pattern of self-regulatory breakdown may look different for different individuals.

Cognitive Regulation

The term cognitive regulation, which basically corresponds to EF, is defined as at set of higher order cognitive functions, that aid the individual in goal directed behavior, by controlling lower level processes (Friedman & Miyake, 2017). The three most studied EFs, are referred to as inhibition, working memory, and shifting. Working memory is usually defined as the ability to monitor and update information, inhibition as the ability to override a dominant or prepotent response in favor of a subdominant one, and shifting as the ability to flexibly shift between tasks, rules, or mental sets (Garon, Bryson, & Smith, 2008). Various models of cognitive regulation have been presented, ranging from a unitary construct to dissociable processes (see Garon et al., 2008 for a review). During the recent years, an influential model that integrates these two perspectives has gained empirical support. This model by Friedman and Miyake (2017) is made up by a set of interrelated but separate functions. In a first draft of the model they investigated inhibition, working memory, and shifting with a latent variable approach, and found that they were interrelated yet separable (Miyake et al., 2000). However, further studies made it clear that another model proved a better fit, in that all three subcomponents loaded on a common EF factor. Specifically, working memory and shifting contributed with unique variance beyond common EF, whereas inhibition did not (Friedman & Miyake, 2017; Miyake & Friedman, 2012). That is, common EF explained all the variation in inhibition, suggesting either that common EF is equal to inhibition, or that common EF reflects the ability to maintain and manage goals, which is important in all EF tasks and perhaps particularly important in inhibitory tasks (Friedman & Miyake, 2017). Similar findings have been found in school-aged children (Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003). For preschoolers the findings are more diverse, with some proposing a unitary construct (Wiebe et al., 2011) and others proposing dissociable factors (Bernier, Carlson, Deschênes, & Matte-Gagné, 2012; Garon, Smith, & Bryson, 2014). In sum, even though the exact make-up of EF is not established, and may never be, as the list of EFs is not exclusively made up by the three "grand" functions, across development most findings support dissociable yet related factors that all concern aspects of self-regulation.

Cognitive regulation is highly heritable (Friedman et al., 2008) and is suggested to develop in a hierarchical fashion, where simple or low level components assemble into complex or higher level functions (Garon et al., 2008; Nigg, 2017). Proposed building blocks comprise early ability to sustain attention and simple inhibition (Garon et al., 2008; Hendry, Jones, & Charman, 2016; Posner, Rothbart, Sheese, & Voelker, 2012; Rothbart, Sheese, & Posner, 2007). Attention is a multi-facet, complex construct, and the prominent attention network model by Posner and colleagues propose different but related attention systems that develop over time, labelled the alerting, orienting,

and executive attention networks (Posner & Petersen, 1990; Posner & Rothbart, 2007). In early infancy, attention rely on the alerting and orienting networks, which concern the infant's sensitivity to incoming stimuli and the selection of stimuli (i.e., the infant orients toward interesting stimuli or away from unwanted stimuli). Early attention is related to rudimentary forms of working memory, in that infants as young as 6 months can hold simple representations in mind (Garon et al., 2008). By the end of the first year, the executive attention network starts to develop, meaning that the infant can exert greater attentional control, which in turn is related to simple forms of inhibition, such as delaying a response when told to (Colombo & Cheatham, 2006; Garon et al., 2008; Posner et al., 2012). A related construct is focused or sustained attention, which undergoes significant development at around 9 months, probably because of the increasing dominance of the executive network over the orienting (Colombo & Cheatham, 2006). Shifting is the last function to come on stage, sometime after the first birthday, which builds on both working memory and inhibition (Garon et al., 2008). This pattern suggests that different aspects of cognitive regulation show separate developmental trajectories, which are later integrated into more complex functions (Garon et al., 2008; Nigg, 2017). A handful of studies have investigated infant sustained attention and simple inhibition in relation to later self-regulation (Friedman, Miyake, Robinson, & Hewitt, 2011; Johansson, Marciszko, Brocki, & Bohlin, 2016; Johansson, Marciszko, Gredebäck, Nyström, & Bohlin, 2015). However, these relations need to be further examined to better understand the progression of self-regulation.

Temperament

Most current theorists would agree that temperament concerns early appearing, relatively stable, and biologically rooted individual differences in affect, activity, attention, and self-regulation (Shiner et al., 2012; Zentner & Bates, 2008). Throughout development, these constitutional traits are affected by genes, environment, and experiences (Shiner et al., 2012). Temperament traits or characteristics are usually expressed in response intensity, latency, duration, and recovery time (Shiner et al., 2012). Several researchers and research groups over the past half century have contributed to the current knowledge, such as Thomas and Chess's empirical approach in the New York Longitudinal Study, Buss and Plomin's criterial approach, and Goldsmith's functionalist perspective focusing on discrete emotions (Shiner et al., 2012). During the last decades Mary Rothbart's neurobiological, developmental approach has had a large influence on the field. She defines temperament as constitutional differences in reactivity and regulation, and describes three broad factors that in turn includes a set of more narrow dimensions (Rothbart, 2007). The first factor is

negative affect, which includes aspects of frustration, fear, discomfort, sadness, and poor soothability. Fear can be seen as a reactive, or bottom-up, kind of regulator, with automatic withdrawal as the mechanism, whereas the other aspects are primarily reactive in nature (Zentner & Bates, 2008). As such, negative affect taxes on both the behavioral inhibition system and the behavioral activation system (Gray, 1987). The second factor is extraversion/surgency, which is also a heterogeneous factor, including aspects of activity, low shyness, high intensity pleasure, smiling and laughter, impulsivity, positive anticipation, and affiliation (Rothbart, 2007). As such, several aspects of surgency load onto the behavioral activation system (Gray, 1987), although aspects such as smiling and laughter and affiliation, also reflect contentment and sometimes load onto the third factor, effortful control (Polak-Toste & Gunnar, 2006). Effortful control concerns the ability to inhibit a dominant response in favor of a subdominant one, to detect errors and plan for the future, and includes attention control, inhibitory control, perceptual sensitivity, and low intensity pleasure (Rothbart, 2007). The contribution of effortful control is an example of integration of developmental neuroscience into the temperament field (Shiner et al., 2012), and as we shall see, the construct is closely related to that of cognitive regulation.

As for interrelations between the three factors, high effortful control is generally related to low negative affect (Rothbart, Ellis, & Posner, 2013). In addition, negative affect and surgency are generally positively correlated, at least during early childhood, possibly because highly surgent children encounter more blocked goals and therefore react with negativity (Pollak-Toste & Gunnar, 2006). With increased effortful control this relation may weaken. In addition, as negative affect and surgency are complex constructs, some aspects such as affiliation and warmth may be related to high effortful control and low negative affect, whereas strong approach may show the opposite pattern (Pollak-Toste & Gunnar, 2006). Likewise, high fear may be negatively related to surgency, the mechanism being that fear inhibits approach behavior, whereas frustration and poor soothability may be positively related to surgency (Derryberry & Rothbart, 1997).

The effect of certain aspects of temperament on functioning may be direct. However, effects of temperament traits may also be expressed through interaction effects with other traits or environmental factors. For instance, certain temperament traits predicted more favorable developmental outcomes when matched with specific demands and expectations of the environment, so called "goodness of fit" (Chess & Thomas, 1987). Similarly, the term differential susceptibility, refers to traits, such as high negative affect, that are malleable in the sense that individuals characterized by these traits are highly sensitive to both negative and positive aspects of parenting (Belsky, Bakermans-Kranenburg, & IJzendoorn, 2007). Likewise, the bottom-up regulatory construct of fear can be beneficial or detrimental depending on parental style (Kochanska & Aksan, 2006). In addition, the combination of high reactivity

and high regulation may have positive outcomes, whereas the combination of high reactivity and poor regulation may be detrimental (Rubin, Coplan, Fox, & Calkins, 1995; Ursache, Blair, Stifter, & Voegtline, 2013). Potential mechanisms for the latter combination could be that intense emotions overwhelm the child, leading to less opportunities for social interactions and learning, or that strong approach tendencies lead to peer rejections (Derryberry & Rothbart, 1997). Furthermore, low reactivity in combination with high regulation was unrelated to cognitive regulation, suggesting that reactivity may have an important role in activating and practicing the regulatory system (Ursache et al., 2013). Finally, the highly reactive, highly regulated infants mentioned above, were often reared by highly sensitive parents, suggesting that differential susceptibility may be at work (Ursache et al., 2013).

Temperament is closely related to the construct of personality, and can be seen as the building blocks from which personality develops with experience (Rothbart, 2007). That is, personality includes temperamental aspects such as reactivity and regulation, but also values, attitudes, and cognitions about the self, others, and the world (Rothbart, 2007).

Development of Temperament

Already at birth, individual variations in temperament are detectable (Rothbart et al., 2007). Some infants are drawn to novelty whereas others like sameness. Some infants are easy to soothe, while others are easily over-aroused and require more effort of the parent to regulate. The newborn infant shows distress by crying when hungry or otherwise dysregulated, and by the age of 2 to 4 months anger and frustration, as well as approach tendencies, such as smiling, laughter, and body movements are present (Rothbart et al., 2007). Fear develops later, at 7 to 10 months, and appears to function as inhibitor of both aggression and approach (Rothbart et al., 2007). The broader control system, effortful control, which permits top-down control of attention and actions shows rapid development during the second and third year of life (Rothbart et al., 2007). However, aspects of temperamental regulation do emerge already during the first year of life. This has been termed orienting/regulation, since it relays on bottom-up processes and is not effortful per se (Putnam, Rothbart, & Gartstein, 2008). Examples of this type of automatic monitoring and regulation are looking away to avoid over-stimulation or negative affect, or self-soothing such as thumb sucking. In addition, early reactivity effects all regulatory functions, since higher reactivity require better regulatory skills. The study of the neurobiological basis of temperament (Rothbart, 2007) is in its early roots, but accumulating data suggest that the temperament dimensions are rooted in separate networks of neural structures (Whittle, Allen, Lubman, & Yücel, 2006). Importantly, the connections between the structures may be more important than the function of the specific structures in isolation.

Emotion Regulation

A whole field is devoted to the construct of emotion regulation alone (Cole, Martin, & Dennis, 2004; Eisenberg & Spinrad, 2004; Gross, 2015), which is closely related to that of self-regulation, but with an exclusive focus on regulating emotional arousal. Like self-regulation in the broader sense, emotion regulation is initially a largely extrinsic process by which the parent aid the child in regulation of arousal, which with time becomes intrinsic within the child (Eisenberg & Spinrad, 2004). Developmentally, emotion regulation is first performed in a bottom-up way, and later also in a top-down fashion regarding regulation of attention, thoughts, and behavior in order to adjust emotional states (Eisenberg & Spinrad, 2004; Gross, 2015). It has been suggested that cognitive and emotion regulation are intricately bound developmental processes, and that similar neural networks that regulate attention and working memory are at work in both (Bell & Wolfe, 2004). This is not a surprising claim, since cognitive regulation can be used in the service of regulating emotions (Nigg, 2017). In addition, concurrent correlations between inhibition and emotion regulation has been found in preschoolers (S. M. Carlson & Wang, 2007), but has not been studied extensively in infancy.

The Connection between Effortful Control and Cognitive Regulation

Both cognitive regulation and effortful control concerns top-down, domain general, regulation of information (Nigg, 2017; Rothbart, 2007). This information can indeed be emotional (Bridgett, Oddi, Laake, Murdock, & Bachmann, 2013; Nigg, 2017), even though regulation of cognitive information is most often stressed in the literature (Zhou, Chen, & Main, 2012). Effortful control excludes complex cognition, and therefore maps onto low-level cognitive regulation (Nigg, 2017). Most theorists agree that cognitive regulation and effortful control are closely related constructs. However, the magnitude of the overlap, and the reason for it, is not settled. Some argue that there are conceptual differences (Nigg, 2017), whereas others argue that potential differences are just an artifact due to different research traditions (Zhou et al., 2012). For instance, the role of working memory in effortful control is not settled (Bridgett et al., 2013; Zhou et al., 2012). The connection between cognitive regulation and effortful control is made complicated by low correlations between lab-based observations (traditionally used to assess cognitive regulation) and parental rating (traditionally used to assess effortful control; Hongwanishkul, Happaney, Lee, & Zelazo, 2005). To settle these questions, the inclusion of both constructs in the same studies has been called for.

Parenting and Self-Regulation

Mounting evidence suggests that parenting affects development of self-regulation (e.g., Bernier et al., 2010; Callaghan & Tottenham, 2016; Conway & Stifter, 2012; Kochanska, 1997). As we have seen, self-regulation is to a large degree influenced by the genetic make-up (Friedman et al., 2008). However, the slow maturation of the prefrontal cortex (PFC) and its connection to the amygdala, makes development of self-regulation malleable also to environmental aspects such as parenting (Callaghan & Tottenham, 2016). Several aspects of parenting have been investigated in relation to self-regulation, such as sensitivity, scaffolding, mind-mindedness, and interference (Bernier et al., 2010; Calkins & Johnson, 1998; Hughes & Ensor, 2005). With slight variations, the focus of these parenting constructs is on responding to the child's needs in an adequate way (physically, verbally, or otherwise), whether it has to do with exploration, problem solving, or emotion regulation. For instance, sensitivity concerns the parent's ability to accurately and promptly perceive, interpret, and respond to the child's signals (Ainsworth, 1969). One proposed mechanism is that the parent acts, guided by signals from the child, as an external regulator of the child's attention and emotions by soothing, comforting, and guiding the child, which in turn support the child's emerging self-regulation (Bernier et al., 2010; Crockenberg & Leerkes, 2004; Shiner et al., 2012). This transaction may be influenced by observational learning and by keeping the child's level of arousal at an optimal level (Kochanska, 1997).

Effects of environmental factors on self-regulation are of course interesting on their own, but the last decades the interest in the interplay between constitutional or genetic and environmental factors has flourished. Both gene-environment correlations (rGE) and gene-environment interactions (GxE) have been described (Rutter & Silberg, 2002; Wermter et al., 2010). rGE refer to genetic effects on the exposure to certain environmental factors. An example of passive rGE is that the parents provide the child with both genes and a particular rearing environment, which may be detrimental for the child if the genetic predisposition is weak self-regulation and the environment is chaotic (Bridgett et al., 2015). An example of evocative rGE is a child characterized by high negative affect that evoke harsh parenting, which in turn may increase negative affect in the child (Rutter & Silberg, 2002), leading to recursive processes between parenting and child characteristics (Kiff, Lengua, & Zalewski, 2011). GxE refer to genetic effects on sensitivity towards an environmental factor (Rutter & Silberg, 2002), and suggests that parenting (among other important environmental factors) moderates the association between core genetic predictors and later functioning (Kiff et al., 2011; Wermter et al., 2010). In particular, two frameworks have been used to investigate and interpret interaction effects, the diathesis-stress model and the theory of differential susceptibility. The diathesis-stress model posits that individuals with a particular genetic or biological vulnerability are more affected by stressors, such as poor

parenting (Goforth, Pham, & Carlson, 2011). And as described above, the theory of differential susceptibility suggests that children characterized by certain characteristics such as a highly reactive temperament are more susceptible to both positive and negative aspects of parenting, possibly due to a highly sensitive nervous system that effectively registers experiences (Belsky et al., 2007). Importantly, rGE and GxE are not mutually exclusive, and can be at work simultaneously (Rutter & Silberg, 2002).

ADHD

So far, I have discussed reactive and regulatory constructs and their relationship to general self-regulation. The remainder of the introduction will focus on the impact of these constructs on ADHD and its symptoms. ADHD is a highly heritable condition (in the range of .56 to .84; Larsson, Chang, Onofrio, & Lichtenstein, 2014), characterized by deficits in self-regulation, both regarding the core behavioral symptoms of inattention and hyperactivity/impulsivity and regarding associated features. These features concern poor cognitive regulation and dysregulation of emotions and behaviors as seen in the comorbidity of externalizing behavior problems, such as ODD (Frick & Nigg, 2012; Shaw, Stringaris, Nigg, & Leibenluft, 2016; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). ADHD is a diagnostic category, but is also described as the extreme of dimensional traits to be found in the general population, and those traits seem to represent the same behavioral and genetic phenotype that makes up the ADHD diagnosis (Middeldorp et al., 2016; Willcutt et al., 2012). As such, it is possible to study progression of symptoms also in samples of typically developing children, starting at an age before the core symptoms are possible to detect.

Recently, there has been an increased interest in identifying early markers of ADHD, with the aim of mapping mechanisms that affect the progression of the disorder, which in turn could make early intervention possible (e.g., Johnson, Gliga, Jones, & Charman, 2015; Shephard et al., 2018). These early signs can be differently related to later outcome, as indicated by variations in terminology. For instance, *markers* or *predictors* concern factors that have predictive validity in relation to later diagnosis (Johnson et al., 2015). A *precursor* concerns a conceptually related marker that indicates approach of the disorder, and an *endophenotype* concerns a heritable attribute, present also in non-affected individuals, that serves as a mediator between the genetic and behavioral levels of explanation (Johnson et al., 2015). The search for these early markers, precursors, or endophenotypes, is often informed by established difficulties in older children with the diagnosis, and attempts to track these difficulties back to their developmental roots. As such, temperament is a valid candidate, due to the early emergence of especially the reactive aspects. Cognitive

regulation is more complex in its structure and harder to assess in infancy because it is not fully developed during the first years of life (Diamond, 2013). Yet, simple aspects of attention and inhibition are, due to their relatively early maturation, suitable candidates. In addition, parenting is an extremely important factor to study early, both because its impact may be stronger early in development (Callaghan & Tottenham, 2016; E. A. Carlson, Jacobvitz, & Sroufe, 1995) and because its proposed moderating effect on child intrinsic factors (e.g., Belsky et al., 2007; Goforth et al., 2011).

ODD

ODD is a condition characterized by a frequent pattern of anger, irritability, and opposition (APA, 2013). It is a common comorbid disorder in children with ADHD, present in approximately half of the cases (Connor, Steeber, & McBurnett, 2010). The genetic liability is suggested to be partially shared (Coolidge, Thede, & Young, 2000), yet slightly different pathways to the two have been suggested. Specifically, deficits in cognitive regulation/effortful control and high surgency may be specific to ADHD, and high negative affect specific to ODD (Brocki, Nyberg, Thorell, & Bohlin, 2007; Loeber, Burke, & Pardini, 2009; Martel & Nigg, 2006; Nigg, 2006). In addition, parenting may be more strongly and consistently associated with ODD than ADHD (Deault, 2010). Taken together, when assessing factors contributing to ADHD symptoms it is of great importance to take symptoms of ODD into consideration. In addition, furthering the knowledge about the factors involved in the different yet overlapping conditions may inform decisions on intervention and treatment.

Cognitive Regulation and ADHD

During the 1990's Russel Barkley constructed a unifying theory of ADHD, suggesting that poor behavioral inhibition is central to the condition, and central to cognitive regulation, which in turn explains the cognitive deficits seen in ADHD (Barkley, 1997). Mechanistically, the association between cognitive regulation and ADHD is straightforward, in that poor cognitive functions at the behavioral level are presented as inattention and hyperactivity/impulsivity (Hinshaw, 2018). Since the 90's, it is well established that groups with ADHD present deficits in cognitive regulation compared to controls (Willcutt et al., 2005). It has even been suggested that no more studies on the specific topic are needed (Nigg, 2005). However, studies on cognitive regulation and its precursors in infancy are scarce (Johnson et al., 2015). Some exceptions show that early poor attentiveness predicted inattention and/or hyperactivity up to three years later (Lawson & Ruff, 2004; Papageorgiou et al., 2014). Also,

atypical sustained attention, such as longer looking times in early infancy but with no growth over time was found in a risk cohort (M. Miller, Iosif, Young, Hill, & Ozonoff, 2016). This pattern is in line with literature suggesting that longer looking early in infancy is associated with slower information processing (Cuevas & Bell, 2014). In contrast, inhibitory control in toddlerhood predicted parent rated ADHD symptoms at 7 years, whereas sustained attention did not (Shephard et al., 2018). As for other cognitive predictors, general intelligence at 15 and 24 months were significantly, but weakly correlated with ADHD severity at 7 years (Arnett, MacDonald, & Pennington, 2013).

Importantly, even though there is an established connection between cognitive regulation and ADHD, Barkley's etiological claim proved to be immature, because of moderate effect sizes and the fact that a substantial percentage of individuals with ADHD do not exhibit deficits in cognitive regulation (Willcutt et al., 2005). Therefore, deficient cognitive regulation seems to be one of several important factors that together may explain progression of the disorder (Willcutt et al., 2005). It has been called for to broaden the etiological model and include multiple constructs, including aspects of temperament and environment, in the same studies to examine heterogeneity in the group and multiple pathways to the disorder (Nigg, 2005). Thus, moving beyond group differences, and instead look for contributions of early cognitive regulation in broader models of progression of ADHD symptoms may bring clarity to the role of cognitive regulation in the etiology of ADHD.

Temperament and ADHD

In parallel to the extensive research on cognitive regulation and ADHD, during the early 2000's a smaller paradigm evolved, that wished to integrate a temperament perspective of ADHD to improve the understanding of its progression (Nigg, Goldsmith, & Sachek, 2004). This paradigm emphasized heterogeneity, that is, children with ADHD vary in phenotypical presentation, and may thus vary in etiology, or put differently, pathways to the disorder (Nigg et al., 2004). In line with the association between cognitive regulation and ADHD, poor effortful control was suggested as a pathway to the disorder, again with quite direct mechanisms at work, in that poor cognitive control will result in dysregulated behaviors such as inattention and hyperactivity/impulsivity. Furthermore, high surgency was proposed as an alternative pathway to hyperactivity/impulsivity specifically. A few possible mechanisms for this association are plausible. First, strong approach map clearly and in a direct way onto impulsivity. In addition, strong approach may stimulate reward related behaviors than in turn may increase impulsivity reciprocally (Derryberry & Rothbart, 1997). Finally, high negative affect was put forward as a potential factor in explaining the overlap between ADHD and externalizing behavior problems (Nigg et al., 2004).

Since then, the relation between temperament and ADHD has been studied to some extent from infancy/toddlerhood to school-aged children, either in children at risk for later ADHD, or as continuous measures in diverse groups. In infancy, the general pattern is that poor regulation is related to ADHD behaviors (Johnson et al., 2015; Shephard et al., 2018; Willoughby, Gottfredson, Stifter, & The Family Life Project Investigators, 2017). Generally, low effortful control was obtained also for school-aged children, particularly in relation to inattention (De Pauw & Mervielde, 2011; Martel & Nigg, 2006). In addition, heightened reactivity and activity level is found in some, but not all studies on early temperament and ADHD (Auerbach, Atzaba-Poria, Berger, & Landau, 2004; Gurevitz, Geva, Varon, & Leitner, 2014; Johnson et al., 2015; N. V. Miller, Degnan, Hane, Fox, & Chronis-Tuscano, 2018; Shephard et al., 2018; Sullivan et al., 2015; Willoughby et al., 2017). In school-aged children several studies have found independent contributions of surgency and regulation of surgency to ADHD symptoms, from an emotion regulation perspective (Brocki, Forslund, Frick, & Bohlin, 2017; Forslund, Brocki, Bohlin, Granqvist, & Eninger, 2016; Sjöwall, Backman, & Thorell, 2015; Sjöwall, Bohlin, Rydell, & Thorell, 2017). Yet some studies using a pure temperamen-tal perspective found no relation between surgency and ADHD symptoms (Cukrowicz, Taylor, Schatschneider, & Iacono, 2006; De Pauw & Mervielde, 2011). The findings on negative affect in relation to ADHD are mixed, possi-bly due to whether or not externalizing behaviors, such as ODD, were con-trolled for (De Pauw & Mervielde, 2011; Forslund et al., 2016).

So how are aspects of temperament linked to ADHD? Several alternatives have been proposed, such as a spectrum model in which ADHD reflects extreme ends of temperament traits (Nigg, 2006). A second model describes extreme temperament as a vulnerability (or resilience) factor (Nigg, 2006). The former should be expressed as main effects of aspects of temperament on ADHD symptoms while the latter would result in interaction effects with other important predictors. Preliminary evidence suggest a spectrum model for pre-schoolers (Martel, Gremillion, Roberts, Zastrow, & Tackett, 2014). More studies are needed, to elucidate how aspects of temperament relate to inatten-tion and hyperactivity/impulsivity, particularly in models including related factors, such as cognitive regulation, and also environmental aspects, such as parenting.

Parenting and ADHD

The question about influences of parenting on ADHD is a delicate one. A pitfall one wants to avoid is the one of blaming parents for child symptoms, the other potential pitfall would be saying that ADHD is entirely genetic in origin and that parenting has nothing to do with it. Adopting a developmental psychopathology framework (Rutter & Sroufe, 2000) can help in understanding

how symptoms of ADHD develop over time, and how multiple factors add and interact, possibly in altered ways for different individuals, to shape the specific presentation of symptoms. In extreme cases adverse environment may be the main trigger (Rutter et al., 2007) whereas ADHD may be primarily determined by genetic risk factors for other children (Larsson et al., 2014). However, in most cases, despite the large heritability, genetic and environmental aspects are suggested to interact, in that the family environment will be important in the manifestation of symptoms and/or associated features (Deault, 2010; Johnston & Mash, 2001). Two important reviews conclude that families with a child diagnosed with ADHD are characterized by, on average, more negative and less sensitive interactions, and that this may be especially true for younger children (Johnston & Mash, 2001) and for children with comorbid externalizing problems (Deault, 2010). However, findings are mixed regarding if parenting predicts both ADHD and externalizing behaviors, or the latter only (Deault, 2010). Furthermore, and as previously mentioned, it is well established that child symptomatology exerts an influence on parenting itself. That is, the demanding nature of inattention, hyperactivity/impulsivity, and associated features such as oppositional behaviors may evoke harsh and inconsistent parenting (Deault, 2010). In turn, this can lead to increases in symptoms, and the escalation of this vicious cycle is not hard to imagine. Here, parenting is not a cause, but a factor that may dampen or amplify symptoms over time (Johnston & Mash, 2001). Another hypothesis is that parenting is indirectly associated with symptoms of ADHD through child temperament, in that parenting, such as inconsistent discipline and poor supervision, could have indirect effects on ADHD symptoms through low levels of conscientiousness in the child (Ullsperger, Nigg, & Nikolas, 2016).

However, findings are mixed. Some suggest that parenting may have an effect on associated features such as conduct disorder and ODD, rather than on core symptoms of ADHD per se (Johnston, Murray, Hinshaw, Pelham, & Hoza, 2002). Yet others have found an effect on ADHD with control for externalizing symptoms (Choenni, Lambregtse-van den Berg, Verhulst, Tiemeier, & Kok, 2018; e.g., B. Ellis & Nigg, 2009; Hawes, Dadds, Frost, & Russell, 2013; Keown, 2012; Ullsperger et al., 2016). Adding parenting in models with other predictors will further our understanding of its role as an independent contributor or moderator of other factors such as cognitive regulation or aspects of temperament.

A Multiple Pathway Perspective on ADHD and ODD

Looking at factors such as cognitive regulation, aspects of temperament, and parenting in isolation may have a value per se. However, empirical examination of broader models has been requested. In line with this, a multiple path-

way perspective on ADHD proposes that several factors influence the progression of symptoms (e.g., Castellanos & Tannock, 2002; Nigg et al., 2004; Sonuga-Barke, 2005). Here, *pathway* concerns a course along which something (i.e., ADHD symptoms) progresses. This is not a groundbreaking theory and goes well in hand with a developmental psychopathology framework, but it is an effort to try to explain the heterogeneity regarding neural, cognitive, and social functioning in individuals with ADHD (Sonuga-Barke, 2005). Several multiple pathway models have been proposed. For instance, a model including temporal processing, inhibitory control, and delay aversion (Sonuga-Barke, Bitsakou, & Thompson, 2010), as well as a model including different temperament pathways to the separate subtypes of ADHD, including its comorbidity (Nigg et al., 2004). In addition, recent empirical studies have found independent contributions of cognitive regulation and emotion regulation to ADHD symptoms, which add support to a multiple pathway perspective (Brocki et al., 2017; Forslund et al., 2016; Graziano, McNamara, Geffken, & Reid, 2013; Sjöwall et al., 2015; Sjöwall, Roth, Lindqvist, & Thorell, 2013). However, most of these models lack inclusion of environmental factors. One exception is Forslund and colleagues who included disorganized attachment in their model, and found no contribution of disorganization to ADHD, but well to conduct disorder (Forslund et al., 2016). In addition, examining contributions of separate factors to ADHD and comorbidity such as ODD symptoms, will add important information. Specifically, deficits in regulation and elevated surgency has been suggested to be independently related to ADHD, and high negative affect and inadequate parenting more closely related to ODD (Brocki et al., 2007; Deault, 2010; Martel & Nigg, 2006; Nigg, 2006).

To sum up, self-regulation is a broad concept that has been described in many ways, with varying terminology, which has brought both richness and confusion to the field (Nigg, 2017). Cognitive regulation, aspects of temperament, and parenting are constructs of importance for the progression of self-regulation including inattention and hyperactivity/impulsivity, but they have rarely been assessed simultaneously. Doing so, starting in infancy, will bring about important empirical information which can feed into recent general frameworks of self-regulation, and elucidate the possibility of finding early markers of later self-regulatory deficiencies, which could enable early intervention and prevention.

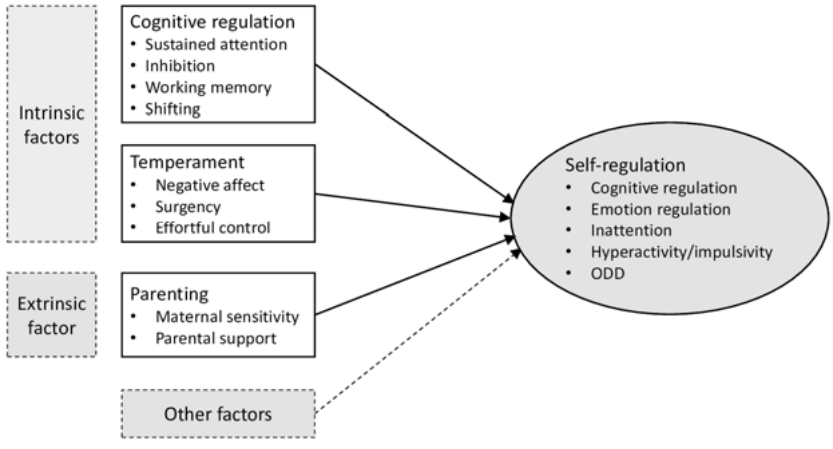

Figure 2. A conceptual multiple pathway model of self-regulation. Self-regulation is used as an umbrella term encompassing psychological constructs (cognitive regulation and emotion regulation) and behavioral manifestations of deficient regulation (inattention, hyperactivity/impulsivity, and ODD). Based on work by Frick and colleagues.

Aims

The overarching aim of the thesis was to examine development of self-regulation across childhood. Self-regulation encompassed different aspects in the separate studies, ranging from cognitive regulation, emotion regulation, and aspects of temperament, to inattention, hyperactivity/impulsivity, and ODD symptoms. See Figure 2 for a broad conceptual depiction of the study model. First, we examined the structure of early self-regulation, by investigating concurrent relations between different constructs. Secondly, we examined development of early cognitive regulation. Finally, we investigated how a set of regulatory constructs (cognitive regulation, aspects of temperament, and parenting) could predict later self-regulation (including cognitive and emotion regulation, symptoms of inattention, hyperactivity/impulsivity, and ODD) and whether parenting moderated the effects of the intrinsic factors. Theoretically, the work was informed by the hierarchical framework of cognitive regulation development (Garon et al., 2008, 2014) and a multiple pathway perspective on ADHD (Nigg et al., 2004; Sonuga-Barke, 2005).

The specific research questions were:

1. *What is the structure of early self-regulation?*
   This aim was addressed in Study I and III, although it is reported on in all studies. We hypothesized that the different self-regulatory constructs

(i.e., cognitive regulation, emotion regulation, and aspects of temperament regulation) would be concurrently, significantly, and positively correlated with each other and that the reactive aspects of temperament would be negatively related to the regulatory constructs.

2. *Do complex cognitive regulation build on simple cognitive functions, in line with the hierarchical model of cognitive regulation development?* This aim was addressed in Study I and in supplementary analyses. We hypothesized that sustained attention and simple inhibition would contribute independently to later cognitive regulation (i.e., inhibition and global EF).

3. *A) Are several factors (cognitive regulation, aspects of temperament, and parenting) involved in the progression of self-regulation (including cognitive and emotion regulation, symptoms of inattention, hyperactivity/impulsivity, and ODD), in line with a multiple pathway perspective?* This aim was addressed in all studies. However, study III did not assess parenting, but examined additive effects of cognitive regulation and temperament over time. We hypothesized that higher levels of cognitive regulation, temperamental regulation, and parenting would be associated with better self-regulation (including lower symptom levels). Hypotheses regarding independent contributions varied across studies.

   B) Does parenting moderate the effects of cognitive regulation and temperament on self-regulation (including cognitive and emotion regulation, symptoms of inattention, hyperactivity/impulsivity, and ODD)?
   This aim was addressed in study I, II, and IV. Generally, patterns of differential susceptibility and/or diathesis-stress were examined.

Method

Overview of the Projects

The four papers in the thesis are based on three projects (EFFECT, MARIA, and CARE), all with the aim of examining predictors of various aspects of self-regulation, including cognitive regulation, emotion regulation, inattention, hyperactivity/impulsivity, and ODD symptoms. EFFECT and MARIA are longitudinal studies of typical development starting in infancy. CARE is a cross-sectional study in school-aged children oversampled for ADHD diagnoses. See Table 1 for general descriptions of the three projects.

Table 1. *Study and participant characteristics*

	Study I	Study II	Study III	Study IV
Project title	EFFECT	EFFECT	MARIA	CARE
Aim	Extrinsic and intrinsic influences on self-regulation		Hierarchical development of early cognitive regulation	Extrinsic and intrinsic influences on ADHD
Sample type	Typically developing		Typically developing	40% clinical diagnoses of ADHD, 60% typically developing
Age at assessment	10 &18 months	10 & 36 months	12, 18, 24, 36 & 72 months	8-12 years
Total n	124	112	66	77
Design	Longitudinal	Longitudinal	Longitudinal	Cross-sectional

Participants

Study I initially included 124 full-term typically developing children (66 boys, 53.2%) and their mothers. They were on average 10.04 months (SD = 0.24) when the study started and 18.06 months (SD = 0.26) at follow-up (n = 117). The mothers were on average 32.1 years (SD = 5.0), born in Sweden (92.5%), and highly educated (76.4% had a college or University degree). The infants were recruited to Uppsala Child- and Baby Lab, via the birth registry of Uppsala, Sweden with a response rate of approximately 30%.

Study II included 112 children from the same sample as Study I (retention rate 91%), who participated in the follow-up at 36 months (mean age 36.40, SD = 1.18; 65 boys, 52.8%).

Study III included 66 full-term typically developing children (31 boys, 47%) of which 47 participated at follow-up at 6 years (20 boys, 43%). The parents were highly educated (86% of the mothers had a college or University degree). The children were assessed at five time points with the following mean ages: 12.46 months (SD = 0.43, n = 66), 18.51 months (SD = 0.73, n = 65), 24.60 months (SD = 0.61, n = 59), 36.97 (SD = 1.08, n = 58), and 74.78 months (SD = 1.18, n = 47). As in Study I and II the children were recruited to Uppsala Child- and Baby Lab, via the birth registry of Uppsala.

Study IV included 77 children aged 8 to 12 years (m = 10.45, SD = 1.35, 59 boys, 78%), of which 30 had a diagnosis of ADHD and the rest were typically developing. The children with a diagnosis were recruited through advertisements in local newspapers, social media, and through child psychiatry departments. The typically developing children were recruited through the population registry and then matched to the clinical group on age, sex, and SES. Children with intellectual disability were not enrolled in the study. Sixty five percent of the mothers and 42% of the fathers had a college or University degree.

Procedure

Study I and II included an initial visit to the Uppsala Child and BabyLab at 10 months, which lasted approximately 1 hour. In Study I this was followed by a second visit at 18 months (also ~1 hour) and in Study II by a survey directed to parents and teachers at 36 months. Study III included four visits to the Uppsala Child and BabyLab during the first 3 years of life, and a survey to teachers when the children were 6 years. Study IV included a 2-hour visit for the child and a survey directed to parents and teachers. The local ethics committee approved of all studies, and informed consent were obtained from all parents (and children in Study IV). The participating children received a small gift in all studies and parents and teachers received gift vouchers worth 10-20 USD.

Measures

Cognitive Regulation

Cognitive regulation or its precursors were assessed in all studies, mainly as predictors, but also as outcome measures in Study I.

Sustained Attention

Task Orientation (Blocks; Study I and II)

The *Task Orientation (Blocks)* from Lab-Tab (Goldsmith & Rothbart, 1999) was used to assess sustained attention in Study I and II. Three colored plastic blocks were placed in front of the child, and the child was left to explore the blocks on his/her own for three minutes. The mother was sitting nearby, but out of reach of the infant, and was instructed to remain neutral towards the child, but to pick up the toys if all three fell to the floor. Time units of 10 s were coded for looking time on a 4-point scale (0 = does not look at all, 1 = looks for 1-4 s, 2 = looks for 5-8 s, 3 = looks for 9-10 s). The mean across the full three minutes (0-3) was used as the measure of sustained attention. Inter-rater reliability was intra-class correlation (ICC) = .98.

Inhibition

The Prohibition Task (Study I, II, and III)

The *Prohibition Task* (Friedman et al., 2011) was used to measure simple inhibition in Study I, II, and III. An attractive glitter wand was placed in front of the child, while the experimenter said "[child's name] don't touch". The trial lasted for a maximum of 30 s, or until the child touched the wand. The measure for inhibition was number of seconds (0-30) that the child could refrain from touching the wand. ICC = .99.

Numerical Stroop the Local-Global Task (Study IV)

A composite of a computerized *Numerical Stroop Task* (Granvald & Marciszko, 2016) and a computerized *Local-Global Task* (Granvald & Marciszko, 2016) was used to assess complex inhibition in Study IV. In the numerical stroop task, the child was presented with two numbers at the time, which were in different sizes. The task was to answer which of the numbers had the highest value, independent of the size. The task consisted of 80 trials and the measure for inhibition consisted of mean number of correct responses across all trials (ranging from 0-1). Reliability was .73 (split-half). In the local-global task, the child was presented with large, global, squares and circles that were made up by small, local, circles and squares. At the bottom of the pictures an additional square and circle that were either large (indicating a global response) or small (indicating a local response) were shown. The task was divided into three blocks, first 40 trials with a global response, then 40 trials with a local

response, and lastly a block of 80 trials, the shifting block, where the child had to alternate between giving a global and local response. The measure consisted of mean number of correct responses during the shifting block (ranging from 0-1). Reliability was .84 (split-half). The numerical stroop and local-global task were significantly correlated (*rho* = .49, $p < .05$) and collapsed into one measure for complex inhibition, theoretically informed by that both tasks provide the child with a conflict that require complex inhibition to be solved.

Working Memory

The Hide and Seek Task (Study III)

The *Hide and Seek Task* (adapted from Garon et al., 2014) was used to measure working memory at 12 and 18 months in Study III. Four trials were administered, and each time a small toy was hidden underneath one of three cups in different colors. The child's task was to find the toy after the experimenter had clapped her hands to break the attention towards the cups. A proportional score (total score divided by maximum score for the administered trials; 0-1) was used as the measure of working memory.

Spin the Pots (Study III)

Spin the Pots (Hughes & Ensor, 2005) was used to measure working memory at 24 and 36 months in Study III. Raisins were hidden underneath 6 out of 8 pots on a tray that was first covered with a cloth and then rotated 180 degrees. The child's task was to search for the raisins, one at the time, and the tray was covered and rotated between each search until all raisins had been found. The score consisted of 12 minus the errors made (ranging from 0-12).

Digit Span (Study IV)

To assess working memory in Study IV *Digit Span* from Wechsler Intelligence Scale for Children – 4th ed (WISC-IV; Wechsler, 2004) was used. An increasing amount of numbers were read to the child, who in the first part had to repeat the numbers in the same order as the experimenter, and in the second part had to repeat them backwards. The number of correct responses was used as the measure of working memory (ranging from 0-32).

Global EF

The *A-not-B Task (Study I)*

The *A-not-B Task* (Piaget, 1954) was used to assess global EF (including inhibition, working memory, and shifting) in Study I. The child was presented with an A-not-B apparatus with two cloth covered screens (A and B). A fixed schedule was used. First, attention was drawn to a small toy that was then hidden behind location A, the experimenter then clapped her hands to draw attention from the hiding place, and then the child was instructed to search for the toy. This was repeated four times at location A, four times at location B,

and then back two times at location A. The mean number of correct searches (including looking and reaching; ranging from 0-10) was used as the measure of global EF. ICC = .98.

Temperament

Temperament was assessed in all studies as predictors. Rothbart's framework was used in Study I, II and IV, whereas Rowe and Plomin's framework was used in Study III. Emotion reactivity and regulation were assessed as outcome measures in Study I.

Negative Affect and Surgency

The Rothbart Scales (Study I, II, and IV)

Parents rated negative affect and surgency using the age-appropriate Rothbart scale: *Infant Behavior Questionnaire Revised Very Short Form* (IBQ-R VSF; Putnam, Helbig, Gartstein, Rothbart, & Leerkes, 2014) for the infants and *Early Adolescent Temperament Questionnaire Revised* (EATQ-R) for the school-aged children (L. K. Ellis & Rothbart, 2001). In IBQ-R VSF parents rated temperamental characteristics on a scale ranging from 1-7 and in EATQ-R on a scale ranging from 1-5. The mean of the scales were used as the measures. Cronbach's alpha ranged from $\alpha = .68$ to .86.

Orienting/Regulation and Effortful Control

The Rothbart Scales (Study II and IV)

Orienting/regulatory capacity was rated by parents using IBQ-R VSF and effortful control using the EATQ-R, as described above. Cronbach's alpha ranged from $\alpha = .67$ to .90.

Activity and Persistence

The Colorado Childhood Temperament Inventory (Study III)

Parents rated activity and persistence using the *Colorado Childhood Temperament Inventory* (CCTI; Rowe & Plomin, 1977). The scales consisted of five items each, and parents rated the temperament traits on a scale from 1-5. The respective mean were used as the measures for activity and persistence. Cronbach's alpha ranged from $\alpha = .64$ to .85.

Emotion Reactivity and Regulation

The Attractive Toy Placed Behind Barrier (Study I)

The *Attractive Toy Placed Behind Barrier* (Goldsmith & Rothbart, 1999) was used to assess emotion reactivity and regulation. The parent was instructed to hand an attractive multi-toy to the child and then remain neutral. The child explored the toy for 15 s and the parent was then asked to remove the toy from the child and place it behind a Plexiglas barrier raised by the experimenter.

The toy was placed behind the barrier, in full sight of the child, for 30 s and was then handed back to the child. This was repeated three times. The procedure was coded for total latency to distress, that is the total number of seconds until the child showed distress (0-90), as a measure of reactivity. Disengagement of attention, that is mean number of seconds per 5-s epoch (0-5), that the child looked away from the toy, was used as a measure of emotion regulation.

Parenting

Maternal Sensitivity (Study I and II)

Maternal sensitivity was assessed in Study I and II using the *Maternal Sensitivity Scales* (Ainsworth, 1969). Mother and child played together during a semi-structured play session that lasted 26 minutes, based on guidelines by Pederson and colleagues (Pederson, Moran, & Bento, 2013). The session contained various elements to ensure a wide range of demands on the mother, comparable to everyday life. First, the mother was requested to fill out a form, while the child had no toys to play with. Secondly, toys were brought to the child while the mother continued to fill out the form. Then different sets of toys were brought to the dyad to play with: first a set of multiple toys, then a toy that was too difficult for the child to master, and then a book for the dyad to read. The last part contained free play for the dyad without toys. The session was recorded and coded as a whole using the maternal sensitivity scales (Ainsworth, 1969). The global scale of sensitivity versus insensitivity towards to the infant's signals (ranging from 1-9) was used as the measure for sensitivity. This particular scale concerns the mother's ability to accurately and promptly perceive, interpret, and respond to the child's signals. A score of 9 corresponds to highly sensitive, 7 to sensitive, 5 to inconsistently sensitive, 3 to insensitive, and 1 to highly insensitive. ~20% of the cases were coded by an independent coder, and interrater reliability was ICC = .74.

Parental Support (Study IV)

Parental support was measured using the *Involvement* and *Conflict* scales from the *Parent Environment Questionnaire* (PEQ; Elkins, McGue, & Iacono, 1997). Mothers and fathers rated items regarding their relationship with the child on a scale from 0-4. The scales were then collapsed into a composite score for parental support. High support indicate high involvement and low conflict. The mean of maternal and paternal ratings was used as the measure of parental support. Cronbach's alpha was in the range of $\alpha = .66$ to .83.

Inattention and Hyperactivity/Impulsivity

The ADHD Rating Scale-5 (Study II, III, and IV)

The *ADHD Rating Scale-5* for children and adolescents (DuPaul, Power, Anastopoulos, & Reid, 2016) was used to assess inattention and hyperactivity/impulsivity. Parents and teachers rated symptoms on a scale from 0-3. In Study II and IV the mean of parent and teacher ratings were used as the measure of inattention and hyperactivity/impulsivity and in Study III the mean of teacher ratings was used. Cronbach's alpha was in the range of $\alpha = .81$ to .95.

Oppositional Defiant Disorder

The Swanson, Nolan, and Pelham Scale – IV (Study IV)

The *Swanson, Nolan, and Pelham Scale – IV* (SNAP-IV; Bussing et al., 2008) was used to measure the DSM-5 symptoms of ODD in Study IV. Parents and teachers rated the eight symptoms on a scale from 0-3. The mean of parent and teacher ratings was used as the measure of ODD symptoms. Cronbach's alpha was $\alpha = .93$.

Empirical Studies

Study I

The role of sustained attention, maternal sensitivity, and infant temperament in the development of early self-regulation

Background and Aims

Self-regulation, including both cognitive regulation and emotion regulation, is essential for a range of socially and clinically relevant behaviors throughout development and later in life (Mischel et al., 2010; Moffitt et al., 2011). Self-regulation begins to develop during the first year of life (Posner et al., 2012), with a proposed hierarchical organization in which simpler functions assemble into more complex ones (Garon et al., 2008, 2014). Attention is believed to be the foundation for development of self-regulation (Colombo & Cheatham, 2006; Garon et al., 2008; Posner et al., 2012). In addition, the progression of self-regulation is affected by aspects of temperament and by the caregiving environment (Fox & Calkins, 2003; Friedman et al., 2008; Garon et al., 2008; Posner et al., 2012; Putnam et al., 2008). However, there is a lack of studies examining early development of self-regulation (Hendry et al., 2016), and few have studied the contribution of intrinsic and environmental factors simultaneously. Thus, the aim of Study I was to examine independent effects of sustained attention, temperamental reactivity, and maternal sensitivity in infancy in relation to cognitive regulation and emotion regulation at 18 months. In addition, interaction effects between maternal sensitivity and the intrinsic factors (sustained attention and temperamental reactivity) were examined. Finally, concurrent relations between cognitive regulation and emotion regulation were investigated.

Method

Sustained attention, negative affect, surgency, and maternal sensitivity were assessed when the infants were 10 months old (n = 124). Sustained attention and maternal sensitivity were observed in the lab and the mothers rated infant temperament. Different aspects of self-regulation (inhibition, global EF, latency to distress, and emotion regulation) were assessed in the lab at 18 months (n = 117). The sample was typically developing.

Results

Sustained attention was positively and significantly correlated with inhibition (*rho* = .25, $p < .05$) and global EF (*rho* = .27, $p < .05$), and contributed independently to inhibition ($\beta = .25$, $p < .01$). Higher levels of maternal sensitivity were significantly correlated with longer latency to distress (*rho* = .26, $p < .05$), and higher emotion regulation (*rho* = .25, $p < .05$), and contributed independently to both. In addition, surgency made an independent contribution to emotion regulation ($\beta = -.31$, $p < .05$), in that higher surgency was associated with poorer emotion regulation. Interaction effects indicated that maternal sensitivity affected latency to distress in children with low to medium levels of sustained attention and emotion regulation in children with low to medium levels of surgency, in positive directions (see Figure 3 and 4). This means that high sustained attention was associated with average latency to distress independent of maternal sensitivity and high surgency was associated with poor emotion regulation independent of maternal sensitivity. Only one significant correlation between cognitive regulation and emotion regulation was found, a negative correlation between inhibition and emotion regulation (*rho* = -.30, $p < .01$).

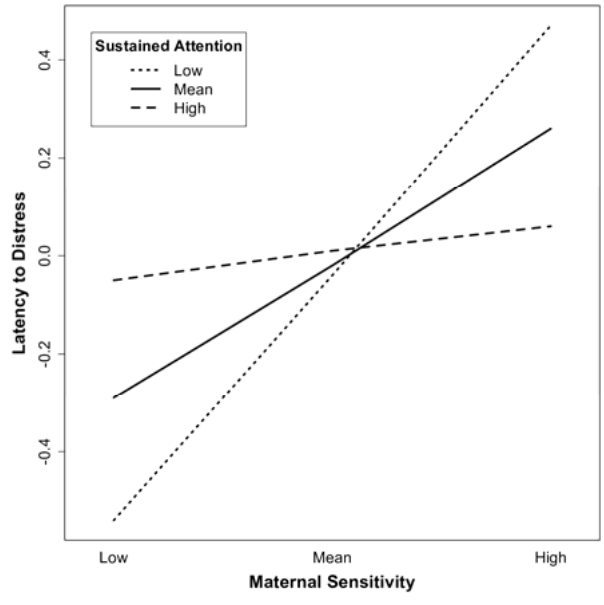

Figure 3. Simple slopes of the regression of maternal sensitivity at 10 months on latency to distress (*z*-scores) at 18 months, at three levels of sustained attention at 10 months. Lines represent low (1 *SD* below the mean), mean, and high (1 *SD* above the mean) levels of sustained attention. At low and mean levels of sustained attention there was a significant relationship between maternal sensitivity and latency to distress ($p < .01$ and $p < .05$, respectively).

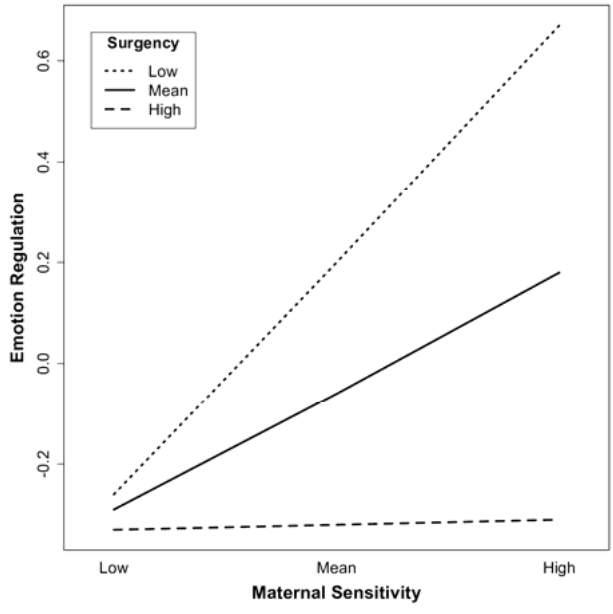

Figure 4. Simple slopes of the regression of maternal sensitivity at 10 months on emotion regulation (*z*-scores) at 18 months, at three levels of surgency at 10 months. Lines represent low (1 *SD* below the mean), mean, and high (1 *SD* above the mean) levels of surgency. At low and mean levels of surgency there was a significant relationship between maternal sensitivity and emotion regulation ($p < .01$ and $p < .05$, respectively).

Discussion

High sustained attention at 10 months predicted better cognitive regulation, which provide support for the hierarchical framework proposing sustained attention to be a foundation for development of cognitive regulation. Higher levels of maternal sensitivity predicted better emotion regulation, whereas high surgency predicted less emotion regulation, suggesting both parenting and aspects of temperament to be important for development of emotion regulation. Interaction effects showed that maternal sensitivity affected emotion regulation when levels of sustained attention and/or surgency were low to medium, suggesting that maternal sensitivity enhances emotion regulation for these children. From another perspective, high sustained attention can be viewed as a protective factor for children with insensitive mothers, and high surgency can be viewed as a general risk factor in relation to aspects of emotion regulation. Cognitive and emotion regulation do not seem to develop in parallel, but may with time become coordinated into more complex self-regulation.

Study II

Can reactivity and regulation in infancy predict inattentive and hyperactive/impulsive behavior in 3-year-olds?

Background and Aims

ADHD is a disorder characterized by deficits in various aspects of self-regulation (Busch et al., 2002; Nigg, 2005; Shaw et al., 2016). Symptoms often emerge during the early years (Kieling et al., 2010), even though the condition is most often not diagnosed until school-age (Visser et al., 2014). Deficits in cognitive regulation, elevated temperamental reactivity, and poor temperamental regulation have all been linked to ADHD in pre-school and school-aged children (Johnson et al., 2015; Nigg, 2006; Willcutt et al., 2005). In addition, certain aspects of parenting are suggested to influence symptomatology, by external regulation of the child's behavior and emotions (B. Ellis & Nigg, 2009; Johnston & Mash, 2001). The influence of parenting may be expressed as main effects or in interaction with intrinsic factors. There is a need to investigate early markers of later symptoms, to enable early detection and intervention (Johnson et al., 2015). Thus, the aim of Study II was to examine cognitive regulation, temperament, and maternal sensitivity in infancy in relation to inattentive and hyperactive/impulsive behavior at 36 months. We set out to study bivariate relations, as well as independent and interactive effects.

Method

One hundred and twelve typically developing children participated in the study. At 10 months assessment of sustained attention, inhibition, and maternal sensitivity was conducted during a visit to the lab and mothers reported on child temperament. At 36 months parents and teachers rated children's inattentive and hyperactive/impulsive behavior.

Results

Temperamental regulation and maternal sensitivity were significantly and negatively correlated with inattention and hyperactivity/impulsivity and contributed independently to both symptom domains (see Table 2 and 3). In addition, surgency contributed independently to hyperactivity/impulsivity. No interaction effects were found.

Table 2. *Linear model of predictors of inattention at 36 months. 95% confidence intervals based on 1 000 bootstrap samples reported in parenthesis.*

	B (CI)	*β*
Constant	1.96 (1.23 - 2.74)	
Surgency	0.02 (-0.10 - 0.14)	.03
Orienting/regulation	-0.23 (-0.34 - -0.12)	-.34**
Maternal sensitivity	-0.06 (-0.10 - -0.02)	-.23**

Note. R^2 = .15. ** p < .01. n = 110.

Table 3. *Linear model of predictors of hyperactivity/impulsivity at 36 months. 95% confidence intervals based on 1 000 bootstrap samples reported in parenthesis.*

	B (CI)	*β*
Constant	1.21 (0.37 - 2.14)	
Sustained attention	0.07 (-0.14 – 0.26)	.05
Surgency	0.12 (0.01 - 0.23)	.20*
Orienting/regulation	-0.18 (-0.29 - -0.07)	-.27**
Maternal sensitivity	-0.09 (-0.14 - -0.04)	-.34**

Note. R^2 = .22. * p < .05, ** p < .01. n = 110.

Discussion

Temperamental regulation, surgency, and maternal sensitivity all contributed independently to inattention and/or hyperactivity/impulsivity. The results are in line with a multiple pathway perspective on ADHD symptoms (e.g., Nigg, 2006). The results also support that parenting is an important factor in the progression of self-regulation (Bernier et al., 2010). Surprisingly, cognitive regulation (i.e., sustained attention and inhibition) was unrelated to inattention and hyperactivity/impulsivity, and none of the expected interaction effects were found. The results add to the scarce literature suggesting that markers of later inattention and hyperactivity/impulsivity can be found early in development (Johnson et al., 2015).

Study III

Temperament and cognitive regulation during the first 3 years of life as predictors of inattention and hyperactivity/impulsivity at 6 years

Background and Aims

Reactive and regulatory aspects of temperament, as well as cognitive regulation are suggested as important factors in the development of inattention and hyperactivity/impulsivity (Barkley, 1997; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Nigg et al., 2004). In addition, there is a need to expand the findings on early predictors of later inattentive and hyperactive/impulsive behavior. In Study III we wanted to replicate and extend some of the findings from Study II, by examining temperament (activity and persistence) and cognitive regulation (inhibition and working memory), measured successively during the first three years of life, as predictors of inattentive and hyperactive/impulsive behavior at 6 years. We also wished to investigate the concurrent relations between cognitive regulation and temperament.

Method

The initial sample consisted of 66 typically developing children, of which 47 participated at follow-up. Inhibition and working memory were assessed with laboratory tasks at 12, 18, 24, and 36 months, and parents rated child temperament at the same time points. At 6 years teachers rated inattentive and hyperactive/impulsive behavior in the child.

Results

Activity at 12 months was positively correlated with inattention (*rho* = .37, $p < .01$) and activity at all time points was positively correlated with hyperactivity/impulsivity (*rho*s = .34 to .46, *p*s < .05). Persistence at 18 and 36 months was negatively correlated with inattention (*rho*s = -.25 to -.27, *p*s < .05) and persistence at 36 months was negatively correlated with hyperactivity/impulsivity (*rho* = -.28, $p < .05$). In addition, activity at 12 months made an independent contribution to inattention, and activity at 18 and 36 months contributed independently to hyperactivity/impulsivity (see Table 4). No additive ef-fects over time were found for any of the predictors. Contrary to our predic-tions, inhibition and working memory were unrelated to later inattention and hyperactivity/impulsivity. Activity, persistence, and inhibition showed some stability over time, whereas working memory did not. Inter-correlations be-tween the predictors were generally low.

Table 4. *Summary of linear bootstrapped regression models. Each model represents predictors at a certain time point (12, 18, or 36 months), in relation to inattention or hyperactivity/impulsivity at 6 years.*

	Outcome Variables at 6 years			
	Inattention		Hyperactivity/ impulsivity	
	β	R^2	β	R^2
Model 1**				
12 months		.28		
Constant				
Activity	.31*			
Inhibition	.38^{+}			
WM	.08			
Model 2 and 3**				
18 months		.06		.26
Constant				
Activity	.15		.37**	
Persistence	-.16		-.26	
Model 4[a]*				
36 months				.22
Constant				
Activity			.41*	
Persistence			-.31	

Note. WM = working memory; [a] = controlling for sex.
$^{+}$= $p < .10$, * $p < .05$, ** $p < .01$. $n = 40 – 45$.

Discussion

In essence, our findings suggest that temperament, already at 12 months, is a reliable marker of later inattentive and hyperactive/impulsive behavior, whereas cognitive regulation is not. Temperament may be more stable than cognitive regulation during the early years, which may be due to developmental aspects, or to problems with assessment at this age. Also, parent ratings may pick up on different aspects of regulation (traits) than lab observations (states), which may have different predictive value for later inattention and hyperactivity/impulsivity. In all, the results support a temperamental pathway to inattention and hyperactivity/impulsivity (Nigg, 2006), and that markers may be found early in development. Importantly, detection of early markers makes early intervention possible.

Study IV

A multi-factorial perspective on ADHD and ODD in school-aged children: What is the role of cognitive regulation, temperament, and parental support?

Background and Aims

ADHD is characterized by deficits in various aspects of self-regulation, including disruptive behavior problems such as ODD (Connor et al., 2010). Both ADHD and ODD are related to poor cognitive regulation, extreme temperament traits, and family dysfunction (Burt, Krueger, McGue, & Iacono, 2001; Castellanos & Tannock, 2002; Deault, 2010; Frick & Nigg, 2012; Hinshaw, 2018; Nigg et al., 2004; Sonuga-Barke et al., 2010). However, different pathways to ADHD and ODD may be at work (Martel, 2009; Nigg, 2006). Based on a multi-factorial perspective on ADHD and ODD, we aimed to study cognitive regulation, temperament, and parental support in relation to symptoms of inattention, hyperactivity/impulsivity, and ODD in a sample of school-aged children of which ~40% had a diagnosis of ADHD. Common and separate contributions of the constructs were examined, as well as interaction effects between the intrinsic factors and parental support.

Method

Seventy-seven children aged 8-12 years participated in the study, of which 30 (39%) had a diagnosis of ADHD. The children were seen for a 2-hour visit, in which complex inhibition and working memory were assessed with laboratory tasks. Temperament and parental support were reported on by mothers and fathers. Parents and teachers reported on inattention, hyperactivity/impulsivity, and ODD.

Results

Cognitive regulation and effortful control were negatively correlated with the outcome measures (*rho*s ranging from -.23 to -.51, all *p*s < .05). Negative affect was positively correlated with the outcome measures (*rho*s ranging from .43 to .68, all *p*s < .05). Parental support was correlated with ODD symptoms only (*rho* = -.35, $p < .01$). Working memory and effortful control contributed independently to inattention ($\beta = -.19$, $p < .05$ and $\beta = -.50$, $p < .01$), and effortful control contributed independently to hyperactivity/impulsivity ($\beta = -.49$, $p < .01$). Negative affect contributed independently to ODD ($\beta = .32$, $p < .05$). In addition, parental support moderated the relation between negative affect and ODD, indicating that the relation was significant for the children who received low to medium levels of support (see Figure 5).

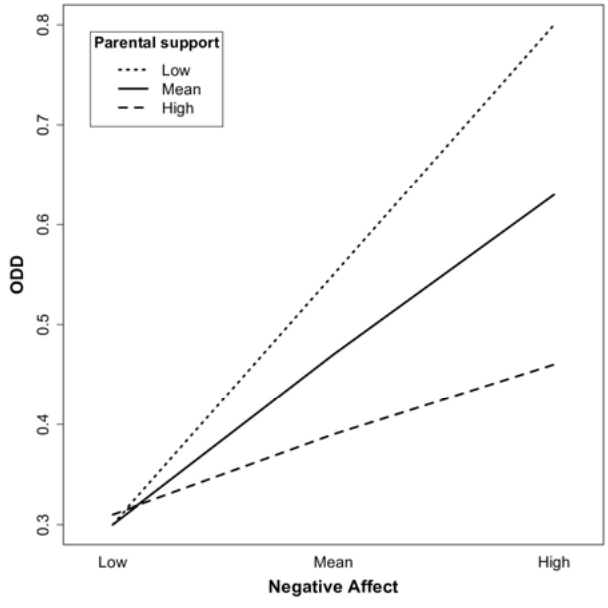

Figure 5. Simple slopes of the regression of negative affect on ODD, as moderated by parental support. Lines represent low (1 *SD* below the mean), mean, and high (1 *SD* above the mean) levels of parental support. At low and mean levels of parental support there was a significant relationship between negative affect and ODD ($p < .001$).

Discussion

The results support a multi-factorial perspective on ADHD, with specific contributions of working memory and effortful control. Different factors are suggested to be involved in ADHD and ODD, with deficits in regulation for the former and elevated negative affect for the latter. Parental support had a moderating role on negative affect in relation to ODD, suggesting that high parental support could be a protective factor for children with high negative affect.

Supplementary Analyses

Study I and II were conducted on the same sample with partly overlapping measures. That is, measures of sustained attention, negative affect, surgency, and maternal sensitivity were included in both studies. However, in Study II we used a more comprehensive model including also temperamental regulation and inhibition. To bridge the gap between the two studies, and to contribute with further knowledge, additional analyses were performed for the sake of the current thesis. Specifically, temperamental regulation and inhibition at 10 months were included as predictors of cognitive regulation and emotion

regulation at 18 months. In a first step, correlations were performed and significant predictors were then included in regression analyses. In addition, the role of cognitive and emotion regulation at 18 months (which were outcome measures in Study I), was examined in relation to inattention and hyperactivity/impulsivity at 36 months (outcome measures in Study II). Again, correlations were performed in a first step, and next it was examined if aspects of self-regulation at 18 months mediated the effect of maternal sensitivity at 10 months on hyperactivity/impulsivity at 36 months. The mediation model was data driven, that is, performed based on significant correlations between maternal sensitivity and emotion regulation in Study I and the results in the supplementary analyses.

Results

See Table 5 and 6 for correlations. Inhibition at 10 months was significantly and positively correlated with inhibition at 18 months. Orienting/regulation at 10 months was unrelated to self-regulation at 18 months. When inhibition at 10 months was entered as a predictor, together with sustained attention and maternal sensitivity, in the regression model regarding inhibition at 18 months, it contributed independently ($\beta = .25$, $p < .05$), in the same magnitude as sustained attention ($\beta = .25$, $p < .05$), and added an extra 6% explained variance.

Table 5. *Correlations between self-regulation at 10 and 18 months*

	10 months		18 months			
	Inhibition	ORC	Inhibition	Global EF	Latency to distress	Emotion regulation
10 months						
Inhibition	1	-.13	.22*	-.00	-.03	-.14
ORC		1	-.00	-.07	.06	-.06

Note. All analyses conducted with Spearman's *rho*. ORC = orienting/regulation. $n = 69 – 123$.

Table 6. *Correlations between measures of self-regulation at 18 months and inattention and hyperactivity/impulsivity at 36 months*

	Inattention	Hyperactivity/impulsivity
18 months		
Inhibition	-.04	.07
Global EF	.02	-.03
Latency to distress	-.14	-.31**
Emotion regulation	-.19	-.24^{+}

Note. All analyses conducted with Spearman's *rho*. n = 67 – 106.

Latency to distress at 18 months was significantly correlated with hyperactivity/impulsivity at 36 months, whereas inhibition and global EF were unrelated to the outcome measures. In the next step, it was examined if latency to distress mediated the relation between maternal sensitivity at 10 months and hyperactivity/impulsivity at 36 months (Study II), but no significant mediation effect was found (see Figure 6). The direct effect of maternal sensitivity was however still significant with latency to distress in the model.

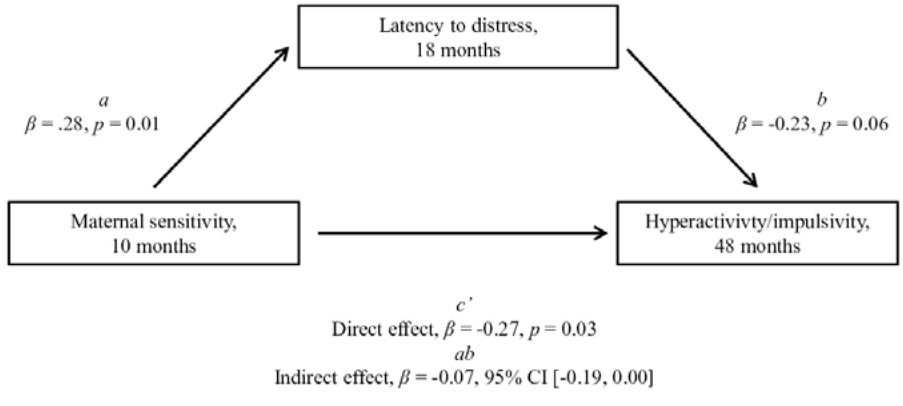

Figure 6. Model of maternal sensitivity as a predictor of hyperactivity/impulsivity mediated by latency to distress. *a* = the influence of the predictor on the mediator, *b* = the independent effect of the mediator, *c'* = the direct or independent effect of the predictor, and *ab* = the indirect effect of the predictor as mediated by the mediator. The confidence interval for the indirect effect is bootstrapped based on 1000 samples. As zero is contained within the confidence interval (CI), the indirect/mediated effect is not considered significant (Field, 2013).

Discussion

Early simple inhibition can, in addition to sustained attention, be considered an early building block for later cognitive regulation. This is consistent with the hierarchical framework of cognitive regulation development (Garon et al., 2008). However, since the same inhibition task is used at 10 and 18 months, an alternative interpretation is that inhibition shows some stability over time. These two perspectives are of course compatible. The otherwise null-findings are contrary to theory, but in line with a large body of empirical findings (e.g., S. E. Miller & Marcovitch, 2015), which will be discussed more thoroughly in the main discussion. Latency to distress was negatively related to hyperactivity/impulsivity, but did not mediate its relationship with maternal sensitivity. This suggests a direct effect of maternal sensitivity on later symptoms.

General Discussion

Self-regulation in general, and inattention and hyperactivity/impulsivity in particular, are complex constructs formed across development, intricately influenced by various intrinsic and extrinsic aspects. In the current thesis, cognitive regulation, aspects of temperament, and parenting were assessed as predictors of self-regulation (i.e., cognitive regulation, emotion regulation, inattention, hyperactivity/impulsivity, and ODD). The hierarchical framework of cognitive regulation development (Garon et al., 2008) and a multiple pathway perspective on ADHD (e.g., Nigg et al., 2004; Sonuga-Barke et al., 2010) informed the work. To cover development over time, a wide range of age groups were included, and typically developing samples as well as a sample oversampled for ADHD diagnoses were examined. Three of the studies comprised longitudinal data and one cross-sectional. Taken together, the results provide support for the hierarchical framework of cognitive regulation development (Garon et al., 2008), suggesting basic attention and inhibition to constitute an early foundation for cognitive regulation. In addition, in line with a multiple pathway perspective, early aspects of temperament and parenting contributed to emotion regulation, inattention, and hyperactivity/impulsivity. Specifically, temperamental surgency contributed to poorer emotion regulation and higher levels of hyperactivity/impulsivity, whereas infant temperamental regulation and maternal sensitivity contributed to lower symptom levels and/or better self-regulation. Cognitive regulation in infancy and toddlerhood was unrelated to later ADHD symptoms. However, in the school-aged sample, deficits in cognitive regulation and the temperamental aspect effortful control were specifically related to inattention and/or hyperactivity/impulsivity, and elevated temperamental negative affect was specifically related to ODD symptoms. The latter was moderated by parental support, in that high parental support seemed to be a protective factor for children with high levels of negative affect. In all, multiple pathways to self-regulation in general and to inattention and hyperactivity/impulsivity in particular are proposed. The pattern of paths seem to differ across development, with clear temperament markers (i.e., high surgency and low regulation) during the early years and primarily poor regulation (i.e., low cognitive regulation and low effortful control) during the school years. In addition, parenting seem to exert a stronger influence on self-regulation early rather than later in development. Importantly, the results stress the value of adapting a developmental perspective on ADHD.

The Structure of Early Self-Regulation: Implications for a General Theoretical Framework

Self-regulation has been investigated from several theoretical perspectives for decades, leading to a jumble of overlapping constructs, such as cognitive self-regulation arising from neuropsychology and effortful control from the temperament literature (Nigg, 2017). Recent attempts have been made to bring order into the mess, with general theoretical concepts that integrate various levels of self-regulation (Bridgett et al., 2015; Nigg, 2017). However, empirically there is still much need for studies elucidating the relations between different but related concepts, such as aspects of temperament and cognitive regulation. Thus, this thesis provides information that can feed into a general theoretical framework of self-regulation from a developmental perspective.

Our findings show that concurrent relations between different aspects of cognitive regulation as well as correlations between cognitive regulation and temperament regulation were generally low and non-significant in infants and toddlers (Study I – III). The lack of coherence among the regulatory constructs during the early years is similar to numerous other empirical findings regarding early cognitive regulation (e.g., S. E. Miller & Marcovitch, 2015; Wiebe, Lukowski, & Bauer, 2010). Several non-mutually exclusive suggestions for this lack of coherence have been proposed. From a theoretical perspective, the lack of coherence may result from differently protracted development for the separate functions and could reflect the initial absence of a common EF (S. E. Miller & Marcovitch, 2015). From a practical perspective, it is difficult to measure functions reliably at this early age, due to a larger influence of states such as fatigue, shyness, and interest in the tasks, which could induce more noise in the data. Relatedly, other basic factors such as motor ability, language, and general cognitive ability may have a stronger influence early in development, which could potentially influence the results. However, the current thesis found that several of the measures, such as inhibition, activity, and persistence, showed coherence over time. Therefore, taken together, the overall pattern of results favor "differently protracted development over time" rather than "just" noise.

In contrast to the lack of coherence between constructs in the younger children, Study IV showed that working memory and effortful control were related in the school-aged sample. This could suggest that different aspects of regulation with time become integrated. Interestingly, in the regression models with inattention as outcome, working memory and effortful control both had independent contributions, suggesting that they are related but dissociated constructs, which has implications for a general theoretical framework of self-regulation. That is, our results suggest that working memory and effortful control are overlapping but distinct processes, favoring Nigg's model of conceptual differences between the two (Nigg, 2017) over Zhou and colleagues', suggesting that the difference is just an artifact (Zhou et al., 2012).

In sum, our results suggest that the separate constructs of self-regulation do not develop in concert during infancy and toddlerhood, but are increasingly integrated towards the early school years. Stability within the self-regulatory constructs over time, in combination with poor correlations between constructs, support the view of differently protracted development for the separate self-regulatory constructs.

The Hierarchical Framework of Early Cognitive Regulation Development

Several theorists have proposed that sustained attention is one of the fundamental building blocks for the development of self-regulation in general (Nigg, 2017; Posner et al., 2012; Ruff & Rothbart, 2001) and of cognitive regulation in particular (Garon et al., 2008). Our results add to the accumulating evidence for this perspective, by showing that observed sustained attention at 10 months was related to cognitive regulation at 18 months. These relations have previously been studied primarily within the temperamental literature (e.g., Kochanska, Murray, & Harlan, 2000), with some important exceptions (e.g., Johansson et al., 2016, 2015). Results from the supplementary analyses show that early inhibition also contributed to later cognitive regulation. Specifically, inhibition at 10 months significantly predicted inhibition at 18 months and added an extra 6% in explained variance (the same magnitude as the contribution of sustained attention). Of note, the same inhibitory task was used at 10 and 18 months, and since this task is simple in its nature, it would be premature to conclude that the relation between inhibition at the two time points is hierarchical. The significant relation could instead reflect stability of simple inhibition over time in early development. Nevertheless, our findings propose simple sustained attention and inhibition as building blocks in the progression of cognitive regulation, which is in line with the reasoning of Garon, Nigg, and others (Garon et al., 2008, 2014; Nigg, 2017). Thus, mechanistically the ability to sustain attention may help the individual to attend to the present situation, which in turn may increase his/her probability of solving the task at hand. In addition, independently of sustained attention, the ability to inhibit a prepotent response seem to longitudinally contribute to better self-regulation.

A Multiple Pathway Perspective on Self-Regulation Development

As hopefully stated clearly, one important focus of the current thesis was to look beyond one-dimensional effects of isolated constructs, and instead investigate common and independent effects of a set of reactive and regulatory predictors, with a multiple pathway perspective in mind. In addition, we examined whether parenting moderated the effects of the intrinsic factors. In the literature, several multiple pathway models of ADHD have been proposed, some focusing on temperament (Nigg, 2006) and some on aspects of neuropsychological functioning (Sonuga-Barke et al., 2010). In this theses, I have examined models model including cognitive regulation, aspects of temperament, and parenting. These constructs all regard aspects of intrinsic or extrinsic regulation and should theoretically predict development of self-regulation, although, to the best of my knowledge, they have never previously been assessed simultaneously. I will first present results regarding the separate predictors, and then move on to describe results corresponding to a multiple pathway perspective. The results regarding the moderating role of parenting will be integrated under the other sub-headings.

Cognitive Regulation

The results regarding the hierarchical model of cognitive regulation development, addressed above, suggest that the effect of sustained attention may be specific for cognitive regulation. Specifically, we found longitudinal relations between sustained attention and later inhibition and global EF, whereas we found no relation between early attention and later emotion regulation. However, high sustained attention seemed to be a protective factor for children of insensitive mothers, in that those children displayed average levels of emotion regulation independently of the level of maternal sensitivity. Therefore, sustained attention may indeed affect also emotion regulation, but in interaction with parenting rather than through main effects. As such, high sustained attention can be considered a resilience factor (i.e., an ability to adapt despite adverse conditions), which helps the individual to calmly attend to the present situation and solve what is at hand.

The last decades have seen a move from a perspective on cognitive regulation as a sole precursor of ADHD (Barkley, 1997) to a more nuanced perspective where it is still clear that poor cognitive regulation is associated with ADHD, although not to be found in everyone with the disorder (Willcutt et al., 2005). However, the association between cognitive regulation and ADHD symptoms is heavily understudied in infancy and toddlerhood, which require further attention. Consistently, we found that cognitive regulation during the first three years of life was a poor predictor of later inattention and hyperactivity/impulsivity, with no significant relationships between these constructs

(Study II, III, and in supplementary analyses). These findings are in sharp contrast to findings in older children (e.g., Biederman et al., 2004; Brocki & Bohlin, 2006; Brocki et al., 2017; Pauli-Pott & Becker, 2011). Indeed, in the school-aged sample we did find the expected relation between cognitive regulation and inattention and hyperactivity/impulsivity, and that working memory contributed to inattention beyond temperament and the control variables (i.e., sex, IQ, age, and SES).

The null findings between cognitive regulation and ADHD symptoms in early childhood were surprising. We used the inhibition task in two different samples and at varying ages (10, 12, 18, 24, and 36 months), with no predictive value in relation to inattention and hyperactivity/impulsivity at neither 36 nor 72 months. However, increased ability and stability of the construct were found in both samples, suggesting reliability of the inhibitory test. Despite ceiling effects at 36 months, we conclude that simple inhibition early in life does not seem to predict inattention and hyperactivity/impulsivity, at least not in samples of typically developing children. This is in partly in contrast to a previous study where this particular task predicted long term self-regulation (Friedman et al., 2011). However, Friedman and colleagues predicted self-regulation not inattention and hyperactivity/impulsivity, and used latent class growth models. That is, they investigated differences in later self-regulation based on group membership (i.e., more or less restrained children), which may explain the different results. In addition, a recent conceptual replication of the delay of gratification paradigm (which is related to the prohibition task) suggests that generally high SES may have afflicted previous results (Watts, Duncan, & Quan, 2018). As such, the poor variation of SES in our study may, at least in part, account for the lack of predictive value of inhibition.

So, how can the lack of association between cognitive regulation and ADHD symptoms during the younger years be explained? It has been suggested that cognitive regulation may not be sufficiently developed to influence behavior until later in toddlerhood (Diamond, 2013). Thus, our results may suggest an increased influence of cognitive regulation on ADHD symptoms over time, explained by maturation effects. This has previously been found for working memory and inhibition, in both clinical and non-clinical groups (Brocki & Bohlin, 2006; Brocki et al., 2007; Pauli-Pott & Becker, 2011). One important aspect to take into consideration is that the pattern of relations may not be the same for typically developing children and children at risk for ADHD, in that variation in cognitive regulation may be of greater importance for later self-regulation in at-risk samples (Rajendran et al., 2013). In addition, the restricted variation in both sustained attention and in the outcome measures may have prevented detection of significant findings. As for working memory, we had adequate variability but poor stability over time, so it is unclear if the particular tests actually capture working memory, or if the developmental changes across time are so large that no stability can be detected. It is also a widely experienced phenomena that it is hard to assess cognitive

regulation reliably during the early years (S. E. Miller & Marcovitch, 2015), which may, at least in part, have impacted the null results. In addition, other attentional processes, such as alerting or executive attention, may be of greater interest than sustained attention per se (Posner et al., 2012).

Taken together, our results suggest that early cognitive regulation is a poor marker of later inattention and hyperactivity/impulsivity, at least in the very early years of life. This could be specific for typically developing children (Rajendran et al., 2013), but it could also reflect a developmental effect, in that cognitive regulation exerts a stronger influence on symptomatology as the child gets older (Pauli-Pott & Becker, 2011). Put differently, bottom-up processes may be more influential early in development and top-down processes later on. Importantly, these two perspectives are not mutually exclusive, in that both the characterization of the sample and developmental aspects affect the impact of cognitive regulation on symptomatology.

Temperament

Aspects of temperament have increasingly been recognized as predictors and markers of poor regulation and heightened levels of inattention and hyperactivity/impulsivity (Nigg, 2006). We investigated the role of reactive and regulatory aspects of temperament in relation to self-regulation, including inattentive and hyperactive/impulsive symptoms. The general pattern of results suggests that negative affect was unrelated to later self-regulation and that surgency was positively associated with dysregulation of emotions and hyperactivity/impulsivity during infancy and toddlerhood, but not in school-aged children. The results regarding temperamental regulation were more disperse, but generally, poor regulation was associated with higher levels of both inattention and hyperactivity/impulsivity.

Nigg and colleagues have suggested that surgency would be primarily associated with hyperactivity/impulsivity, and effortful control primarily associated with inattention (Martel & Nigg, 2006; Nigg, 2006). We could confirm the specific relationship between surgency in infancy and hyperactivity/impulsivity in toddlerhood. However, activity in infancy contributed independently to both symptom domains at 6 years. In addition, orienting/regulation and effortful control had independent effects (with similar magnitudes) to both inattention and hyperactivity/impulsivity in Study II and IV, whereas persistence had no independent effects on any of the domains beyond activity in Study III. Taken together, our results do not support that effortful control, or related constructs, are primarily related to inattention, and the results regarding the specificity of surgency are inconclusive. As such, temperamental regulation seems to be involved in ADHD symptoms generally, and not in any symptom domain specifically. Medium to high inter-correlations between inattention and hyperactivity/impulsivity (*rho* = .54 in Study III, .65 in Study II, and .78 in Study IV) may in part account for the lack of specificity. On the

other hand, while we controlled for several possible confounds, we did not control for the other symptom domain, which could have inflicted these result.

A spectrum model proposes that ADHD reflects extreme ends of temperament traits, whereas a vulnerability model proposes that temperament interacts with other factors in shaping ADHD symptoms (Nigg, 2006). No interactive or additive effects were found in relation to ADHD symptoms in the current studies, suggesting that our results are more consistent with a spectrum model than with a vulnerability model. This is in line with previous findings in preschoolers (Martel et al., 2014). Still, one has to bear in mind that the samples in Study II and III were typically developing, and that certain temperament traits may constitute vulnerabilities in children at risk for ADHD, even though non-clinical and clinical symptoms reflect the same behavioral and genetic phenotype (Middeldorp et al., 2016; Willcutt et al., 2012).

In all, the results suggest that temperament is a construct that can bring understanding to ADHD symptoms from a trait perspective. In addition, negative affect, surgency, and regulatory aspects of temperament seem to have slightly different effects across development. First, negative affect seems to be unrelated to self-regulation and ADHD symptoms per se, in accordance with previous theory and some findings (Forslund et al., 2016; Nigg et al., 2004). Surgency on the other hand has a clear impact on self-regulation across the early years, also in concordance with theory and previous results (e.g., Auerbach et al., 2004; Nigg et al., 2004; Shephard et al., 2018). A few different mechanisms for this association have been suggested. First, highly surgent children may encounter more blocked goals, which may result in frustration and over-arousal, putting greater stress on the regulatory systems (Polak-Toste & Gunnar, 2006). Secondly, as surgency maps directly onto impulsivity and high activity level, no mediator may be needed. Finally, Derryberry and Rothbart proposed that strong approach may stimulate reward related behaviors, and as such reciprocally increase impulsivity over time (1997). All these mechanisms could be activated simultaneously. It is also possible that different mechanisms could be at work for different individuals.

Surgency seems to have a stronger impact early in development rather than later. However, even though we used Rothbart's temperamental framework in Study IV, as in Study I and II, we suspect that the particular scale for school-aged children (the EATQ-R) captures something quite different from basic positive affect and strong approach. That is, the EATQ-R seems to describe rather integrated personality traits taxing openness to experience (with items such as "appreciating adventurous travelling and activities" and "looking forward to moving to a new city"). Our finding regarding surgency is consistent with literature on school-aged children using temperament scales with null results (Cukrowicz et al., 2006; De Pauw & Mervielde, 2011). However, studies using pure emotionality scales found positive results between exuberance (a construct closely related to surgency) and hyperactivity/impulsivity (Forslund et al., 2016; Sjöwall et al., 2015). Thus, as surgency become integrated

with personality, repeated social failure and possibly fewer opportunities to explore the world may result in a lower association between surgency (as captured in the EATQ-R) and ADHD symptoms. However, if assessed from a pure reactive emotionality perspective significant associations may still be present (Forslund et al., 2016; Sjöwall et al., 2015).

Temperament regulation seems to have varying influence on self-regulation and ADHD symptoms across development. That is, from none or smaller magnitudes in infancy, when the regulation is mainly bottom-up and non-effortful, significant correlations but without independent effect during toddlerhood, to clear and larger independent effects in school-aged children. This can be interpreted as in line with developmental aspects of temperament, in that regulation/persistence develops later than the reactive aspects of temperament (Rothbart, 2007). This pattern of effects of temperamental regulation corresponds quite well with the pattern of effects we found for cognitive regulation. The plausible explanation for the pattern of both cognitive and temperament regulation is that with increased maturity of top-down regulation, the more impact do different aspects of regulation have on general functioning. The mechanism behind the association between temperamental regulation and aspects of self-regulation is probably straightforward, in that poor attentional and inhibitory control are displayed as inattention and hyperactivity/impulsivity at a behavioral level.

Parenting

Parenting has for decades been considered as an important extrinsic influencer of self-regulation and inattentive and hyperactive/impulsive symptoms (E. A. Carlson et al., 1995; Deault, 2010; Johnston & Mash, 2001). However, this relation is confounded by child symptoms that may evoke less wanted parental behaviors (Deault, 2010; Johnston & Mash, 2001). Thus, it is of great importance to take child characteristics and comorbidity into account when examining these relations. Our results show that maternal sensitivity contributed independently to self-regulation, including emotion regulation, inattention, and hyperactivity/impulsivity, during the younger years, but that parental support during the school years was associated with comorbidity of ODD symptoms rather than with ADHD symptoms per se. In addition, as discussed above, maternal sensitivity interacted with surgency and sustained attention in the display of distress and emotion regulation in toddlerhood.

Our results suggest that maternal sensitivity may be particularly important for the development of emotion regulation, rather than cognitive regulation. The lack of relation between parenting and cognitive regulation is partially in contrast to previous findings (Bernier et al., 2012, 2010; Hughes & Ensor, 2005; Rochette & Bernier, 2016). However, these previous studies suggest that maternal autonomy support is a better predictor of cognitive regulation than maternal sensitivity, possibly due to its larger focus on problem solving

(Bernier et al., 2010). Maternal sensitivity is focused on sensitive responses to the child's signals rather than on problem solving or learning (Ainsworth, 1969), which may explain the positive association with emotion regulation. The proposed mechanism could be that prompt, sensitive, and adequate external responses from the parent, with time converts into intrinsic emotion regulation, which in turn could be mediated through optimal arousal and/or observational learning (Kochanska, 1997).

One of the studies referenced above found effects of sensitivity in relation to hot rather than cool aspects of cognitive regulation, again suggesting that sensitivity affects more emotionally valenced functions (Rochette & Bernier, 2016). Rochette and Bernier found that this was true especially for children with a more difficult temperament, in line with a differential susceptibility pattern. We could not confirm this finding. Instead, we found that children with low to medium levels of surgency were most receptive of sensitive parenting, and that high surgency seemed to constitute a risk factor independently of level of maternal sensitivity. In contrast, a pattern of differential susceptibility seemed to occur for sustained attention, in that low and mean sustained attention constituted the susceptibility factor. However, theoretically poor sustained attention do not clearly translate into a susceptibility factor.

To conclude, we found an effect of maternal sensitivity in infancy on emotion regulation, inattention, and hyperactivity/impulsivity in a typically developing sample. However, we found no effect of parental support on ADHD symptoms in the school-aged sample oversampled for ADHD diagnoses. The effect of parenting on self-regulation in general and inattention and hyperactivity/impulsivity in particular, may be stronger for typically developing children compared to children with an ADHD diagnosis. Yet, perhaps a more plausible explanation would be that parenting has a stronger influence early in development, due to a sensitive window for environmental influences (Callaghan & Tottenham, 2016; E. A. Carlson et al., 1995; Sulik, Blair, Mills-Koonce, Berry, & Greenberg, 2015). This sensitive period would be due to neural plasticity and to the fact that the child is more dependent on the parent during the early years. It also needs to be mentioned that maternal sensitivity was observed in a laboratory, whereas parental support was self-rated, which may have had an influence on the results. In addition, it is important to emphasize, to avoid misunderstandings, that having an influence on self-regulation in general and on inattention and hyperactivity/impulsivity is not equal to cause a deficit or disorder. It should not be controversial to state that parenting affects child regulation, and that this would hold true for children with various levels of inattention and hyperactivity/impulsivity.

Multiple Pathways

As one important aim of the thesis, we assessed concurrent contributions of cognitive regulation, aspects of temperament, and parenting, as a way of addressing multiple pathways to self-regulation in general and to ADHD and ODD symptoms in particular. Primarily, the results show that separate contributions of the constructs could be detected already in infancy, with clear temperament markers (i.e., poor regulation and elevated surgency) of later emotion dysregulation, inattention and hyperactivity/impulsivity. Furthermore, maternal sensitivity contributed independently beyond the temperament markers. In the school-aged sample, we found contributions of working memory and effortful control to ADHD symptoms, but not of parenting. These results are in line with a multiple pathway perspective on ADHD. In addition, the results suggest that different factors and mechanisms may be involved at different developmental stages, supporting a neurodevelopmental perspective on ADHD. Specifically, parenting and bottom-up processes seem to exert a stronger effect early in development and top-down regulation later on.

In sum, we found results in line with early emerging multiple pathways to emotion regulation, inattention and hyperactivity/impulsivity, from a temperamental and parental perspective, but with no effects of cognitive regulation (Study I and II). In Study III, where parenting was not included, activity was the only independent predictor of later inattention and hyperactivity/impulsivity. Again, we did not find an effect of cognitive regulation. In contrast, study IV showed multi-factorial effects of working memory and effortful control on ADHD symptoms, suggesting that several aspects of regulation are at work in this age group. The pattern of results proposes that primarily high surgency and also poor orienting/regulation are valid longitudinal markers of later inattentive and hyperactive/impulsive symptoms. A marker concerns a construct that has predictive validity. However, temperament markers could in this case potentially be considered as precursors, as poor regulation and/or high surgency/activity are conceptually related to the core features of ADHD (Johnson et al., 2015). The temperament markers may also fit the description of endophenotypes, as temperament is heritable (Saudino, 2005), neurologically based (Whittle et al., 2006), and could be seen as mediators between the genetic predisposition for ADHD symptoms (Larsson et al., 2014) and the behavioral symptoms presented later on (Johnson et al., 2015). However, it is not clear if temperament is state independent, that is manifested independently of whether the diagnosis is present or not (Rommelse, Geurts, Franke, Buitelaar, & Hartman, 2011). To label the aspects of temperament as markers, precursors, or endophenotypes properly, the findings need to be replicated in clinical or risk samples, with estimated higher prevalence of formal ADHD diagnoses. As for the dual contributions of working memory and effortful control in the school-aged sample, it appears as if the more trait like effortful control contributes beyond the more pure cognitive abilities of inhibition and

working memory. First, effortful control is by definition more broad than the cognitive constructs. On the other hand, our results may suggest that how an individual self-regulates on a daily basis may be something different from how the individual performs under optimal conditions in a lab setting. Importantly, these two types of self-regulatory mechanisms both contribute to symptom presentation.

Maternal sensitivity contributed to emotion regulation, inattention, and hyperactivity/impulsivity, with control for child temperament. This suggests that the (albeit small) effect of parenting is driven by the parent and not by child characteristics. Supplementary analyses showed that the effect of maternal sensitivity on hyperactivity/impulsivity was direct, and not mediated by latency to distress at 18 months. In addition, interaction effects between maternal sensitivity and sustained attention and surgency were found in relation to emotion regulation, suggesting that the effect of parenting depends in part on the temperament profile and levels of cognitive regulation. Specifically, sensitivity had a positive effect on emotion regulation for children with low to mean levels of surgency, and low to mean levels of sustained attention. Here, the functions for surgency and sustained attention goes in opposite directions, in that high surgency seems to be a risk-factor for all children, whereas high sustained attention seems to be a protective factor for children of insensitive mothers. Put differently, maternal sensitivity can be seen as a buffer for children with lower levels of sustained attention.

To conclude, perhaps the unifying theory, so much needed in the ADHD field, includes multiple pathways to the same heterogeneous disorder, which, depending on an individual's specific genetic make-up, environment, and age could have different weight. That is, developmental heterogeneity could be present (Sonuga-Barke & Halperin, 2010; Sonuga-Barke, 2005). This is consistent with the developmental psychopathology framework outlined by Rutter and Sroufe, in which they discuss how psychopathology develop over time, and that multiple factors, including neurobiological risk and environmental aspects, feed into the presentation of symptoms (2010).

Different Routes to ADHD and ODD Symptoms

ODD is a common comorbid condition to ADHD, present in roughly half of the cases, with at least partially shared genetic liability (Connor et al., 2010; Coolidge et al., 2000). Yet, distinct pathways or associations are suggested, and as such, it is of great importance to control for ODD when examining ADHD, which will bring about important information about ODD as well. In the school-aged sample, we found that parental support had a clear effect on ODD symptoms in interaction with negative affect. Specifically, for children who received high levels of support, there was no relationship between negative affect and ODD. Thus, low to medium levels of support seemed to result in higher levels of oppositional behaviors for children characterized by high

levels of negative affect, whereas high support seemed to be a protective factor. This is in line with theory and previous findings, and a possible mechanism behind the association could be de-escalation of conflicts and reinforcement of prosocial behaviors which may prevent the child with high negative affect from developing oppositional problems (Beauchaine, Hinshaw, & Pang, 2010; Deault, 2010). Parental support was unrelated to ADHD symptoms in Study IV, suggesting that in school-aged children parenting affects comorbidity but not core symptoms of ADHD. In addition, distinct temperamental associations were found in Study IV, where elevated negative affect was specifically related to ODD symptoms, as moderated by parental support, and deficient regulation (i.e., poor effortful control and working memory) was specifically related to ADHD. This suggests that elevated negative affect may constitute a vulnerability factor in relation to ODD. That is, high negative affect is not sufficient for ODD symptoms to emerge, but in combination with low parental support, the risk is elevated. This adds empirical support to the unsettled question about the role of parenting in relation to ADHD and the common comorbidity of externalizing behavior problems (Deault, 2010).

Clinical Implications

Detection of early markers or precursors of later symptomatology is a prerequisite for early prevention and intervention. The field of intervention studies is huge, complicated, and essentially beyond the scope of the present thesis, but I want to mention some proposed implications based on the results of the current thesis. The efficacy and effectiveness of behavioral and cognitive training on ADHD symptoms has been questioned, in that positive outcome often is dependent on the time of assessment (i.e., positive results for short term but not long term outcome) and whether or not the rater is blind to intervention type (Sonuga-Barke et al., 2013). In addition, interventions most often do not have an impact on actual cognitive functions and transfer effects are seldom present (e.g., Barkley et al., 2000), suggesting that a match between the specific "problem" and the intervention is of high importance. As for interventions targeting parenting, studies show that it is possible to increase parental sensitivity, and that increased sensitivity in turn may reduce overactive behavior problems in toddlers, and internalizing and externalizing behaviors in pre-teens (IJzendoorn, Juffer, & Duyvesteyn, 1995; Moretti, Obsuth, Craig, & Bartolo, 2015; Van Zeijl et al., 2006). However, it has been stressed that parental training need to be well anchored in the parent in order to be efficient (Barkley et al., 2000). To conclude, there is a need for more efficient interventions with enduring effects. The younger years is a period characterized by neural plasticity in relation to environmental influences (Callaghan & Tottenham, 2016), which theoretically should pave the way for more lasting effects of interventions (Halperin, Bédard, & Curchack-Lichtin, 2012). With this in

mind, targeting early emerging pathways to the disorder may alter the trajectory and possibly prevent the full disorder to evolve, or at least prevent comorbidity (Halperin et al., 2012; Sonuga-Barke & Halperin, 2010).

Results from this thesis propose secondary interventions, in that individuals with early risk-markers such as poor regulation and/or high surgency, perhaps in combination with low parental sensitivity towards the child, should be targeted. One way of doing so, in a non-intrusive way, would be to screen for parents' and teachers' concern for a child during evaluations at child health care centers or developmental talks in kindergarten. These concerns should then be taken seriously by offering support (i.e., secondary intervention). A potentially effective type of early intervention is parent-delivered interventions that target regulation, for instance by inclusion of games that require turn-taking, sustained attention, and delaying-gratification (Halperin et al., 2013; Sonuga-Barke & Halperin, 2010). This type of intervention may indirectly also improve the parent-child relationship. If nedded, intervention blocks that specifically target parental sensitivity should be added. The effectiveness and efficacy of this type of early interventions are still open empirical questions and need to be further investigated. In addition, interventions need to be cost-effective and favorable also for children who would not have moved on to a disorder, as "false positives" will certainly be included.

Limitations

There are several limitations in the studies making up this thesis, which need to be noted. The main one concerns the samples in Study I-III, and have briefly been touched upon previously. These two samples were typically developing with rather high SES, which implies that the results may not generalize to samples at risk for developing ADHD. In turn, this has a spillover effect on some of the measures, which present poor variation that could potentially have left "true" significant relations undetected. In addition, some of the scales show construct overlap, such as effortful control and inattention, and negative affect and ODD, which may have inflated the magnitude of associations concerning those measure. Similarly, a possible theoretical limitation is the relation between self-regulation and symptoms of ADHD. Should inattention and hyperactivity/impulsivity be viewed as *equal* to poor self-regulation, or as *caused* by poor self-regulation? The current thesis treats these symptoms as behavioral manifestations of deficit in psychological functions, but this is an empirical and theoretical question that needs to be further investigated. We examined all relations continuously, which has several advantages, but a person centered or categorical approach may have added important information about how the impact of the specific constructs can vary across individuals.

One marked difference between assessment of cognitive regulation and aspects of temperament is that cognitive regulation often is assessed with laboratory tasks and temperament with questionnaires directed to parents. This means that cognitive regulation generally is measured as states, and temperament as traits, which may have implications for assessment of young children, making the temperament measures more reliable, since the rater can make global ratings based on how the child usually behaves. Conversely, cognitive regulation is more influenced by the present situation with a larger impact of for instance shyness or fatigue. Thus, a measurement bias may have inflated differences. Indeed, a recent meta-analysis showed that rating scales of self-regulation are more reliable than laboratory tasks, even in adults (Enkavi et al., 2019). The current thesis examined the three broad aspects of temperament, negative affect, surgency, and effortful control. A large body of work suggest that the more fine-grained aspects that make up these broader constructs are also of importance (e.g., Derryberry & Rothbart, 1997). Finally, only maternal sensitivity was assessed in Study I and II, which could potentially limit our understanding of parental effects on development.

Future Directions

The limitations mentioned above should be addressed in future studies. First, the results need to be replicated in samples at risk for developing ADHD. One way of doing so would be to recruit a risk cohort, such as younger siblings of children with an ADHD diagnosis, or children of a parent with a diagnosis, and assess them using the same paradigms as in Study I and II. Adding screening for ODD in the younger samples would also be of value. Together, this would bring about important information about similarities and differences in effects of the constructs of interest in typical and deviant development of self-regulation. In addition, the results obtained in the thesis can guide the work of building predictive models with the aim of identifying children at risk for developing ADHD diagnoses. This would inform the question whether early aspects of temperament are best described as markers, precursors, or endophenotypes. Such a model should preferably include latent variables. Also, when addressing specificity in relation to inattention and hyperactivity/impulsivity, controlling for the other symptom domain would be valuable. As for temperament, examining the fine-grained aspects of temperament, rather than just the three broad constructs, could answer questions about which aspects in negative affect or surgency drive the significant or non-significant relations to self-regulation. Relatedly, genetically informed work are of importance, as genetic risk can be expressed through higher exposure to environmental stressors and heightened sensitivity towards them. Several candidate genes of minor effects have been suggested to influence the progression of ADHD (Hawi et al., 2015) and a polygenetic architecture of the disorder is most likely (Middeldorp et

al., 2016). Moreover, although heavily understudied, it has been suggested that epigenetic factors, i.e., heritable or acquired processes such as methylation that regulate gene expression independent of DNA sequencing, are also important (Mill & Petronis, 2008; Walton et al., 2017; Wilmot et al., 2016). Large sample sizes are needed for valid results on genetic and epigenetic risk, and as such several research sites need to be involved. Moreover, repeated measures of predictors, symptomatology, and deficits can bring about important information on trajectories and reciprocal effects, which could further elucidate the connection between symptoms and psychological constructs. In addition, including paternal sensitivity and also parental behaviors targeting problem solving (e.g., scaffolding), may increase our understanding of parental effects on self-regulation. Finally, observed parenting in school-aged children could be used as a conceptual replication of our results on self-reported parental support.

Concluding Remarks

In summary, the current thesis contributes with important information about development of self-regulation across childhood. Distinct predictors of cognitive and emotion regulation are suggested, which in turn do not seem to develop in parallel during the early years, but are getting more integrated as children reach school age. The results support the hierarchical model of cognitive regulation development (Garon et al., 2008). In addition, the results are in line with a multiple pathway perspective on self-regulation during the early years, with contributions of aspects of temperament and maternal sensitivity to emotion regulation, inattention and hyperactivity/impulsivity. Moreover, different factors seem to be involved in ADHD and ODD symptoms, with deficient regulation in the former and elevated emotionality in the latter. Early temperament markers of later inattention and hyperactivity/impulsivity were found, with contributions of both reactive and regulatory aspects. No associations between cognitive regulation and inattention and hyperactivity/impulsivity were detected in infancy and toddlerhood. Parental support in school-aged children was associated with ODD symptoms rather than with core symptoms of ADHD. The thesis contributes to the complexity and heterogeneity of ADHD and proposes that ADHD is best viewed as a developmental disorder. Specifically, that the influence of various factors change over time with stronger parental influences and bottom-up processes early in development and top-down processes later on. My hope is that these results can feed into general theoretical frameworks of self-regulation, expand our understanding of self-regulatory impairments in ADHD across development, and inform research on early interventions.

Summary in Swedish – Sammanfattning på Svenska

Självreglering handlar om förmågan till målinriktat beteende och är till hjälp för individen både i vardagslivet och vad gäller att nå långsiktiga mål. Självreglering utvecklas genom att enkla funktioner hos det lilla barnet (som till exempel förmågan att hålla kvar uppmärksamheten eller hålla tillbaka impulsen att röra något) över tid fogas samman till mer komplexa förmågor. Det kallas för en *hierarkisk utveckling*. ADHD är en komplex funktionsnedsättning som oftast debuterar i barndomen. ADHD kännetecknas av svårigheter att bibehålla uppmärksamheten, hög grad av impulsivitet och hyperaktivitet samt en generellt nedsatt förmåga till självreglering. Ungefär 50 % av barn med ADHD uppvisar också tecken på trots eller uppförandestörningar. De senaste årtiondena har det skett ett skifte, där man gått från enkla förklaringsmodeller till mer komplexa, som betonar att flera faktorer påverkar utvecklingen, så kallade *multipla vägar till ADHD*. Dessutom pågår forskning om tidiga tecken på ADHD, vilket kan öka vår förståelse för hur tillståndet utvecklas, leda till tidig upptäckt, tidiga interventioner och kanske också till att vi på sikt kan hindra tillståndet från att utvecklas fullt ut. Kognitiv reglering (t ex arbetsminne och impulskontroll), olika aspekter av temperament (negativ affekt, extraversion och reglering) och föräldraskap är tre områden som verkar vara viktiga för självregleringsförmågan generellt, men också specifikt för utvecklingen av ADHD symtom. Min avhandling tar avstamp i dessa tre områden och är baserad på teorierna om hierarkisk utveckling av självreglering och multipla vägar till ADHD. Syftet har varit att kartlägga utvecklingen av självreglering med ett särskilt fokus på ouppmärksamhet och hyperaktivitet/impulsivitet. Jag har genomfört fyra studier, baserade på tre grupper av barn i åldrarna 10 månader till 12 år. Tre studier är genomförda på typiskt utvecklade barn och i en studie hade 40 % av barnen en ADHD diagnos.

I **Studie 1** fann vi att tidig förmåga till uppmärksamhet predicerade senare kognitiv självreglering, vilket ger stöd för den hierarkiska modellen för utveckling av självreglering. Vi fann också att mödrarnas lyhördhet gentemot barnens signaler bidrog till bättre emotionsreglering, medan extraversion hos barnet var relaterat till sämre emotionsreglering. I **Studie II** fann vi stöd för multipla vägar till ADHD på så sätt högre regleringsförmåga hos barnet och mer lyhörda mödrar bidrog till lägre grad av ouppmärksamhet och hyperaktivitet/impulsivitet. Dessutom bidrog extraversion till ökade nivåer av hyperaktivitet/impulsivitet. **Studie III** bekräftade fyndet om tidiga temperamentella

markörer för senare ouppmärksamhet och hyperaktivitet/impulsivitet samt att tidig kognitiv reglering var en dålig prediktor för senare symtom. **Studie IV** visade att flera olika aspekter av självreglering påverkade graden av ADHD-symtom. Hög grad av temperamentsdraget negativ affekt var istället relaterat till trots. Detta samband var i sin tur påverkat av föräldrastöd, på så sätt att hög grad av stöd verkade vara en skyddsfaktor för barn med mycket negativ affekt.

Sammanfattningsvis pekar studierna på att både inre och yttre faktorer påverkar självregleringsförmågan, som i sin tur verkar utvecklas på ett hierarkiskt sätt. Olika aspekter av temperament snarare än kognitiva faktorer verkar utgöra valida tidig tecken på senare ouppmärksamhet och hyperaktivitet/impulsivitet. Därtill verkar det vara så att barnens temperament och mödrarnas lyhördhet bidrar till symtombilden tidigt i utvecklingen, medan olika regleringsfunktioner bidrar till symtombilden i skolåldern. Dessutom verkar höga nivåer av negativ affekt i kombination med svagt stöd från föräldrarna vara associerat med trots snarare än ADHD symtom. Avhandlingen bidrar till förståelsen av ADHD som ett komplext och mångfacetterat tillstånd, som bäst kan beskrivas som en utvecklingsrelaterad funktionsnedsättning, där vilka faktorer som påverkar symtombilden varierar över tid.

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