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DISENTANGLING CHILDREN'S SELF-REGULATION:
The role of dynamic dyadic coregulation

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To my family, specially my mom and dad. I started this for me, but I finished it for you.

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Abstract

Self-regulation (SR), the ability to modulate own's cognition, emotion, and/or behavior has a foundational role in promoting wellbeing across the lifespan. Parent-child coregulation is a strong candidate as a process that supports SR in early childhood because it reflects the moment-to-moment coordination of goal-oriented behaviors and expressed affect between parent and child (Calkins, 2011; Lunkenheimer et al., 2017). However, the field lacks systematic empirical study of how these parent–child coregulation processes contribute to typical self-regulatory development in early childhood. In this dissertation, I aim to provide a deeper understanding of the development of children SR in early childhood, by examining the role of dyadic co-regulation in the development of children SR in three independent studies from a dynamic and multilevel approach. Overall, the three studies offer evidence that individual parent effects, individual child effects, and dyadic patterns should all be considered to represent a more complete picture of the effects of parent–child coregulation on children's regulatory skills. Future studies should expand on this line, examining the stability and change of this coregulation patterns in parent-child interactions, for example, across different tasks and developmental time points.

Chapter 1: Introduction

Self-regulation (SR), the ability to modulate own's cognition, emotion, and/or behavior is arguably the single most important skill a child develops during the first years of life (McClelland & Cameron, 2011). SR has a foundational role in promoting wellbeing across the lifespan, including physical, emotional, social, and economic health and educational achievement (Posner & Rothbart, 2000; Vohs & Baumeister, 2011).

Supporting SR development in early childhood is an investment in later success, because stronger SR predicts better performance in school, better relationships with others, and fewer behavioral difficulties. In this vein, SR was recognized as one of the key areas of early child development in the Head Start Early Learning Outcomes Framework (Administration for Children and Families, 2015), where skills related to self-regulation are included into several domains.

Early childhood is considered a particular sensitive period for emerging regulatory skills, where the rapidly developing brain is more susceptible to influences of the environment (Lupien et al., 2009; Shonkoff et al., 2012). As such, understanding the emergence and development of regulatory skills during this developmental period has important implications for early intervention to promote optimal child development and prevent psychopathology.

Given that SR underlies individual differences in key competencies for young children, the study of antecedent processes that promote children's SR is necessary to inform etiology and intervention. During early childhood, the parent or primary caregiver plays an essential role in the child's emerging SR. Young children rely heavily on scaffolding processes from interactions with caregivers in order to regulate themselves (Tronick, 1989). The parent-child relationship is an especially important context through which children learn to regulate their physiological arousal, emotions, and behaviors early in life (Calkins, 2011). Several theories have attempted to provide an adequate explanation of the process in which a child transitions from absolute dependence on caregivers to regulate his or her psychobiological states, to increasing autonomy and independence in his or her ability to self-regulate.

Parent-child coregulation is a strong candidate as a process that supports SR in early childhood because it reflects the moment-to-moment coordination of goal-oriented behaviors and expressed affect between parent and child (Calkins, 2011; Lunkenheimer et al., 2017). However, the field lacks systematic empirical study of how these parent–child coregulation processes contribute to typical self-regulatory development in early childhood. Advances in analytical methods have enabled more nuanced examinations of the dynamics of parent-child emotion and behaviour, capturing both aspects of child SR and coregulation in interactive contexts.

With relational developmental systems theories at its core, the overall aim of my dissertation was to explore the role of parent-child coregulation in the development of children's SR in early childhood. To do so, I conducted three empirical studies each addressing a specific aspect of the relation between parent-child coregulation and children SR. In the next section, I present a general statement of the problem that motivated the studies.

Next, in Chapter 2 I provide the literature review and theoretical background that supports the three studies. In chapter 3 to 5, I present the three empirical studies I conducted with their theoretical and empirical background, methodology, and results well as a discussion of the findings. In study 1, I investigated the relationship between dyadic behavioral and emotional coregulation and executive functions- a main component of children SR- in a sample of 3-year-old children and their parents. In study 2, I aimed to contribute to the scarce literature on the role of parent-child physiological coregulation on children's physiological SR by examining physiological coregulation processes in mother-child and father-child dyads with a 3-year-old child, and its role in the physiological component of children self-regulation. In study 3, I explored the behavioral and emotional coregulation of parents and children, examining the specific contribution of both members of the dyad, and its relation to children's SR. Finally, in Chapter 6, I provide a general discussion for all three studies.

Statement of the Problem

Self-regulation (SR), that is, the ability to direct or modulate one's attention, emotion, thoughts, and actions in facilitating adaptation and achieving personal goals is arguably the single most important skill a child develops during the first years of life, and is considered an early marker for later life successes (Blair et al., 2016; Colman et al., 2006; Kopp, 1989; McClelland & Cameron, 2011a, 2011b).

Children's SR follows different developmental trajectories, heavily depending on their environment (Duncan et al., 2017). Accordingly, developmental research has sought to explore the parent-child relationship as a key context in which we can elucidate sources of variability in the development of SR. Parent-child interactions are considered a proximal determinant of child outcomes, and research studies have demonstrated that children's daily interactions with their caregivers foster gains in their self- regulation (Fay-Stammbach et al., 2014; Vandenbroucke et al., 2018). Most of the research examining the links between parent-child relationships and children's SR, has shown that parenting sensitivity and responsiveness are robust predictors of children's SR (Bernier et al., 2010; Hammond et al., 2012; Olson et al., 2017; Pauli-Pott et al, 2018; Perry et al., 2016). For example, research suggests that parent-child interactions in which parents are responsive to child´s needs (i.e., display behaviors such as positive affect, sensitivity, and warmth and use positive controlling strategies and scaffolding) foster the self-regulatory capabilities of their children (Kochanska & Aksan, 1995; Lindsey et al., 1997; Putnam et al., 2002; Strand, 2002). On the contrary, negative controlling strategies may undermine the development of self-regulation (Fay-Stammbach et al, 2014; Kochanska & Aksan, 1995). All in all, evidence consistently supports the significant role that parents play in the development of children's SR.

Despite the consensus in developmental research, that posits that the parent-child relationship are a bidirectional process, and thus both members of the dyad are active agents (Bronfenbrenner & Morris, 1998, 2006; Sameroff, 2009, 2010), most studies to date have examined the parent-child relationship from the adult perspective, addressing parental (mostly maternal) qualities displayed in the dyadic interaction, and thus pointing to parents as the main drivers of relationship quality (Bell, 1968; O'Connor, 2002). For example, sensitivity focuses on the actions and intentions of the mother, without considering the interactive behaviors or responses of the infant (Harrist & Waugh, 2002).

Based on bio-ecological and transactional theories of human development, that state that parent (caregiver)–child interactions are of central consequence to children´s development and that parents *and* children play an active role in these interactions (Beeghly et al., 2011; Bronfenbrenner & Morris, 2006; Sameroff, 2009), examining the dyadic contribution in shaping the development of SR is salient. However, the bulk of the extant research on child development has mostly exclusively focused on the static contribution of one actor of the dyad, namely the mother. Much less is known about the contribution of children to the dyadic interaction. In addition, the literature provides little evidence on the specific contribution of fathers to the development of children' SR. As well, global measures of parental behavior are helpful to understand how parents impact children's developmental outcomes, but they do not provide information on the way in which parents and children, together, support children's developmental outcomes, such as SR.

More recent conceptualization of the parent-child relationship describes it as interaction of coregulatory processes. Coregulation refers to the moment-to-moment dynamic interactions between parent and child, in which both contribute interdependently to the relationship and thus to child development of SR skills. Each individual dyad co-creates a unique way of interaction which cannot be predicted by the simple sum of each partner's attributes (Beeghly et al., 2011; Tronick, 2007). Therefore, dyad's communicative interaction (e.g. dyadic gaze patterns, affective exchanges, vocalizations, bodily postures, touch) during social exchanges constitutes the distinguishing characteristic of co-regulation and is the most critical component of young children's regulatory system (Tronick, 2007). To be consistent with developmental systems and transactional models, which predict that the quality of co-regulation is influenced by a complex and dynamic interplay of transacting factors (e.g. biological and environmental factors; Bronfenbrenner & Morris, 2006), a multilevel approach to the study of SR is needed.

Research on coregulatory processes is rapidly increasing, contributing with a new perspective in studying child regulatory processes and the parent-child relationship. A focus on dynamic interactional processes, specifically coregulation, provides an understanding on the timing and contingent relations between the emotions and behaviors of social partners as the driver of child development. Alongside new analytical methods, research based on a dynamic systems perspective has successfully captured both child self- regulation and coregulation in interactive contexts.

While traditional methods (i.e., lineal and unidirectional) have been shown to be reliably predictive of child outcomes, they don´t capture the complexity and specificity of micro-level processes. A microanalytic and multilevel approach to dyadic co-regulation allows to assess how the process is displayed moment-to-moment in response to each partner and environmental changes, and how it changes depending on individual characteristics of each partner of the dyad; information that qualitative measures cannot capture (Beebe et al., 2016).

I aim to provide a deeper understanding of the development of children SR in early childhood, by examining the role of dyadic co-regulation in the development of children SR in three independent studies. The use of a dynamic approach allows to assess the role of parent-child coregulation in children's SR, considering the parent-child dyad as a system (Study 1), but also examining the unique contribution of parents and children in the process of co-regulation as it unfolds (Study 3). Likewise, adopting a multilevel approach to the study of children's SR, permits to assess the patterns of dyadic physiological and behavioral co-regulation, and how these patterns play a role in the development of children's SR (Study 2).

In the next chapter, I provide the theoretical and empirical background that support the three studies I conducted and is organized as follows. First, I begin describing the concept of SR and presenting a brief review of prevalent models that have been proposed to the study of SR, the neurobiological underpinnings of early self-regulatory processes and how self-regulatory systems develop over time in early childhood. Next, I argue that the emergence of SR occurs primarily in a relational context, and that the capacity for SR emerges from self- and parent–infant co-regulatory experiences that are repeated over time (Beeghly & Tronick, 2011; DiCorcia et al., 2013; Easterbrooks et al., 2008; Tronick, 1989, 2007; Tronick & Beeghly, 2011). To this end, I review the theoretical models and the empirical evidence that help explain the role of dyadic processes in the development of children's SR and present the gaps in the literature and methodological issues that are worth exploring.

Chapter 2: Review of the Literature

What is Self-Regulation and Why is Worth Studying It?

The ability to effectively self-regulate, that is, the ability to control (conscious and/or automatic) own's cognition, emotion, and/or behavior is arguably the single most important skill a child develops during the first years of life, and is considered an early marker for later life successes (Blair et al., 2016; Colman et al., 2006; Kopp, 1989; McClelland & Cameron, 2011).

Self-regulation is critical to positive development and adaptive functioning throughout the life cycle (Beeghly et al., 2016; Posner & Rothbart, 2000; Vohs & Baumeister, 2011). Several studies have established wide variation in the level of SR skills children manifest during early childhood, and that the achievement of adequate SR during childhood consistently predicts a multitude of short- and long-term outcomes, such as school readiness and academic achievement (Blair, 2002; Blair & Razza, 2007; Bohlmann & Downer, 2016), emotional development (Eisenberg et al., 2004, 2010; Gerstein et al., 2011; Graziano et al., 2007), and social competence (Calkins & Keane, 2004; Olson et al., 2005). Some longitudinal studies further suggest that differences in preschool age SR predict adolescent and adult outcomes (Casey et al., 2011; McClelland et al., 2013; Moffitt et al., 2011; Shoda et al., 1990).

On the other side, the absence of adequate SR, whether due to poor control or excessive control, predicts a broad spectrum of negative developmental outcomes, including high negative emotionality (Blair & Diamond, 2008; Feldman, 2009; Feldman & Eidelman, 2004), behavioral problems (Bradley et al., 2011; Bridgett et al., 2015; Crockenberg et al., 2008), and low academic performance and social impairment (Hill et al, 2006).

There is also evidence that SR is malleable (Dignath et al., 2008), and thus a meaningful target for intervention, highlighting its relevance for program developers and policy makers. A large empirical literature demonstrates the effectiveness of interventions that target specific aspects of SR, such as self-control (Piquero et al., 2010), executive function (Diamond, 2012), and social-emotional outcomes (Greenberg, 2006). Thus, thorough study of early development of SR is critical for understanding and promoting lifelong adaptive functioning.

Despite the general consensus on its significance in adaptive functioning there is a lack of clarity about the broad concept, underlying components, and measurement specificity of SR (McClelland & Cameron, 2011a). The broad range in which this construct is conceptualized and measured across fields makes it difficult to present a unique and consensual definition of SR (Karreman et al., 2006).

Conceptualization of SR

Researchers have addressed the study of SR from diverse perspectives, yet it remains one of the most challenging constructs to define, both theoretically and operationally (Diaz & Eisenberg, 2015; McClelland & Cameron, 2011a). SR encompasses a variety of processes that assist individuals in pursuing and attaining their goals (McClelland & Cameron, 2011a). Besides these general ideas about SR, specific conceptualizations of SR and consequently the associated research methods to assess it vary markedly. Over the last decades, the development of self-regulation has been studied from a temperamental (effortful control; Rothbart, 1989; Rothbart et al., 2004, 2006), neuropsychological (executive functions; Barkley, 2001; Diamond 2006, 2013), affective (emotion regulation; Gross 2014), and motivational (self-control; Baumeister & Vohs, 2007) perspective. The overlap in constructs related to SR is so pervasive that it has even been referred to as “conceptual clutter” (Morrison & Grammer, 2016). Therefore, SR has become an umbrella term, making the consolidation of findings across fields difficult (Nigg, 2017). Calls for and attempts to formulate an integrative framework have multiplied in recent years (Bridgett et al. 2013; Diamond, 2013; Liew, 2012; McClelland and Cameron 2012; Nigg, 2017; Welsh & Peterson, 2014; Zhou et al., 2012), yet no consensus has been reached. In this section I will present a brief overview of the most influential conceptualizations of SR.

Traditionally, self-regulation has been conceptualized as comprising three overlapping domains: cognitive, emotional, and behavioral (McClelland & Cameron, 2012; Montroy et al., 2016). **Cognitive self-regulation** includes effortful attentional control, goal setting, self-monitoring, problem solving, perspective taking (i.e., theory of mind and future orientation), decision-making and executive functions, the hallmark of cognitive SR. **Emotional self-regulation** involves intentional processes to manage strong and unpleasant feelings, which can include cognitive regulatory processes such as attention shifting and reappraisal. Indeed, the integration of cognitive and emotional self-regulation is an important developmental task necessary for behavioral regulation (McClelland et al., 2015; Montroy et al., 2016). **Behavioral self-regulation** includes delay of gratification, persistence, control of impulses, and goal-oriented behaviors. Although these components are conceptually defined as different, they interrelate in complex ways, and it is difficult to disentangle the separate domains empirically. Moreover, because language skills are not fully developed during childhood and the assessment of SR relies heavily on observation of behavior, cognitive and behavioral SR seem to merge.

In her seminal work, Kopp (1982) provided a framework for the development of SR in the early years that is cited most frequently. She defined SR broadly as the set of regulatory capacities that allows individuals to modulate the intensity, frequency, and duration of behavior in diverse settings, that progresses from externally to internally regulated behavior, supported by maturation of attention and cognition and parental socialization. Specifically, between 12 and 18 months of age, children become capable of control, which encompasses the awareness of social demands and the ability to initiate, maintain, and cease behavior, and to comply with caregivers' requests. At this stage, SR is manifested as monitored and directed compliance (Calkins, 2007;

Kopp, 1982). Gradually, with the increasing ability to internalize parental values, children become able to modulate their behavior without external directives or supervision (Kochanska et al., 2001). At roughly age 3, children begin to display internally motivated self-regulatory behaviors (Kopp, 1982). Compliance with caregivers' requests is generally considered as a prototypic form of self-regulation because it requires the modulation of one's behaviors in accordance with direct demands, while SR represents a more generalized and internalized management of behavior with regard to changing personal and social needs and goals (Kochanska et al., 2001; Kopp, 1982). Kopp (1982, 1989) posited that extrinsic and intrinsic factors interact to contribute to the emergence of children's autonomous modulation of their impulses. Her model also states that as caregivers socialize children, they draw on children's intrinsic factors, including children's emerging attention control, receptive and expressive language, memory, and restraining skills. Together, these factors lead children to recruit their own internal resources to regulate their actions, without direct instruction or monitoring (i.e., SR).

Researchers and theoreticians in developmental psychology have argued that diverse regulatory capacities together comprise self-regulation (e.g., Blair & Ku, 2022; Eisenberg et al., 2014; Rothbart et al., 2004; Ursache et al., 2012). For example, Eisenberg and colleagues (2014) suggested a differentiation between internally motivated and externally enforced regulation processes and between more or less volitional regulatory processes (Eisenberg et al., 2014).

Furthermore, Ursache and colleagues (2012) highlight the distinction between emotion-related and cognitive-related self-regulation capacities. They conceive SR as a bidirectional system linking cognitive aspects of regulation - referred to as executive functions and defined as abilities used to regulate information and to organize thinking in goal directed activities - and the development of reactivity and regulation in stimulus-driven emotion, attention, and physiological stress response systems (Ursache et al., 2012). Thus, SR would emerge through the interaction of emotion and cognition, in which top-down executive control of thought and behavior develops in reciprocal and interactive relation to bottom-up influences of emotion and stress reactivity.

In their Intergenerational Transmission of SR model, Bridgett and colleagues (2015) posit that SR can be differentiated into two more specific behaviorally and neurobiologically separable, but interacting components: top-down and bottom-up SR. These two components interact but have well-defined biological substrates and psychological functions that are hierarchically organized and integrated by development into particular forms and behaviors (Blair et al., 2016; Bridgett et al., 2015). Top-down SR consists of centralized cortical processes associated with effortful and executive control of emotions (emotional regulation) and behavior (executive functions) (Blair et al., 2016; Vohs & Baumeister, 2011). Bottom-up SR, refers to automatic processes and is responsible for behavioral inhibition and the regulation of prepotent responses to environmental stressors. Bottom-up SR is represented by subcortical structures and the coordinated activation of the stress response system, including both branches of the autonomic nervous system (ANS), the sympathetic and the parasympathetic, and of the neuroendocrine systems (Bridgett et al., 2015; Calkins & Fox, 2002; Fox & Calkins, 2003; Porges, 2007).

The Cognitive Component of SR

Cognitive researchers often examine executive function (EF), which is thought to underlie self-regulated action (Best & Miller, 2010). EF are a set of interrelated neurocognitive abilities that support the conscious, top-down control of thought, action, and emotion and allow us to control thought and emotion and behave in a flexible, goal-directed fashion. They help individuals to understand, monitor, and control their own reaction to the environment, as well as problem solve regarding desired future behaviors and/or outcomes (Montroy et al., 2016). It is generally agreed that EF comprises three components: working memory, inhibitory control, and cognitive flexibility (Diamond, 2013; Garon et al., 2008; Hughes, 2002; Miyake et al., 2000, 2012; Zelazo 2015). **Working memory** is the a active maintenance or updating of information over a relatively short time period and allows to process the current task while holding a rule or set of rules in mind. **Inhibitory control** is the ability to ignore or stop an automatic but nonoptimal or incorrect response, in order to respond in a counterintuitive and more adaptive way. **Cognitive flexibility** is the ability to shift the focus of attention or cognitive set flexibly and to adjust behavior accordingly (Zelazo, et al., 2003). There is empirical evidence that the degree that each EF component relates to children's overall self-regulation skills may vary with age and skill level (Kochanska et al., 1997; Kochanska et al., 2000; Willoughby et al., 2011). Further, EF appears more unitary for younger children but emerges as distinct components for older individuals (Diamond & Kirkham, 2005; Garon et al., 2008; Miyake et al., 2012; Miyake & Friedman, 2012).

Even though EF research tends to focus on seemingly emotionally neutral skills, emotion and cognition are tightly intertwined in our brain and behavior (for a review see Lewis & Todd, 2007). In order to address the integrated aspect of cognition and emotion, a distinction has been made in recent years between EF at the service of abstract or decontextualized environments and EF at the service of adapting to environments that require the regulation of affect and motivation (e.g., Hongwanishkul et al., 2005; Zelazo et al., 2008; Blair & Ursache, 2011; Zhou et al., 2012). By this distinction, EF plays primarily a top-down role in directing attention and organizing cognitive resources (Miller & Cohen, 2001) and in regulating emotion (Ochsner & Gross, 2005). However, EF are dependent on activity in attention, emotion and stress response systems, such as that EFs are facilitated in contexts in which automatic aspects of attentional, emotional and physiological responses are in a moderate range, but can be impaired in contexts of particularly high or low attentional focus, arousal or emotion (Arnsten, 2009; Blair & Dennis, 2010; Gray, 2004).

In an effort to bridge the affective and cognitive aspects of EF, Zelazo and Müller (2002) proposed the distinction of cool and hot executive functions. Under this framework, cool EF refers to affectively neutral, slow acting processes such as working memory and complex response inhibition and flexibility tasks (Bassett et al., 2012). In contrast, the term hot EF describes fast acting processes that have been elicited under affective conditions and motivationally salient situations (e.g., delay of gratification) (Bassett et al., 2012; Brock et al., 2009). Hot aspects are usually more associated with socioemotional health and outcomes such as the ability to concentrate and tolerate frustration (Mischel et al., 1988; Willoughby et al., 2011) and to better social competence as rated by parents and teachers (Denham et al., 2012), whereas cool aspects are more associated with cognitive and academic outcomes such as performance on literacy and math skills (Brock et al., 2009; Kim et al., 2013; McClelland et al., 2007; Thorell, 2007; Willoughby et al., 2011).

Some commonly used assessment of children`s cognitive regulation include delay of gratifications (i.e., inhibitory control) tasks such as the well-known “Marshmallow test” (Mishel et a., 1972), snack delay, wrap gift, or forbidden toy (Caughy et al., 2013) all tapping on hot EF. Tasks such Head-Toes-Knees-Shoulders task (HTKS), shape stroop, spatial spam, and tower of Hanoi (see Hammond et al., 2012) tap on cool EF. More recently, researchers have developed computerized tasks to assess the three components of EF, e.g.

The Minnesota Executive Functioning Scale (MEFS; Carlson & Zelazo, 2014) or the Early Years Toolbox (EYT; Howard & Melhuish, 2017).

Another line of research has focused on the relation between biologically based tendencies towards reactivity and the regulation of this reactivity through approach and withdrawal behavioral strategies and involuntary and voluntary attentional strategies (Kochanska et al., 2001; Posner & Rothbart, 2000; Rothbart et al., 2000). Rothbart's model focuses on effortful control, a temperamental ability to suppress a dominant response and perform a subdominant response, based on biologically primed predispositions in reactivity and regulation (Rothbart, 1989; Rothbart & Bates, 2006; Rothbart et al., 2000a; Rothbart et al., 2000b). Reactivity, referred to as negative affectivity, reflects prepotent readiness to react with anger or fear to environmental change. Regulation, referred to as effortful control, reflects the capacity to be soothed easily or regulate behavior readily. Although it is believed that effortful control begins to emerge at the end of the first year of life, its development continues at least through the preschool years (Eisenberg et al., 2004). Thus, the system of SR that emerges over time becomes more differentiated, more voluntary, and more systematically deployed. Nevertheless, this system is relatively slow to develop and its development, while influenced by temperamental reactivity, is likely a function of several internal and external factors as well (Calkins, 2007). Effortful control develops during the third year of life and is attributable largely to maturation of an executive attention neural network, which enables control of attention despite stimulus salience. Authors adopting this model have assessed SR through a series of tasks tapping on effortful control including delay, slowing down motor activity, go-no-go, modulating voice, cognitive reflectivity, and effortful attention (e.g., Murray & Kochanska, 2002). Assessment in this line include questionnaire such as the childhood behavioral questionnaire, (CBQ; Putnam & Rothbart, 2006). Other researchers have evaluated effortful control with tasks assessing children's ability to delay such as, Snack Delay, Tongue, Dinky Toys, and Home Gift (e.g., Murray & Kochanska, 2002). Much of these tasks overlap with the assessment of inhibitory control.

More recently, developmental science based on a relational framework describe SR as the complex and dynamic interplay among multiple levels of influence. Individuals constantly regulate their behavior in reaction to, and with support from, the opportunities and constraints afforded by their environments (Sameroff, 2010). Optimal self-regulation therefore requires orchestrating a diverse set of self-regulatory skills and abilities.

The Emotional Component of SR

In contrast, another line of research has focused primarily on the study of development of regulation of emotion. This component of SR consists of processes or competencies that involve awareness, evaluation, maintenance, and/or modulation of emotional states to accomplish one's goals (see Calkins & Marcovitch, 2010; Thompson, 1994). Emotion regulation refers to children's ability to appropriately regulate their emotions (e.g., fear, anxiety, joy) as well as the behaviors influenced by such emotional reactions (Bridges et al., 2004). Emotion regulation may be conscious and deliberate, or unconscious and automatic; self-managed or externally supported (e.g., caregiver soothing a crying infant); and may occur in the context of both positive and negative emotions. Calkins & Marcovitch (2010) describes emotion regulation as a process that becomes more automatic and improves with practice, which enables the child to manage increasingly complex and stressful environments. In infancy, early regulatory tasks are tied to regulating children's attention and affective, temperament-based reactions to stimuli and information in the environment. These actions most clearly relate to emotion regulation in early childhood when children must exert considerable effort to regulate their overt behaviors (Eisenberg et a., 2004). Different types of emotion regulatory strategies have been proposed to help young children effectively manage their affect and emotions, such as instrumental strategies (e.g., trying to change a situation, such as trying to get a parent's attention, comforting strategies (e.g., calming oneself), distracting strategies (e.g., redirecting attention by looking away), and cognitive strategies (e.g., negotiating or reframing the situation into a better perspective).

Some distinctive assessments of children`s emotional regulation range from questionnaires such as the Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997) to frustration tasks such as Attractive toy in a transparent box task, arm restrain and maternal prohibition (Calkins et al., 2002).

The Physiological Component of SR

Developmental psychophysiological work emphasizes that certain underlying physiological processes and functioning may play an important role in the etiology of early regulatory behaviors (Calkins, 2007; Fox, 1994; Porges, 1995, 2007). Theories that focus on underlying biological components of regulation assume that maturation of different biological support systems lays the foundation for increasingly sophisticated emotional and behavioral regulation that is observed across childhood (Fox & Calkins, 2003). Other researchers have emphasized the role of biological stress responses (Stansbury & Gunnar, 1994) and physiological regulation as processes that support behavioral manifestations of regulation (Calkins, 1997; Calkins & Dedmon, 2000).

Porges' theory (1995, 2007) further suggests that one particular measure of cardiac activity that may be more directly related to the kinds of regulatory behaviors children begin to display in toddlerhood and early childhood is vagal activity. Vagal activity is an index of parasympathetic functioning, via the activity of the vagal nerve, which is assessed through respiratory sinus arrhythmia (RSA). RSA is a natural variation in heart rate that occurs during a breathing cycle and is used as a non-invasive measure of vagal activity. Polyvagal theory postulates that dynamic shifts in vagal activity (represented by increases and decreases of RSA) represent adaptive coping efforts (Porges, 1995, 2007).

In absence of challenging situations, basal reactivity or vagal tone reflects the ability to maintain homeostasis when physiological systems are not perturbed and the capacity to react to environmental stressors. Vagal tone can be indexed by baseline RSA, in which high baseline RSA reflects better vagal tone. In particular, low resting *vagal tone* (indexed by low baseline RSA) has been considered an indicator of emotion dysregulation (Beauchaine et al., 2007). For example, children with lower baseline vagal tone may be more prone to increase their physiological arousal and negative emotionality in birthdays parties, when they are exposed to many environmental stimuli, which can be expressed behaviorally as withdrawal (Miller et al., 2015). *Vagal augmentation* (indexed by a high RSA or an increase in RSA level) characterizes episodes of low social or environmental demand or stress (e.g. infant and caregiver are playing together) (Porges, 2007). On the other hand, in the face of a stressor (e.g. caregiver takes the child to daycare for the first time), an adaptive parasympathetic response is typically manifest as vagal suppression (indexed by a decrease in RSA), which implies a readiness for behavior in response to threat or challenge (e.g. child decreases his RSA level in order to cry in response to separation) (Porges, 1995, 2007). Vagal suppression reflects putting a ‘brake’ on parasympathetic regulatory processes in order to activate the body’s sympathetic (i.e., fight or flight) regulatory processes, thus representing a mobilization of resources to respond to environmental demands (Bornstein & Suess, 2000). Thus, vagal augmentation in response to a stressor (i.e. failing to decrease RSA level in response to a stressor) has been associated with dysregulated emotion and behavior (e.g. child does not decrease her RSA level in response to separation from the caregiver) (Hastings et al., 2008).

Children with a high level of baseline RSA have been shown to have better development of SR (Bazhenova et al., 2001). For example, Calkins and Keane (2004) assessed two-year-old children with a series of emotionally and behaviorally challenging laboratory procedures, and recorded baseline RSA, RSA increase and decrease, and SR. They found that children who displayed a pattern of stable and high RSA suppression were less emotionally negative and had fewer behavior problems and better social skills than other children. Furthermore, low baseline levels of RSA have been associated with negative developmental outcomes, e.g., development of externalizing, internalizing problems and sleep regulation (Beauchaine et al., 2007; El-Sheikh, 2005). However, other studies have found that RSA suppression is associated with better SR in challenging contexts (Degangi et al., 1991; Stifter & Corey, 2001). These apparently contradictory results show that the response of the parasympathetic system (i.e. vagal augmentation and suppression) and its impact on SR depends both on the context and the task; the same measure can indicate both the child's initial response to the challenging situation (reactivity) and his or her ability to regulate in the face of a demanding situation (Kahle, Miller, Helm, & Hastings, 2018). To make it even more complex, high decrease in RSA levels in response to a stressor is not per se an index of regulatory capacity. Recent studies have shown that moderate (not high) levels of vagal suppression (i.e. moderate levels of RSA) and increased vagal tone (i.e. high baseline RSA), are indicative of greater regulatory capacity and are associated with greater adaptive outcomes, such as better academic performance (Graziano & Derefinko, 2013), better executive functioning (Marcovitch et al., 2010), and greater social competence in the preschool period (Blair & Peters, 2003).

Thus, suppression of RSA is thought to be a physiological strategy that permits sustained attention and behaviors indicative of active coping that are mediated by the parasympathetic nervous system (Porges, 1991; 1996; Wilson & Gottman, 1996). Moreover, the RSA suppression measure does seem to be an indicator of both the degree of challenge the task imposes on the child's regulatory ability, and the extent to which the child can generate a coping response independently versus with environmental support. Conversely, children's physiological response to challenge has been shown to be augmented when the caregiver is involved in helping the child manage the task versus when the child must deal with the challenge alone (Calkins & Dedmon, 2000; Calkins & Keane, 2004). This response is observable in early infancy and differs across infants with differing levels of attentional and emotional regulation abilities (Calkins et al., 2002). Given its early appearance in the child's repertoire, and that it is influenced by caregiver support, physiological regulation is very likely to provide a foundation for later appearing regulatory competencies.

In sum, although researchers have studied SR from a diverse set of perspectives, the literature suggests some common grounds. First, in its broadest sense, it represents the ability to volitionally plan and, as necessary, modulate one's behavior to an adaptive end (Gross & Thompson, 2007). Second, there is consensus that adequate development of SR has important implications for individual positive development and well-being starting early in life (Geldhof et al., 2010; McClelland et al., 2010). Third, most models emphasize the simultaneous multilevel operation of various regulatory capacities in SR (Lunkenheimer et al., 2017; Smith et al., 2011). SR depends on the coordination of many processes across levels of function, with children's ability to draw on, integrate, and manage these multiple processes increasing across developmental time (McClelland & Cameron, 2012; McClelland et al., 2014).

In the next section, I present a description of the most important milestones in the development of SR in early childhood.

Development of SR in Early Childhood

The ability to effectively self-regulate starts early in development but takes time to fully develop. In fact, evidence show that the basic skills of SR begin to manifest since birth (Bernier et al., 2010), show accelerated development during early childhood (Anderson, 2002) and a maturation, complexation and stabilization during adolescence (Crone, 2009).

The development of SR is hierarchically organized, with basic biological processes contributing to developments in emotional and cognitive functioning

(Calkins, 2007). Thus, the specific systems that reflect children's primary self-regulatory challenges at different ages (e.g., physiological, emotion regulation, attentional, and social-cognitive) vary (Feldman, 2009). The extended period of self-regulatory development corresponds to the relatively slow maturation of prefrontal brain areas associated with inhibitory control and their transactions with other brain regions and associated biobehavioral processes.

SR emerges in parallel with the development and gradual maturation of the cerebral prefrontal cortex, which exerts incremental levels of inhibitory control over basic brain structures associated with emotional activation (e.g. amygdala, hypothalamus, brain stem) (Fox & Calkins 2003, Posner & Rothbart, 2000; Rothbart et al., 2011; Thompson et al., 2013). Because of its dependence on the maturation of prefrontal-limbic connections, the development of SR processes are relatively prolonged (Beauregard et al., 2004), from the development of basic and automatic regulation of physiology in infancy and toddlerhood to the more self-conscious and intentional regulation of cognition emerging in middle childhood (Calkins, 2007; Ochsner & Gross, 2004).

Although even young infants have rudimentary self-regulatory capacities that manifest from the interplay among multiple biopsychosocial somatic and brain systems, these capacities are limited and cannot be sustained without caregiver regulatory support (Tronick, 2005; Tronick & Beeghly, 2011). From a developmental perspective then, opportunities for success and failure of self-regulation are numerous over the course of toddlerhood, particularly given the potential of environmental factors - such as parenting - to facilitate or disrupt development in these domains (Calkins, 2007). Over the course of development, the child's increasing capacity to regulate her motoric and affective behavior, first as a result of a supportive caregiving context and later as a function of voluntary and effortful control, moderates these initial reactive responses.

During the first few months of life, regulation is mostly reactive, characterized by a rapid physiological (e.g., arousal) and behavioral response driven by stimuli (e.g. crying). Underlying physiological processes and functioning may play an important role in the etiology of early regulatory behaviors (Fox, 1994; Fox & Card, 1999; Porges, 1991, 1996). Infants may differ initially in their threshold to respond to visual or auditory stimuli of a certain intensity (e.g. Calkins, Fox, & Marshall, 1996). This reactivity is thought to be present at birth and reflect a relatively stable characteristic of the infant (Rothbart et a., 2000). In this initial period the objective of emergent SR skills in the infant is the regulation of the autonomic arousal, sleep-wake cycles and basic emotions and behavior (Calkins et al., 1998; Kopp, 1982). As early as 6 months, infants begin to use basic SR strategies to decrease the impact of sensory-motor stress (Kopp, 1982; Stifter & Braungart, 1995). These basic SR strategies seem to grow in a timely fashion (Crokenberg & Leerkes, 2004; Harman et al., 1997). Six-month-old infants tend to use attention and gaze aversion (e.g. looking at the caregiver's face, or looking away from negative stimuli) as their primary regulatory strategy, while 12-month- old`s engage in more self-soothing (e.g., thumb sucking and hair twirling) than 18-month-olds, and 12- and 18-month- old toddlers use more behavioral avoidance and self-distracting strategies than 6-month-olds (Kopp, 1982; Stifter & Braungart, 1995; Mangelsdorf et a., 1995). Infants increase the effective and flexible use of these strategies in the following months and acquire new strategies (Rothbart et al., 1992; Stifter & Braungart, 1995; Tronick, 2007). There appears to be a decline in the use of self-soothing between 24 and 48 months, coupled with the emergence of new and more complex use of objects and interactions to regulate emotional state (see Diener & Mangelsdorf, 1999). By 24 months of age, reorientation (i.e., self-distraction and behavioral avoidance) may be the most common and successful regulatory strategy in fearful and frustrative situations (Grolnick et al., 1996) and may represent the primary regulatory system until regulatory functions with cognitive control (e.g. cognitive flexibility, inhibitory control) are developed (Posner & Rothbart, 2007).

Likewise, the ability to focus attention, fundamental for the subsequent development of cognitive regulation, appears around 8- to 10-months (Kochanska et al., 1998), and becomes more voluntary between 9 and 18 months of age (Posner & Rothbart, 2007). Around 12-months, infants develop the ability to inhibit predominant responses (Diamond, 1991), involved in the development of later capacity to execute intentional behavior, planning, and the resistance of more automatic or reactive tendencies.

With the maturation of attentional mechanisms, the ability to inhibit motor behavior effortfully improves greatly around 24 months (Kochanska et al., 2000; Rothbart & Bates, 2006; Posner & Rothbart, 2000). Between 24 and 36 months, advances in cognitive, motor, and language development support more elaborate regulatory skills that allow children to adjust their behavior in order to achieve their goals. During this period, infants show a greater ability to delay gratification (Carlson, 2003, 2005; Casey et al., 2011); to plan their actions based on their goals (Garon et al., 2008); to reduce negative emotional states (e.g., focus attention on stimuli that provide positive arousal); divert attention from stressful stimuli and actively engage with different objects (Bronson, 2000; Grolnick et al., 1996; Kopp, 1982).

The focus of attention on significant figures, also called social referencing, allows children to self-regulate by looking to their caregivers for clues to respond to new or ambiguous situations (Kopp, 1989). Likewise, between 12 and 18 months of age, children start to show compliance, that is, they become increasingly aware of social demands and capable to initiate, maintain, and cease behaviors complying with caregivers' requests (Kochanska et al., 2001; Kopp, 1982). During this age, toddlers also show significant advances in the regulation of emotions, such as referring to their internal states verbally, naming their emotions, commenting on the causes of their feelings, and sometimes even including self-regulatory references (e.g., "scared. Close my eyes") (Thompson et al., 2008). They start constructing an understanding of the prototypical situational causes of basic emotions like distress, fear, and anger (e.g., falling down, being hit by another, separating from caregiver). They also begin to comprehend the internal origins of emotional experience, such as how feelings arise from one's perception of emotionally arousing events (e.g., sadness from unfulfilled desires, anger from blocked goals, surprise from unrealized expectations, etc.) (Thompson et al., 2008).

Around the third year of life, as a result of their improved cognitive and language skills, children begin to autonomously initiate voluntary control behaviors to modulate their emotions and impulses, also known as executive functioning (Kopp, 1982, 1989; Rothbart et al., 2006). For example, children at this age are able to delay gratification, that is, to voluntarily wait and control prepotent responses (i.e. receive an immediate reward, e.g. a candy) in order to achieve their goals (i.e. receive a lagged bigger reward, e.g. two candies) (Casey et al., 2011). Moreover, around 30 months, the ability to selective attention (i.e., to concentrate on a task and ignore irrelevant information) increases dramatically (Garon et al., 2008). Likewise, there is a significant increase in cognitive flexibility, that allows children to switch between thinking about different concepts, or to think simultaneously about different concepts. It also allows them to take perspective and resolve conflicts that have different sources of information (Rothbart et al., 2006).

Similarly, these cognitive skills help children to regulate their emotions in a more conscient, reflective and context-specific manner (Woltering, & Lewis, 2009). Preschool children are capable of enlisting several constructive strategies of emotion regulation and, on occasionally, talking about them, leaving an emotionally arousing situation, removing or restricting one's perception of emotionally arousing events, seeking comfort from a caregiver, and other behavioral strategies (Thompson, 2008).

Between the ages of 3 and 4, social demands and expectations about the child increase (e.g., focused attention, following instructions, taking perspective and empathy, tolerating distress in the absence of parents), which increases even more when children enter preschool (Calkins et al., 1998; Rothbart et al., 2011; Rothbart et al., 2006). This leads to the expectation that more sophisticated SR strategies will be present in the physiological, emotional, and behavioral domains (e.g., diverting attention from stressful stimuli to actively engage in symbolic play, reassessment of the situation, control emotional responses through language, delay gratification, and inhibit responses for longer periods) (Carlson, 2009; Casey et al., 2011; Feldman et al., 2011; Kopp, 1982).

It is not until middle childhood, however, that children acquire a more fully SR, involving strategies such as internal distraction, redirection of thoughts, cognitively reframing the situation, evoking conflicting emotions (e.g., thinking of happy things in scary situations), among others.

Table 1. Development of Self-Regulation in Early Childhood

<table>
<tr><th>0-6 months</th><th>6-12 months</th><th>12-18 months</th><th>18-24 months</th><th>24-36 months</th><th>36-48 months</th><th>48-60 months</th></tr>
<tr><td colspan="7">Cognitive SR</td></tr>
<tr><td colspan="2">Notices regularities and novelties in the social and physical environment</td><td colspan="5"></td></tr>
<tr><td colspan="2">Gaze aversion as primary SR strategy</td><td colspan="5"></td></tr>
<tr><td colspan="2">Focuses attention on specific others, objects, and own</td><td colspan="5"></td></tr>
<tr><td colspan="3">Begins to participate and predict sequences</td><td colspan="4"></td></tr>
<tr><td colspan="3">Begins to initiate behavior sequences with people and objects</td><td colspan="4"></td></tr>
<tr><td></td><td colspan="2">Notices effects of own actions</td><td colspan="4"></td></tr>
<tr><td></td><td colspan="4">Self-soothing as primary SR strategy</td><td colspan="2"></td></tr>
<tr><td></td><td colspan="5">Shows cognitive organization by matching, sorting and classifying</td><td></td></tr>
<tr><td colspan="2"></td><td colspan="4">Behavioral avoidance and self-distraction as primary SR strategy</td><td></td></tr>
<tr><td colspan="2"></td><td colspan="3">Can choose among a limited number of alternatives</td><td colspan="2"></td></tr>
<tr><td></td><td colspan="4">Wants predictable routines and resists change</td><td colspan="2"></td></tr>
<tr><td colspan="2"></td><td colspan="3">Goal directed behavior</td><td colspan="2"></td></tr>
<tr><td colspan="2"></td><td colspan="4">Begins to notice and correct errors in goal directed activities</td><td></td></tr>
<tr><td colspan="3"></td><td colspan="4">Uses an increasing number of strategies to reach goals</td></tr>
<tr><td colspan="3"></td><td colspan="4">Can engage in a wider range of cognitive activities</td></tr>
<tr><td colspan="4"></td><td colspan="3">More able to carry out multi-step activities</td></tr>
<tr><td colspan="4"></td><td colspan="3">More able to control attention and resist distraction</td></tr>
<tr><td colspan="4"></td><td colspan="3">Can learn to use more advanced problem solving strategies</td></tr>
<tr><td colspan="4"></td><td colspan="3">More able to choose tasks for own level of skill</td></tr>
<tr><td colspan="7">Emotional SR</td></tr>
<tr><td colspan="2">Regulation of arousal and sleep/wake cycles</td><td colspan="5"></td></tr>
<tr><td colspan="3">Responsive interaction with others</td><td colspan="4"></td></tr>
<tr><td colspan="3">Begins to anticipate and participate in simple routines</td><td colspan="4"></td></tr>
<tr><td colspan="3">Responsiveness to emotional expressions of others</td><td colspan="4"></td></tr>
<tr><td></td><td colspan="2">Attempts to influence others</td><td colspan="4"></td></tr>
<tr><td colspan="2"></td><td colspan="4">Increasing voluntary control and voluntary self-regulation</td><td></td></tr>
<tr><td colspan="2"></td><td colspan="4">Growing ability to comply with external requests and awareness of situational demands</td><td></td></tr>
<tr><td colspan="2"></td><td colspan="3">Increasing assertiveness/desire for independent action</td><td colspan="2"></td></tr>
<tr><td colspan="2"></td><td colspan="3">Increasing awareness of others/feeling of others</td><td colspan="2"></td></tr>
<tr><td colspan="3"></td><td colspan="3">Some spontaneous helping, sharing and comforting behaviors</td><td></td></tr>
</table>

	Increasing awareness of social rules and sanctions		
	Increasing ability to inhibit prohibited activities and delay upon request		
		More capable of controlling emotions, abiding by rules, and refraining from forbidden behaviors	
		More capable of using language to regulate own behavior and influence others	
		Can learn more effective interaction strategies	
		Internalizing standards of behavior	
			More apt to regulate self in relation to peers
			Better understanding how others may feel
			Can engage deliberate helping, sharing, and comforting behaviors
			Can engage in play with roles and rules
			Begins to talk about mental states of self- others
			Developing more stable prosocial attitudes and behaviors

Parent Child Interaction and SR

The developmental psychology literature has highlighted the role of parents as agents that promote and facilitate children's SR. Early SR is said to develop through interactions with caregivers, and is dependent on environments that are predictable, responsive, and supportive (Rosanbalm & Murray, 2017). Parental role on the development of child SR has been studied mostly through a global approach of the qualitative features of parent-child interaction. Many authors have argued that maternal sensitivity, as well as maternal warmth and responsiveness are integral factors for child positive development (Fay-Stammbach et al., 2014; Vandenbroucke et al., 2018). Studies indicate that when parents demonstrate responsiveness to their child's needs—such as showing positive emotions, sensitivity, and warmth—while also establishing consistent interactions that adapt to the child's behavior, they can enhance their children's ability to self-regulate (Kochanska & Aksan, 1995; Lewis & Carpendale, 2009; Lindsey et a., 1997; Maccoby & Martin, 1983). Moreover, employing positive methods of control and providing encouragement for problem-solving, coupled with reinforcing successful self-regulation, can further bolster children's capacity for self-regulation (Rimm-Kaufman et al., 2009; Putnam et al., 2002; Strand, 2002). Thus, these studies use traditional tools measuring broad constructs that map onto different qualities of parent-child relationship (e.g. maternal sensitivity and responsiveness). However, this line of evidence focuses solely on the actions and intentions of the mother, without considering the interactive behaviors or responses of the infant (Harrist & Waugh, 2002) and therefore constitutes a monadic process within the interaction of the dyad, neglecting to consider the dyadic processes that take place (Skuban et al., 2006). Additionally, this literature has been controversial because the direction of effects has often been presented as unilateral (i.e. caregiver affects child) (Beeghly et al., 2011). For example, even though the concept of maternal sensitivity, as originally defined by Ainsworth, was dyadic in nature, in the subsequent years the literature has operationalized the concept focusing mostly on caregiver behavior, and using relatively broad, interrelated (although not identical) dimensions of positive parenting, such as warmth and responsiveness (Beebe et al., 2016).

Global assessments of the parent-child relationship quality sometimes lack specificity, making it hard to disentangle closely related constructs that occur in tandem (Loulis et al., 1997; Dishion et al., 2017). For example, a high level of positive emotion accompanied by extreme intrusiveness, (such as a mother vigorously playing with her child while not noticing the child is not enjoying the interaction), may in fact, be indicative of low sensitivity to the child’s needs and goals despite the high displays of warmth.

In general, traditional global approaches (i.e. macro-level assessments) evaluate parents' spontaneous behaviors and responses to the children´s needs (e.g. sensitivity, responsiveness, warmth), which have been shown to be predictive of children’s regulatory skills (Beeghly et al., 2011). However, this approach does not account for the active mutual regulation that occurs in dyadic interactions. Nor do they consider the child's spontaneous actions and expressions and his or her responses to parental behaviors, reducing dyadic interaction to a one-way perspective (Leclere et al., 2014; Moore, 2010; Moore et al., 2009).

Tronick was among the first to provide a formalized and consistent theoretical model of the reciprocal nature of caregiver-infant-interactions called the Mutual-Regulation-Model (Gianino & Tronick, 1988). This model was mainly grounded in the growing assumption supported by the infant research field, which highlighted that the caregiver-infant-dyad forms a mutually coordinated, communicative unit that quickly oscillates between synchronous states of affective-behavioral matches and asynchronous states of affective-behavioral mismatches in a continuous moment-to-moment process of mutual behavioral adaption, emotional exchange and affect regulation.

More recently, the dynamic systems approach has argued that parent–infant interactions are built through a mutually regulated process, related to a bidirectional system wherein both partners play an important role in shaping the relationship (Beebe et al., 2016; Mantis et al., 2014). The concept of parent-child interaction as a bidirectional process is complex and nuanced, and it has been suggested that several different dyadic processes are simultaneously co-occurring, such as reciprocity (Feldman et al., 2012), mutual regulation (Van Egeren et al., 2001), self- and interactive contingencies (Beebe et al., 2016), and synchrony (Feldman, 2007c). Further nonlinear dynamic systems theory (Hollenstein, 2007) has suggested that the dyad is organized in such a way that both partners can move with flexibility into and between matched states of behavior as appropriate (Provenzi et al., 2015).

Developmental approaches that include a dynamic systems perspective are part of the relational developmental system framework (Lerner & Overton, 2008). In the next section, I explain this framework and describe in more detail the theories that lay the basis for the tree studies I present later.

Theoretical Perspectives

The relational developmental system framework suggests that children's development arises from integrative and bidirectional relations between an individual and multiple levels of their environment (Lerner, 2006; Lerner & Overton, 2008; Overton, 2006). According to this view, children's overt behaviors emerge from the interplay between their characteristics (e.g., gender, temperament) and interactions with others (Calkins, 2007; Lengua & Kovacs, 2005). Moreover, Relational Developmental Systems theory points to the importance of considering parent-child relationships in their entirety, as opposed to the often-prevalent approach of assessing children and parents separately. These theoretical assertions have made significant contributions to our understanding of the role of the parent-child relationship in children’s social and emotional development (Deater- Deckard & O’Connor, 2000), and have crucially formed the basis for new conceptualizations of relationships as comprising bidirectional, interpersonal processes. While a full examination of these theoretical frameworks is beyond the scope of this literature review, three conceptual models are particularly key to understanding why new conceptualizations of the parent-child relationship are necessary. These are the bioecological theory of development (Bronfenbrenner & Morris, 1998, 2006), transactional theory (Sameroff, 2009) and Dynamic Systems (DS) theory (Smith & Thelen, 1993, 2003; Thelen & Ulrich, 1991).

Bioecological Theory of Development

According to the bioecological model of human development (Bronfenbrenner & Morris, 1998, 2006), child's development occurs within multiple contexts and is affected by factors at many levels, including individual (biological) characteristics, family processes, and the environmental context, as well as the interactions among these levels.

Bronfenbrenner highlights the importance of four aspects in human development: processes, person, context, and time (Bronfenbrenner & Morris, 1998, 2006). Processes, especially proximal processes, refer to the exchanges between the developing person and her/his immediate environment and are the major driving force of development. To be effective, these interactions, or proximal processes, must occur on a regular basis (Bronfenbrenner & Morris, 1998). The parent-child interaction is considered a proximal process. Context refers to the multiple spheres of the social and physical environment and includes micro, meso, exo, and macrosystems. Finally, the fourth of the components, time, refer to aspects such as chronological age, duration and continuity of exposure, and historical period.

Bronfenbrenner emphasizes the role of the active individual as an agent in his or her own development, within a specific ecological context. His theory considers that the characteristics of the person function both as an indirect producer and as a producer of development. Consequently, the parent-child relationship is conceptualized as a bidirectional and dynamic relation among the members of the dyad. Bronfenbrenner also emphasized that de parent-child relationships is not static, it evolves and changes over time. Parent and child continuously adapt, respond, and influence each other during development. Thus, to understand development, the bioecological theory states that we need to account for the bidirectional and dynamic nature of human relationships and examine how parents and children shape each other´s development within their ecological context. In sum, this bioecological model of development suggests that the role of caregiver-child interactions is critical, which ultimately become a driving force of children's cognitive and socioemotional development, including SR.

Transactional Theory of Development

Sameroff's (2009, 2010) transactional model of development emphasized the continual reciprocal influences between parent and child. In this model, transactional effects are considered to represent dynamic exchanges within parent-child dyads that stimulate both dyadic and individual-level changes

(Sameroff, 2009, 2010; Sameroff & MacKenzie, 2003). The model highlights that development occurs through ongoing transactions or interactions between a person's characteristics (e.g., abilities, behaviors) and their environment (e.g., parents, friends, culture). These transactions are reciprocal and bidirectional, meaning that both the individual and their environment influence each other. Similar to Bronfenbrenner's perspective, Sameroff (2009) emphasizes the dynamic and ever-evolving nature of these transactions. As individuals grow and develop, their interactions with their environment change, and these changes in turn influence their development. These ongoing transactions create patterns and pathways that influence future development. Positive interactions and supportive environments can foster healthy development, while negative or adverse interactions might lead to developmental challenges.

Dynamic Systems Theory

Recently, developmental researchers have argued that a Dynamic Systems approach can help increase understanding of children's social and emotional development by capturing the underlying processes at work when there are momentary shifts in the system (Hollenstein, 2011). Such transactional models provide a more accurate picture of dyadic interactions by assessing patterns reflecting each member's ongoing contribution to the relationship, with the child seen as active agent.

Dynamic systems theory (DS) theory is a metatheoretical framework comprising of several abstract principles that have been applied to various disciplines (e.g., physics, mathematics, and developmental psychology). This framework extends Bronfenbrenner's hierarchy of nested systems, and Sameroff's transactional processes, providing a framework for understanding how various factors dynamically interact and contribute to the development of individuals over time (Sander, 1977, 1985; Hollenstein, 2007; Lewis, 1999; Lewis, 2011).

While DS theory comprises a broad number of concepts, I will review here the DS most relevant assumptions that guide my studies. First, the most important assumption in DS is that development and change is always individual-based. The individual-based approach to development does not necessarily refer to the study of an individual person but refers to the study of individual *systems*, and the objective does not have to be solely to understand individual development, may also be to find similarities or differences between individuals in order to generalize a specific finding to a larger group. The system chosen as the unit of analysis in a study depends on the phenomenon in question and can in principle be defined at any level (i.e., an individual, a dyad, a group, to whole societies or cultures). After defining a system, the researcher may then ask relations between variables within that individual system, or trajectories of development of the system, and ask whether these vary between different individual systems.

Secondly, development is inherently *iterative*, causing a system to continuously evolve over time. Development proceeds step by step, and the next step builds upon the previous step. The outcome of each iteration, a task or an interaction for example, changes the system, and that changed system is the starting point for the next iteration. Micromomentary changes in the subcomponents, when repeated, form the basis of a self-organizing system over the course of development with its own internal feedback mechanism (Lewis, 2000). The mechanisms of developmental change can be seen in real-time (i.e., second-by-second), short time periods (i.e., days or weeks) and longer time periods (i.e., years) (De Ruiter et al., 2019). Consequently, the aim of studies that adopt a dynamic systems approach is most generally to understand or describe how a system (person/dyad/group) changes over time (real-time/short-term/long-term).

A third key assumption of the dynamic systems theory is that there is *interdependency* between the system's states and the context (see Figure 1). In dynamic systems approach the role of the context is not considered to be a stable background variable, but as continuously and bidirectionally related to the system and possibly changing over time. That means that if, for example, we are studying child SR and we define parental behavior as the context, then we have to define how child SR and parental behavior change over time, and how they mutually affect each other over time.

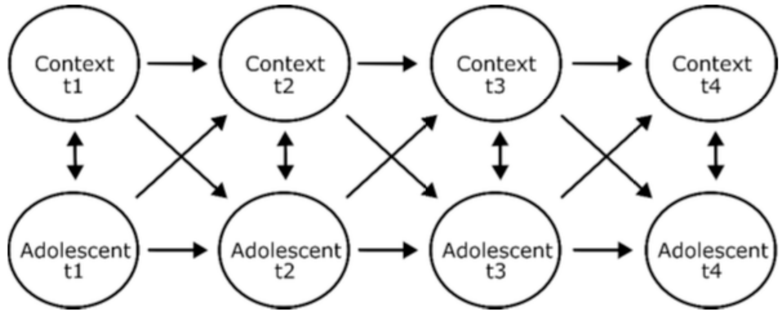

Figure 1. Schematic of Iterativity and interdependency. This figure illustrates iterativity and the interdependency between the systems states and its context. In this case the system represents an adolescent. In each time-point, the adolescent interacts with the context, and both the adolescent and context change as a result of this. This changed state is then the building block for the state of the adolescent and the context in the next time-point, this is known as iterativity. Figure from “Iterativity and interdependency” by M.A.E. van der Gaag, 2018. Copyright 2018 by CC BY 4.0.

Fourthly, DS focuses on *bi-directional relationships* between components of the system across time (see Figure 2). Changes in one of the components (may) influence another component in the system, which in turn can affect other components, etc. (e.g., Van Geert, 2008). Although it is possible to focus on the changes of only one or a few components of a system, a dynamic systems approach implies that these mutual interactions are considered, such that the interactions themselves or the consequences of the interactions are taken into account.

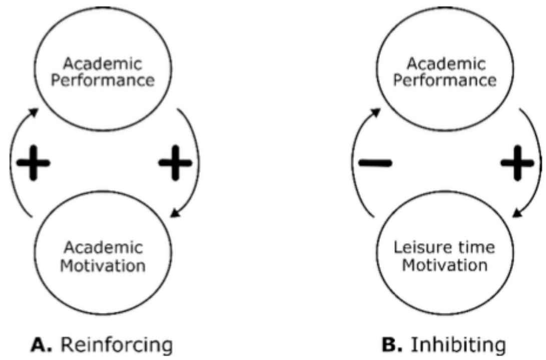

Figure 2. Feedback loops: a reinforcing (or positive) feedback loop (A) and a inhibiting (or negative) feedback loop (B). These types of bidirectional relationships between components within a system result in either rapid growth or stabilization. Example A represents an adolescent who, when performing well in school, is motivated to focus more on her studies, leading to better performance, and then again higher motivation until some boundary condition is met (e.g., energy limits). Example B represents a different adolescent who, when performing well in school, becomes motivated to focus on leisure time as a self-reward for a job well done. However, this focus on leisure time decrease her academic performance, which in turn decreases her focus on leisure time, which increases her performance etc., leading the individual to stably oscillate (i.e., non-linearly) between higher and lower performance states. Figure from “Feedback loops” by M.A.E. van der Gaag, 2018. Copyright 2018 by CC BY 4.0.

Recursive interactions between the subcomponents of a system are not always uniform, thus, while some components reinforce others in the same or opposing direction, others may have an inhibiting effect (Figure 2). These interactions are also collectively defined as *feedback loops*. Interactions between reinforcing components can lead to rapid growth and long-term stability of these patterns. This points to the nonlinear (i.e., dynamic) nature of these processes.

A system of interacting elements is characterized by the potential for *self-organization*. This means that the continuously interacting components may begin to “move together”, such that their interactions give rise to a more-or-less stable pattern that is more than the sum of these components. In this way, the interactions between components can be seen as lower-level processes, and the stable pattern that they form can be seen as a higher-level process that is emergent, which explains how a system becomes a coherent whole. Self-organization is a key concept for conceptualizing the relation between different time scales. For example, in child SR development, at a lower time scale, different elements (emotions, actions, thoughts) emerge in one specific constellation during one concrete experience (e.g., a child trying to accomplish a challenging task). We could call that a state. Self-organization can be seen when these lower-level network of emotions, actions, and thoughts at a higher time scale give rise to relatively stable and coherent patterns of specific emotions, actions and thoughts that can be characterized as that child's SR (see Figure 3). Accordingly, in a parent-child dyad, the interactions between the subcomponents (e.g., parent and child) are considered as lower-level processes and the stable patterns they produce (e.g., dyadic pattern of coregulation) are high-level processes that emerge from these interactions. Importantly, the relationship between the time scales is mutual. Not only do the lower-level states give rise to the higher-level time scales patterns, but at the same time the higher-level patterns influence and restrict the possible lower-level states.

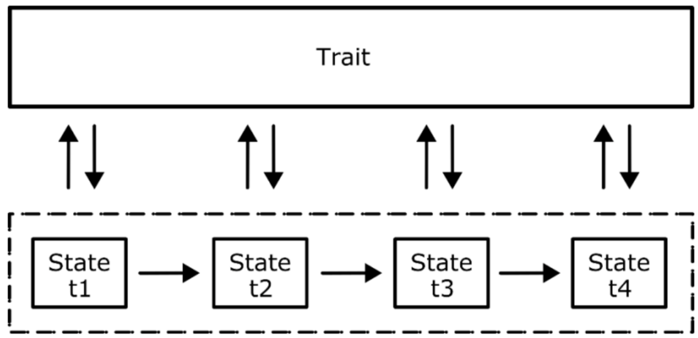

Figure 3. Schematic of Self-organization. Higher-level structures such as traits emerge from interactions between subcomponents of the system over time. These states (interrelations between subcomponents) are also constrained by the higher order trait. Reprinted from "Self-organization" by M.A.E. Van der Gaag, 2018,Iterativity and interdependency, 83, 18. Copyright [2018] by the CC BY 4.0.

This approach can be applied to the study of multiples aspects of co- and self-regulation processes. For example, one may examine the development of self-regulation (i.e., high-level structure) in a child as an individual system, looking at the interaction between the subcomponents of his/her SR (e.g., physiological arousal, executive functions). One may also study the interactions of the child with other relevant individual systems in his/her immediate context (e.g., caregiver, teacher, peers, school, neighborhood, etc.). We can even then compare the children's individual trajectories of SR across development (i.e., preschoolers).

Thus, how regulated a child remains while performing a challenging task on his/her own (e.g., a puzzle) is going to be the result of micromomentary interactions between the child's subcomponents of SR, as well as of the repeated interactions with his/her immediate context across time. The SR the child displays at that moment reflects the accumulated micromomentary interactions, while also how this pattern updates itself by that experience of self-regulating herself.

Likewise, we could consider the parent-child dyad as the target system. In this case, when we observe a parent-child interaction (e.g., parent and child playing with a set of toys), we are witnessing the high-level structure of dyadic coregulation as we observe that particular dyad pattern of interaction, while also how coregulation in this particular dyad updates by the dynamic interchange of parental and child behavioral and emotional momentary states.

A key concept in DS theory is the one of attractor. Attractors are specific high-level patterns (i.e., behavior, emotion) that pull the system into absorbing states or interaction patterns. The strength of an attractor is defined by how broad and steep it is (see Figure 4). A broad basin covers a large “surface” of possible situations, which means that many situations pull the system into the attractor. When an attractor is steep it is very difficult for the system to escape from the attractor (e.g., children with high irritability respond with negative affect in a broad range of situations that other children may not, and when they get upset, is more difficult to calm them). Internal or external triggers can result in behavior moving toward these attractors through the self-organization of the system and as these attractors occur repeatedly over developmental time, they eventually stabilize into increasingly predictable patterns (Thelen & Smith, 1994). Therefore, the particular set of SR skills a child has, or the quality of the interaction observed in a parent-child dyad, can be seen as attractors that have emerged over the course of weeks, months or years and stabilized into predictable traits. Strong attractors are habits or styles that are very salient for an individual, are triggered very easily, are experienced very often, and as such, are difficult to change.

This idea has important implications in the study of the development of SR. On one side, implies that children that develop adaptive SR skills earlier are more prone to continue on that positive developmental trajectory, and that young children are dependent on their caregivers to develop SR. On the other hand, this idea highlights the sensitive period that is early childhood in the development of SR and the short- and long-term effects that inadequate SR in the first years can have later in development. The developmental model presented by the DS theory suits well to understand the development of SR through coregulation. I focus on the concept of coregulation in the next section.

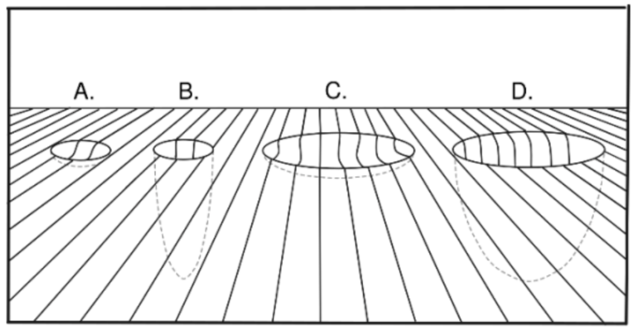

Figure 4. Schematic of Attractors. The attractor landscape consists of attractor basins with varying widths (representing the pervasiveness of a state) and depths (signifying the strength of a state). Deep basins reflect deeply entrenched states that are hard to get out of (such as B and D). The wide basins are pervasive states that are easily activated as they involve numerous aspects of an individual's life (e.g., C and D). Narrow and shallow basins (e.g., A) reflect states that are rarely frequented and are easy to get out of. Reprinted from "Attractor basins" by M.A.E. Van der Gaag, 2018, Iterativity and interdependency, 83, 19. Copyright [2018] by the CC BY 4.0.

Parent-child (Dyadic) Coregulation

Dyadic co-regulation involves the active organization and coordination of parents' and children's behaviors, emotions, and/or physiological states over time (Feldman, 2006, 2012b; Lunkenheimer et al., 2017). Since birth, parents establish patterns with their infants, who cannot fully regulate themselves, to provide coregulation of behavior and affect. Co-regulation between parents and children can thus be seen as an asymmetric process in terms of responsibility and capability (Zachariou & Whitebread, 2019). In a co-regulated interactive process, however, the parties involved mutually adjust by adapting to the others' ongoing actions and emotional states and expressions (Lavelli et al., 2019). Dyadic coregulation implies a two-way interaction between the caregiver and the child, where both are active agents of the regulation process (Lukenheimer et al., 2015). Consistent with dynamic systems framework, the caregiver-infant-dyad is viewed as an interactional system, in which both partners hierarchically organize levels of functioning (behavioral, affective, physiological, etc.) by reciprocally and mutually coordinating their behaviors, communicative signals and emotional states in various domains, in which changes on one level affect the functioning (and development) on others. This view allows us to assess not only the unique contribution of both partners in the dyad (parent and infant) in the interaction, but also assess the dynamic influence that each partner's response has on the response of the other partner (Beebe et al., 2011; Beeghly et al, 2011). There is empirical evidence that coregulation may represent a crucial developmental achievement for significant dyadic relationships, one that facilitates social, emotional, and cognitive growth for the child (Harrist, & Waugh, 2012).

Several terms closely related to the concept of coregulation have been used in the literature, leading to both theoretical and methodological confusion. Terms such as synchrony (Feldman, 2007; Harrist & Waugh, 2002; Isabella & Belsky, 1991; Lindsey, et al., 2009), attunement (Stern, 1985), mutuality (Deater-Deckard & O'Connor, 2000; Deater-Deckard, et al., 2004; Deater-Deckard & Petrill, 2004; Lindsey & Mize, 2000; Lindsey et al., 1997) and mutually responsive orientation (Aksan, et al., 2006; Kochanska & Murray, 2000) have often been used interchangeably with coregulation, describing various aspects of adaptive parent-child relationships.

For example, Feldman (2007) referrers to synchrony as a process of sensory, hormonal, physiological, and social coordination between parent and infant (e.g., temporal coordination of gaze, attention, vocalization, touch, and affect) that provides external regulation for salient needs such as hunger, arousal, and attachment in the infant. Synchrony involves close temporal coordination or simultaneous occurrence of parent and child behavior (Feldman, 2007). Central to the concept of synchrony is the notion that the essence of human experience is one's emotions and actions being situated in time (Feldman, 2007). In terms of the parent-child relationship, a process-oriented view of synchrony could be said to reflect the temporal and organizational features of the dyadic system. Specifically, the time-bound, coregulatory experiences within attachment relationships, providing the foundation for children's capacities for emotion understanding, empathy, and understanding the intentions of others through joint action. In terms of children's adjustment, research has reported associations between low levels of synchrony and higher child internalizing and externalizing problem behaviors (Criss et al., 2003; Deater-Deckard et al., 2004). Further, synchronous parent-child relationships have been demonstrated to be associated with children's adaptive SR (Kochanska et al., 2008; Suveg et al., 2016). Thus, synchrony provides an opportunity for children to attune their co-regulatory skills which can be applied to other social contexts where SR is used. Leclere et al's (2014) review of the literature's conceptualizations of dyadic synchrony found that various terms (e.g., mutuality, reciprocity, rhythmicity, and harmony) were used to characterize synchrony as a construct despite some being processes and others meta-theoretical concepts. Their review pointed to the overlap (i.e., assessment of different constructs as attributes of one another) of global constructs such as mutuality and reciprocity with synchrony, which could instead be best characterized as an interactive process. The term “positive synchrony” has been used to describe parent–child interactions in early childhood that are harmonious, reciprocal, and mutually responsive, whereas “negative synchrony” has been used to reflect mutual orientations around negative emotions or behaviors (Harrist & Waugh, 2002). Higher parent–child positive synchrony tends to be associated with better child self-regulation (Kochanska et al., 2008), whereas negative synchrony has been linked to children’s dysregulated behavior (Harrist et al., 1994). Others have used the terms “positive” and “negative” synchrony to index the direction of the interaction, that is, that both members of the dyad are moving in the same direction, or in the contrary, are behaving in opposite directions. Though the synchrony literature is informative, it often does not address which specific behavioral contingencies are salient for child development or whether the parent or child is driving the exchange.

Researchers have also conceptualized interconnected patterns of affect within close relationships as not only synchrony, but also attunement (Harrist & Waugh, 2002; Delaherche et al., 2012). While concepts such as synchrony and attunement have been shown to be related to coregulation (i.e., through harmonization of moment-to-moment changes in the goals and agendas of each interactive partner) (Harrist & Waugh, 2002; Feldman, 2003), they are often operationalized in global assessment tools as primarily indicating the matching of social partners’ emotional systems (Skuban et al., 2006). Attunement within the parent-child dyad is said to foster a sense of “togetherness”, where both interactive partners become accommodated to the intentions and emotions of each other (McMahon & Newey, 2018), increasingly anticipating each other’s actions and reciprocating emotional expressions over time to facilitate the emergence of new dyadic states.

Maccoby and Martin (1983) used the concept of reciprocal compliance to demonstrate how reciprocity denotes the co-constructed nature of emotional and behavioral states. Parent’s compliance with their child’s needs and requests in turn elicits the child’s compliance with parental requests, reflecting an ability to reciprocate the actions of others, cooperate willingly, and pursue shared goals. In accordance with DS theory, this could be said to reflect the predictable sequencing of actions and intentions and point to underlying organizational processes (Morelen & Suveg, 2012). Research has also implicated reciprocity in outcomes of child social adjustment. For example, Gardner et al. (2003) earlier showed that early cooperative play is linked to reduced conduct problems, and Criss et al. (2003) found that boys in dyads with high levels of positive reciprocity were reported to be less likely to engage in antisocial behavior (Criss et al., 2003).

The operationalization of mutuality by Kochanska and colleagues emphasizes the importance of assessing the dyad as a unit of analysis. Based on Maccoby's conceptualization of reciprocity, Kochanska et al. pointed to the role of mutually responsive orientation (MRO), characterized by shared positivity, shared cooperation, and responsiveness in the parent-child dyad (Kochasnka, 1997; Kochanska & Murray, 2000). Their measure of MRO comprises ratings of how cooperative, responsive and harmonious interactions between a parent and child were (Aksan et al., 2006). Specifically, mutual cooperation with conflicts resolved with ease, positive emotional ambiance (i.e., frequent instances of shared joy and affection), coordination of routine behavior, and a harmonious flow of communication indicated high MRO.

Pointing again to conceptual overlap, synchrony has been labelled as both mutuality (Deater- Deckard & Petrill, 2004) and mutually responsive orientation (MRO; Kochanska & Aksan, 2004). Yet, mutuality and reciprocity differ in the way they characterize bidirectional interactive patterns in the dyad. For example, reciprocal interactions assume that the contributions of each partner are equal in frequency and intensity (Trevarthen, 1980); whereas in mutual interactions, both partners' contributions to the interaction may vary both quantitatively and qualitatively (Beebe et al., 2010).

The dyad is said to be an interactional system in which both partners organize its behavioral and affective functioning. Through the mutual coordination of behavior, communicative signals, and emotional states; changes at one level impact functioning at other levels of the dyadic system; pointing to the involvement of multiple processes. The use of different global constructs emphasizes the lack of conceptual clarity in the literature and calls for more research efforts to tease apart which of these concepts are indeed interrelated broad theoretical constructs, and which are best understood as interactive processes that describe the structural and organizational dynamics of parent-child interaction.

Among the constructs described, mutuality and reciprocity would appear to be best framed as broader, global metatheoretical concepts than as processes. They provide distinct indications of coregulatory interactive patterns; reciprocity assumes equality in the influence of the parent and child (Trevarthen, 1980), while mutuality incorporates the different quantities and qualities of both partner's contributions to the dyadic system (Beebe et al., 2010). A number of lower-level processes already touched upon above could then be said to underly these constructs and reflect the dynamics of coregulatory processes. Contingency refers to reciprocal adjustments of behavior and affect within a micro-temporal window. This process is said to facilitate the child's learning and regulation skills (Provenzi et al., 2018). Coordination is said to foster both attunement and mirroring of emotional states within the dyad. Moreover, insights from studies on reciprocity also show that it is important to note that the parent-child dyad can achieve both coordination of emotion/behavior and coordination of intentions.

Issues in the Study of Coregulation

Measures of Coregulation

The incorporation of models of bidirectional effects within developmental theories, such as dynamic systems and transactional models, has led to the advancement of methods of examination and assessment. These methods capture the dynamic and transformative associations between genetic, biological, behavioral, and psychological characteristics that contribute to observable individual and relationship-level characteristics (O'Connor, 2002). These methods vary in their units of analysis (Granic et al., 2003), as well as their ability to reliably detect effects and draw conclusions.

Another problem for research to overcome is how assessment methods can utilize precise units of measurement to capture the dynamics of coregulatory processes. Despite newer conceptualizations of the parent-child relationship as bidirectional, most observational research has focused on the unidirectional influences of parent behavior on child outcomes. This is reflected in the predominance of global observation systems in current literature. In global systems of parent-child interaction, each variable is coded according to a scale or rating-point system, based on the frequency and quality of the observed behavior. In this sense, global systems enable the incorporation of a wide range of content cues to evaluate the meaning and appropriateness of parental behavior. For example, global interaction scales of dyadic synchrony (e.g., Synchrony Global Coding System SGCS; Skuban, 2006), comprise of qualitative descriptions of the dyad's reciprocity, shared affect, and mutual focus, treating synchrony as a global concept. Parental behaviors are coded explicitly in the context of child behaviors to imply levels of synchrony, but there is no direct measurement of the co-constructed nature of the dyadic interaction. Moreover, global measures may be subject to the "halo effect" where the observer's positive impression of an interaction are driven by certain aspects of synchrony more so than others (Bardack et al., 2017). Finally, global systems are unable to objectively tease apart which specific composites of observed behavior drive global ratings. Thus, there is a need for methods that can reveal the constellation of interactive behaviors that best characterize coregulation.

One way to measure coregulation involves the use of micro-level systems which code the onset and offset of observed pre-defined behaviors as they occur, and analytical methods that represent the patterns of behavior. Parental behavior is initially coded irrespective of the preceding child behavior, using a predefined set of observable indicators (e.g., Specific Affect Coding System SPAFF; Shapiro & Gottman, 2004). Thus, micro- level systems enable the objective evaluation of latent constructs. Micro-coded analytical methods are predominantly based on statistical approaches, which typically include frequency counts and durations of specific child and parent behaviors, which are subsequently used to assess temporal and structural patterns via statistical modelling (Cox, 1972).

Research has suggested that it is important to distinguish between the content of modalities such as body movement, gaze direction, and facial affect (i.e., ‘what is assessed’); and the temporal link between social partners’ modalities (i.e., onset and offset, sequential relations) (Delaherche et al., 2012). Accordingly, moment-to-moment covariation of behavior and emotion over time may provide the basis for the early development of self-regulation through the co- construction of interactions (Gianino & Tronick, 1985; Tronick, 1989). Global systems may be helpful in detecting certain qualities of relationships and have been shown to reliably predict developmental outcomes (Aoki et al., 2002; Shmueli-Goetz et al., 2008), yet the growing body of literature informed by DS theory is increasingly evidencing the utility of identifying patterns in the sequencing of behaviors and emotional responding (Granic & Patterson, 2006; Guo et al., 2017; Lunkenheimer et al., 2020; Morris et al., 2018; Stanger, 2019). The adoption of quantitative analytical methods is thus most effective in helping us understand the structure and organization of parent-child relationships.

Coregulation and Child Age

Since birth, parents establish patterns with their infants, who cannot fully regulate themselves, to provide coregulation of behavior and affect. Coregulation patterns become more complex as children age, offering them opportunities to practice and gradually internalize their SR skills in a relational context. As the capacity for self-regulation develops over time, the optimal amount of coregulation varies according to the developmental period. Early childhood and adolescence are two developmental periods where self-regulation ability sees a dramatic increase, due to corresponding changes in brain development (Rosanbalm & Murray, 2017). Hence, supportive coregulation in these developmental windows may be particularly vital for smooth transitions into new phases such as the start of school and entering adolescence (Rosanbalm & Murray, 2017). Most theorists agree that the ability to regulate behavior in the absence of an external coregulator does not emerge until after 3 years (Vaughn et al., 1984). Thus, at the midpoint of the third year, toddlers still rely on caregivers to regulate themselves.

Mothers and Fathers

Positive coregulation among both mother–child and father–child dyads has been related to child SR (Kochanska & Kim, 2014; Lindsey et al., 2009). However, some studies have demonstrated discrepant results when both mother–child and father–child coregulation were examined in relation to children's SR. For instance, Kim and Kochanska (2012) reported that mother–child, but not father–child, coregulation when children were 15 months old, was significantly, positively correlated with children's effortful control across a series of behavioral observation tasks at 25 months of age. In addition, some research has demonstrated that the magnitude of the correlation between mother–child coregulation and child self-regulation is larger than the corresponding correlation for father–child coregulation (Kochanska & Kim, 2014; Kochanska et al., 2008).

Researchers have speculated about reasons for their divergent findings on the role of mother–child and father–child coregulation in child development. For instance, Kochanska et al. (2008) suggested that the stronger relations between maternal mutual orientation and indices of child adjustment, including SR, might have been due to differences in the amount of time mothers and fathers generally spend with their children. Mothers have long been viewed as the primary attachment figures (Bowlby, 1958) and though fathers' involvement in childcare has increased in the last few decades, mothers typically continue to spend more time with their children than do fathers (Craig et al., 2014).

When directly compared with fathers, some research has found that mothers tend to exhibit greater emotional reciprocity when interacting with their children (Thomassin & Suveg, 2014). In contrast, other research has found that mother–child and father–child dyads share in similar degrees of coregulation, although the nature of coregulation itself appears different, and perhaps has varying implications for particular aspects of youth development (Feldman, 2003). In part, differences in patterns of coregulation among mother– and father–child dyads are likely due to differences in each gender's interaction styles, with fathers engaging in higher-intensity interactions that often involve more physical play (MacDonald & Parke, 1986). Regardless, both interaction styles offer opportunities for various forms of emotional and social learning (Feldman, 2003).

Based on this literature review several gaps can be identified. First, it is not clear if these theoretical constructs are meant to be actual interactive processes describing what happens in the dyad in a moment-by-moment fashion or rather if they are broader meta-theoretical accounts of mother-infant dyads. Notably, there is a lack of systematization regarding which theoretical items are concepts (i.e., meta-theoretical views of mother-infant dyadic interactions) and which of them are processes (i.e., detailed descriptions of specific joint actions observable within the mother-infant dyad). Moreover, the relationships among these dyadic concepts have not been previously accounted for. The literature suggests all these dyadic constructs reflect specific facets of the complex micro-temporal dyadic nature of the mother-infant system. Additionally, there is also a lack of agreement and systematization at the methodological level. For instance, interactive reparation might be alternatively measured as the frequency of transitions from mismatched to matched states (e.g., Provenzi et al., 2015) or as the average mismatch duration (e.g., Müller et al., 2015), while synchrony is usually assessed by time-series-analyses and concurrent or lead-lag-relationships (e.g., Feldman, 2003). Even though, while not identical, each of these constructs intent to move beyond the focus on one partner only and capture the mutuality and bidirectional quality of infant-caregiver interactions (Harrist & Waugh, 2002). In each of these constructs is the understanding that both partners of the dyad contribute simultaneously and moment-by-moment to the quality of dyadic co-regulation.

Chapter 3: Study 1

Introduction

Children's self-regulatory abilities lay the foundation for their success in academic achievement and social adjustment (Robson et al., 2020). Self-regulation (SR) is a broad and contextualized construct and refers to an individual's ability to monitor and manage their own thoughts, emotions, and actions to achieve a goal (McClelland & Cameron, 2012; Bailey & Jones, 2019). At the core of SR is executive function (EF), a set of high-level cognitive processes that underlie the self-regulation of individual behavioral responses (Koziol et al., 2012). Children's EF skills go through a period of rapid development during the first years of life and there is substantial evidence that high levels of EF in the preschool years are significantly related to children's concurrent growth in academic skills and subsequent successes in school achievement and social adjustment (Blair & Raver, 2015).

Given the importance of the first years of life in the development of EF skills, research has focused on parenting as source of individual differences in children's EF (Bernier et al., 2012; Bernier et al., 2010; Bibok et al., 2009; Hughes & Ensor, 2009). These studies have focused on various aspects of parenting in relation to EF, such as scaffolding (or autonomy support), sensitivity, and mind-mindedness (Carlson, 2003). In this study, I focus on coregulation - the active organization and coordination of parents' and children's behaviors, emotions, and/or physiological states over time (Lunkenheimer et al., 2017). There is empirical evidence that coregulation may represent a crucial developmental achievement for significant dyadic relationships, one that facilitates social, emotional, and cognitive growth for the child (Harrist, & Waugh, 2012). In this study I extend the literature on the contribution of coregulation in children's´ regulatory skills in several aspects. First, I examine the dyadic interaction including behavioral and affect dyadic coregulation. Many studies assess either behavioral coregulation (e.g., Lunkenheimer et al., 2020) or affective coregulation (Cole et al., 2003). The approach in this study provides a more sophisticated way of conceptualizing coregulation. Second, I assess both the mother – child and the father – child coregulatory processes. Although few studies have included fathers, among those that have, evidence is mixed concerning differences between mother–child and father–child coregulatory processes (Feldman, 2003; Kochanska et al., 2015; Lindsay et al., 2009; Lunkenheimer et al., 2020). Third, I evaluate children´s SR through all three executive function processes. It is common that studies include specific aspect of EF such as delay of gratification (Shoda, Mischel, & Peake, 1990; Mischel et al., 2011) or inhibitory control (Kochanska et al., 2000; Kochanska et al., 1997). Using a integrative measure of EF provides a more robust portrait of the abilities that support SR.

Review of the Literature

Executive Function

One of the core components of SR is executive function (EF), a set of high-level cognitive processes that underlie the self-regulation of individual behavioral responses (Koziol et al., 2012). Children use EF skills in various situations, such as inhibiting misbehavior, holding multi-step instructions, and switching between tasks when needed (Blair & Raver, 2015; McClelland & Cameron, 2012; Montroy et al., 2016). As a vital domain-general skill, EF enables children to regulate their thoughts and actions to develop more adaptive goal-directed behavior during learning and social interactions.

Executive function has three key components: working memory, inhibitory control, and cognitive flexibility (Duncan et al., 2007). Each component supports the mechanisms through which children regulate their thoughts and behaviors in the pursuit of goals (McClelland et al., 2010). Working memory (i.e., updating) is the ability to hold and maintain (or otherwise manipulate) information during ongoing mental activities. It enables children to hold instructions in mind as they carry them out. Inhibitory control (i.e., inhibition) is the ability to inhibit a dominant response in favor of a more adaptive one and is important for children controlling their impulses and following instructions. Finally, cognitive flexibility (i.e., shifting) is the ability to shift attention and adapt to changing goals while ignoring distractions. It enables children to persist during challenging tasks or instructions. Successful behavioral self-regulation typically involves the behavioral integration of all three executive functions (Spinola et al., 2017). For example, a child must integrate the three components when following a series of instructions: holding the instructions in mind, updating them as they complete each step, shifting between tasks effectively, and ignoring distractions (Cameron et al., 2008; McClelland et al., 2007; Morrison et al., 2010). Evidence suggests that measures of SR that capture all three executive function processes are more effective, as all these functions underpin self-regulation in children (Caughy et al., 2013; McClelland et al., 2014) (for a more detailed description of executive function see Chapter 2).

Parent-child Coregulation and Children Executive Function

Children’s early regulatory abilities develop within the context of parent–child interactions, with parents serving as the primary sources of regulation for their offspring during infancy (Feldman, 2007c). As children transition into early childhood, they become capable of greater SR, yet they still rely on their caregivers as sources of support (Kopp, 1982). SR abilities continue to develop throughout childhood (Raffaelli et al., 2005), with aspects of the parent–child relationship influencing SR even into adolescence (Eisenberg et al., 2005).

One of the mechanisms that has been found to be critical to child regulatory development is parent-child coregulation, that is, the active organization and coordination of parents’ and children’s behaviors, emotions, and physiological states over time (Lunkenheimer et al., 2017). Since birth, parents establish patterns with their infants, who cannot fully regulate themselves, to provide coregulation of behavior and affect. Coregulation patterns become more complex as children age, offering them opportunities to practice and gradually internalize their SR skills in a relational context.

Co-regulation between parents and children can thus be seen as an asymmetric process in terms of responsibility and capability (Zachariou & Whitebread, 2019). In a co-regulated interactive process, however, the parties involved mutually adjust by adapting to the others' ongoing actions and emotional states and expressions (Lavelli et al., 2019). More specifically, co-regulatory processes in this context involve the mutual influence that parents and children have on each other – that is, both parties are regulated by the other party's emotions, behavior, and physiology (Calkins, 2011; Fogel, 1993; Lunkenheimer et al., 2017). The evident sensitivity of this process involves a parent's capacity to respond to ongoing changes as well as the child's ability to be flexible in various situations (Cassidy, 2016). Thus, patterns of coregulation may be more informative as the content and quality of parental behavior in promoting child outcomes (Woltering et al., 2015).

Several studies suggest that investigating coregulation in the parent-child dyad may provide additional, independent, and more specific data (e.g., timing of maternal and child behaviors) about parent-child interaction than global assessments of scaffolding or sensitivity (Feldman, Greenbaum, & Yirmiya, 1999; Leclere et al., 2014; Lunkenheimer, Kemp, Lucas-Thompson, Cole, & Albrecht, 2017; Moore et al., 2013). From a Dynamic Systems approach (see

Chapter 2) the parent-child dyad is conceptualized as a mutually regulating system, in which both members of the dyad play an active role. Thus, to understand children's social and emotional development, the patterns reflecting each member's ongoing contribution to the relationship need to be addressed.

Studies on coregulation have shown that it plays an important role in children´s EF skills. In a meta-analysis Davis et al (2017) identified that behavioral coregulation (conceptualized as different constructs between studies) was significantly and positively correlated with different components of SR, such as executive function and effortful control, with a medium effect size. In addition, coregulation in preschool has been linked to multiple indices of concurrent and later child functioning (Cole et al., 2003; Hollenstein et al., 2004; Scaramella, Sohr-Preston, Mirabile, Robison, & Callahan, 2008).

For example, Feldman and colleagues (1999) assessed behavioral coregulation (indexed as the co-occurrence of affective states between mother and child) at 9 months in 36 mother-child dyads. The results showed that this type of coregulation was related to children's ability to follow instructions and delay gratification (i.e., EF skills) at 2 years of age (controlling for temperament, IQ, and maternal sensitivity). A study by Kochanska and colleagues (2008) found that higher parent–child coregulation was associated with better child EF. According to Kochanska, parent-child coregulation reduces the parent's need for using power or coercion strategies (Kochanska 1997; Kochanska & Murray, 2000). When a coregulation pattern becomes established between the parent and the child, the parent finds it easier to obtain the child’s willingness to comply without the need to use strong pressure (Kochanska, 1997). In a sample of 100 mother-child dyads, Lunkenheimer and colleagues (2020) examined dyadic patterns of coregulation and its relation to child EF. Their findings showed that more flexible and contingent affective mother–child processes, as long as the affective content was primarily positive or neutral, predicted higher levels of EF in early childhood. However, when mother-child dyads engaged in more negative affective and behavioral content, higher levels of affective and behavioral contingency predicted lower levels of child EF.

An open question is whether the effect of coregulation on children´s EF operates equally in the mother-child and father- child dyad. The few studies that include fathers suggest that the association between behavioral coregulation and child EF differs in mother-child versus father-child dyads. For example, a study with preschool children observed that only behavioral coregulation in the mother-child dyad predicted children's EF, despite no differences found in the average coregulation in mother-child versus father-child dyads during a problem-solving task (Garcia-Sellers & Church, 2000). In contrast, Lindsey and colleagues (2009) evaluated the relationship between coregulation of 80 mother/father-child dyads at 18 months and child regulatory skills, measured as the ability to resist playing with a "forbidden" toy, at 36 months. This team assessed various aspects of behavioral coregulation (dyadic interactions, shared emotion, and mutual cooperation) during a free play session. The results indicated that mother-child and father-child interactions related similarly to children's regulatory skills (i.e., less manipulation of the forbidden toy). However, a more specific analysis indicated that for the mother-child dyad, dyadic reciprocity (i.e., back-and-forth responses) mattered, while for the father-child dyad, shared positive emotion related to children's regulatory skills. In another more recent study, by Schueler and Prinz (2013) observed mothers and fathers interacting with their 3 to 6-year-old children during two tasks (a model building activity and a craft task) and assessed the children's regulatory abilities (ability to follow parental requests i.e., compliance). Behavioral coregulation was operationalized as contingent responsiveness and coded every 10 seconds. Similar to the Garcia-Seller & Church (2000) study, the average contingent responsiveness of both parents with their children was similar. Coregulation and children’s regulation related in both tasks in the mother-child dyad, but only in the second task (craft task) for father-child dyads. Overall, these studies suggest that both mothers and fathers exhibit similar levels of coregulation with their children, but mother-child coregulation seems to play a more predominant—or at least a different—role compared to father-child coregulation in their children’s regulatory skills. This might be due to fathers spending less time interacting with their children compared to mothers (Cabrera et al., 2018). Given the increasing involvement of fathers with their children and data indicating that both parents are equally capable of achieving coregulation with their children, involving fathers in studies opens another window for potential interventions.

This Study

Building upon a Dynamic Systems approach and empirical foundation, the present study aims to examine the relationship between dyadic coregulation and children's EF in mother-child and father-child dyads. To do so, I examined whether (1) coregulation of behavior and affect in mother-child and father-child relates to children's EF at age 36-months, and (2) the relation between coregulation of affect and behavior differed between mother–child and father–child interactions. I hypothesized that higher levels of dyadic coregulation will be associated with better EF skills in children, even after controlling for child gender, parental education, and family income. I controled for gender because previous studies tend to show that overall girls outperform boys (Bassett et al., 2012; Li-Grining, 2007; McCabe & Brooks-Gunn, 2007). As well, I controled for parental education and income because studies have shown that parental socioeconomic status affect children´s EF directly and indirectly by negatively (Blair et al, 2011; Mistry et al., 2010).

Methods

Participants

The sample consisted of 115 low-middle income Chilean families (preschoolers and their parents). All children lived with both parents. To be eligible, parents had to be at least 18 years old and not diagnosed with a severe psychiatric disorder (e.g. schizophrenia, bipolar disorder, major depressive disorder), and children had to have no diagnosis of intellectual impairment or neurodevelopmental disorder. Children's mean age at the moment of the assessment was 35.78 months (SD = 3.77, range = 30-46), 47% were boys, and 51.3% were enrolled in childcare. Mothers' and fathers' mean age was 31.15 years (SD = 6.10) and 33.9 years (SD = 7.09), respectively. Most of the mothers (87%) and fathers (86%) reported receiving a high school diploma or above, which mimics national data. In Chile, 88% of the population has a HS diploma and the mean years of education is 11.05. Families in this study were considered low-middle income, with an average monthly household income between 734 -1468 USD (Ministerio de Desarrollo Social y Familia, 2017); average income in Chile was 796 USD per month and minimum wage was 415 USD per month at the time of the assessment (see Table 1).

Procedure

The research team recruited participants through wall-posters or approached by research assistants in the waiting rooms of four primary health care centers in the south area of Chile's capital, Santiago. If families expressed interest in participating, one of the research assistants contacted them by phone for further explanation of the project and scheduled an appointment for the assessment, performed at the health care center. After giving written consent, one of the parents filled out questionnaires (regarding demographic information and parental behaviors), while the other parent was videotaped during a 10-minute free play session with his/her child for later offline coding. Later, the child performed the EF tasks and then the same free play procedure was performed with the other parent. The order of the parent-child interactions was counterbalanced. The total assessment lasted 1.5 to 2 hours. Each family received financial compensation and children were given a sticker for their participation. Study procedures were approved by the University Institutional Review Board.

Measures/Instruments

Sociodemographic Variables. Each parent answered independently a sociodemographic questionnaire with questions related to age, income, educational level, and marital status.

Dyadic Coregulation of Behavior and Affect. The mother-child and father-child free play interactions were coded using the dyadic codes of the Parent-Child Interaction System (PARCHISY; Deater-Deckard, Pylas & Petrill, 1997). Reciprocity (i.e., shared positive affect, presence of eye contact, a “turn taking” or conversation-like quality of interaction), conflict (i.e., minor or major disagreement, mutual or shared negative affect, arguing, tussling over toy), and cooperation (i.e., explicit agreement and discussion, about how to proceed with and complete task) were coded on a seven-point Likert scale ranging from very low (1) to very high (7). All father-child and mother-child interactions were coded independently by two researchers (trained by the PI) with good inter-rater reliability for 25% of the entire sample (Cronbach's $\alpha = .93$). A composite score of the ones obtained in the reciprocity and cooperation subscales was computed as an index of dyadic coregulation. No evidence of conflict was found in the interactions, so these scores were excluded in the computation.

Child Executive Functions. Children's executive functions were measured using the Minnesota Executive Function Scale (MEFS; Carlson & Zelazo, 2014), a standardized measure of EF administered on a tablet. The MEFS is a computerized game-like task that consist of sorting cards following two rule sets: (a) sorting based on a specific dimension (i.e. color) and (b) switching the sorting rule (i.e. shape). The MEFS is an adaptive task in which the recommended starting level is based on age. In total, there are seven levels of increasing difficulty, with higher levels involving multiple rule-switching. Subjects must answer correctly 4 out of 5 trials in every level to continue to the next one. Children were seated next to an experimenter with the tablet in front of them and asked to sort virtual cards based on different dimensions (e.g., color or shape) by dragging them into the boxes on the screen. Children continued to move up a level until they failed or completed Level 7. If the child did not pass the starting level, they moved down a level, and continued to move down until they passed or completed Level 1. The MEFS takes approximately 5 min and provides a standardized score (60-140 points) that considers accuracy and response time and is adjusted by participant's age. The scale is reliable, valid, and normed based on a sample of over 52,000 typically developing children ages 2–17.9 years old (Carlson, 2021). Reliability and validity of this task has been established and reported extensively elsewhere (e.g., test-rest reliability is 0.73; Carlson, 2021).

Data Analysis

Prior to analyses, I checked the data for normality. First, I computed descriptive and bivariate correlations to examine associations between the main study variables. Next, I used hierarchical regression analyses, controlling for child gender, parental educational level, and family income, to determine association between dyadic coregulation in mother-child and father-child dyads and children's EF. I conducted all analyses using IBM SPSS Statistics version 29.0.

Results

Descriptive statistics for all measures can be found in Table 1. Bivariate correlations are shown in Table 2. Bivariate correlations showed that coregulation of father-child and mother-child dyads was related to the parents' own educational level. Likewise, a significant association was found between mother-child and father-child coregulation and child gender, with higher coregulation found for mother- and father-daughter dyads.

I performed a hierarchical multiple regression analysis to examine the contribution of father-child and mother-child coregulation to child EF with separate models for father-child and mother-child dyads. Parental educational level, family income and child gender were included as covariates in Step 1. Father-child and mother-child coregulation were included in Step 2.

Results showed that in mother-child dyads, dyadic coregulation predicted better EF skills, even after controlling for child gender, parental education, and family income. The results don´t show this relation for father-child dyads.

Table 1. Descriptive Statistics Study 1

	Fathers				Mothers			
	M	SD	Range	%	*M*	SD	Range	%
Age	33.9	7.09	20-56		31.15	6.10	21-53	
Relationship status								
Married				49				
Co-habiting				51				
Educational level								
Less than high school				13.9				13
Completed high school				28.7				26.1
Some college				33.9				39.2
4-year degree or higher				23.4				21.7
Ethnicity								
Yes				18				8.3
No				82				91.7
Family income								
Low				40.7				
Middle				59.3				
High				0				
Dyadic coregulation	3.41	1.24	1.50-7.00		3.46	1.24	1.50-6.50	
Child								
Age (months)	35.78	3.77	30-46					
Child is a boy				47				
Executive Function (MEFS)	92.86	12.17	76-132					

Table 2. Correlations between fathers', mothers', and children characteristics (N = 115)

		1.	2.	3.	4.	5.	6.
1.	Child gender	-					
2.	Educational level father	.04	-				
3.	Educational level mother	.07	.47***	-			
4.	Family income	.10	.39***	.41***	-		
5.	Coregulation father-child dyad	.25***	.19*	.25***	.02	-	
6.	Coregulation mother-child dyad	.32***	.16	.19*	.04	.41***	-
7.	Child EF (MEFS)	.19	.14	.06	.19*	.13	.22*

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

Table 3. Results of hierarchical regression analysis

	Father-child dyads						Mother-child dyads					
	β	*SE*	*t*	*R*	R^2	$R^2\Delta$	β	*SE*	*t*	*R*	R^2	$R^2\Delta$
Dependent variable: Child EF												
Step 1				.24	.06	.06				.28*	.08*	.08
Child gender	3.60	2.11	1.70				4.44	2.25	1.98			
Educational level parent	.35	.75	.46				1.93	. 75	.25			
Family income	1.37	1.05	1.31				1.94	.81	2.38*			
Step 2				.26	.07	.01				.34**	.12**	.04
Child gender	3.13	2.17	1.44				2.93	2.32	1.26			
Educational level parent	.21	.77	.27				3.98	2.34	1.69			
Family income	1.46	1.05	1.38				2.06	.80	2.57*			
Coregulation parent-child	.84	.87	.95					2.72	1.42*			

Discussion

The present study investigated the relationship between dyadic coregulation and children's executive function (EF) skills in mother-child and father-child dyads. It is more common that studies examine the role of parental sensitive or scaffolding on children´s regulatory skills. Instead, through dynamic systems approach the parent-child interactions is seeing as a system, accounting got the contribution of both member of the dyad. Such perspective provides a different insight into the influence of the parent-child interactions on children's SR development.

Results from this study showed that parent-child coregulation manifest similarly in the father-child and mother-child dyads. Previous studies tend to report higher levels of coregulation in the mother-child dyads. For example, in sample of 7–9-year-old British and Indian children Deater-Deckard et al. (2009)

found that coregulation (conceptualize as mutuality) was higher in the mother child vs father-child dyads. Similarly, Lunkenheimer et al., (2011) reported higher levels of dyadic positive affect in mothers-children vs fathers children's dyads in 5-year-old children. Perhaps, the type of tasks used to assess coregulation may explain the different results. The task in this study consisted in free play while in the other two studies the parent-child dyad had to complete a challenging task together. Mothers might be more used to display more didactic and teaching type behaviors when interacting with their children (e.g., Schoppe-Sullivan et al, 2013), thus the mother -child dyad may have had more practice than the father-child dyad in coordinating while completing a task together. In this sense, free play could be a more egalitarian context to assess mothers and fathers coregulation with their children.

Despite similar levels of coregulation in mothers and fathers, only the coregulation with the mother related to children´s EF. Higher levels of positive coregulation in mother-child dyads were associated with better EF skills in children, even after controlling for child gender, parental education, and family income. Children in dyads that display shared positive affect, turn taking and explicit agreement about how to proceed showed better EF in a computerized test. These results are in line with Davis and colleagues´ metanalyses (2017) showing that that the correlation between parent-child coregulation and children´s SR is stronger in the mother-child vs father-child dyad. However, others such as Kochanska et al., (2008) found that father- child and mother child coregulation (conceptualized as mutually responsive orientation) were equally related to children´s SR (inhibitory control).

Why was this association only significant for mothers and not for fathers? It could be an effect of dosage. Fathers in Chile – and many other countries- tend to spend less time with their children compared to mothers (Aldoney & Prieto, 2023). Even though fathers are as able as mothers to display coregulation with their children they may need to spend more time with their children in order to have a significant influence on children´s EF. Future studies should examine the distribution of childcare between mothers and fathers and the type of activities both parents participate with their children. Data on Chilean samples show that mothers tend to devote more time on more structure activities (e.g., Aldoney & Prieto, 2023) with their children while fathers only show comparable involvement with mothers in play activities.

The inclusion of both parents provides a more comprehensive picture of dyadic coregulation. My findings support the theoretical frameworks that emphasize the importance of dyadic coregulation for children's social and emotional development (see chapter 2), extending this understanding to include the domain of cognitive development. The link between mother-child dyadic coregulation and EF provides further evidence for the critical role of dyadic interactions in fostering children's emotional regulation and cognitive skills. These results can be used to advance existing conceptual models regarding the role of the parent–child relationship in child development. A dyadic perspective provides a different understanding of the ways in which parent–child interactions can contribute to children´s SR.

The study has a few limitations that warrant consideration. First, the cross-sectional design limits our ability to establish causal relationships. Longitudinal studies are needed to determine whether positive dyadic coregulation experiences causally influence children's EF development over time. Second, the study focused on low-middle income Chilean families, which may limit the generalizability of the findings. Future research should investigate the relationship between dyadic coregulation and EF across diverse populations. However, the findings from this study have important implications for interventions aimed at promoting children's social, emotional, and cognitive development. Programs that focus on enhancing parent-child interactions and fostering positive dyadic coregulation experiences may be beneficial for children's EF development. Additionally, interventions tailored to specific needs of mothers and fathers could be developed to address potential gender differences in parenting styles and their impact on children's cognitive skills.

By understanding the role of dyadic coregulation, we can better equip parents and caregivers with the tools and knowledge they need to nurture children's social, emotional, and cognitive abilities, laying the foundation for success in all aspects of their lives.

Chapter 4: Study 2

Introduction

Self-regulation (SR), the ability to control one's cognition, emotions, and behavior (consciously or automatically), is considered a crucial skill for young children to develop (Blair & Ursache, 2011, Blair & Ku, 2022; McClelland & Cameron, 2011). Strong SR skills in early childhood are associated with positive developmental outcomes later in life, including academic achievement and healthy socioemotional functioning (Blair et al., 2016; Diamond & Aspinwall, 2003). Conversely, children who develop ineffective SR skills are more likely to experience negative outcomes, potentially developing internalizing or externalizing psychopathology (Abulizi et al., 2017; Liu et al., 2018; Thompson, 2006). Due to the importance of SR for young children's development, understanding the factors that promote it is crucial.

As stated in previous chapters, self-regulation is composed of cognitive, emotional, behavioral, and biological levels which are reciprocally related (Blair & Ku, 2022) (see Chapter 2 for a literature review). All these aspects of SR contribute in a specific manner to the understanding of regulatory processes (Smith et al., 2011). For example, when faced with a challenging situation, physiological arousal increases behavioral and emotional reactivity, which in turn feeds forward to demand the control of attention and executive function. Activity at each level also feeds back on the level below. Even though these multilevel components are directed to achieve SR as a whole, the relation between physiological and behavioral regulation is not linear, and reflect different processes. At moderate increase in physiological reactivity, the volitional control of attention is increased and regulation characterized by executive function is maximized. At very low or very high levels of physiological reactivity, however, the volitional control of attention is decreased and higher-order processes of SR (i.e., executive function) is less likely to occur (Blair & Ku, 2022). Likewise, research has shown that ones' subjective perception of own's regulatory processes not always matches physiological indexes of those processes (Silva et al., 2017).

In line with relational developmental systems theories, children SR develops within the reciprocal interactions with their proximal and broad context (Bronfenbrenner & Morris, 2006). At the contextual level, the parent- child relationship has been described as the motor of development that allow children to move from external to internal regulation (Calkins, 2007, 2011; Gianino & Tronick, 1988). Consistent with this framework, the caregiver-infant-dyad is viewed as an interactional system, in which both partners hierarchically organize levels of functioning (behavioral, affective, physiological, etc.) by reciprocally and mutually coordinating their behaviors, communicative signals and emotional states in various domains, in which changes on one level affect the functioning (and development) on others.

In infancy, the child is fully dependent on the caregiver for all aspects of physiological regulation (i.e., body temperature, feeding, sleeping). Caregivers actively entrain the child's ability to effectively regulate physiology in ways that, in theory, will ultimately support reactive or reflective responses to stimulation depending on the context, with implications for behavioral, emotional, and cognitive regulation (Feldman, 2015, 2017). The physiological response to stress establishes the basis upon which reactive vs. reflective responses to stimulation are prioritized (Blair & Raver, 2015). As children age into the toddler and preschool periods, caregivers are scaffolding attention control and emotion regulation strategies that are setting the stage for the development of executive functioning.

Most research has focused on the behavioral component of child self-regulation and dyadic interaction (Blair & Raver, 2015; Blair & Ursache, 2011). In the past two decades, there has been growing interest in the study of physiological regulation as a complement to behavioral studies (e.g. Conradt & Ablow, 2010; Moore & Calkins, 2004; Perry, Calkins, & Bell, 2016). For example, research has documented the effects of the quality of mother-child interaction on individual differences in children's physiological and behavioral regulation abilities (Gianino & Tronick, 1988; Porter, 2003; Calkins, et al., 2008; Rothbaum & Weisz, 1994). This study extends on this literature by focusing on a specific aspect of parent-child interaction, dyadic coregulation.

The following sections present a review of the theoretical background of the study, followed by the description of the methods and results.

Review of the Literature

Physiological regulation

As a component of SR, physiological functioning plays an important role. Individuals differ in their physiological reactivity triggered by diverse situations, as well as in their ability and efficiency to regulate their arousal to maintain homeostasis. Physiological regulation can be assessed by examining underlying physiological processes, such as hormone levels (e.g., cortisol) and cardiac measures (e.g., cardiac activity). The parasympathetic branch of the autonomous nervous system (PNS) offers a unique insight as a marker of physiological regulation because it responds dynamically to mild and moderate social and emotional experiences from moment to moment (Porges, 2007). Traditionally, researchers have used both heart rate (i.e., HR, beats per minute) and cardiac interbeat interval (IBI) to quantify physiological regulation. But, because HR and IBI are linked with both sympathetic and parasympathetic nervous system activity, they may be unclear measures of physiological activity (Beauchaine, 2015; Berntson et al., 2007). Much of this research has focused on parasympathetic functioning as a physiological substrate of emotional reactivity and regulation (Beauchaine, 2015; Berntson et al., 2007; Blandon et al., 2010).

Current research on physiological regulation uses respiratory sinus arrhythmia (RSA), a measure of the variability of the heart rate that occurs at the rate of spontaneous breathing (i.e., our heart rate increases as we inhale and decreases as we exhale) (Berntson et al., 2007). RSA is a physiological index of vagal tone and reactivity and parasympathetic functioning, that allows us to respond flexibly to our changing social environments, key to adaptive SR (Porges et al., 1994; Porges, 2007). Vagal tone at rest (indexed by higher values of RSA) reflects the ability to maintain homeostasis when physiological systems are not perturbed, and the capacity to react to stressors; thus, high resting RSA values have been considered an indicator of regulation (Beauchaine, 2001). In the face of stress, an adaptive parasympathetic response is typically manifest as vagal suppression, resulting in decreased RSA (Porges, 2007). Vagal suppression/withdrawal (indexed by a decrease in RSA values) reflects putting a 'brake' on parasympathetic regulatory processes, in order to activate the body's sympathetic (i.e., fight or flight) responses to stress, thus representing a mobilization of resources to respond to environmental demands (Bornstein & Suess, 2000). On the other hand, vagal augmentation (indexed by increased RSA values) characterizes episodes of low social or environmental demand or stress (Porges, 2007), and thus, higher RSA values while responding to stress have been associated with dysregulated emotion and behavior (Hastings et al., 2008). However, RSA suppression or augmentation can also occur in the absence of other expected behavioral or psychological indicators (Porges, 2007). In terms of assessment, RSA can be measured through electrocardiography (ECG) and calculated repeatedly across short periods of time or "epochs" (i.e., which traditionally last 30 s).

Parent-child physiological coregulation

The development of SR occurs rapidly in early infancy and is highly dependent on experience in social interactions with parents (Calkins, 1994; Gunnar & Donzella, 2002; Schore, 2000; Tronick, 1989). Initially, infants rely on their parents' responsiveness to their affective signals for the regulation of emotion (Tronick, 1989), including help in regulating physiological arousal related to behavioral organization (e.g., Spangler & Grossman, 1993; Spangler et al., 1994).

Parent-child coregulation may be a central aspect of parenting to support self-regulation in early childhood because it reflects moment-to-moment coordination of biological responses between parents and children (Feldman, 2012a, 2012b). Accordingly, the last decades, a growing number of studies has aimed to examine the critical role of parent-child coregulation on child SR (Bardack et al., 2019; Bell, 2020; Lunkenheimer et al., 2017; MacPhee et al., 2015). Physiological coregulation constitutes a uniquely formative experience for children's neurological, social, and emotional development (Feldman, 2012a; Feldman et al., 2017). Indeed, several studies have shown that coregulation is a key feature of the parent-child interaction that has long-term effects on behavioral and emotional regulation (Feldman, 2007a, 2010; Leclere et al., 2014; Levy et al., 2017,2021) but very few have examined the relation between physiological coregulation and children´s SR.

One of the most used frameworks when examining the parent-child temporal coordinated psychobiological responses (i.e., coregulation) in early childhood is Feldman's Bio-behavioral Synchrony Model (Feldman, 2012a; Feldman, 2012b). According to this framework, which is deeply rooted in relational systems theory, humans are wired to learn to physiologically and behavioral self-regulate with the help of a coregulating caregiver. Coordinated interactions between parents sensitive and attuned responses to child's emerging social abilities and neurobiological states, provide the basis for child´s SR (Feldman, 2007b; Carollo et al., 2021; Feldman, 2015, 2017; Maccoby, 1992). Therefore, the emergence of children's SR is an interactive back and forth between parent and child´s behavior, affect and physiology in response to changes in environmental conditions (Mayo & Gordon, 2020; Somers et al., 2012).

Physiological aspects of SR associated with RSA are a time-varying measure that can be calculated continuously. Measuring child and parent physiology continuously and simultaneously reveals variability in the extent to which their physiological responses dynamically covary or synchronize during dyadic interaction and allows to examine dyadic physiological coregulation (Davis et al., 2018). In other words, physiological coregulation reflects increases or decreases in the child's physiological activation corresponding to changes in the parent's physiological activation, and vice versa. Parents and children may both independently show increased physiological arousal, indexed by RSA decrease (i.e., RSA withdrawal) during more challenging moments compared with less challenging moments, which cannot be adequately captured by average RSA levels across the task. Similarly, dyadic interaction may also be characterized by dynamic variation in the extent of coregulation that cannot be captured adequately by a global (average) coregulation measure.

Such dynamic changes in dyadic concordance may be particularly meaningful in early childhood. In infancy, consistent concordance may support homeostasis and arousal modulation as young children rely on caregivers to guide social interactions (Feldman, 2012). As children enter the preschool years and gain better motor, language, and cognitive abilities, they behave more autonomously, but they may continue to depend on caregivers for support in emotionally challenging situations (Kopp, 1989). Thus, parents and preschool-aged children may not display physiological coregulation constantly - as it may be adaptive for children to regulate independently or have divergent reactions from their parent on occasions - but may show physiological coregulation in emotionally challenging moments when they require support.

In the past 25 years, several studies have investigated parent–child coregulation of fluctuations in the parasympathetic nervous system in early childhood, yielding mixed findings (Davis et al., 2018). These differences may be potentially due to conceptual and methodological factors, such as the temporal approach to the phenomenon (i.e., concurrent vs time-lagged models), the tasks used (i.e., low vs high stressors), and the characteristics of the sample (e.g., age or SES), among others. In the next sections, I present a summary of the empirical evidence on physiological parent-child coregulation.

Positive versus negative physiological coregulation. It is important to note that physiological coregulation can be positive or negative in direction (Abney et al., 2021). Positive coregulation refers to children's and parents' parasympathetic activity changing in the same direction, for example, the parent increases his/her RSA while the child also increases his/her RSA. Negative coregulation does not refer to the absence of coregulation, but rather parents' and children's parasympathetic activity changing in opposite directions, that is, the parent increases his/her RSA while the child decreases his/her RSA or vice versa (see Davis et al., 2018 for a recent review).

Parents and children have been observed to engage in positive and negative physiological coregulation during face-to-face play and free play problem-solving tasks (Bornstein & Suess, 2000; Lunkenheimer et al., 2015). Lunkenheimer and colleagues with a sample of 47preschoolers found that fluctuations in parent and child RSA were positively associated with each other during a free play, clean up, and teaching task (Lunkenheimer et al., 2015; Lunkenheimer, Tiberio, Skoranski, Buss, & Cole, 2018). The same was found by Armstrong-Carter and colleagues (2021) in a sample of 96 families with a 5-year-old; parent-child dyads showed positive coregulation while completing a puzzle teaching task, such that parent and child RSA were significantly and positively associated with each other simultaneously.

In a longitudinal study that followed physiological coregulation of mothers and children from 2-months to 5 years, Bornstein & Suess (2000) found that vagal regulation was marginally concordant between child and mother at 2-months, and concordant at 5 years, when children and their mothers participated in the same task. This results suggest that during the first years, mothers and children had developed a shared characteristic response style that was reflected in similar patterns of vagal regulation to environmental challenges. Another group of studies have found negative patterns of coregulation. In a sample of 105 mothers and their 5-month-old infants, Ostlund and colleagues (2017) found negative mother-child coregulation (i.e., that mother's RSA increases were associated with child RSA decreases) during the recovery phase of a stress induction task (i.e., still-face procedure). Similarly, a study done by Pratt and colleagues (2015) in a sample of 122 mother-infant dyads 4-6 months with an adaptation of the original task (i.e., still-face procedure with 3 experimental conditions: standard, with touch, and with arm's restraint) found evidence of this positive and negative coregulation, depending on how reactive were infants. Infants high in negative reactivity receiving high mother–infant coregulation showed greater vagal withdrawal (RSA decrease), which in turn predicted comparable levels of vagal return to baseline to that of nonreactive infants. On the opposite, highly negative reactive infants displayed high levels of distress and disengagement if in dyads with low mother-child coregulation. The authors suggested two pathways by which coregulation may bolster regulation in children of high and low reactivity. Among low reactive infants, coregulation builds a social repertoire for handling interpersonal stress, whereas in highly reactive infants, it constructs a platform for repeated reparation of momentary interactive "failures" and reduces the natural tendency of stressed infants to disengage from source of distress.

Interestingly, studies do not always show either positive or negative coregulation, but sometimes find both types. For example, in a sample of middle school children from low-socioeconomic background, parent and child RSA were only significantly associated with each other for parents and children with low levels of internalizing symptoms, during a baseline or conflict discussion, but not in the child stress task. In the child stress task the authors found no coregulation (Suveg et al., 2019). Similarly, Lunkenheimer and colleagues (2015) found positive RSA coregulation in mother-child dyads (i.e., mother RSA predicted changes in the same direction in child RSA), but only for children with low levels of behavioral problems. In dyads with children with high level behavioral problems coregulation was negative.

These results suggest that negative coregulation may be adaptive when levels of stress are high and the mother-child dyad has to work hard to attain a regulated state. This may be the case for young children (infants) who are beginning to learn how to coregulate, and for children with behavioral problems where regulation is harder to reach. This hypothesis is in line with a polyvagal perspective (Porges, 2007), the stressful nature of a tasks might lead to increased individual variability in PNS activation, which may hinder the coregulation process. In the case of older children (Suveg et al., 2019) the lack of coregulation may reflect increasing levels of autonomy as and/or increasing parental efforts to support autonomy.

Concurrent versus time-lagged models. Besides the direction of the coregulatory patterns, physiological coregulation can be analyzed on multiple time frames (Obradović & Boyce, 2012). On one hand, coregulation can be examined concurrently, by testing whether both parent and child physiological activation increase or decrease simultaneously within each epoch of time (e.g., Li, Sturge-Apple, Liu, & Davies, 2020). In addition, researchers can examine time-lagged coregulation by testing whether increases or decreases in the physiological activation of one partner corresponds with changes in the physiological activation of the other in a “subsequent” epoch (e.g., Helm, Miller, Kahle, Troxel, & Hastings, 2018). Although both concurrent and time-lagged models reflect dynamic physiological coregulation between parents and children, each approach offers unique insights. First, concurrent models indicate the extent to which parent and child physiological changes co-occur simultaneously. As such, concurrent parent–child coregulation is the correlation between simultaneous changes in parent and child´s RSA and is understood as the extent to which parent and child are attuned to each other in the moment (Feldman et al., 2017). In contrast, investigating time-lagged coregulation sheds light on potential directionality, that is, the extent to which the parent may influence the child or vice versa (Helm et al., 2018). Time-lagged models illustrate not just that coregulation occurs, but "how" it emerges. For instance, if only parent physiology predicts subsequent child physiology (but child physiology does not predict parent physiology), then this would suggest that child physiological changes are sensitive and attuned to prior parent physiological changes. If changes in parent physiology predict subsequent changes in child physiology and vice versa, this would suggest that parent and child physiology are reciprocally related, potentially indicating that parents and children adjust their physiological arousal in response to their partner's prior physiological state. In this way, investigating time-lagged coregulation can elucidate whether physiological coregulation is driven initially by changes in parent or child physiology.

Depending on their conceptual approach, different studies have used diverse temporal models. Most studies have focused on concurrent parasympathetic nervous system coregulation between infants and mothers, as is the case off all studies presented in the previous section. Only a few studies have investigated time-lagged coregulation of RSA. The study by Helm and colleagues (2018), in a sample of 83 preschoolers that completed a set of dyadic tasks with their mothers, found no concurrent but lagged association between parent and child RSA during reading and puzzle tasks. Parent RSA positively predicted subsequent child RSA 30 s later, but child RSA was not related to subsequent parent RSA. Armstrong-Carter and colleagues (2021) tested 96 kindergartners in four structured tasks; free play, clean up, problem solving discussion, and geometric puzzle. The authors found that time-lagged coregulation occurred only during the problem-solving task, such that parent RSA was positively associated with child RSA 30 seconds later, and child RSA was negatively associated with parent RSA 30 seconds later. This is the only study that has investigated concurrent and lagged synchrony in the same task and sample.

Choosing one or another model should depend on different testable hypotheses regarding physiological synchrony. However, theory and evidence are not always clear in relation to whether lagged or concurrent coregulation underlie parent-child interaction, nor on possible variables (e.g., age, type of task, etc.) that could be related to the timing of coregulation. Clearly, more research on this topic is needed.

The more the better? The degree of “optimal” coregulation has also been a matter of discrepancy. Initial research conceptualized parent-child physiological coregulation as intrinsically positive for development (Feldman et al., 2006). But the adaptive value of positive physiological coregulation (i.e., increased arousal in one partner relates to increased arousal in the other) may differ as a function of individual differences or situational factors (Lunkenheimer, Tiberio, Skoranski, Buss, & Cole, 2018; Skoranski, Lunkenheimer, & Lucas-Thompson, 2017; Smith, Woodhouse, Clark, & Skowron, 2016; Suveg et al., 2019). In community samples, some studies have shown positive RSA coregulation among parent-child dyads. For example, Hu and colleagues (2021), in a community sample of 110 preschool aged children and their mothers, reported that only dyads that demonstrated high mutually responsive displayed positive RSA during a puzzle and pretend play tasks. However, evidence of negative coregulation (i.e., increased arousal in one partner relates to decreased arousal in the other) has emerged in more high-risk contexts (e.g., maternal mental health problems, maltreatment) (Creavy, Gatzke-Kopp, Zhang, Fishbein, & Kiser, 2020; Lunkenheimer et al., 2015; Suveg et al., 2019; West, Oshri, Mitaro, Caughy, & Suveg, 2020). Several studies including families considered at risk have found either negative RSA coregulation or statistically non-significant RSA coregulation. For example, the study by Ostlund and colleagues (2017) conducted in a sample of 105 mother-5-month-old child dyads at risk for parenting difficulties, found negative coregulation in the reunion episode after a stress induction task. Another study of 82 3-year-olds at risk for externalizing problems found that children with high levels of externalizing problems displayed negative RSA coregulation during a parent-child challenge task (Lunkenheimer Brown et al., 2021). In one study of 146 3- to 5-year-olds and their mothers, non-maltreating dyads showed positive RSA coregulation during problem-solving tasks, while maltreating dyads did not show RSA coregulation (Lunkenheimer, Busuito, et al., 2018). Notably, one study of 104 3 to 5-year-olds found no evidence of significant RSA coregulation among either maltreated or non-maltreated dyads (Creaven et al., 2014). Although the literature has produced some inconsistent findings, overall, these studies suggest that dyads at low-risk show positive coregulation in RSA during parent-child interaction, and thus, may be promotive of adaptive child outcomes. In contrast high risk dyads (i.e., presenting maltreatment, parental and child psychopathology) show weaker or no coregulation at all (Smith et al., 2016). The latter has been argued to reflect an adaptive response from at least one of the partners in the dyad, where in the context of high-risk, refraining to engage in interactions that can be dysregulating for them can be adaptive.

Coregulation and context

Dyadic physiological coregulation also seems to depend on the type of task and context. Prior studies have used a variety of tasks, ranging from those that are low in challenge and emotionally positive (e.g., free play) to those that are challenging, emotionally negative eliciting, or stressful (e.g., completing a difficult task). In a systematic review, Davis et al. (2018) reported that the strength and direction of mother-child physiological coregulation for RSA varied by social context (e.g., child behavioral problems) and task type. In a study of preschoolers, positive RSA coregulation was strongest during free play and a clean-up task, compared to a structured teaching task (Lunkenheimer et al., 2018). The authors suggest that the teaching task may pose high demands for parents, diminishing their energy or opportunities for coordination with their children. However, two different studies suggest the opposite. A study of 94 5-year-old children and their parents showed that parent and child RSA synchronized positively on average during more demanding tasks (i.e., problem-solving and puzzle teaching tasks) but not in less demanding task such as free play and clean up (Armstrong- Carter et al., 2021). Similarly, a study of 158 3- to 4-year-old children and their mothers who watched a short, emotional film clip together found positive coregulation only during seconds of the film when there was an increase in negative emotional content (Ravindran et al., 2021). These findings suggest that physiological coregulation may increase during tasks that are more demanding and emotionally challenging compared to more neutral or positive, although the nature of these differences is unclear (e.g., RSA coregulation could be more positive or more negative in challenging contexts). Similar to my previous explanation, perhaps it is the perceived demands of the task that may hinder or allow parents to be coregulators. If the demands are perceived as too high or low, the opportunities to coordinate with the child may be limited.

Mothers versus fathers physiological coregulation

Even though the aforementioned studies only collected data con mothers, they report their results as applicable for “parents”. Fathers play a key role in children’s regulatory development (Cabrera et al., 2004; Davidov & Grusec, 2006; McDowell et al., 2002; Rinaldi & Howe, 2012). Research has shown that models of paternal and maternal parenting are different (Cabrera et al., 2014), and it is likely that dyad coregulation is different, as well. Feldman (2003) posits that during the first year, mothers and fathers co-create distinct types of coregulation with the infant, with mother-infant coregulation being more cyclical and social oriented, while paternal coregulation orients towards the environment and encourages exploration. Each one of them has important implications for the development of children’s social competence. Interestingly, studies examining coregulation of behavior have shown that father-child coregulation predicts better child SR than mother- child coregulation (Kochanska et al., 2015; Lindsay et al., 2009; Lunkenheimer et al., 2020).

However, empirical data on father-child RSA coregulation in early childhood, and how it differs by individual or dyadic factors are scarce. Three studies have reported including fathers´ in their samples, but they comprise a small percentage (less than 5%) of the total sample (Armstrong-Carter et al., 2021; Creavy et al., 2020; Fuchs et al., 2021). Lunkenheimer et al. (2021) included mothers and fathers from 104 children, finding differences in parent-child coregulation. Results suggested that mothers may be more attuned to children's regulatory capacities, whereas fathers may be more influenced by the immediate behavioral context. To date, there are no published studies comparing fathers and mothers physiological coregulation and children´s SR within the same family.

A couple of studies have investigated physiological coregulation in father-child dyads with older children. Waters and colleagues (2000) found differences in the direction coregulation between mothers and fathers, where mothers physiological regulation shaped child’s, but children shaped fathers’ physiological regulation. Conversely, the study done by Li and colleagues (2020) in a sample of 191 families with adolescents did not find evidence of father-adolescent coregulation. Given the few published studies and the inconsistent results, the literature offers little guidance on the understanding of father-child physiological coregulation. Including fathers in future studies of parent-child dyad coregulation would be informative of the diversity of social contexts in which infants and children develop (Davis et al., 2018).

Physiological coregulation and SR

Even though the large body of research that has suggested the foundational role of parent-child coregulation in the development of children SR, only a handful of studies have attempted to examine that relation. In a sample of 96 5-year-old children and their parents, Armstrong and colleagues (2020) found that children with higher levels of positive parent-child co-regulation exhibited higher physiological SR (decreases in RSA) while receiving critical feedback, which may indicate active engagement or coping with the challenging situation. Another study by Lunkenheimer and colleagues (2015) did not directly examined the association between dyadic coregulation and children SR, but examined how parent-child coregulation differed by children's externalizing processes (i.e., a proxy of children's SR). Results showed positive physiological coregulation, such that changes in mothers' RSA predicted changes in the same direction in child RSA and vice versa. However, when children's externalizing behaviors were higher, coregulation was negative such that changes in real-time mother and child RSA showed divergence rather than positive concordance, suggesting that children's higher externalizing behavior problems are related to disruptions in these processes.

This Study

Considering the importance of parent-child coregulation for children's developing SR (Feldman, 2007; Hastings et al., 2008; Lunkenheimer et al., 2020; Porges, 2007), in this study I am to contribute to the scarce literature on the role of parent-child physiological coregulation on children's physiological SR by answering the following research questions:

1. Do parents and their 3-year-old children exhibit coregulation of RSA during a dyadic interaction? And, does this coregulation occur with a time lag?
2. Does parent-child coregulation differ between mothers and fathers?
3. Is children's physiological SR associated with the degree of parent-child coregulation, both concurrently and with a time lag?

I hypothesized that: (1) parent and child RSA values across the course of dyadic interaction will be significantly and positively associated with each other in both concurrent and timed-lagged models, and (2) higher levels of concurrent and time-lagged physiological coregulation will be associated with higher children's physiological SR. Given the exploratory nature of existing evidence, I do not suggest a hypothesis for the specific effect of concurrent and time-lagged models and mother-child and father-child dyadic coregulation.

Methods

Participants

The sample consisted of 24 Chilean families (3-year-old children and their mothers and fathers). I excluded eight families from the analysis due to incomplete dyadic physiological data. Additionally, I excluded two fathers and one mother due to excessive noise in the signal. The research team (two research assistants and I) recruited families through advertisements posted in day care centers, preschools, and social media. We excluded the families if the child had been diagnosed with a developmental disorder or intellectual impairment, if the parents had been diagnosed with a severe psychiatric disorder (i.e., schizophrenia, bipolar disorder, mayor depressive disorder), or if parents or child had a heart condition that could interfere with physiological data collection. The final sample size was 14 families with complete data.

Mothers were slightly younger than fathers ($M_{mothers}$ = 35.25 years, SD = 3.12; $M_{fathers}$= 37.5, SD=4.89). Parents were highly educated (100% had completed College) and had upper income (median family monthly income = $5.712, which represents 7.5 times the median income in Chile). All children (M_{age} = 38.54 months; SD = 2.02; 45.83% female [n = 11]) lived with both parents. All couples were cohabiting and 95% were married.

Procedure

Two research assistants trained by me collected the data during a 2-hour laboratory visit. Upon arrival, research assistants greeted the parents and children, introduced them to the laboratory setting and the study protocol, and set up the equipment for measuring physiological responses. After families gave consent and a familiarization period, one of the research assistants attached the electrodes to one parent-child dyad, while the other parent completed an in-person survey in an adjacent room. After finishing the activities with one parent, the research assistant offered the child a break time before starting the same set of activities with the other parent. Mother-child and father-child dyads were counterbalanced.

The parent-child interaction protocol lasted for approximately 30 minutes (including transition time between tasks) and was video recorded for later offline micro-coding. First, the research assistant asked parent-child dyads to watch a calm 5-min video for baseline set up. Then, the research assistant provided the dyad a set of toys and gave them the instruction to play together “as they usually do at home” to complete a 10-min free play session. Finally, the research assistant asked dyads to complete an origami folding task. Between the two parent-child interactions (with the mother and the father or vice versa), the research assistant asked the parents to temporarily leave the room and assessed children’ SR with the Transparent Locked Box Task (Goldsmith & Reilly, 1993), which is described in the following Measures section.

Measures

Sociodemographic variables

A self-report questionnaire was administered independently to both parents, that asked for sociodemographic information such as age, income, educational level, marital status, number of children, among other variables.

Origami task

Children were provided with a piece of colored origami paper, and mothers/fathers were given a piece of paper with pictures of the steps necessary to fold the origami paper into a puppy or fox face. Parents were told that they should use these instructions to show the child how to fold the paper, but that the child should do all the folding and that they should not touch the origami paper. Dyads were given 5 min to finish the origami task and were encouraged to finish earlier to win a special price. This task is meant to be challenging and has been used in several other studies (Hane, Cheah, Rubin, & Fox, 2008; Hastings et al., 2008, 2015).

Transparent box

In this task, a small toy desirable to the child is placed in a transparent acrylic box that is locked. The evaluator leaves the room and leaves the child alone, after telling him/her that he/she can keep the toy if he/she opens the box. However, the child is given an inappropriate set of keys. After three minutes, the evaluator returns to the room apologetically with the correct set of keys so that the child can open the box and play with the toy (Goldsmith & Reilly, 1993).

Physiological response

During the origami and the transparent box tasks we collected the parent and child RSA response, as collected using Mindware Technologies ambulatory monitors (Gahanna, OH). Three disposable electrodes were attached to the chest using a lead II placement to collect ECG signal, which was wirelessly transmitted to a computer for storage and processing. The high-frequency band-pass parameters to quantify RSA were set to .12 to .40 for adults and .24 to 1.04 for children, and sampling rate was set at 500 ms. The dZ/dt signal was used as an estimate of respiration (Ernst, Litvack, Lozano, Cacioppo, & Berntson, 1999) and was controlled for in the computation of RSA. Using Mindware software, spectral analysis of the interbeat interval (IBI) data was used to compute RSA values (Berntson et al., 1997).

Prior to analyses, I verified each waveform, checked visually the interbeat intervals, and removed the artifacts. In order to do that, I underwent a rigorous training process at UC Davis for processing the ECG data at and calculating RSA values using Mindware software, and personally trained a research assistant to double check the physiological data collected, demonstrating good reliability (ICC > .99). During the preprocessing of the physiological data, I found that the rest period (watching a calm video) at the beginning of the assessment was apparently arousing for several participants, therefore it was not used as a baseline measure.

I calculated parent and child RSA in 30-s epochs over the course of the origami task. To test for dyadic coregulation, I calculated two RSA variables. First, for each individual (i.e., parent or child), I calculated their average RSA value across all their epochs in the origami task. Second, I mean-centered each RSA value in each epoch around that individual's person-mean in the origami task. These mean-centered RSA variables varied across epochs.

As a measure of child SR, I calculated child RSA in 30-s epochs during the Transparent Locked Box Task and then averaged to calculate child physiological SR in the stress induction and recovery phases of the task.

Control variables

Based on previous studies that report differences in coregulation depending on mothers' mental health symptoms (Skoranski et al., 2020; Weinberg et al., 2006) and stress levels (Azhari et al., 2022), I included measures of depressive symptoms and parental stress as covariates.

Depressive symptoms. Mothers and fathers reported on their depressive symptoms using the Spanish version of the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977). This scale is composed by 10 items that define a spectrum of depressive symptoms experienced during the past week, such as "I was bothered by things that usually don't bother me" and are rated from 0 (Rarely or none of the time - less than a day) to 3 (Most or all of the time - 5 to 7 days). Higher scores indicate higher depressive symptoms (range 0-30). Cronbach's α was .82 for mothers and .76 for fathers, indicating a moderate to high internal consistency.

Parental stress. Both parents completed the Parental Stress Scale (PSS; Berry & Jones, 1995). The PSS is composed of 18 items describing perceptions and feelings about the experience of being a parent (e.g. "I feel overwhelmed by the responsibility of being a parent", "It is difficult to balance different responsibilities because of my child"), which they have to answer in a 5-point Likert Scale, ranging from 1 (Strongly disagree) to 5 (Strongly agree) Eight items are reverse-coded so the total score range from 18 to 90, the latter indicating the higher level of stress. Internal consistency of the scale was moderate (Cronbach's α = .79 for mothers and fathers).

Data Analysis

To account for the study objectives, I used hierarchical linear models that nested epochs (Level 1) within dyads (Level 2). Following expert recommendations, I person-centered all Level 1 RSA values, and controlled for person-average values for RSA (Davis et al., 2018; Helm et al., 2018). This statistical approach helps to isolate within-dyad versus between-dyad effects (Curran & Bauer, 2011; Wang & Maxwell, 2015), and therefore is well-suited to the temporal and dyadic nature of the data. Given that the primary predictors were mean-centered and not standardized, I report here unstandardized beta estimates that cannot be interpreted as effect sizes.

My first research question was whether parents and children showed concurrent and timed-lagged physiological coregulation. For concurrent physiological coregulation, I tested person-centered child RSA as a function of person-centered parent RSA in the same epoch and person-average parent RSA across epochs (Model 1).

$$\text{(Model 1) } cRSA_{i,e} = \beta_0 + \mu_{Pi} + \beta pRSA_{i,e} + \varepsilon_{Ci,e}$$

For time-lagged coregulation, I tested whether parent RSA predicted subsequent child RSA over and above concurrent child RSA, and vice versa. Specifically, I tested whether parent RSA in a given epoch predicted child RSA in the next epoch (i.e., 30 s later), controlling for parent mean RSA values and child RSA in the same epoch.

$$\text{(Model 2) } cRSA_{i,e+1} = \beta_0 + \mu_{Pi} + \beta pRSA_{i,e} + \beta cRSA_{i,e} + \varepsilon_{Ci,e}$$

Conversely, in a separate model, I tested whether child RSA in a given epoch predicted parent RSA in the next epoch (i.e., 30 s later), again controlling for child mean RSA levels and parent RSA in the same epoch.

$$\text{(Model 3) } pRSA_{i,e+1} = \beta_0 + \mu_{Ci} + \beta cRSA_{i,e} + \beta pRSA_{i,e} + \varepsilon_{Pi,e}$$

My second research question was whether physiological concurrent and time-lagged coregulation varied by parent gender (i.e., mother vs fathers). For this, I tested the previous depicted models (i.e., Model 1, Model 2, and Model 3) separately for mother-child and father-child dyads.

My third research question was whether children's physiological SR was associated with concurrent and time-lagged physiological coregulation. For this, I tested whether father-child and mother-child coregulation at lag-0 and lag-1 related to child physiological SR during stress and recovery phases in the transparent box stress induction task.

I conducted all analyses using IBM SPSS Statistics version 29.0. Child gender, age, parental mental health, parental educational level, and family income were not correlated significantly with parent or child RSA (*ps* > .05), so I decided not to include them as covariates.

Results

Table 1 and 2 display bivariate correlations for study constructs in father-child and mother-child dyads, using levels of RSA and parent–child co-regulation averaged across the interaction.

Parent-child Concurrent Coregulation

Table 3 displays the results of the hierarchical linear models. Because mother and father-child dyads were nested within the same families, I tested separate models for mother-child and father-child dyads. Model 1 represents concurrent coregulation in parent and child RSA, over and above the average in parent and child RSA, with separate models for father-child and mother-child dyads. I did not find concurrent coregulation across the interaction, such that parent and child RSA were not significantly associated with each other ($b_{\text{father-child}}$ = -.09, SE = .09, p = .31; $b_{\text{mother-child}}$ = .00, SE = .09, p = .97).

Table 1. Means, standard deviations and correlations between fathers and children variables

		M	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.
1.	Age child	38.54	2.02	-								
2.	Gender child			.09	-							
3.	Age father	37.50	3.89	.09	.19	-						
4.	Education level father	8.33	.48	-.01	.24	-.12	-					
5.	Family income	7.46	1.47	.03	-.00	-.03	.14	-				
6.	Depression father	7.42	3.57	-.12	.18	-.16	.37	-.15	-			
7.	Parental stress father	35.13	6.64	-.20	-.21	.08	-.03	-.20	.37	-		
8.	RSA origami father	6.02	.92	-.52	-.27	.00	-.28	-.12	-.36	-.19	-	
9.	RSA origami child	5.16	1.46	.05	-.06	.39	.28	.27	.24	.11	-.20	-
10.	RSA SR child	5.29	1.22	-.03	.05	.33	.42	.26	.29	.12	-.31	.91***

$^{*}p$<.05, $^{**}p$<.01, $^{***}p$<.001

Table 2. Means, standard deviations and correlations between mothers and children variables

		M	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.
1.	Age child	34.54	2.02	-								
2.	Gender child			.09	-							
3.	Age mother	35.25	3.12	-.02	-.08	-						
4.	Education level mother	8.42	.50	.11	.07	.46*	-					
5.	Family income	7.17	1.31	-.00	-.05	.16	.02	-				
6.	Depression mother	5.63	3.27	-.17	.45*	-.48*	-.35	-.10	-			
7.	Parental stress mother	36.54	7.09	-.18	.18	.11	.24	.03	.50*	-		
8.	RSA origami mother	6.50	.68	-.09	-.07	-.53*	.03	-.08	.24	.44	-	
9.	RSA origami child	5.05	1.09	-.01	.43	.22	.48	.19	.11	.22	-.12	-
10.	RSA SR child	5.29	1.22	-.03	.05	.26	.36	.20	-.09	.02	.02	.87***

$^{*}p$<.05, $^{**}p$<.01, $^{***}p$<.001

Parent-child Time-lagged Coregulation

Table 3 displays the results of time-lagged coregulation models run separately for father and mother- child dyads. Model 2 tested the effect of parent RSA predicting child RSA, controlling for prior epoch levels of each member of the dyad. Neither father nor mother RSA significantly predicted child subsequent RSA over and above concurrent child RSA ($b_{father\text{-}child}$ = -.08, SE = .10, *p* = .41; $b_{mother\text{-}child}$ = .05, SE = .09, *p* = .57) (see Table 3).

I found similar results for the effect of child RSA on parent subsequent RSA controlling for child average RSA level and concurrent parent RSA in the same epoch (Model 3). Child RSA did not show to predict father or mother RSA in the next epoch, even controlling for concurrent parent RSA and child RSA average level ($b_{father\text{-}child}$ = -.06, SE = .11, *p* = .60; $b_{mother\text{-}child}$ = -.06, SE = .10, *p* = .60).

Because neither concurrent nor time-lagged coregulation was found for parent-child dyads, I did not test for differences between father-child and mother-child dyads, as well as the association between parent-child concurrent and time-lagged coregulation and children SR.

Table 3. Hierarchical linear model nesting epochs within participants, demonstrating within-dyad and between-dyad associations between parent and child RSA

	Father					Mother				
	Estimate	SE	*p*	95%CI		b	SE	*p*	95% CI	
Model 1: concurrent coregulation parent RSA predicts child concurrent RSA										
Intercept	7.15	3.04	.04	.46	13.84	5.10	3.15	.08	-.94	12.93
Same epoch parent RSA	-.09	.09	.31	-.27	.09	.00	.09	.97	-.17	.18
Average parent RSA	-.25	.51	.63	-1.36	.86	-.15	.49	.76	-1.22	.91
Model 2: time-lagged coregulation parent RSA predicts child subsequent RSA controlling for parent average RSA level and concurrent child RSA in the same epoch										
Intercept	6.72	3.03	.05	-.15	13.58	5.02	3.03	.13	-1.78	11.83
Previous epoch parent RSA	-.08	.10	.41	-.27	.11	.05	.09	.57	-.13	.24
Previous epoch child RSA	.03	.10	.77	-.17	.23	.08	.09	.38	-.10	.26
Average parent RSA	-.22	.49	.66	-1.34	.90	-.12	.46	.80	-1.16	.92
Model 3: time-lagged coregulation child RSA predicts parent subsequent RSA controlling for child average RSA level and concurrent parent RSA in the same epoch										
Intercept	6.49	1.13	.00	4.12	8.86	7.60	1.25	.00	4.96	10.25
Previous epoch child RSA	-.06	.11	.60	-.29	.16	-.06	.10	.56	-.26	.14
Previous epoch parent RSA	.01	.10	.95	-.19	.20	-.12	.09	.22	-.30	.07
Average child RSA	-.04	.21	.84	-.48	.40	-.00	.23	.99	-.50	.49

$^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$

Discussion

The current study investigated parent-child physiological coregulation and its relation to children's self-regulation. To do so, I analyzed RSA data from mother-child and father-child dyads in 14 families during a teaching task. I calculated children´s self-regulation from children´s RSA during a frustration task (transparent box task).

My first research question was whether parents and children showed concurrent and timed-lagged physiological PNS coregulation. The integration of physiological measures, particularly RSA, aligned with previous studies (Porges, 2007; Feldman et al., 2017), which highlighted the role of RSA in shaping parent-child interactions and child self-regulatory outcomes. I expected to find that parents and children coordinated their physiological responses across the interaction, however, the present findings did not support the hypothesized concurrent or time-lagged relations between parent and child RSA across the interaction.

Several factors might contribute to the unexpected absence of coregulation effects. First, the results may be related to the small sample size of the study. Previous research suggests that larger sample sizes are necessary to detect subtle but meaningful relationships in research on parent-child interactions (Belsky et al., 2018). Second, it may be that an "optimal" level of stress is needed to elicit coregulation. The specific task employed in the study (i.e., origami folding task) may not have caused sufficient physiological arousal to trigger robust coregulation patterns. Children may use their parents as coregulators when they need support in their own regulation (e.g., Lunkenheimer et al., 2015). If a task is not sufficiently demanding, it may not produce dysregulation, thus limiting the need for coregulation (Calkins, 2011; Suveg et al., 2019) . However, if the task is highly demanding the parent-child dyad may display negative coregulation as a results of the efforts to attain a regulated state. What constitute a stressful or charged situation may vary as children develop regulatory skills and as a function of the history of parent-child coregulation. For example, the same task may be highly demanding for dyads with young children (infants) who are beginning to learn how to coregulate, or for children with low regulatory skills. But, it may be of low stress for dyads with older children, who already have developed rudimentary regulatory skills, which makes them less dependent on a coregulatory process. For example, a lack of coregulation may be indicative of children with higher levels of autonomy or with parents who support autonomy. It also may be that no physiological coregulation is a reflection of a successful history of discoordination and coregulation between the dyad. Based on the characteristics of my sample (parents with high educational level and income) it is plausible to think that these dyads had plenty of opportunities to practice coregulation in a supportive and responsive context. Thus, they are more attuned to each other and low levels of stress do not affect this attunement, consequently there is no need to coregulate.

A third reason may be related that the time scale resolution I used (i.e., 30 s epochs) may have been not enough to reveal the presence of dyadic coregulation. Although the parasympathetic system can regulate arousal on the order of seconds, current available measures of parasympathetic activity do not have this temporal resolution. For example, RSA captures the variability in heart rate across the respiration cycle, and as such must be measured across a sufficient duration for this variability to be observed. The typical minimum measurement duration for RSA is 30 s, whereas emotion dynamics and parasympathetic activity are much more rapid (Beuchaine, 2001; Cole et al., 2017). It could be possible that the extent of parent-child physiological coregulation varied more rapidly within the interaction, with moments of greater concordance and moments where individuals regulate independently, which lasted less than 30 s and thus could not be captured adequately by the measures in this study. Recently, researchers have applied statistical tapering techniques in a moving-window approach to generate a second-by-second time series of RSA that reveals temporal dynamics in physiology on the level of the temporal dynamics of emotion (Abney et al., 2021; Gates et al., 2015; van der Ende et al., 2019). These new methodologies offer a promising approach to understanding the intricate dynamics of parent-child coregulation. Nevertheless, interpreting the complex dynamics of second-by-second RSA remains a challenge, and standardized methods and metrics are needed to facilitate comparison across studies.

Finally, individual differences in parents' and children's temperamental and behavioral characteristics could have influenced coregulation dynamics. It is possible that some parent-child dyads naturally exhibit higher levels of physiological synchrony than others, leading to heterogeneity in the data and potentially masking overall effects.

In my second objective, I aimed to explore differences in physiological coregulation between fathers and mothers, thus contributing to the almost nonexistent data on RSA coregulation between fathers, mothers and preschoolers (see Lunkenheimer et al., 2020 for an exception). However, because the presence of physiological coregulation was not evident in this sample, it was not possible to explore similarities and differences in the father/mother -child coregulation.

In the third objective, I aimed to explore the interplay between physiological parent-child coregulation and child physiological self-regulation. The unexpected absence of concurrent and time-lagged coregulation observed in my results prompts a reevaluation of the assumed link between parent-child physiological coregulation and children's self-regulation. While our initial hypothesis suggested a positive association, the nuanced dynamics uncovered by our study call for a deeper exploration of the factors influencing these intricate physiological processes.

Finally, the high heterogeneity in the operationalization of coregulation in the field, that makes difficult the replication of results. As future research moves more into dynamic modeling and the corresponding operationalization of coregulation, I hope we gain a more consistent knowledge base on how coregulation operates that allows us to correctly interpret our findings.

It is also important to consider the possibility of publication bias in the literature on physiological coregulation. Positive findings are often more likely to be published, that non-significant results and might be underreported. Only two of the studies reviewed in this paper reported no presence of physiological coregulation.

Limitations, Future Directions and Conclusions

The generalizability of my findings is constrained by the small and specific nature of our sample. Recognizing the preliminary nature of our study, caution is warranted in drawing broad conclusions about parent-child physiological synchrony in this age group. Replication studies with diverse populations of 3-year-olds and their parents are essential to validate and extend our results.

A small sample size impacts the statistical power of the analysis. The small sample size may have contributed to a lack of sensitivity in detecting subtle associations between parent and child RSA. The concept of statistical power becomes particularly relevant in light of my findings, because it underscores the potential for a Type II error, where a genuine association may exist but was not detected due to limitations in sample size.

Future research in this area should prioritize larger sample sizes to enhance the statistical power and generalizability of findings. Furthermore, investigating alternative physiological measures or refining the tasks used in data collection may contribute to a more comprehensive understanding of parent-child physiological synchrony in 3-year-olds.

In addition to that, it is important to note that the participants in this sample were fairly homogeneous, highly educated, and economically stable, which limits the generalization of my results.

Although the current study did not confirm initial hypotheses regarding parent-child physiological coregulation, it highlights the need for continued exploration and refinement of research methods. Future research that addresses the limitations outlined here can significantly advance our understanding of this complex and multifaceted phenomenon and its influence on children's development helping to answer many of the questions that my study opens.

CHAPTER 5: Study 3

Introduction

Self-regulation (SR), that is, the ability to direct or modulate one's attention, emotion, thoughts, and actions in facilitating adaptation and achieving personal goals lay the foundation for their success in academic achievement and social adjustment (McClelland & Cameron, 2012; Bailey & Jones, 2019; Robson et al., 2020). At the core of SR is executive function (EF), a set of high-level cognitive processes that underlie the self-regulation of individual behavioral responses (Koziol et al., 2012). Executive function refers to behavioral SR and provides the cognitive mechanisms necessary to monitor and control behaviors, plan, and execute tasks, and make decisions that align with specific goals. In essence, executive functions provide the mental infrastructure for effective SR. Children's EF skills go through a period of rapid development during the first years of life and there is substantial evidence that high levels of EF in the preschool years are significantly related to children's concurrent growth in academic skills and subsequent successes in school achievement and social adjustment (Blair & Raver, 2015).

Given the importance of the first years of life in the development of EF skills, research has focused on exploring individual differences in children's EF (Bernier et al., 2012; Bernier et al., 2010; Bibok et al., 2009; Hughes & Ensor, 2009). These studies have focused on various aspects of parenting in relation to

EF, such as scaffolding (or autonomy support), sensitivity, and warmth (Carlson, 2003).

More recently, several developmental models within relational developmental systems view posit that children develop self-regulatory skills in the context of parent-child coregulation (Harrist, & Waugh, 2012). Coregulation refers to the active moment-to-moment organization and coordination of parents' and children's behaviors, emotions, and physiological states over time (Lunkenheimer, Kemp, Lucas-Thompson, Cole, & Albrecht, 2017). As children age, coregulation processes introduce children to increasingly complex experiences, offer them opportunities to practice self-regulation in a relational context, and model patterns that are eventually internalized as regulatory skills (Lunkenheimer et al., 2017). However, the field lacks systematic empirical study of how these parent– child coregulation processes contribute to typical self-regulatory development in early childhood.

The present study explored affective and behavioral coregulation in a sample of families with a 3-year-old to better understand the processes by which preschoolers' regulatory skills develop in the parent–child relationship. I focus on a central aspect of SR namely EF (see Chapter 2).

This study extends the literature on the contribution of coregulation in children's regulatory skills in several aspects. First, I examine the dyadic interaction including behavioral and affect dyadic coregulation. Many studies assess either behavioral coregulation (e.g., Lunkenheimer et al., 2020) or affective coregulation (Cole et al., 2003). The approach in this study provides a more sophisticated way of conceptualizing coregulation, examining behavior and affect coregulation on a moment-to-moment basis using a microanalytical approach. Second, I assess both the mother – child and the father – child coregulatory processes. Although few studies have included fathers, among those that have, evidence is mixed concerning differences between mother–child and father–child coregulatory processes (Feldman, 2003; Kochanska et al., 2015; Lindsay et al., 2009; Lunkenheimer et al., 2020). Third, I evaluate children´s SR through both observational and parent-report measures. These instruments provide a more comprehension view of children´s skills because one captures observations of everyday, real-world behaviors (parental report) and the other focuses on processing efficiency of cognitive abilities under highly structured conditions (Toplak et al., 2013).

Review of the Literature

Executive Function in Early Childhood

One of the core components of SR is executive function (EF), a set of high-level cognitive processes that underlie the self-regulation of individual behavioral responses (Koziol et al., 2012). Children use executive function (EF) skills in various situations, such as inhibiting misbehavior, holding multi-step instructions, and switching between tasks when needed (Blair & Raver, 2015; McClelland & Cameron, 2012; Montroy et al., 2016). As a vital domain-general skill, EF enables children to regulate their thoughts and actions to develop more adaptive goal-directed behavior during learning and social interactions.

EF has three key components: working memory, inhibitory control, and cognitive flexibility (Duncan et al., 2007). Each component supports the mechanisms through which children regulate their thoughts and behaviors in the pursuit of goals (McClelland et al., 2010). Working memory (i.e., updating) is the ability to hold and maintain (or otherwise manipulate) information during ongoing mental activities. It enables children to hold instructions in mind as they carry them out. Inhibitory control (i.e., inhibition) is the ability to inhibit a dominant response in favor of a more adaptive one and is important for children controlling their impulses and following instructions. Finally, cognitive flexibility (i.e., shifting) is the ability to shift attention and adapt to changing goals while ignoring distractions. It enables children to persist during challenging tasks or instructions. Successful behavioral self-regulation typically involves the behavioral integration of all three executive functions (Spinola et al., 2017). For example, a child must integrate the three components when following a series of instructions: holding the instructions in mind, updating them as they complete each step, shifting between tasks effectively, and ignoring distractions (Cameron et al., 2008; McClelland et al., 2007; Morrison et al., 2010). Evidence suggests that measures of self-regulation that capture all three executive function processes are more effective, as all these functions underpin self-regulation in children (Caughy et al., 2013; McClelland et al., 2014) (for a more detailed description of executive function see Chapter 2).

Parent-Child Coregulation

A large body of research suggests that children begin to acquire the ability to appropriately express and regulate emotions and behavior in the context of their early caregiving experiences. Parents provide external regulation for children who cannot fully regulate themselves by establishing behavioral and affective patterns with their children (Feldman, 2007). The parent, as a more capable other, guides, modelates, and shares regulatory strategies helping the child to gradually internalize these strategies and become more capable of self-regulating (Bernier et al. 2010; Kopp 1982). Parent-child interactions provide ample opportunities for parents to model effective ways of coping and respond to children's emotions and behavior in a manner that communicates empathy and encourages independent thinking.

More recently, several developmental models within relational developmental systems view (Fogel, 2015; Kopp, 1982; Sameroff, 2009,2010; Tronick 1989; Tronick & Beeghly, 2011) posit that children develop self-regulatory skills in the context of parent-child coregulation. Coregulation refers to the active moment-to-moment organization and coordination of parents' and children's behaviors, emotions, and physiological states over time (Lunkenheimer et al., 2017). Contrary to traditional parenting characteristics (e.g., sensitivity, scaffolding) that refer to the behavior of the adult with the child (e.g., sensitivity, scaffolding), coregulation refers to a mutual (or bidirectional) influence between parent and child during their social exchanges (Gentzler et al, 2005; McKee et al., 2015). Better-coordinated exchanges are thought to directly support young children’s emotional, behavioral, and physiological regulation (Feldman, 2007).

The last decade has experienced an increased interest in applying a dynamic systems approach to the study of child development. The dynamic systems (DS) approach has promoted a shift from viewing bidirectionality as an additive combination of unidirectional influences in parent child interaction (i.e. parent to child, and child to parent), to considering the bidirectional dynamics of the parent and child (Granic, 2005; Granic et al., 2016; Coburn et al., 2015; Hollenstein et al., 2016; Lunkenheimer et al., 2013; Van der Giessen et al., 2015).

A Dynamic Systems Approach to the Study of Parent-Child Coregulation

The DS approach provides a valuable framework for the study of the process of parent-child coregulation (see Chapter 2 for more details), highlighting characteristics of dynamic systems such as bidirectionality, recursiveness, interdependence, reinforcement, and self-organization, that are applicable to the study of parent-child coregulation and child self-regulation.

From a DS view, parent and child are interdependent, and thus it is important to consider the evocative effects of child behavior on parental behavior and vice versa. Each member of the dyad elicits different responses from the other member, and the corresponding interaction that occurs contributes to the dynamic process of child development (Dennis, 2006; Lytton, 1990; Scaramella et al., 2008). Co-regulation between parents and children can thus be seen as an asymmetric process in terms of responsibility and capability (Zachariou & Whitebread, 2019). In a co-regulated interactive process, however, the parties involved mutually adjust by adapting to the others' ongoing actions and emotional states and expressions (Lavelli et al., 2019). More specifically, co-regulatory processes in this context involve the mutual influence that parents and children have on each other – that is, both parties are regulated by the other party's emotions, behavior, and physiology (Calkins, 2011; Fogel, 1993; Lunkenheimer et al., 2017).

DS approach suggests that the parent-child relationship can be understood as a system that self-organizes into predictable behavioral, emotional, and physiological patterns that serve a function for the system (Lunkenheimer et al., 2011). Accordingly, in a parent-child dyad, the interactions between the subcomponents (e.g., parent and child) are considered as lower-level processes and the stable patterns they produce (e.g., dyadic pattern of coregulation) are high-level processes that emerge from these interactions. Importantly, the relationship between the time scales is mutual. Not only do the parent and child behavior and emotional lower-level states give rise to the higher-level time scales coregulation patterns, but at the same time these coregulation patterns influence and restrict the possible parent and child behavioral and emotional states. For example, when we observe a parent-child interaction (e.g., parent and child playing with a set of toys), we are witnessing the high-level structure of dyadic coregulation as we observe that particular dyad pattern of interaction, while also how coregulation in this particular dyad updates by the dynamic interchange of parental and child behavioral and emotional momentary states. This predictability is often operationalized as coregulation in interpersonal interactions, or the predictable and consistent coordination of parent and child affect and behavior during the course of face-to- face interactions (Harrist & Waugh, 2002). Arguably, when patterns are more predictable, they foster the foundation upon which self-regulation processes are built (Feldman, 2007).

Recursive interactions between the subcomponents of a system are not always uniform and linear, leading to the emergence of feedback loops, that is, some components reinforce others in the same or opposing direction. Interactions between reinforcing components can lead to rapid growth and long-term stability of these patterns. A key concept in DS theory is the one of attractor, which are specific high-level patterns (i.e., behavior, emotion) that pull the system into absorbing states or interaction patterns. Internal or external triggers can result in behavior moving toward these attractors through the self-organization of the system and as these attractors occur repeatedly over developmental time, they eventually stabilize into increasingly predictable patterns (Thelen & Smith, 1994). Therefore, the particular set of SR skills a child has, or the pattern of coregulation of a particular parent-child dyad, can be seen as attractors that have emerged over the course of weeks, months or years and have stabilized into predictable patterns that reinforce themselves.

Examining Dyadic Coregulation

Macro and micro coding procedures have been employed to measure parent–child coregulation (Criss et al., 2003; Feldman et al., 1999). Whereas macro coding requires researchers to assign a global code to a given interaction (Criss et al., 2003), micro approaches for assessing coregulation involve moment-to-moment coding of parent–child exchanges (Feldman, 2007b; Feldman et al., 1999; Pesonen et al., 2010). Undoubtedly, both coding approaches have their benefits and drawbacks. An advantage of using micro coding is that this approach allows for the consideration of the temporal nature of coregulation, that has been described as a critical component of dyadic coregulation (for a review, see Harrist & Waugh, 2002). Micro coding procedures can also capture the moments of behavioral and affective mismatch between members of the dyad and ways that these interactive mismatches are repaired to achieve coregulation (Tronick & Gianino, 1986), which may be washed out by global coding approaches. In addition, it is possible that global measures are subject to a “halo effect” (Bernieri et al., 1988). Thus, it may be the case that raters’ observations of certain aspects of coregulation lead to an overall positive impression of the interaction. As Bernieri et al. (1988) articulated, it can be difficult to know exactly what any given rater is taking into account when they assign global codes. This means that it is not only possible that certain aspects of coregulation composites could drive global ratings more than others, but it also leaves open the possibility that individuals' behaviors may inadvertently impact raters' global impressions of the parent–child interaction. Thus, micro coding may help to avoid artificial inflation in coregulation and thus decrease the likelihood of overestimating the relation between parent–child coregulation and children SR.

Parent-child Coregulation and Children Behavioral SR (Executive Function)

Children's early regulatory abilities develop within the context of parent–child interactions, with parents serving as the primary sources of regulation for their offspring during infancy (Feldman, 2007c). As children transition into early childhood, they become capable of greater self-regulation, yet they still rely on their caregivers as sources of support (Kopp, 1982). Self-regulation abilities continue to develop throughout childhood (Raffaelli et al., 2005), with aspects of the parent–child relationship influencing self-regulation even into adolescence (Eisenberg et al., 2005).

Although substantial research has demonstrated the importance of the parent–child relationship for children's SR, literature has often focused on the contributions of parental behavior within this relationship (e.g., parental responsiveness, warmth; Goin & Wahler, 2001; Kochanska & Kim, 2013).

Emerging literature has demonstrated that it is advantageous to consider dyadic dynamics as they relate to children SR.

Studies on coregulation have shown that it plays an important role in children´s behavioral SR (i.e., EF). In a meta-analysis, Davis et al (2017) identified that behavioral coregulation (conceptualized as different constructs between studies) was significantly and positively correlated with different components of SR, such as executive function and effortful control, with a medium effect size. In addition, coregulation in preschool has already been linked to multiple indices of concurrent and later child functioning (Cole et al., 2003; Hollenstein et al., 2004; Scaramella et al., 2008). For example, Feldman and colleagues (1999) assessed behavioral coregulation (indexed as the co-occurrence of affective states between mother and child) at 9 months in 36 mother-child dyads. The results showed that this type of coregulation was related to children's ability to follow instructions and delay gratification (i.e., EF skills) at 2 years of age (controlling for temperament, IQ, and maternal sensitivity). A study by Kochanska and colleagues (2008) found that higher parent–child coregulation was to be associated with better child EF. According to Kochanska, parent-child coregulation reduces the parent’s need for using power or coercion strategies (Kochanska 1997; Kochanska & Murray, 2000). When a coregulation pattern becomes established between the parent and the child, the parent finds it easier to obtain the child’s willingness to comply without the need to use strong pressure (Kochanska, 1997). In a sample of 100 mother-child dyads, Lunkenheimer and colleagues (2020) examined dyadic patterns of coregulation and its relation to child EF. Their findings showed that more flexible and contingent affective mother–child processes, as long as the affective content was primarily positive or neutral, predicted higher levels of EF in early childhood. However, when mother-child dyads engaged in more negative affective and behavioral content, higher levels of affective and behavioral contingency predicted lower levels of child EF.

An open question is whether the effect of coregulation on children´s EF operates equally in the mother-child and father- child dyad. The few studies that include fathers suggest that the association between behavioral coregulation and child EF differs in mother-child versus father-child dyads. For example, a study with preschool children observed that only behavioral coregulation in the mother-child dyad predicted children's EF, despite no differences found in the average coregulation in mother-child versus father-child dyads during a problem-solving task (Garcia-Sellers & Church, 2000). In contrast, Lindsey and colleagues (2009) evaluated the relationship between coregulation of 80 mother/father-child dyads at 18 months and child regulatory skills, measured as the ability to resist playing with a "forbidden" toy, at 36 months. This team assessed various aspects of behavioral coregulation (dyadic interactions, shared emotion, and mutual cooperation) during a free play session. The results indicated that mother-child and father-child interactions related similarly to children's regulatory skills (i.e., less manipulation of the forbidden toy). However, a more specific analysis indicated that for the mother-child dyad, dyadic reciprocity (i.e., back-and-forth responses) mattered, while for the father-child dyad, shared positive emotion related to children's regulatory skills. In another more recent study by Schueler and Prinz (2013) observed mothers and fathers interacting with their 3 to 6-year-old children during two tasks (a model building activity and a craft task) and assessed the children's regulatory abilities (ability to follow parental requests i.e., compliance). Behavioral coregulation was operationalized as contingent responsiveness and coded every 10 seconds. Similar to the Garcia-Seller & Church (2000) study, the average contingent responsiveness of both parents with their children was similar. Coregulation and children’s regulation related in both tasks in the mother-child dyad, but only in the second task (craft task) for father-child dyads. Overall, these studies suggest that both mothers and fathers exhibit similar levels of coregulation with their children, but mother-child coregulation seems to play a more predominant—or at least a different—role compared to father-child coregulation in their children’s regulatory skills. This might be due to fathers spending less time interacting with their children compared to mothers (Cabrera et al., 2018). Given the increasing involvement of fathers with their children and data indicating that both parents are equally capable of achieving coregulation with their children, involving fathers in studies opens another window for potential interventions.

This Study

The interest in examining coregulation between parents and infants has increased in the last decades (Cerezo et al., 2012; Feldman, 2003; Moore et al., 2013; Lunkenheimer et al., 2017; Woltering et al., 2015). However, there are still important gaps in the literature. First, the predominant perspective has been to examine stable dyadic patterns between parent (mostly mother) and child. Thus, we know less about how the dynamic coordination of parental and child exchanges unfolds. Examining coregulation moment-to-moment offers insight into the processes that may support or hinder child effective regulation. In addition, gaps remain in the literature regarding how specific co-ocurrences of parent and child behavioral and emotional states may shape the coregulatory process. Second, little research to date has addressed how dynamic mother-child and father–child interaction patterns contribute to the development of regulatory skills. Previous studies have shown that mothers and fathers display different levels of dyadic coordination and affect with their children (Feldman, 2003; Kochanska & Aksan, 2004; Lukenheimer et al., 2011), suggesting that each parent may facilitate different modes of coregulation (Feldman, 2003) and may contribute differentially to children's regulatory skills (Lukenheimer et al., 2011; Lunkenheimer et al., 2017).

In this study, I aimed to analyze the patterns of father-child and mother-child coregulation using a dynamic systems approach and examine how these patterns relate to children SR, indexed as EF. More specifically I aimed to answer the following research questions:

1. What patterns of behavioral and affective coregulation do parents and their 3-year-old children exhibit during a dyadic interaction?
2. Does parent- child coregulation of behavior and affect differ between mothers and fathers?
3. Is children's EF associated with parent-child coregulation?

I hypothesized that higher levels of behavioral coregulation will be associated with higher children's SR. Given the exploratory nature of existing evidence, I do not suggest a hypothesis for the specific effect of mother-child and father-child dyadic coregulation.

Methods

Participants

The sample consisted of 110 Chilean families (3-year-old children and their mothers and fathers). The research team (two research assistants and I) recruited potential participants through online flyers and social media. We excluded families if the child had been diagnosed with a developmental disorder or intellectual impairment, or if the parents had been diagnosed with a severe psychiatric disorder (i.e., schizophrenia, bipolar disorder, mayor depressive disorder).

Mothers were slightly younger than fathers ($M_{mothers}$ = 34.83 years, SD = 4.29; $M_{fathers}$= 37.1, SD=5.39). Most parents had completed college and around 40% of the sample corresponded to high income families. All children (M_{age} = 40.89 months; SD = 3.61; 54% male) lived with both parents. All couples were cohabiting and 71% were married (see Table 1).

Procedure

Families were assessed online via zoom due to the covid-19 pandemic. Participating families were sent a kit a couple of days before the assessment, that included all the materials needed in separate closed envelopes (i.e., set of toys for free-play, colored paper and instructions for the origami task). Two research assistants trained by me collected the data during a 1-hour remote observational assessment.

After families gave consent, mother-child and father-child dyads completed the parent-child interaction protocol. The parent-child interaction protocol lasted for approximately 30 minutes (including transition time between tasks) and was video recorded for later offline micro-coding. First, the research assistant asked the dyad to open the free-play envelope with the set of toys and gave them the instruction to play together “as they usually do at home” to complete a 10-min free play session. Then, the research assistant asked dyads to put away the toys and open the next envelope, containing the colored paper and instructions, to complete an origami folding task. After finishing the activities with one parent, the research assistant offered the child a break time before starting the same set of activities with the other parent. Mother-child and father-child dyads were counterbalanced. Children completed a SR task with the research assistant (i.e. the Early Years Toolbox; Howard, 2014) adapted to be used online. During the next days, parents completed an online questionnaire that included sociodemographic measures.

Measures

Sociodemographic variables. A self-report questionnaire was administered online independently to both parents, that asked for sociodemographic information such as age, income, educational level, marital status, number of children, etc.

Origami task. Children were provided with a piece of colored origami paper, and mothers/fathers were given a piece of paper with pictures of the steps necessary to fold the origami paper into a puppy or fox face. Parents were told that they should use these instructions to show the child how to fold the paper, but that the child should do all the folding and that they should not touch the origami paper. Dyads were given 5 min to finish the origami task and were encouraged to finish earlier to win a special price. This task is meant to be highly challenging and has been used in several other studies (Hane et al., 2008; Hastings et al., 2008, 2015).

Affect Coding. Parent and child affect was coded in epochs each 30 sec with the Dyadic Interaction Coding System (Lunkenheimer, 2009) based on observable vocal tone, facial expressions, and body movements. There were four mutually exclusive codes for parent and child verbal and nonverbal affect based on valence and intensity of expression: negative, neutral, low positive, and medium-high positive. Negative affect referred to narrowed or rolled eyes, frowns, sounds of exasperation or irritation, mocking, or nervous, repetitive movements reflective of distress or anxiety. Positive affect was characterized by positive fluctuations in vocal tone, smiles, laughing, a sing-song tone, warm eye contact, and body movements indicating warmth, affection, or happiness (e.g., hugs). Though codes for parent and child were the same, their intensity was coded based on developmentally appropriate behaviors (e.g., medium-high positive affect might involve excited shouting for children, whereas it might involve a higher-pitched, sing-song tone for parents). Four coders were tested for reliability on 20% of the data set. Average interrater agreement was good (.90).

Behavior coding. Goal-directed behavior was coded each 30 sec using the Dyadic Interaction Coding System (Lunkenheimer, 2009). Five mutually exclusive parent behaviors and four mutually exclusive child behaviors (persistence, compliance, social conversation/engagement, noncompliance/disengagement) were coded. Parent codes included: (1) *Proactive structure* (i.e., instances when parent encouraged, guided, or prompted child to behave in a positive manner); (2) *Teaching* (i.e., instances when the parent explained how something worked, e.g., 'I think we have to fold it in half' or 'You might be able to flip it around', or when the parent asked a question that allowed the child the opportunity to learn or respond), (3) *Emotional Support* (i.e., instances when parent emphasized with child, helped child label emotions, provided verbal support or praise, or physically comforted the child); (4) *Directive* (i.e., instances where the parent made clear commands for a specific response or behavior the parents did or did not want the child to enact, e.g., ‘Grab the paper’ or ‘No, you do it’ or ‘Don’t throw it’); and (5) *Intrusion* (i.e., instances when parent physically took over the task, and/or physically completed some of the task for the child). Child codes included: (1) *Persistence* (i.e., instances when child persisted at completing the task without preceding prompts by the parent); (2) *Compliance* (i.e., instances when child clearly responded to parent’s bid for a behavioral change); (3) *Engagement* (i.e., instances when child engaged with parent in non-task related conversation); and (4) *Non-compliance/disengagement* (i.e., instances when child did not comply with parent’s bid for behavioral change, by ignoring, disagreeing with, or refusing request, or instances when child was not engaged with the parent or task, seemed spaced out, or lost focus). Four coders were tested for reliability on 20% of the data set. Average interrater agreement was good (.93).

Child EF. I assessed children´s self-regulation through two instruments, one observational and the other reported by mothers and fathers.

Early Years Toolbox (EYT; Howars & Melhuish, 2017). The EYT is a freely available iPad-based battery of EF. It consists of a total of three tasks, one for each dimension of EF: working memory, inhibition, and cognitive flexibility.

Each task is designed to be brief (approximately 5 minutes per task, including instruction and practice). Children completed the “card sorting” task, which is based on the protocols of Zelazo (2006) and requires children to sort cards (i.e., red rabbits, blue boats) by a sorting dimension (i.e., color or shape) into one of two locations (identified by a blue rabbit or a red boat), and then switch to the alternate sorting rule. After a demonstration trial and two practice trials, children begin sorting by one dimension for six trials. In the subsequent postswitch phase, children are required to sort cards by the other sorting dimension, as prompted by auditory instructions preceding postswitch test trials. Scores represent the number of correct sorts after the preswitch phase; with higher scores indicate better inhibitory control.

Behavior Rating Inventory of Executive Function- Preschool version (BRIEF-P; Gioia, et al., 2003)**.** This inventory represents a multicomponent view of EF, providing information about specific subcomponents in EF through observable behavioral manifestations of these processes in children aged 2 through 5 years. The preschool version is an adaptation of the original inventory, BRIEF (Gioia et al., 2000). Contains 63 items referring to behaviors in the last 6 months with 3 response options (0 = never to 2 = very often/always) reflecting the degree to which these behaviors are a problem. It takes approximately 10 to 15 min to complete. It was answered by mothers and fathers. The Spanish version provided by the publisher was used for the study. The BRIEF-P consists of five subscales, assessing EF within five domains labeled Inhibit, Shift, Emotional Control, Working Memory, and Plan/Organize. Together, these subscales form three broad indexes, including Inhibitory Self-Control (Inhibit and Emotional Control), Flexibility (Shift and Emotional Control), Emergent Meta-cognition (Plan/Organize and Working Memory), and a GEC (all subscales). It also includes a negativity and inconsistency scale. The first indicates the extent to which the respondent answered selected BRIEF items in an unusually negative manner relative to the clinical sample, and the second indicates the extent to which similar BRIEF-P items were endorsed in an inconsistent manner relative to the combined normative and mixed clinical samples. Results in this inventory should not be considered if scores in the inconsistency and negativity scales are higher than 9. For this study, I focused on the inhibit and the shift scale, because these two tap in similar aspects as the Ipad task. The inhibit scale evaluates the child's ability to resist responding or acting on an impulse (i.e., inhibit) and to stop his or her behavior at the appropriate time. Items on the BRIEF-P related to inhibition include such items as “Is impulsive” and “Acts too wild or out of control.” The shift scale measures a child's ability to move from one situation to another (e.g., from one aspect of a problem to another) as is required by the current conditions. BRIEF-P items include “Is upset by change in plans or routines, “Becomes upset with new situations,” and “Has trouble with activities that involve more than one step.” Higher scores indicate more problem in inhibition and shifting respectively.

Data Analysis

Of the sample of 110 families, 97 had complete dyadic data for fathers and 93 had complete data for mothers. Following the publisher recommendations, three father-reported and one mother-reported scores on the BRIEF were excluded due to their high scores in the negativity and inconsistency scales.

State space grids (SSGs; Lewis, Lamey, & Douglas, 1999) were utilized to plot the time series of parent and child behavior and affect for each dyad. I created a 4x4 SSG for affect (i.e., medium-high positive, low positive, neutral, and negative affect for parent and child) and a 5x4 SSG for behavior (i.e., the five parent behavior codes and four child behavior codes described above). Each cell represented a particular combination of a parent and child affective or behavioral state, respectively. I plotted the individual trajectories of dyadic states using GridWare Version 1.15 (Lamey, Hollenstein, Lewis, & Granic, 2004).

In order to explore patterns of coregulation and reinforcing interactions, I visually inspected the presence of states that were functioning as attractors to the dyad. In addition, I computed the number of times (i.e., 30 s epochs) the dyads spent in the following behavioral regions: (1) On-task (i.e., instances when parent was proactive/teaching/emotional support/directive and child was persistent/compliance); (2) Off-task (i.e., instances when parent was intrusive and child was engaged/noncompliant-disengaged); (3) Mismatch parent on-task/child off-task (i.e., instances when parent was proactive/teaching/emotional support/directive and child was engaged/noncompliant-disengaged); and (4) Mismatch parent off-task/child on-task (i.e., instances when parent was intrusive and child was persistent/compliance). For affect, I computed the number of times (i.e., 30 s epochs) the dyads spent in the same positive or negative affective state, and in mismatched affective states. Finally, for each father-child and mother-child dyad, I computed the number of times the dyad spent in each particular combination of parent and child behavioral and affective state. Then I analyzed the association of these parent-child coregulation processes on children's EF using Spearman's correlation coefficients.

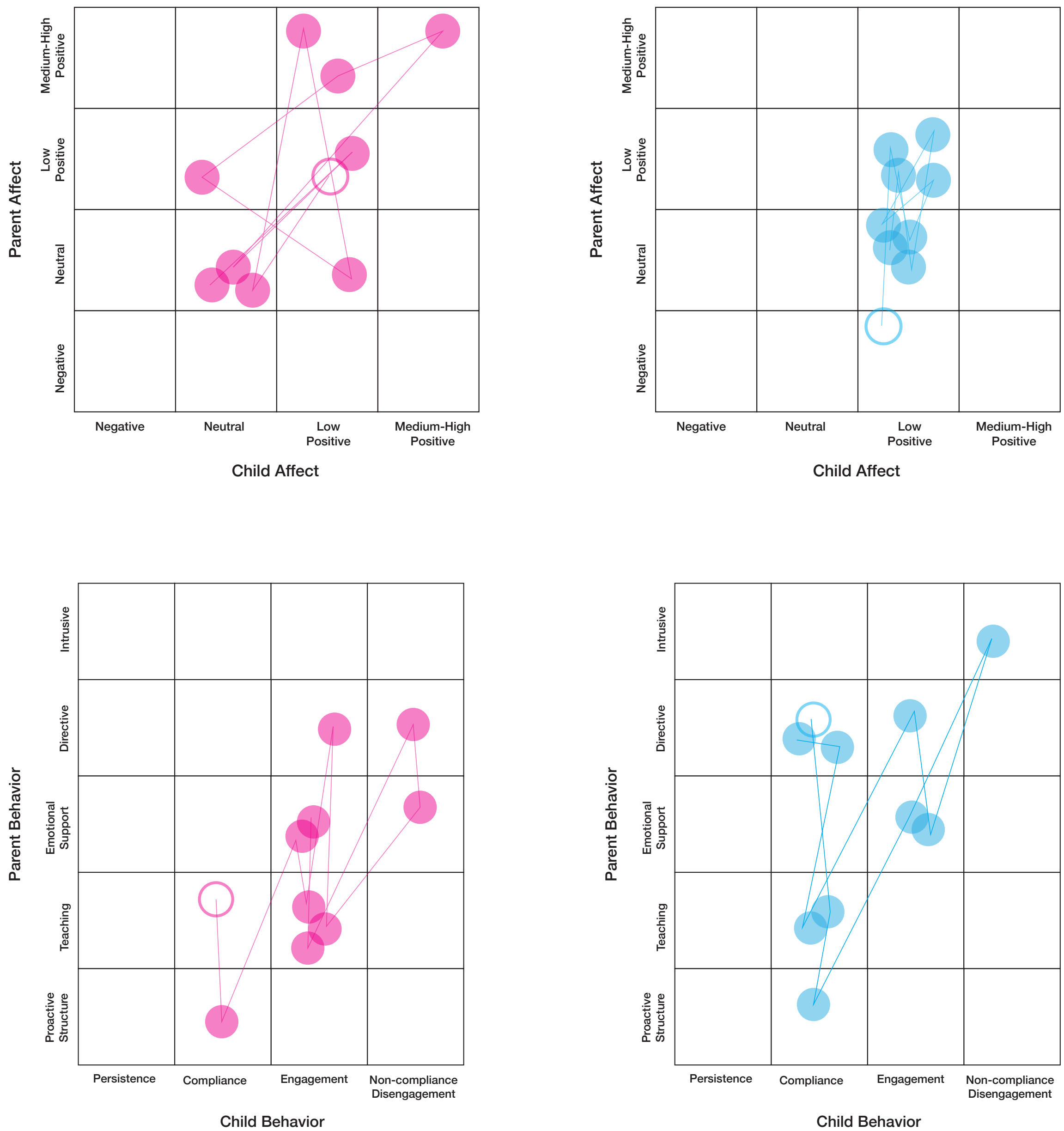

Figure 1. State space grid examples of dyadic affective and behavioral states during parent-child interaction.

Results

Descriptive statistics of the sample can be found in Table 1. Table 2 displays the frequency of dyads that spent interaction time in each region (i.e., on-task, off-task, mismatch parent on-task/child off-task, and mismatch parent off-task/child on-task). Table 3 shows the frequency for dyadic states in the mother-child and father-child interactions.

Results showed that it is more common that mothers display emotional support when children are being persistent or show noncompliance than fathers. Mothers also display proactive structure strategies more often when the child is persistent compared to fathers. But fathers - more than mothers - display intrusiveness when children persist in completing the task or are engaged in a non-task related activity. It is more frequent that father-child dyads are in the directive – compliance or directive- engagement state that mother child dyads.

For affective coregulation, data show that fathers tend to express negative affect more often than mothers when the child displays negative or neutral affect. The mother-child dyads show more frequently a matched - either negative or medium-high positive - affective state than the father-child dyads. Fathers and children show more frequently a dyadic state in which the father displays low positive affect and the child displays neutral affect.

Table 5 and 6 shows bivariate correlations among coregulation predictors, covariates, and EF outcomes from fathers and mothers respectively. The correlation analysis showed that for fathers, being a girl was positively related with dyads being in parent directive -child persistence (*r* = .20, *p* = .04) and parent directive -child compliance (*r* = .19, *p* = .04) states. Children´s performance on the observational EF task (EYT) was positively associated with dyadic states in which the father was being intrusive while the child was either persisting on the task on its own or complying with parental requests. The correlations related to the BRIEF scores showed a negative relation between inhibitory control problems in the child (reported by the father) and the dyad state in which fathers displayed proactive structure (i.e., encouragement, guidance in a positive manner) while the child is complying with father request. On the contrary, children who were engaged with their fathers but were off task (child engagement off-task) while the father was teaching (e.g., explaining how something related to the task worked) showed higher inhibitory control problems, as reported by the father. In terms of father-child affect coregulation, the dyadic state of father in medium-high positive affect and child negative affect was associated with more inhibitory control problems in children as reported by fathers.

Table 1. Descriptive statistics

	Father					Mother				
	N	*M*	SD	Range	%	N	*M*	SD	Range	%
Parent age	110	37.06	5.39	23-52		110	34.83	4.29	22- 43	
Marital Status	110					110				
Married					71					71
Cohabiting					38					38
Educational level	110					110				
Less than High School					3.8					1
High School					11					9
More than HS, less than college degree					17.7					16.2
College degree					66					73
Paid work	110				94					84
Nationality										
Chilean					87.3					90.2
Other					12.7					9.8
Family income (monthly)	110									
Less than min wage					5.4					5.4
Low income					17.1					17.1
Medium income					23.1					23.1
Medium/ high income					13.5					13.5
High income					40.5					40.5
Behavioral regulation										
BRIEF: Inhibition	93	51.96	9.26	36-76		109	51.38	9.68	36-82	
BRIEF: Shift	93	50.72	12,4	38-92		109	49.93	10.49	38-98	
Ipad task	81	3.58	3.78	0-12						
Child age	110	40.89	3.61	34-48						
Child is a boy					46.8					

Income categories are calculated as follows: monthly income less than $500.000= low income; between $500.00 and $1MM= low/medium-income; between $1MM and 2 MM= medium income; between $2MM and $3MM=medium/high income; more than $3MM= high income. The minimum wage in Chile is $460.000 (US $525 approx.) and the medium income is $757.000 (US $863 approx.)

Table 2. Frequencies of dyads in on-task, off-task, and mismatch behavioral and affective states

	Father-child (n=96)			Mother-child (n=93)		
	% None	% Some	% All	% None	% Some	% All
On-task	4.10	57.80	38.10	3.20	63.50	33.30
Off-task	84.5	15.5	.00	87.10	12.90	.00
Mismatch parent on-task/child off-task	49.50	50.00	1.00	47.30	50.50	2.20
Mismatch parent off-task/child on-task	79.40	20.6	.00	78.50	20.40	1.10
Positive affect(P+ N+)	1.00	42.30	56.70	1.00	43.80	55.20
Negative affect (P- N-)	84.50	15.20	.00	92.70	7.20	.00
Mismatch Aff (P+ N-)	59.80	40.20	.00	59.40	40.60	1.00
Mismatch Aff (P- N+)	85.60	14.30	.00	93.80	6.20	.00

Table 3. Frequencies of dyads in behavioral states

	Persistence		Compliance		Engagement		Non-compliance/ Disengagement	
	Father	Mother	Father	Mother	Father	Mother	Father	Mother
Proactive Structure	3	9	25	24	2	2	12	15
Teaching	11	13	45	53	5	6	19	16
Em.Support	9	15	32	36	24	21	14	28
Directive	7	7	63	52	15	4	25	28
Intrusive	4	2	15	16	8	4	15	12

Table 4. Frequencies of dyads in affective states

	Father-child (n=97)	Mother-Child (n=96)
Parent Negative - Child Negative	15	7
Parent Negative - Child Neutral	10	4
Parent Negative - Child Low Positive	6	2
Parent Negative - Child Medium-high Positive	0	0
Parent Neutral - Child Negative	16	22
Parent Neutral - Child Neutral	37	46
Parent Neutral - Child Low Positive	12	13
Parent Neutral - Child Medium-high Positive	0	0
Parent Low Positive - Child Negative	30	24
Parent Low Positive - Child Neutral	64	56
Parent Low Positive - Child Low Positive	50	59
Parent Low Positive - Child Medium-high Positive	4	4
Parent Medium-high Positive - Child Negative	5	1
Parent Medium-high Positive - Child Neutral	13	13
Parent Medium-high Positive - Child Low Positive	14	11
Parent Medium-high Positive - Child Medium-high Positive	11	19

As for the father-child dyads, in the mother-child dyads being in the dyadic state of mother directive and child compliance was more frequent for girls than boys. The coregulatory state of mother being proactive while child was being compliant was related to children´s higher scores in the Ipad EF task. For the EF parent-reported measure (BRIEF), the dyadic state in which the child was persistent and mother was either teaching or emotionally supportive related negatively with inhibitory control problems in the child as reported by mothers. However, the combination of child persistence and mother intrusiveness was related to higher maternal reports of inhibitory control problems in the child. Regarding affective coregulation, correlations indicated that the dyadic state of mother and child displaying low positive affect was related to better inhibitory control skills as reported by the mother. The combination of mother teaching while the child was engaged in a non-task conversation with the mother was negatively related to children´s problem in the ability to shift attention and plan alternative solutions for a problem (i.e., flexibility) as reported by mothers.

Table 5. Means, standard deviations and correlations between mothers and children behavior states

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.
1.	Gender child	-																						
2.	Proact/persist	.09	-																					
3.	Proact/comp	.19	-.04	-																				
4.	Proact/engag	-.16	-.05	-.09	-																			
5.	Proact/non-comp	.01	-.05	.21*	.12	-																		
6.	Teach/persist	.06	.28**	-.18	-.06	-.18	-																	
7.	Teach/comp	-.00	-.20*	-.08	.15	-.25*	-.03	-																
8.	Teach/engag	-.01	-.09	-.16	-.04	-.12	.29**	.07	-															
9.	Teach/non-comp	.04	-.15	-.08	.11	.08	.06	.09	.01	-														
10.	EmSupp/persist	-.01	.28**	-.10	-.07	-.11	.38***	-.17	.11	-.12	-													
11.	EmSupp/comp	.04	-.05	.01	.07	-.12	-.08	.10	-.03	-.13	.12	-												
12.	EmSupport/engag	-.03	-.09	-.04	.08	-.06	-.15	.17	.08	-.00	-.02	-.01	-											
13.	EmSupp/non-comp	-.11	-.21*	.25	.07	.20	-.14	-.11	.10	.04	-.17	-.14	.32**	-										
14.	Direct/persist	-.14	.05	-.09	-.04	-.13	-.01	-.00	-.08	-.13	.32**	.14	.13	-.11	-									
15.	Direct/comp	.23*	-.22*	.01	-.15	-.07	-.26*	-.24	-.16	-.11	-.07	.05	-.02	-.22*	.05	-								
16.	Direct/engag	.09	.11	-.03	-.03	.04	-.09	.04	.16	-.10	.07	.13	.03	-.04	-.06	-.06	-							
17.	Direct/non-comp	-.03	-.21*	-.25*	-.09	.03	-.20*	-.25*	-.09	.22*	-.17	-.14	.08	.29**	.01	.21*	-.14	-						
18.	Intrus/persist	-.01	-.05	-.09	-.02	-.07	-.06	-.05	-.04	-.07	-.07	.08	-.08	-.10	-.04	-.01	-.03	-.10	-					
19.	Intrus/comp	.08	.05	-.11	-.07	-.20	-.01	-.10	-.02	-.21*	-.12	-.03	-.04	.00	-.13	.03	-.10	.04	.13	-				
20.	Intrus/engag	-.12	.12	-.13	-.03	-.09	.05	-.06	-.06	-.10	.18	.01	-.12	.00	.14	-.10	-.05	-.14	-.03	.05	-			
21.	Intrus/non-comp	-.15	-.13	-.04	-.06	-.17	.03	-.27*	-.10	.06	-.17	-.18	.01	.10	-.11	.04	-.08	.31**	-.06	.25*	.07	-		
22.	Inhibition(EF BRIEF)	-.09	-.16	-.03	-.12	-.05	-.38***	-.13	-.06	-.07	-.25*	-.08	.11	.18	.01	.18	-.12	.16	.16	.20	.11	.22*	-	
23.	Flexibility (EF BRIEF)	-.20*	.04	-.03	.01	.05	-.07	-.02	-.21*	.09	-.04	-.03	-.18	-.02	.11	-.06	-.07	.01	.09	-.10	.06	.09	.35***	-
24.	EF task	.07	.02	.25*	-.08	.02	.02	-.17	.22	-.18	-.12	-.01	.05	.07	.15	-.04	-.05	-.03	.06	.14	.23	-.06	.01	-.17

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

Table 6. Means, standard deviations and correlations between fathers and children behavior states

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.
1.	Gender child	-																						
2.	Proact/persist	.17	-																					
3.	Proact/comp	.09	.03	-																				
4.	Proact/engag	-.16	-.03	.06	-																			
5.	Proact/non-comp	.10	-.07	.35**	-.06	-																		
6.	Teach/persist	.08	.12	-.21*	.18	-.14	-																	
7.	Teach/comp	-.05	-.04	-.12	.01	-.15	-.07	-																
8.	Teach/engag	-.06	-.04	.05	-.03	-.09	.08	-.06	-															
9.	Teach/non-comp	-.11	-.09	-.18	-.07	.07	.14	.04	.11	-														
10.	EmSupp/persist	.10	.38**	-.12	.19	-.12	.33***	-.18	.07	-.08	-													
11.	EmSupp/comp	-.09	.13	.18	-.10	-.02	-.04	.07	-.16	-.07	-.08	-												
12.	EmSupport/engag	-.09	.15	.13	-.08	.16	.09	.19	.12	-.11	.16	.04	-											
13.	EmSupp/non-comp	-.02	-.07	-.03	-.06	.04	.05	-.10	-.09	.40**	-.02	.05	-.11	-										
14.	Direct/persist	.19	.41**	-.16	-.04	-.11	.66***	-.20	.13	.06	.49**	.14	.09	-.12	-									
15.	Direct/comp	.19	-.15	-.03	-.06	-.16	-.33***	-.03	-.23*	-.28*	-.31*	-.05	-.14	-.18	-.25*	-								
16.	Direct/engag	.00	.08	-.10	.13	-.16	-.02	-.28**	.14	-.21*	.04	-.01	-.12	-.11	.09	.13	-							
17.	Direct/non-comp	-.19	-.11	-.16	.11	-.04	-.14	-.17	-.14	.05	-.09	-.25	-.18	.10	-.09	.15	.19	-						
18.	Intrus/persist	-.02	-.04	-.12	-.03	-.08	.24*	-.18	-.05	.02	.10	-.13	.03	-.09	.14	-.11	.06	-.12	-					
19.	Intrus/comp	-.05	-.08	-.06	-.06	-.09	-.07	-.11	.29**	.00	.13	-.14	.02	-.03	-.12	-.2*	.04	-.12	.19	-				
20.	Intrus/engag	.05	-.05	-.03	-.04	-.00	.12	-.27**	.26*	-.15	.27**	-.20	.03	-.12	.06	-.19	.27*	-.02	.49*	.26*	-			
21.	Intrus/non-comp	-.06	-.08	-.14	-.06	.00	-.06	-.23*	.02	.07	-.03	-.06	-.25*	.14	-.12	-.23	.02	.21*	.07	.38*	.30	-		
22.	Inhibition (EF BRIEF)	-.17	-.08	-.25*	-.11	-.08	.05	.11	.22*	.19	-.02	-.01	.13	.02	.11	-.06	.00	.11	-.02	.16	-.05	.03	-	
23.	Flexibility (EF BRIEF)	-.20*	.02	-.28*	-.05	-.15	-.03	.20	-.03	.07	-.12	.14	-.05	-.13	.01	.03	.04	.09	.01	-.01	-.06	.07	.56***	-
24.	EF task	.07	.03	.13	.15	-.09	-.02	-.11	-.06	-.07	.02	-.05	-.12	-.09	-.01	.33	.13	-.10	.20	.17	.14	-.06	-.07	-.04

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

Discussion

Guided by dynamic systems theory, this study examined how affective and behavioral coregulation patterns in father-child and mother-child dyads were associated with SR development in early childhood.

Overall, the results suggest that the drivers of parent-child coregulation are complex, that there are similarities and differences across mother-child and father-child dyads, and that parents and children behavioral and affective states play a role in shaping coregulation. Better regulatory skills in children were associated with fathers displaying proactive structuring strategies, such as encouragement and guidance, while the child was complying with the task, were found to have better SR skills (inhibition reported by father). On the contrary, children who were engaged with their fathers, but were not paying attention to the task (child engagement off-task) while the father was teaching them, showed higher inhibitory control problems, as reported by the father. Similar results were found for mothers. The coregulatory state of mother being proactive while the child was being compliant was related to children´s higher scores in the Ipad EF task. For the EF parent-reported measure (BRIEF), the dyadic state in which the child was persistent, and mother was either teaching or emotionally supportive was found to be related to better inhibitory control in the child.

These findings contribute to a more nuanced examination of parenting behaviors that the literature has described as “positive” or “negative”. For example, according to the literature, parental intrusive behaviors are supposed to be detrimental for child development (Eisenberg et al., 2015; Smith & Pederson, 1988; Stevenson & Crnic, 2013). However, in this study for father-child dyads – but not mother-child dyads - intrusive behavior, such as taking over the task and/or physically completing some of the task for the child, while the child was compliant or persistent was positively associated to child EF. Why? Previous studies that have examined paternal intrusiveness (Ispa et al., 2004; Karberg et al., 2019) may contribute to state some hypothesis. First, previous studies have shown that even though mothers and fathers displayed similar frequency of intrusive behaviors, the intensity of the intrusive behavior may differ for mothers and fathers. Fathers tend to more active and engaged in more arousing interactions with their children, such as rough and tumble play. But, when this type of behavior is accompanied by warmth (i.e., shared eye-contact, smiles, positive voice fluctuations), it has been shown to promote children's regulatory skills (Flanders et al., 2009). A second possibility is that culturally, children are more used to paternal than maternal intrusiveness. In Chile, gender stereotype related to *machismo* are still part of the socialization process. Mothers are viewed as responsible for taking care of the children and providing support, while father are supposed to be in charge of discipline and norms (Aguayo et al., 2012). It's good to remember that fathers intrusiveness was only positively related to children´s EF when it was displayed while child was being on task. This suggests that intrusiveness is not "always" or "never" positive for child development. In fact, for the mother- child dyad maternal intrusive behaviors while the child was completing the task on his/her own was related to lower inhibitory control in the child. Same dyadic state (i.e., paternal intrusiveness and child compliance) relates to child development differently. These are important findings because they suggest that differences between mothers' and fathers' relationships with their children might be evident in the meaning of such interactions for children rather than in the frequency (Cabrera et al., 2014). Our findings also extend current research by suggesting that mothers and fathers may engage in intrusive behaviors for different reasons and that whether a particular behavior is interpreted by the child as interfering with autonomy or as being frustrating, really depends on the pattern of coregulation developed by the dyad (Ispa et al., 2004). These findings also lend support to the specificity principle, that specific inputs are related to specific outcomes (i.e., paternal intrusiveness and child compliance/parental proactive structure and child compliance and child EF) (Bornstein, 2001). A dyadic and dynamic perspective of the parent – child relationship allows us to examine this nuances and advance in our understanding on how to promote better child regulatory skills.

Most of the states that were related to better children´s EF included child either being persistent or compliant. One argument could be that children´s persistence is already reflecting better regulatory skills. However, these children´s states had to be displayed in tandem with some specific paternal behaviors in order to show positive relations with EF skills. Thus, child characteristics are not alone explaining child´s performance; it is a specific combination (or coregulation process) between parent and the child that contributes to the outcome. In the case of the mother -child dyads child persistence was associated to better reported EF skill, only when it was accompanied by maternal emotional support or teaching. For the father-child dyad it was encouragement and positive guidance. So, even though children were already on-task a specific type of help from parents was necessary to foster better EF skills. The help could be either a behavior like scaffolding (teaching) or support (emotional support) in the case of mother-child dyads or encouragement in the case of the father-child dyads. Although parents do not typically receive training in teaching methods, they must teach their children beginning early in life. High levels of parental support are supposed to provide a context for children’s regulatory development as children learn how to persist in the face of difficulty (Vygotsky, 1978). Previous research suggests this, showing that behaviors such as scaffolding and responsiveness (Denham et al., 2000; Mulvaney et al., 2006), and positive reinforcement and proactive parenting (Lunkenheimer et al., 2008) predict higher levels of self-regulation and behavioral adjustment in early childhood. One proposed theoretical mechanism is that teaching that involves support for autonomy contributes to the child’s repertoire of regulatory strategies, thus increasing persistence on caregiver-directed tasks. For instance, open ended teaching questions could prompt the child to consider other task solutions (Sigel et al., 1993), which could activate regulatory strategies. When parents provide instruction, it may also help children avoid the inattention associated with task difficulty (Fagot & Gauvain, 1997; Hoffman et al., 2006). Parent–child interactions are interdependent, and thus it is also important to consider the evocative effects of child behavior on parental behavior. Mothers are likely to engage more when it is needed to keep the child on task (Robinson et al., 2009), and child performance becomes progressively caregiver regulated with increasing task difficulty (McNaughton & Leyland, 1999). There is also general support for the importance of evocative child effects, showing that characteristics of the child (e.g., temperament) elicit different responses from parents and caregivers, and the corresponding interaction that occurs contributes to the dynamic process of child development (Dennis, 2006; Scaramella et al., 2008). Again, why for same child behavior states, different behaviors from mothers and fathers relate to better regulatory skills is an open question that future studies should address.

In terms on parent- child affect coregulation, more father-child dyads presented a state of matched negative affect than mother-child dyads, but these states were not related to children´s EF skills. However, the state of child displaying negative affect and father displaying medium/high positive effect was related to more inhibitory control problems as reported by the father. This result support previous findings showing that negative synchrony (i.e., father + child -) may be detrimental for child development.

This particular dyadic state, when the child is experiencing negative feelings (i.e., irritation, sadness, distress, etc.) and the father's affect is not contingent to the child's, might reflect a dyadic emotional coregulation pattern where negative emotions are dismissed, and the child has less opportunities to practice emotional regulation skills relevant to SR of behavior.

Regarding mother-child affective coregulation, the dyadic state of mother and child displaying low positive affect was related to better inhibitory control in the child, as reported by the mother. These results offer a more detailed examination of the effects of positive affect (Feldman, 2009; Karberg et al., 2019). Previous studies have categorized affect either as positive or negative, obscuring the understanding of how dyads may adapt the expression of affection depending on the demands or conditions of the context. In this case, the match state of high positive affect between mother and child did not contribute to better EF skills, but a lower intensity of positive affect did. Given the characteristics of the task, high positive affect could have been disruptive and impede the dyad to complete the task, so low positive matching affect in the dyad could be more adaptive.

Limitations, Future Directions and Conclusion

There are several limitations that should be considered when interpreting the findings of this study. First, data come from a convenience sample of medium-high income parents and their 3-year-old children, and thus the generalizability of findings is limited. Second, the type of analysis done (i.e., space grids) did not allow to include control variables.

Although the study allowed for the examination of processes during a period crucial to regulatory development, the cross-sectional design of the study limits the extent of predictive analyses. Multiple assessments could offer more information about relations between dyadic patterns and children’s developing regulatory skills over time.

An important next step is to replicate these findings with larger and more diverse samples and with mothers and fathers using event-based coding schemes that can account for the specific coregulation patterns that emerge in the context of parent-child interaction. The findings of this study suggest that while both father-child and mother-child dyads may engage in similar combination of behavioral and emotional states, the impact on children may be different. Future studies should expand on this line, examining the stability and change of this coregulation patterns in parent-child interactions, for example, across different tasks and developmental time points.

In conclusion, the present findings suggest that it is not only the parent’s or child’s individual behaviors that matter in parent–child interactions, but also the patterning of the parent’s and child’s responses to one another that may be an important precursor of children’s regulatory competence across development (Cole et al., 2003; Dumas et al., 2001; Feldman, 2003). The process by which parent–child coregulation leads to children’s individualized self-regulatory ability during this crucial developmental stage could be better elucidated using dyadic and dynamic methods that reflex the complex nature of these processes (Olson & Lunkenheimer, 2009).

Chapter 6: General Discussion and Conclusions

In this dissertation, I aimed to contribute to the emerging literature examining the role of parent-child coregulation in children self-regulatory development in early childhood from a dynamic and multilevel approach. Each of the three studies represents a specific objective.

In study 1, I examined coregulation in mother-child and father-child dyads using a global index that captured dyadic affective and behavioral aspects of the interaction parent-child interaction. Then, I analyzed whether parent-child coregulation was related to children SR. In study 2, I explored parent-child coregulation at a physiological level, and its association with child physiological SR. Finally, in study 3, I examined the parent-child coregulation at its core, exploring the micro coregulatory interactions that configure the dyadic patterns of coregulation that we may see from a macro-level.

Overall, the findings of these studies contribute to the literature on parent-child coregulation and its role in the development of SR in early childhood in several ways.

First, in line with current research in developmental science, the three studies adopted a relational developmental systems framework to the study of parent-child interaction and children SR development. This framework highlights dynamic and transactional processes between the child and the context as promotive of positive child development across time. These studies contribute to the growing body of literature that conceive parent-child interaction as intrinsically bidirectional and dynamic, in which parents and children co-create their own tailored pattern on interaction.

The result of these studies contribute a step forward to clarify the mixed results in the literature. These are robust results given the different ways that coregulation was assessed in each study (global, physiological and micro-level).

Study 2 aimed to contributed to the almost nonexistent data on parasympathetic coregulation in father-child and mother-child dyads in early childhood. The “no findings” should be examined with cautions. The small sample size cannot be ruled out as explanation. Even though, it contributes to thinking about how to evaluate physiological processes. It was a worthwhile exercise to start examining physiological processes using novel analysis. Recently, researchers have applied statistical tapering techniques in a moving-window approach to generate a second-by-second time series of RSA that reveals temporal dynamics in physiology on the level of the temporal dynamics of behavior and emotion (Abney et al., 2021; Gates et al., 2015; van der Ende et al., 2019). These new methodologies offer a promising approach to understanding the intricate dynamics of parent-child coregulation. Nevertheless, interpreting the complex dynamics of second-by-second RSA remains a challenge, and standardized methods and metrics are needed to facilitate comparison across studies. Future studies should incorporate physiological measures to their designs, in order to expand the scarce evidence on physiological coregulation in this age group.

Study 1 and study 3 approached the phenomenon of dyadic coregulation at different levels (macro vs micro), yielding complementary results. Taken together, these studies show that coregulation processes are similar in mothers and fathers. That is, mothers and fathers are equally able to temporally coordinate their behavioral, emotional, and physiological states with his/her child and vice versa. The finding in Study 1 that only mothers predicted children's SR does not necessarily mean that fathers do not contribute to their children's development. It is possible that the methodology used in the study was not sensitive enough to detect differences in the strategies used by fathers and mothers, or to explore specific differences between fathers and mothers. Study three addressed these limitations by using a micro-analytical method that examined coregulatory states Whitin the mother-child and father-child dyads. Results showed that some specific and different dyadic states were significantly related to child SR for the mother-child and father-child dyads. Moreover, this observed patterns of coregulation were some positively and other negatively associated with children SR. These findings not only further demonstrate the utility of micro-analytical methods in capturing interactional parent-child dynamics in a social context, but also demonstrates how, unlike traditional global methods, micro-analytical methods can allow us to detect underlying important nuances of coregulatory process that global approaches may obscure, contributing to the understanding of this important process for child development.

Overall, the three studies offered evidence that individual parent effects, individual child effects, and dyadic patterns should all be considered to represent a more complete picture of the effects of parent–child coregulation on children's regulatory skills. Future studies should expand on this line, examining the stability and change of this coregulation patterns in parent-child interactions, for example, across different tasks and developmental time points.

Results also address possible differences between the ways mother and fathers interact with their children. Other research has shown similarities and differences in dyadic interaction patterns mother-child vs. father-child dyads, and how these patterns affect children's regulatory skills (Feldman, 2003; Lunkenheimer et al., 2011). The literature shows mixed results in this area; perhaps more fain grained methodology, like the one used in study 3, may help to dilucidated further these differences.

These are important findings because they suggest that differences between mothers' and fathers' relationships with their children might be evident in the meaning of such interactions for children rather than in the frequency (Cabrera et al., 2014). Parent–child interactions are interdependent, and thus it is also important to consider the evocative effects of child behavior on parental behavior. Mothers are likely to engage more when it is needed to keep the child on task (Robinson et al., 2009), and child performance becomes progressively caregiver regulated with increasing task difficulty (McNaughton & Leyland, 1999). There is also general support for the importance of evocative child effects, showing that characteristics of the child (e.g., temperament) elicit different responses from parents and caregivers, and the corresponding interaction that occurs contributes to the dynamic process of child development (Dennis, 2006; Scaramella et al., 2008). A dyadic and dynamic perspective of the parent – child relationship allows us to examine these nuances and advance in our understanding on how to promote better child regulatory skills. Future studies could include children´s temperament or examine moderation between behaviors and affect.

The case of intrusiveness is worth exploring in more detail. These findings contribute to a more nuanced examination of parenting behaviors that the literature has described as “positive” or “negative”. Results in study 3 extend current research by suggesting that mothers and fathers may engage in intrusive behaviors for different reasons and that whether a particular behavior is interpreted by the child as interfering with autonomy or as being frustrating, really depends on the pattern of coregulation developed by the dyad (Ispa et al., 2004). These findings also lend support to the specificity principle, that specific inputs are related to specific outcomes (i.e., paternal intrusiveness and child compliance/parental proactive structure and child compliance and child EF) (Bornstein, 2001).

In conclusion, the findings of this studies suggest that it is not only the parent’s or child’s individual behaviors that matter in parent–child interactions, but also the patterning of the parent’s and child’s responses to one another that may be an important precursor of children’s regulatory competence across development (Cole et al., 2003; Dumas et al., 2001; Feldman, 2003). The process by which parent–child coregulation leads to children individualized self-regulatory ability during this crucial developmental stage could be better elucidated using dyadic and dynamic methods that reflex the complex nature of these processes (Olson & Lunkenheimer, 2009). Better understanding the role of parent and child contributions to dyadic coregulating interactions may inform the identification of malleable factors for the early promotion of behavioral regulation.

The findings of the studies have important implications for the way we understand and intervene with families. First, they suggest that the coregulation process is similar in mothers and fathers. This means that both parents are equally able to influence and be influenced by their children. This finding helps continuing to challenge the traditional view that mothers are the primary caregivers and that they are therefore more responsible for the child's development.

Moreover, results suggest that the same parenting strategy can have different effects depending on the child's behavior. For example, a parent's intrusive behavior may be helpful in some situations, but it may be harmful in others. This finding suggests that it is important to be sensitive to the individual needs of each child and parent when providing parenting interventions. This means that the one fits all approach is not always effective and may even hinder the promotion of positive development for some children.

Overall, studies like the ones presented in this dissertation, contribute with evidence to answer the key “what questions” for developmental scientists: “What attributes of what individuals, in relation to what contextual conditions, can be integrated to promote what instances of positive human development?” (Lerner et al., 2015, pp. 26).

References

Aguayo, F., Levtov, R., Brown, V., Barker, G., & Barindelli, F. (2017) Estado de la paternidad: América Latina y el Caribe 2017. Nueva York: IPPF/RHO, Washington, D.C.: Promundo-US.

Aksan, N., Kochanska, G., & Ortmann, M. R. (2006). Mutually responsive orientation between parents and their young children: toward methodological advances in the science of relationships. *Developmental Psychology, 42*(5), 833.

Aldoney, D., & Prieto, F. (2023). Paternal and maternal predictors of affective and cognitive involvement of three-year-old Chilean children in Chile (Predictores del involucramiento afectivo y cognitivo de padres y madres con sus hijas/os de tres años en Chile). *Infancia y Aprendizaje*, 00(00), 1–30. https://doi.org/10.1080/02103702.2022.2159614

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology, 8*(2), 71-82.

Aoki, Y., Zeanah, C. H., Heller, S. S., & Bakshi, S. (2002). Parent–infant relationship global assessment scale: A study of its predictive validity. *Psychiatry and Clinical Neurosciences, 56*(5), 493-497. https://doi.org/10.1046/j.1440-1819.2002.01044.x

Arnsten, A. F. T. (2009). Stress signaling pathways that impair prefrontal cortex structure and function. *Nature Reviews Neuroscience, 10*, 410–422.

Atzil, S., Gao, W., Fradkin, I., & Barrett, L. F. (2018). Growing a social brain. *Nature Human Behaviour, 2*(9), 624-636.

Bailey, R., & Jones, S. M. (2019). An integrated model of regulation for applied settings. *Clinical Child and Family Psychology Review, 22*, 2-23.

Bardack, S., Herbers, J. E., & Obradović, J. (2017). Unique contributions of dynamic versus global measures of parent–child interaction quality in predicting school adjustment. *Journal of Family Psychology, 31*(6), 649.

Barkley, R. A. (2001). The executive functions and self-regulation: An evolutionary neuropsychological perspective. *Neuropsychology Review, 11*, 1-29.

Bassett, H. H., Denham, S., Wyatt, T. M., & Warren-Khot, H. K. (2012). Refining the preschool self-regulation assessment for use in preschool classrooms. *Infant and Child Development, 21*(6), 596– 616. doi:10.1002/icd

Baumeister, R. F., & Vohs, K. D. (2007). Self-Regulation, ego depletion, and motivation. *Social and Personality Psychology Compass, 1*(1), 115-128.

Bazhenova, O. V., Plonskaia, O., & Porges, S. W. (2001). Vagal reactivity and affective adjustment in infants during interaction challenges. *Child Development, 72*(5), 1314-1326.

Beauchaine, T. P., Gatzke-Kopp, L., & Mead, H. K. (2007). Polyvagal theory and developmental psychopathology: Emotion dysregulation and conduct problems from preschool to adolescence. *Biological Psychology, 74*(2), 174-184.

Beauregard, M., Lévesque, J., & Paquette, V. (2004). Neural basis of conscious and voluntary self-regulation of emotion. *Consciousness, Emotional Self-regulation and the Brain*, 163-194.

Beebe, B., Messinger, D., Bahrick, L. E., Margolis, A., Buck, K. A., and Chen, H. (2016). A systems view of mother–infant face-to-face communication. *Developmental Psychology, 52*, 556–571. doi: 10.1037/a0040085

Beeghly, M., Perry, B. D., & Tronick, E. (2016). Self-regulatory processes in early development. *The Oxford Handbook of Treatment Processes and Outcomes in Psychology: A Multidisciplinary, Biopsychosocial Approach*, 42-54.

Beeghly, M., & Tronick, E. (2011). Early resilience in the context of parent–infant relationships: A social developmental perspective. *Current Problems in Pediatric and Adolescent Health Care, 41*(7), 197–201. https://doi.org/10.1016/j.cppeds.2011 .02.005

Beeghly, M., Fuertes, M., Liu, C. H., Delonis, M. S., & Tronick, E. (2011). Maternal sensitivity in dyadic context: Mutual regulation, meaning-making, and reparation.

Bell, R. Q. (1968). A reinterpretation of the direction of effects in studies of socialization. *Psychological Review, 75*(2), 81. https://doi.org/10.1037/h0025583

Bernier, A., Carlson, S. M., & Whipple, N. (2010). From external regulation to self-regulation: Early parenting precursors of young children's executive functioning. *Child Development, 81*(1), 326–339.

Bernier, A., Beauchamp, M. H., Carlson, S. M., & Lalonde, G. (2015). A secure base from which to regulate: Attachment security in toddlerhood as a predictor of executive functioning at school entry. *Developmental Psychology, 51*(9), 1177.

Bernier, A., Carlson, S. M., Deschênes, M., & Matte-Gagné, C. (2012). Social factors in the development of early executive functioning: A closer look at the caregiving environment. *Developmental Science, 15*(1), 12-24.

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development, 81*(6), 1641–1660. https://doi.org/10.1111/j.1467-8624. 2010.01499.x

Bibok, M. B., Carpendale, J. I., & Müller, U. (2009). Parental scaffolding and the development of executive function. *New Directions for Child and Adolescent Development, 2009*(123), 17-34.

Blair, C. (2002). School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist, 57*, 111–127

Blair, C., & Dennis, T. (2010). An optimal balance: The integration of emotion and cognition in context. In S. D. Calkins & M. A. Bell (Eds.), *Child*

Development at the Intersection of Emotion and Cognition (pp. 17–35). American Psychological Association. https://doi.org/10.1037/12059-002
Blair, C., & Diamond, A. (2008). Biological processes in prevention and intervention: The promotion of self-regulation as a means of preventing school failure. *Development and Psychopathology, 20*(3). doi:10.1017/s0954579408000436
Blair, C., & Ku, S. (2022). A hierarchical integrated model of self-regulation. *Frontiers in Psychology, 13*, 725-828.
Blair, C., & Peters, R. (2003). Physiological and neurocognitive correlates of adaptive behavior in preschool among children in Head Start. *Developmental Neuropsychology, 24*(1), 479-497.
Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. *Annual Review of Psychology, 66*, 711-731.
Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*, 647–663
Blair, C., & Ursache, A. (2011). A bidirectional model of executive functions and self-regulation. In K. D. Vohs & R. F. Baumeister (Eds.), *Handbook of Self-regulation: Research, Theory, and Applications* (2nd ed., pp. 300–320). New York, NY: Guilford Press
Blair, C., McKinnon, R. D., & Family Life Project Investigators. (2016). Moderating effects of executive functions and the teacher–child relationship on the development of mathematics ability in kindergarten. *Learning and Instruction, 41*, 85–93
Boekaerts, M., Pintrich, P. R., & Zeidner, M. (Eds.) (2000). *Handbook of self-regulation*. San Diego: Academic Pres.
Bohlmann, N. L., & Downer, J. T. (2016). Self-regulation and task engagement as predictors of emergent language and literacy skills. Early Education and Development, 27(1), 18-37.
Bohlmann, N. L., Maier, M. F., & Palacios, N. (2015). Bidirectionality in self-regulation and expressive vocabulary: Comparisons between monolingual and dual language learners in preschool. *Child Development, 86*, 1094-1111. doi :10.1111/cdev.12375
Bornstein, M. H., & Suess, P. E. (2000). Child and mother cardiac vagal tone: continuity, stability, and concordance across the first 5 years. *Developmental Psychology, 36*(1), 54.
Bowlby, J. (1958). The nature of the child's tie to his mother. *International Journal of Psychoanalysis, 39*, 350–373.
Bradley, B., DeFife, J. A., Guarnaccia, C., Phifer, J., Fani, N., Ressler, K. J., & Westen, D. (2011). Emotion dysregulation and negative affect: Association with psychiatric symptoms. *The Journal of Clinical Psychiatry, 72*(5), 6427.

Bridges, L. J., Denham, S., & Ganiban, J. M. (2004). Definitional issues in emotion regulation research. *Child Development, 75*(2), 340–345. https://doi.org/10.1111/j.1467-8624.2004.00675.x

Bridgett, D. J., Burt, N. M., Edwards, E. S., & Deater-Deckard, K. (2015). Intergenerational transmission of self-regulation: a multidisciplinary review and integrative conceptual framework. *Psychological Bulletin, 141*, 602–654. https://doi.org/10.1037/a 0038662.

Bridgett, D. J., Oddi, K. B., Laake, L. M., Murdock, K. W., & Bachmann, M. N. (2013). Integrating and differentiating aspects of self-regulation: Effortful control, executive functioning, and links to negative affectivity. *Emotion, 13*(1), 47. https://doi.org/10.1037/a0029536

Brock, L. L., Rimm-Kaufman, S. E., Nathanson, L., & Grimm, K. J. (2009). The contributions of “hot” and “cool” executive function to children’s academic achievement, learning-related behaviors, and engagement in kindergarten. *Early Childhood Research Quarterly, 24*, 337–349.

Bronfenbrenner, U., & Morris, P. (2006). The bioecological model of human development. *Handbook of Child Psychology, Theoretical Models of Human Development*, 793–828. http://dx.doi.org/10.1002/9780470147658.chpsy0114

Bronfenbrenner, U., & Morris, P. A. (1998). The ecology of developmental processes. In W. Damon (Series Ed.) & R. M. Lerner (Vol. Ed.), *Handbook of child psychology: Vol.1. Theoretical models of human development* (5th ed., pp. 993–1028). New York: Wiley.

Bronson, M. B. (2000). *Self-regulation in early childhood: Nature and nurture*. New York: Guilford.

Cabrera, N. J., Volling, B. L., & Barr, R. (2018). Fathers are parents, too! Widening the lens on parenting for childrens development. *Child Development Perspectives, 12*(3), 152–157. hTtps://doi.org/10.1111/cdep.12275

Calkins, S. D., & Marcovitch, S. (2010). Emotion regulation and executive functioning in early development: Integrated mechanisms of control supporting adaptive functioning. In S. D. Calkins & M. A. Bell (Eds.), *Child development at the intersection of emotion and cognition* (pp. 37–57). American Psychological Association. https://doi.org/10.1037/12059-003

Calkins, D. D., & Dedmon, S. E. (2000). Physiological and behavioral regulation in two-year-old children with aggressive/destructive behavior problems. *Journal of Abnormal Child Psychology, 28*, 103 – 118.

Calkins, S. D. (1994). Origins and outcomes of individual differences in emotion regulation. *Monographs of the Society for Research in Child Development*, 53-72.

Calkins, S. D. (1997). Cardiac vagal tone indices of temperamental reactivity and behavioral regulation in young children. *Developmental Psychobiology, 31*(2), 125-135.

Calkins, S. D. (2007). The emergence of self-regulation: Biological and behavioral control mechanisms supporting toddler competencies. In C. Brownell, & C. Kopp (Eds.). *Transitions in early socioemotional development: The toddler years* (pp. 261–284). New York, NY: Guilford Press

Calkins, S. D. (2011). Biopsychosocial models and the study of family processes and child adjustment. *Journal of Marriage and the Family, 73*(4), 817.

Calkins, S. D., & Keane, S. P. (2004). Cardiac vagal regulation across the preschool period: Stability, continuity, and implications for childhood adjustment. *Developmental Psychobiology, 45*(3), 101-112.

Calkins, S. D., Dedmon, S. E., Gill, K. L., Lomax, L. E., & Johnson, L. M. (2002). Frustration in infancy: Implications for emotion regulation, physiological processes, and temperament*. Infancy, 3*(2), 175-197.

Calkins, S. D., Fox, N. A., & Marshall, T. R. (1996). Behavioral and physiological antecedents of inhibited and uninhibited behavior. *Child Development, 67*, 523 – 540

Calkins, S. D., Smith, C. L., Gill, K. L., & Johnson, M. C. (1998). Maternal interactive style across contexts: Relations to emotional, behavioral, and physiological regulation during toddlerhood. *Social Development, 7,* 350–369

Calkins, S., & Fox, N. (2002). Self-regulatory processes in early personality development: A multilevel approach to the study of childhood social withdrawal and aggression. *Development and Psychopathology, 14*, 477–498.

Cameron, C. E., Brock, L. L., Murrah, W. M., Bell, L. H., Worzalla, S. L., Grissmer, D., & Morrison, F. J. (2012). Fine motor skills and executive function both contribute to kindergarten achievement. *Child Development, 83*(4), 1229–1244. https://doi. org/10.1111/j.1467-8624.2012.01768.x .

Carlson, S. M. (2003). Executive function in context: Development, measurement, theory, and experience. *Monographs of the Society for Research in Child Development, 68,* 138–151

Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology, 28*(2), 595–616. https://doi. org/10.1207/s15326942dn2802 _ 3

Carlson, S. M., & Zelazo. (2014). *Minnesota Executive Function Scale. Test manual*. St. Paul, MN.

Casey, B. J., Somerville, L. H., Gotlib, I. H., Ayduk, O., Franklin, N. T., Askren, M. K., ... & Shoda, Y. (2011). Behavioral and neural correlates of delay of gratification 40 years later. *Proceedings of the National Academy of Sciences, 108*(36), 14998-15003.

Caughy, M. O., Mills, B., Tresch, M., & Hurst, J. R. (2013). Emergent self-regulation skills among very young ethnic minority children: A confirmatory factor model. *Journal of Experimental Child Psychology, 116*(4), 839–855.

Cole, P. M., Armstrong, L. M., & Pemberton, C. K. (2010). The role of language in the development of emotion regulation. In S. D. Calkins & M. A. Bell (Eds.), *Child development at the intersection of emotion and cognition* (pp. 59–77). Washington, DC: American Psychological Association.

Cole, P.M., Teti, L.O., & Zahn-Waxler, C. Mutual emotion regulation and the stability of conduct problems between preschool and early school age. *Development and Psychopathology, 15*, 1–18. doi: 10.1017/S0954579403000014.

Colman, R.A., Hardy, S.A., Albert, M., Raffaelli, M., & Crockett, L. (2006). Early predictors of self-regulation in middle childhood. *Infant and Child Development, 15*, 421– 437.

Craig, L., Powell, A., & Smyth, C. (2014). Towards intensive parenting? Changes in the composition and determinants of mothers' and fathers' time with children 1992–2006. *The British Journal of Sociology, 65*(3), 555–579. https://doi.org/10.1111/1468-4446.12035

Criss, M. M., Shaw, D. S., & Ingoldsby, E. M. (2003). Mother–son positive synchrony in middle childhood: Relation to antisocial behavior. *Social Development, 12*(3), 379-400.

Crockenberg, S. C., & Leerkes, E. M. (2004). Infant and maternal behaviors regulate infant reactivity to novelty at 6 months. *Developmental Psychology, 40*, 1123–1132. https://doi.org/10. 1037/0012-1649.40.6.1123.

Crockenberg, S. C., Leerkes, E. M., & Jó, P. S. B. (2008). Predicting aggressive behavior in the third year from infant reactivity and regulation as moderated by maternal behavior. *Development and Psychopathology, 20*(1), 37-54.

Crone, E. A. (2009). Executive functions in adolescence: inferences from brain and behavior. *Developmental Science, 12*(6), 825-830.

de Ruiter, N. M. P., van der Gaag, M. A. E., Jeronimus, B. F., & Kunnen, E. S. (2019). Introduction to a dynamic systems approach to psychosocial development in adolescence. In E. S. Kunnen, N. M. P. de Ruiter, B. F. Jeronimus, & M. A. E. van der Gaag (Eds.), *Psychosocial Development in Adolescence: Insights from the Dynamic Systems Approach* (pp. 1-16). (Studies in Adolescent Development). Routledge. https://doi.org/10.4324/9781315165844-1

Deater-Deckard, K., &O'Connor, T. (2000). Parent–child mutuality in early childhood: Two behavioral genetic studies. *Developmental Psychology, 36*, 561–570

Deater-Deckard, K., Atzaba-Poria, N., & Pike, A. (2004). Mother—and father—child mutuality in Anglo and Indian British families: A link with lower externalizing problems. *Journal of Abnormal Child Psychology, 32*, 609-620.

Deater-Deckard, K., & Petrill, S. A. (2004). Parent–child dyadic mutuality and child behavior problems: An investigation of gene–environment processes. *Journal of Child Psychology and Psychiatry, 45*(6), 1171-1179.

Deater-Deckard, K., Mullineaux, P. Y., Beekman, C., Petrill, S. A., Schatschneider, C., & Thompson, L. A. (2009). Conduct problems, IQ, and household chaos: A longitudinal multi-informant study. *Journal of Child Psychology and Psychiatry, 50*(10), 1301-1308.

Degangi, G. A., Dipietro, J. A., Greenspan, S. I., & Porges, S. W. (1991). Psychophysiological characteristics of the regulatory disordered infant. *Infant Behavior and Development, 14*(1), 37-50.

Delaherche, E., Chetouani, M., Mahdhaoui, A., Saint-Georges, C., Viaux, S., & Cohen, D. (2012). Interpersonal synchrony: A survey of evaluation methods across disciplines. *IEEE Transactions on Affective Computing, 3*(3), 349-365.

Denham, S. A., Bassett, H. H., Way, E., Mincic, M., Zinsser, K., & Graling, K. (2012). Preschoolers' emotion knowledge: Self-regulatory foundations, and predictions of early school success. *Cognition & Emotion, 26*(4), 667-679.

Denham, S. A., Workman, E., Cole, P. M., Weissbrod, C., Kendziora, K. T., & Zahn-Waxler, C. (2000). Prediction of externalizing behavior problems from early to middle childhood: The role of parental socialization and emotion expression. Development and Psychopathology, 12, 23–45. doi: 10.1017/S0954579400001024

Diamond, A. (2012). Activities and programs that improve children's executive functions. *Current Directions in Psychological Science, 21*(5), 335-341.

Diamond, A. (2006). The early development of executive functions. In E. Bialystok & F. I. M. Craik (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 70–95). New York, NY: Oxford University Press.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*, 135– 168. https://doi.org/10.1146/annur ev-psych -11301 1- 143750

Diamond, A., & Kirkham, N. (2005). Not quite as grown-up as we like to think: Parallels between cognition in childhood and adulthood. *Psychological Science, 16*(4), 291-297.

Diaz, A., & Eisenberg, N. (2015). The process of emotion regulation is different from individual differences in emotion regulation: Conceptual arguments and a focus on individual differences. *Psychological Inquiry, 26*,37–47. https://doi.org/10.1080/1047840X. 2015.959094

DiCorcia, J. A., Sravish, A. V., & Tronick, E. (2013). The everyday stress resilience hypothesis: Unfolding resilience from a perspective of everyday stress and coping. In Laviola, G. & Macri, S. (Eds.), *Adaptive and mal-adaptive aspects of developmental stress* (pp. 67–93). New York: Springer

Diener, M. L., & Mangelsdorf, S. C. (1999). Behavioral strategies for emotion regulation in toddlers: Associations with maternal involvement and emotional expressions. *Infant Behavior and Development, 22*, 569 – 583.

Dignath, C., Buettner, G., & Langfeldt, H. P. (2008). How can primary school students learn self-regulated learning strategies most effectively? A meta-analysis on self- regulation training programmes. *Educational Research Review, 3*(2), 101–129. https://doi.org/10.1016/j.edurev.2008.02.003.

Dishion, T. J., Mun, C. J., Tein, J. Y., Kim, H., Shaw, D. S., Gardner, F., ... & Peterson, J. (2017). The validation of macro and micro observations of parent–child dynamics using the relationship affect coding system in early childhood. *Prevention Science, 18*, 268-280.

Dumas, J. E., LaFreniere, P. J., & Serketich, W. J. (1995). "Balance of power": a transactional analysis of control in mother-child dyads involving socially competent, aggressive, and anxious children. *Journal of Abnormal Psychology, 104*(1), 104–113. https://doi.org/10.1037//0021-843x.104.1.104

Easterbrooks, M. A., Driscoll, J. R., & Bartlett, J. D. (2008). Resilience in infancy: A relational approach. *Research in Human Development, 5*(3), 139-152.

Eisenberg, N., Vidmar, M., Spinrad, T. L., Eggum, N. D., Edwards, A., Gaertner, B., & Kupfer, A. (2010). Mothers' teaching strategies and children's effortful control: A longitudinal study. *Developmental Psychology, 46*, 1294–1308. http://dx.doi.org/10.1037/a0020236 Feldman,

Eisenberg, N., Duckworth, A. L., Spinrad, T. L., & Valiente, C. (2014). Conscientiousness: Origins in childhood?. *Developmental Psychology, 50*(5), 1331.

Eisenberg, N., Hofer, C., Sulik, M. J., & Spinrad, T. L. (2014). Self-regulation, effortful control, and their socioemotional correlates. In J. J. Gross (Ed.), *Handbook of Emotion Regulation* (pp. 157–172). The Guilford Press.

Eisenberg, N., Smith, C. L., Sadovsky, A., & Spinrad, T. L. (2004). Effortful control: Relations with emotion regulation, adjustment, and socialization in childhood. In R. F. Baumeister & K. D. Vohs (Eds.), *Handbook of self-regulation: Research, theory, and applications.* New York, NY, US: Guilford Press

Eisenberg, N., Spinrad, T. L., Fabes, R. A., Reiser, M., Cumber- land, A., Shepard, S. A., et al. (2004). The relations of effortful control and impulsivity to children's resiliency and adjustment. *Child Development, 75*, 25–46

El-Sheikh, M. (2005). The role of emotional responses and physiological reactivity in the marital conflict-child functioning link. *Journal of Child Psychology and Psychiatry, 46*, 1191–1199.

Entwisle, D. R., Alexander, K. L., & Olson, L. S. (2007). Early schooling: The handicap of being poor and male. *Sociology of Education, 80*, 114-138. doi:10.1177/003804070708000202

Fagot, B. I., & Gauvain, M. (1997). Mother–child problem solving: Continuity through the early childhood years. *Developmental Psychology, 33*, 480–488. doi: 10.1037/0012-1649.33.3.480

Fay-Stammbach, T., Hawes, D. J., & Meredith, P. (2014). Parenting influences on executive function in early childhood: A review. *Child Development Perspectives, 8*(4), 258–264

Feldman R., Eidelman A.I. (2007) Maternal Postpartum Behavior and the Emergence of Infant–Mother and Infant–Father Synchrony in Preterm and Full-Term Infants: The Role of Neonatal Vagal Tone. *Developmental Psychobiology 49*, 290–302.

Feldman, R. (2009). The development of regulatory functions from birth to 5 years: Insights from premature infants. *Child Development, 80*(2), 544-561.

Feldman, R., Dollberg, D., & Nadam, R. (2011). The expression and regulation of anger in toddlers: Relations to maternal behavior and mental representations. *Infant Behavior and Development, 34*(2), 310-320.

Feldman, R. (2003). Infant-mother and infant-father synchrony: The coregulation of positive arousal. *Infant Mental Health Journal, 24*(1), 1–23. https://doi.org/10.1002/imhj.10041

Feldman, R. (2007a). Maternal versus child risk and the development of parent – Child and family relationships in five high-risk populations. *Development and Psychopathology*,

Feldman, R. (2007b). On the origins of background emotions: From affect synchrony to symbolic expression. *Emotion, 7*(3), 601.

Feldman, R. (2007c). Parent-infant synchrony and the construction of shared timing; physiological precursors, developmental outcomes, and risk conditions. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 48*(3–4), 329–354. https://doi.org/10.1111/j.1469-7610.2006.01701.x

Feldman, R. (2012). Bio-behavioral Synchrony: A Model for Integrating Biological and Microsocial Behavioral Processes in the Study of Parenting. *Parenting, 12*(2–3), 154–164. https://doi.org/10.1080/15295192.2012.683342

Feldman, R., Greenbaum, C. W., & Yirmiya, N. (1999). Mother-infant affect synchrony as an antecedent of the emergence of self-control. *Developmental Psychology, 35*(1), 223–231. https://doi.org/10.1037/0012-1649.35.1.223

Feldman, R., Masalha, S., & Alony, D. (2006). Microregulatory Patterns of Family Interactions : Cultural Pathways to Toddlers ' Self-Regulation.

Journal of Family Psychology, 20(4), 614–623. https://doi.org/10.1037/0893-3200.20.4.614

Flanders, J. L., Leo, V., Paquette, D., Pihl, R. O., & Séguin, J. R. (2009). Rough-and-tumble play and the regulation of aggression: An observational study of father-child play dyads. *Aggressive Behavior, 35*(4), 285–295. https://doi.org/10.1002/ab.20309

Fogel, A. (1993). Two principles of communication: Co-regulation and framing. In J. Nadel & L. Camaioni (Eds.), *New Perspective in Early Communicative Development* (pp. 9–22). London: Routledge

Fox, N. A. (1994). The development of emotion regulation: Biological and behavioral considerations. *Monographs of the Society for Research in Child Development, 59*(2–3).

Fox, N. A., & Calkins, S. D. (2003). The development of self-control of emotion: Intrinsic and extrinsic influences. *Motivation and Emotion, 27*(1), 7–26. https://doi.org/10.1023/A:1023622324898

Fox, N. A., & Calkins, S. D. (1993). Pathways to aggression and social withdrawal: Interactions among temperament, attachment, and regulation. In K. Rubin & J. Asendorpf (Eds.), *Social withdrawal, inhibition, and shyness in childhood* (pp. 81–100). Hillsdale, NJ: Erlbaum

Fujita, K. (2011). On conceptualizing self-control as more than the effortful inhibition of impulses. *Personality and Social Psychology Review, 15*,352–366. https://doi.org/10.1177/1088868311411165.

Garcia-Sellers, M. J., Church, K. (2000) Avoidance, frustration, and hostility during toddlers' interaction with their mothers and fathers. *Infant Toddler Intervention, 10*, 259–274

Gardner, J. M., Walker, S. P., Powell, C. A., & Grantham-McGregor, S. (2003). A randomized controlled trial of a home-visiting intervention on cognition and behavior in term low birth weight infants. *The Journal of Pediatrics, 143*(5), 634–639.

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134*, 31–60. doi:10.1037/0033- 2909.134.1.31

Geldhof, G. J., Little, T. D., & Colombo, J. (2010). Self-regulation across the life span. *The Handbook of Life-Span Development.*

Gerstein, E. D., Pedersen y Arbona, A., Crnic, K. A., Ryu, E., Baker, B. L., & Blacher, J. (2011). Developmental risk and young children's regulatory strategies: Predicting behavior problems at age five. *Journal of Abnormal Child Psychology*, 39, 351-364.

Gianino, A., & Tronick, E. Z. (1988). The mutual regulation model: The infant's self and interactive regulation and coping and defensive capacities. In T. M. Field, P. M. McCabe, & N. Schneiderman (Eds.), *Stress and coping across development* (pp. 47–68). Lawrence Erlbaum Associates, Inc.

Granic, I., & Patterson, G. R. (2006). Toward a comprehensive model of antisocial development: A dynamic systems approach. *Psychological Review, 113*, 101–131. doi: 10.1037/0033-295X.113.1.101
Granic, I., Hollenstein, T., Dishion, T.J., & Patterson, G.R. (2003). Longitudinal analysis of flexibility and reorganization in early adolescence: A dynamic systems study of family interactions. *Developmental Psychology, 39*, 606–617.
Gray, J. R. (2004). Integration of emotion and cognitive control. *Current Directions in Psychological Science, 13*(2), 46-48.
Graziano, P. A., Reavis, R. D., Keane, S. P., Calkins, S. D. (2007). The role of emotion regulation in children's early academic success. *Journal of School Psychology, 45*, 3-19. http://dx.doi.org/10.1016/j.jsp.2006.09.002
Graziano, P., & Derefinko, K. (2013). Cardiac vagal control and children's adaptive functioning: A meta-analysis. *Biological Psychology, 94*(1), 22–37. https://doi.org/10.1016/j.biops ycho.2013.04.011
Greenberg, M. T. (2006). Promoting resilience in children and youth: Preventive interventions and their interface with neuroscience. *Annals of the New York Academy of Sciences, 1094*(1), 139-150.
Grolnick, W. S., & Pomerantz, E. M. (2009). Issues and challenges in studying parental control: Toward a new conceptualization. Child Development Perspectives, 3(3), 165–170. https://doi.org/10.1111/j.1750-8606.2009.00099.x
Grolnick, W. S., Bridges, L. J., & Connell, J. P. (1996). Emotion regulation in two-year-olds: Strategies and emotional expression in four contexts. Child Development, 67, 928–941
Gross, M., Buac, M., & Kaushanskaya, M. (2014). Conceptual scoring of receptive and expressive vocabulary measures in simultaneous and sequential bilingual children.
Guo, Y., Leu, S. Y., Barnard, K. E., Thompson, E. A., & Spieker, S. J. (2015). An examination of changes in emotion co-regulation among mother and child dyads during the Strange Situation. *Infant and Child Development (Special issue: Innovative Methods in the Science of Parent-Child Relations),* 24(3), 256–273. https://doi.org/10.1002/icd.1917.
Hammond, S. I., Muller, U., Carpendale, J. I. M., Bibok, M. B., &Liebermann-Finestone, D. P. (2012). The effects of parental scaffolding on preschoolers' executive functioning. *Developmental Psychology, 48*, 271–281.
Harman, C., Rothbart, M. K., & Posner, M. I. (1997). Distress and attention interactions in early infancy. *Motivation and Emotion, 21*, 27 – 43.
Harrist, A. W., & Waugh, R. M. (2002). Dyadic synchrony: Its structure and function in children's development. *Developmental Review, 22*(4), 555–592. https://doi.org/10.1016/S0273 - 2297(02)00500 - 2

Harrist, A. W., Pettit, G. S., Dodge, K. A., & Bates, J. E. (1994). Dyadic synchrony in mother– child interaction: Relation with children's subsequent kindergarten adjustment. *Family Relations, 43*, 417–424

Hastings, P. D., & De, I. (2008). Parasympathetic regulation and parental socialization of emotion: Biopsychosocial processes of adjustment in preschoolers. *Social Development, 17*(2), 211–238. https://doi.org/10.1111/j.1467-9507.2007.00422.x

Heckhausen, J. (1999). Balancing for weaknesses and challenging developmental potential: A longitudinal study of mother–infant dyads in apprenticeship interactions. In: Lloyd, P. & Fernyhough, C., (Eds). *Lev Vygotsky: Critical assessments. III*. Florence, KY: Taylor & Frances/Routledge;. pp. 81–100.

Hill, A. L., Degnan, K. A., Calkins, S. D., & Keane, S. P. (2006). Profiles of externalizing behavior problems for boys and girls across preschool: the roles of emotion regulation and inattention. *Developmental Psychology, 42*(5), 913.

Hoffman, C., Crnic, K. A., & Baker, J. K. (2006). Maternal depression and parenting: Implications for children's emergent emotion regulation and behavioral functioning. *Parenting: Science and Practice, 6*, 271–295. doi: 10.1207/s15327922par0604_1

Hollenstein T. (2011). Twenty years of dynamic systems approaches to development: Significant contributions, challenges, and future directions. *Child Development Perspectives, 5*, 256–259.

Hollenstein, T. (2007). State space grids: Analyzing dynamics across development. *International Journal of Behavioral Development, 31*(4), 384–396. https://doi.org/10.1177/0165025407077765

Hollenstein, T., Granic, I., Stoolmiller, M., & Snyder, J. (2004). Rigidity in parent-child interactions and the development of externalizing and internalizing behavior in early childhood. *Journal of Abnormal Child Psychology, 32*(6), 595–607. https://doi.org/10.1023/B:JACP.0000047209.37650.41

Hongwanishkul, D., Happaney, K. R., Lee, S. C., & Zelazo, P. D. (2005). Developmental neuropsychology assessment of hot and cool executive function in young children: Age-related changes and individual differences. *Developmental Neuropsychology, 28*(2), 617–644. https://doi.org/10.1207/s15326942dn2802

Howard, S. J., & Melhuish, E. (2017). An early years toolbox for assessing early executive function, language, self-regulation, and social development: Validity, reliability, and preliminary norms. *Journal of Psychoeducational Assessment, 35*(3), 255-275.

Hughes, C. (2002). Executive functions and development: Emerging themes. *Infant and Child Development: An International Journal of Research and Practice, 11*(2), 201-209.

Hughes, C. H., & Ensor, R. A. (2009). How do families help or hinder the emergence of early executive function? In C. Lewis & J. I. M. Carpendale (Eds.), *New Directions in Child and Adolescent Development* (pp. 35–50). doi:10.1002/cd

Isabella, R. A., & Belsky, J. (1991). Interactional synchrony and the origins of infant-mother attachment: A replication study. *Child Development, 62*(2), 373-384.

Kahle, S., Miller, J. G., Helm, J. L., & Hastings, P. D. (2018). Linking autonomic physiology and emotion regulation in preschoolers: The role of reactivity and recovery. *Developmental psychobiology, 60*(7), 775-788.

Kahle, S., Miller, J. G., Lopez, M., & Hastings, P. D. (2016). Sympathetic recovery from anger is associated with emotion regulation. *Journal of Experimental Child Psychology, 142*, 359-371.

Karberg, E., Cabrera, N. J., Malin, J., & Kuhns, C. (2019). Longitudinal contributions of maternal and paternal intrusive behaviors to children's sociability and sustained attention at prekindergarten. In B. L. Volling & N. J. Cabrera (Eds.), *Advancing research and measurement on fathering and children's development. Monographs of the Society of Research in Child Development, 84*(1), 79–93. https://doi.org/10.1002/mono.12404

Karreman, A., Van Tuijl, C., van Aken, M. A., & Deković, M. (2006). Parenting and self-regulation in preschoolers: A meta-analysis. *Infant and Child Development: An International Journal of Research and Practice, 15*(6), 561-579.

Kim, S., Nordling, J. K., Yoon, J. E., Boldt, L. J., & Kochanska, G. (2013). Effortful control in ¨hot¨and ¨cool¨tasks differentially predicts children´s behavior problems and academic performance. *Journal of Abnormal Child Psychology, 41*(1), 43–56. https://doi.org/10.1007/s11103-011-9767-z.

Kochanska, G. (1997). Multiple pathways to conscience for children of different temperaments: From toddlerhood to age 5. *Developmental Psychology, 33*, 228 – 240.

Kochanska, G., & Aksan, N. (1995). Mother-child mutually positive affect, the quality of child compliance to requests and prohibitions, and maternal control as correlates of early internalization. *Child Development, 66*(1), 236-254.

Kochanska, G., & Kim, S. (2014). A complex interplay among the parent–child relationship, effortful control, and internalized, rule-compatible conduct in young children: Evidence from two studies. *Developmental Psychology, 50*(1), 8.

Kochanska, G., & Murray, K. T. (2000). Mother–child mutually responsive orientation and conscience development: From toddler to early school age. *Child Development, 71*(2), 417-431.

Kochanska, G., Aksan, N., Prisco, T. R., & Adams, E. E. (2008). Mother–child and father–child mutually responsive orientation in the first 2 years and children's outcomes at preschool age: Mechanisms of influence. *Child Development, 79*(1), 30-44.

Kochanska, G., Brock, R. L., Chen, K. H., Aksan, N., & Anderson, S. W. (2015). Paths from mother-child and father-child relationships to externalizing behavior problems in children differing in electrodermal reactivity: A longitudinal study from infancy to age 10. *Journal of Abnormal Child Psychology, 43*, 721-734.

Kochanska, G., Coy, K. C., & Murray, K. T. (2001). The development of self-regulation in the first four years of life. *Child Development, 72*(4), 1091-1111.

Kochanska, G., Coy, K. C., Tjebkes, T. L., & Husarek, S. J. (1998). Individual differences in emotionality in infancy. *Child Development, 69*(2), 375-390.

Kochanska, G., Murray, K. T., & Harlan, E. T. (2000). Effortful control in early childhood: continuity and change, antecedents, and implications for social development. *Developmental Psychology, 36*(2), 220-232.

Kochanska, G., Murray, K., & Coy, K. C. (1997). Inhibitory control as a contributor to conscience in childhood: from toddler to early school age. *Child Development, 67*, 263–277.

Kopp, C. B. (1982). Antecedents of self-regulation: a developmental perspective. *Developmental Psychology, 18*(2), 199.

Kopp, C. B. (1989). Regulation of distress and negative emotions: A developmental view. *Developmental Psychology, 25*(3), 343–354. https://doi.org/10.1037/0012-1649.25.3.343

Koziol, L. F., Budding, D. E., & Chidekel, D. (2012). From movement to thought: executive function, embodied cognition, and the cerebellum. *The Cerebellum, 11*(2), 505-525.

Lamey, A., Hollenstein, T., Lewis, M. D., & Granic, I. (2004). Gridware (Version 1.1). http://www.statespacegrids.org

Lavelli, M., Carra, C., Rossi, G., & Keller, H. (2019). Culture-specific development of early mother–infant emotional co-regulation: Italian, Cameroonian, and West African immigrant dyads. *Developmental Psychology, 55*(9), 1850.

Leclère, C., Viaux, S., Avril, M., Achard, C., Chetouani, M., Missonnier, S., & Cohen, D. (2014). Why synchrony matters during mother-child interactions: a systematic review. *PloS one, 9*(12), e113571.

Lengua, L. J., & Kovacs, E. A. (2005). Bidirectional associations between temperament and parenting and the prediction of adjustment problems

in middle childhood. *Journal of Applied Developmental Psychology, 26*(1), 21-38.
Lerner, R. M. (2006). Developmental Science, Developmental Systems, and Contemporary Theories of Human Development. In R. M. Lerner & W. Damon (Eds.), *Handbook of child psychology: Theoretical models of human development* (pp. 1–17). John Wiley & Sons, Inc..
Lerner, R. M., & Overton, W. F. (2008). Exemplifying the integrations of the relational developmental system: Synthesizing theory, research, and application to promote positive development and social justice. *Journal of Adolescent Research, 23*(3), 245-255.
Lewis M. D., Lamey A. V., Douglas L. (1999). A new dynamic systems method for the analysis of early socioemotional development. *Developmental Science, 2*, 457–475.
Lewis, M. D. (2011). Dynamic systems approaches: Cool enough? Hot enough? Child Development Perspectives, 5(4), 279–285. https://doi.org/10.1111/j.1750-8606.2011.00190.x
Lewis, C., & Carpendale, J. I. (2009). Introduction: Links between social interaction and executive function. *New Directions for Child and Adolescent Development, 2009*(123), 1-15.
Lewis, M. D., & Todd, R. M. (2007). The self-regulating brain: Cortical-subcortical feedback and the development of intelligent action. *Cognitive Development, 22*(4), 406–430. https://doi.org/10.1016/j.cogdev.2007.08.004
Li-Grining, C. P. (2007). Effortful control among low-income preschoolers in Three Cities: Stability, change, and individual differences. *Developmental Psychology, 43*(1), 208–221. https://doi.org/10.1037/0012-1649.43.1.208
Liew, J. (2012). Effortful Control, Executive Functions, and Education: Bringing Self-Regulatory and Social-Emotional Competencies to the Table. *Child Development Perspectives, 6*(2), 105–111. https://doi.org/10.1111/j.1750-8606.2011.00196.x
Lindsey, E. W., & Mize, J. (2000). Parent-child pretense and physical play: links to children's social competence. *Merrill-Palmer Quarterly, 46*, 565–590.
Lindsey, E. W., Cremmens, P., Colwell, M. J., & Caldera, Y. M. (2009). The structure of parent-child dyadic synchrony in toddlerhood and children's communication competence and self-control. *Social Development, 17*, 375–396.
Lindsey, E. W., Mize, J., & Pettit, G. S. (1997). Mutuality in parent-child play: Consequences for children's peer competence. *Journal of Social and Personal Relationships, 14*(4), 523-538.
Loulis, S., & Kuczynski, L. (1997). Beyond one hand clapping: Seeing bidirectionality in parent-child relations. *Journal of Social and Personal Relationships, 14*(4), 441-461.

Lunkenheimer, E. S., Olson, S. L., Hollenstein, T., Sameroff, A. J., & Winter, C. (2011). Dyadic flexibility and positive affect in parent-child coregulation and the development of child behavior problems. *Development and Psychopathology, 23*(2), 577–591. https://doi.org/10.1017/S095457941100006X

Lunkenheimer, E., Hamby, C. M., Lobo, F. M., Cole, P. M., & Olson, S. L. (2020). The role of dynamic, dyadic parent–child processes in parental socialization of emotion. *Developmental Psychology, 56*(3), 566.

Lunkenheimer, E. S., Dishion, T. J., Shaw, D. S., Connell, A. M., Gardner, F., Wilson, M. N., et al. (2008). Collateral benefits of the family check-up on early childhood school readiness: Indirect effects of parents' positive behavior support. Developmental Psychology, 44, 1737– 1752. doi: 10.1037/a0013858

Lunkenheimer, E., Kemp, C. J., Lucas-Thompson, R. G., Cole, P. M., & Albrecht, E. C. (2017). Assessing biobehavioural self-regulation and coregulation in early childhood: The parent-child challenge task. *Infant and Child Development, 26*(1), e1965. https://doi.org/10.1002/icd.1965

Lunkenheimer, E.S. (2009). Unpublished manual. Colorado State University. Dyadic Interaction Code.

Lupien, S. J., McEwen, B. S., Gunnar, M. R., & Heim, C. (2009). Effects of stress throughtout the lifespan on the brain, behavior, and cognition. *Nature Reviews Neuroscience, 10*, 434-445.

Lytton H. (1990). Child and parent effects in boys' conduct disorder: A reinterpretation. *Developmental Psychology, 26*(5), 683–697. doi: 10.1037/0012-1649.26.5.683.

Maccoby, E. E., & Martin, J. A. (1983). Socialization in the context of the family: Parent-child interaction. In P. H. Mussen (Ed.), *Manual of child psychology* (Vol. 4, p. 1983). New York, NY: John Wiley and Sons, Inc.

MacDonald, K., & Parke, R. D. (1986). Parent-child physical play: The effects of sex and age of children and parents. *Sex Roles, 15*(7-8), 367-378.

Mangelsdorf, S. C., Shapiro, J. R., & Marzolf, D. (1995). Developmental and temperamental differences in emotion regulation in infancy. *Child Development, 66*(6), 1817-1828.

Mann, T., De Ridder, D., & Fujita, K. (2013). *Self-regulation of health behavior: social psychological approaches to goal setting and goal striving* (Vol. 32, No. 5, p. 487). American Psychological Association.

Mantis, I., Stack, D. M., Ng, L., Serbin, L. A., & Schwartzman, A. E. (2014). Mutual touch during mother–infant face-to-face still-face interactions: Influences of interaction period and infant birth status. *Infant Behavior and Development, 37*(3), 258-267.

Marcovitch, S., Leigh, J., Calkins, S. D., Leerks, E. M., O'Brien, M., & Blankson, A. N. (2010). Moderate vagal withdrawal in 3.5-year-old children is associated with optimal performance on executive function tasks. *Developmental Psychobiology, 52*(6), 603-608.

Matthews, J. S., Cameron Ponitz, C., & Morrison, F. J. (2009). Early gender differences in self-regulation and academic achievement. *Journal of Educational Psychology, 101*, 689–704

Matthews, J. S., Marulis, L. M., & Williford, A. P. (2014). Gender processes in school functioning and the mediating role of cognitive self-regulation. *Journal of Applied Developmental Psychology, 35*(3), 128-137.

McCabe, L. A., & Brooks-Gunn, J. (2007). With a little help from my friends?: Self-regulation in groups of young children. *Infant Mental Health Journal, 28*(6), 584-605.

McClelland, M. M., Acock, A. C., Piccinin, A., Rhea, S. A., & Stallings, M. C. (2013). Relations between preschool attention span-persistence and age 25 educational outcomes. *Early Childhood Research Quarterly, 28*(2), 314-324.

McClelland, M. M., Cameron, C. E., Duncan, R., Bowles, R. P., Acock, A. C., Miao, A., & Pratt, M. E. (2014). Predictors of early growth in academic achievement: The head-toes-knees-shoulders task. *Frontiers in Psychology, 5*, 599.

McClelland, M. M., Geldhof, J., Cameron, C. E., & Wanless, S. B. (2015). Development and self-regulation. In W. F. Overton & P. C. M. Molenaar (Eds.), *Handbook of Child Psychology and Developmental Science* (7th ed., Vol. 1, pp. 523–565). Hoboken, NJ: Wiley.

McClelland, M. M., & Cameron, C. E. (2011a). Self- regulation in early childhood: Improving conceptual clarity and developing ecologically valid measures. *Child Development Perspectives, 6*(2), 136–142.

McClelland, M. M., & Cameron, C. E. (2011b). Self-regulation and academic achievement in elementary school children. *New Directions for Child and Adolescent Development, 2011*(133), 29-44.

McClelland, M. M., Cameron, C. E., Connor, C. M. D., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers’ literacy, vocabulary, and math skills. *Developmental Psychology, 43*(4), 947–959. https://doi.org/10.1037/0012-1649.43.4.947 .

McClelland, M. M., Ponitz, C. C., Messersmith, E. E., & Tominey, S. (2010). Self-regulation: Integration of cognition and emotion. In W. F. Overton & R. M. Lerner (Eds.), *The handbook of life- span development, cognition, biology, and methods* (Vol. 1, pp. 509–553). New York: Wiley

McMahon, C., & Newey, B. (2018). Non-attuned mind-mindedness, infant negative affect, and emotional availability: Assessing mind-mindedness during the still-face paradigm. *Infancy, 23*, 873–892. https://doi.org/10.1111/infa.12245.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, 24*(1), 167-202.

Miller, J. G., Kahle, S., & Hastings, P. D. (2015). Roots and Benefits of Costly Giving: Children Who Are More Altruistic Have Greater Autonomic Flexibility and Less Family Wealth. *Psychological Science, 26*(7), 1038-1045. https://doi.org/10.1177/0956797615578476

Mischel, W., Shoda, Y., & Peake, P. K. (1988). The nature of adolescent competencies predicted by preschool delay of gratification. *Journal of Personality and Social Psychology, 54*(4), 687.

Mischel, W., Ebbesen, E. B., & Raskoff Zeiss, A. (1972). Cognitive and attentional mechanisms in delay of gratification. *Journal of Personality and Social Psychology, 21*(2), 204.

Mistry, R. S., Benner, A. D., Biesanz, J. C., Clark, S. L., & Howes, C. (2010). Family and social risk, and parental investments during the early childhood years as predictors of low-income children's school readiness outcomes. *Early Childhood Research Quarterly, 25*(4), 432-449.

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21*(1), 8-14.

Miyake, A., Emerson, M. J., & Friedman, N. P. (2000). Assessment of executive functions in clinical settings: problems and recommendations. *Seminars in Speech and Language, 21*, 169e183.

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., Caspi, A. (2011). A gradient of childhood self- control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences of the United States of America, 108*, 2693–2698.

Montroy, J. J., Bowles, R. P., Skibbe, L. E., McClelland, M. M., & Morrison, F. J. (2016). The development of self-regulation across early childhood. *Developmental Psychology, 52*, 1744–1762. https://doi.org/10.1037/dev0000159

Moore, G. A., Hill-Soderlund, A. L., Propper, C. B., Calkins, S. D., Mills-Koonce, W. R., & Cox, M. J. (2009). Mother-Infant Vagal Regulation in the Face-To-Face Still- Face Paradigm Is Moderated by Maternal Sensitivity. *Child Development, 80*(1), 209–223. https://doi.org/10.1111/j.1467-8624.2008.01255.x

Morelen, D., & Suveg, C. (2012). A real-time analysis of parent-child emotion discussions: the interaction is reciprocal. *Journal of Family Psychology, 26*(6), 998.

Morrison, F. J., & Grammer, J. K. (2016). Conceptual clutter and measurement mayhem: A proposal for a cross disciplinary approach to conceptualizing and measuring executive function. In J. Griffin, P. McCardle & L. Freund (Eds.), *Executive function in preschool age children: Integrating measurement, neurodevelopment and translational research* (pp. 327–348). Washington, DC: American Psychological Association.

Morrison, F. J., Ponitz, C. C., & McClelland, M. M. (2010). Self-regulation and academic achievement in the transition to school. In S. D. Calkins & M.

Bell (Eds.), *Child development at the intersection of emotion and cognition* (pp. 203–224). Washington, DC: American Psychological Association.
Müller, U., Dick, A. S., Gela, K., Overton, W. F., & Zelazo, P. D. (2006). The role of negative priming in preschoolers' flexible rule use on the Dimensional Change Card Sort Task. *Child Development, 77*(2), 395–412.
Mulvaney, M. K., McCartney, K., Bub, K. L., & Marshall, N. L. (2006). Determinants of dyadic scaffolding and cognitive outcomes in first graders. Parenting: Science and Practice, 6, 297–320. doi: 10.1207/s15327922par0604_2
Murray, K.,& Kochanska, G. (2002). Effortful control: Factor structure and relation to externalizing and internalizing behaviors. *Journal of Abnormal Child Psychology, 30*, 414–503.
Nigg, J. T. (2017). Annual research review: On the relations among self-regulation, self-control, executive functioning, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psychopathology. *Journal of Child Psychology and Psychiatry, 58*(4), 361–383. https://doi.org/10.1111 /jcpp.12675
O'Connor, T. G. (2002). Annotation: The 'effects' of parenting reconsidered: findings, challenges, and applications. *The Journal of Child Psychology and Psychiatry, 43*(5), 555-572.
Ochsner, K. N., & Gross, J. J. (2004). Thinking makes it so: A social cognitive neuroscience approach to emotion regulation. *Handbook of self-regulation: Research, theory, and applications,* 229-255.
Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Science, 9*(5), 242-249. doi: 10.1016/j.tics.2005.03.010.
Ochsner, K.N., Ray, R.D., Cooper, J.C., Robertson, E.R., Chopra, S., Gabrieli, J.D., Gross, J.J., (2004). For better or for worse: neural systems supporting the cognitive down- and up-regulation of negative emotion. *NeuroImage, 23*, 483–499
Olson, S. L., Sameroff, A. J., Kerr, D. C., Lopez, N. L., & Wellman, H. M. (2005). Developmental foundations of externalizing problems in young children: The role of effortful control. Development and Psychopathology, 17(1), 25–45.
Olson, S.L., & Lunkenheimer, E.S. (2017). Expanding concepts of self-regulation to social relationships: Transactional processes in the development of early behavioral adjustment. In: Sameroff AJ, editor. *The transactional model of development*. Washington, DC: APA, 55–76.
Overton, W. F. (2006). Developmental Psychology: Philosophy, Concepts, Methodology. In R. M. Lerner & W. Damon (Eds.), *Handbook of child psychology: Theoretical models of human development* (pp. 18–88). John Wiley & Sons, Inc.

Patterson, G.R., & Bank, L. (1989). Some amplifying mechanisms for pathologic processes in families. In Gunnar, M.R. & Thelen, E. (Eds). *Systems and development.* Hillsdale, NJ: Erlbaum;. pp. 167–209.

Pauli-Pott, U., Schloß, S. & Becker, K. (2018). Maternal Responsiveness as a Predictor of Self-Regulation Development and Attention-Deficit/Hyperactivity Symptoms Across Preschool Ages. *Child Psychiatry & Human Development, 49*, 42–52. https://doi.org/10.1007/s10578-017-0726-z

Perry, N. B., Swingler, M. M., Calkins, S. D., & Bell, M. A. (2016). Neurophysiological correlates of attention behavior in early in- fancy: Implications for emotion regulation during early childhood. *Journal of Experimental Child Psychology, 142*, 245–261. https://doi.org/10.1016/j.jecp.2015.08.007

Piquero, A. R., Jennings, W. G., Farrington, D. P. (2010) On the malleability of self-control: Theoretical and policy implications regarding a general theory of crime. *Justice, 27,* 803–834.

Porges, S. W. (1991). Vagal tone: An autonomic mediator of affect. In J. Garber & K. A. Dodge (Eds.), *The development of emotion regulation and dysregulation* (pp. 111–128). NewYork: Cambridge University Pres

Porges, S. W. (1995). Cardiac vagal tone: A physiological index of stress. *Neuroscience & Biobehavioral Reviews, 19*(2), 225–233. https://doi.org/10.1016/0149-7634(94)00066-A

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology, 74*(2), 116–143. https://doi.org/10.1016/j.biopsycho.2006.06.009

Porges, S. W., Doussard-Roosevelt, J. A., Portales, A. L., & Greenspan, S. I. (1996). Infant regulation of the vagal 'brake' predicts child behavior problems: A psychobiological model of social behavior. Developmental Psychobiology, 29(8), 697–712

Posner, M. I., & Rothbart, M. K. (2000). Developing mechanisms of self-regulation. *Development and Psychopathology, 12*, 427 – 441.

Provenzi, L., Borgatti, R., Menozzi, G., & Montirosso, R. (2015). A dynamic system analysis of dyadic flexibility and stability across the Face-to-Face Still-Face procedure: Application of the state space grid. *Infant Behavior and Development, 38*, 1–10. https://doi.org/10.1016/j.infbeh.2014.10.001

Putnam, S. P., & Rothbart, M. K. (2006). Development of short and very short forms of the Children's Behavior Questionnaire. *Journal of Personality Assessment, 87*(1), 102-112.

Putnam, S. P., Spritz, B. L., & Stifter, C. A. (2002). Mother-child coregulation during delay of gratification at 30 months. *Infancy, 3*(2), 209–225. https://doi.org/10.1207/S15327078IN0302

Raffaelli, M., Crockett, L. J., & Shen, Y. (2005). Developmental stability and change in self-regulation from childhood to adolescence. *Journal of Genetic Psychology, 166*, 54–75. doi:10.3200/ GNTP.166.1.54-76

Rimm-Kaufman S.E., Curby T.W., Grimm K.J., Nathanson L., Brock L.L. (2009). The contribution of children's self-regulation and classroom quality to children's adaptive behaviors in the kindergarten classroom. *Developmental Psychology, 45*(4):958–72

Robinson, J. B., Burns, B. M., &Davis, D. (2009). Maternal scaffolding and attention regulation in children living in poverty. *Journal of Applied Developmental Psychology, 30*, 82–91. doi: 10.1016/j.appdev.2008.10.013

Robson, D. A., Allen, M. S., & Howard, S. J. (2020). Self-regulation in childhood as a predictor of future outcomes: A meta-analytic review. *Psychological Bulletin, 146*(4), 324–354. https:// doi. org/ 10. 1037/ bul00 00227

Rosanbalm, K. D., & Murray, D. W. (2017). Promoting Self-Regulation in the First Five Years: A Practice Brief. OPRE Brief 2017-79. Administration for Children & Families.

Rothbart, M. K. (1989). Temperament and development. In G. A. Kohnstamm, J. A. Bates, & M. K. Rothbart (Eds.), *Temperament in childhood* (pp. 187–247). New York: Wiley.

Rothbart, M. K., & Bates, J. E. (2006). Temperament. In W. Damon (Series Ed.) & N. Eisenberg (Vol. Ed.), *Handbook of child psychology: Vol. 3. Social, emotional, and personality development* (6th ed., pp. 99–166). New York: Wiley.

Rothbart, M. K., Ahadi, S. A., & Evans, D. E. (2000a). Temperament and personality: origins and outcomes. *Journal of personality and social psychology, 78*(1), 122.

Rothbart, M. K., Derryberry, D., & Hershey, K. (2000b). Stability of temperament in childhood: Laboratory infant assessment to parent report at seven years. In V. J. Molfese & D. L. Molfese (Eds.), *Temperament and personality development across the life span* (pp. 85–119). Hillsdale, NJ: Erlbaum

Rothbart, M. K., Ellis, L. K., & Posner, M. I. (2004). Temperament and self-regulation. *Handbook of self-regulation: Research, theory, and applications, 2*, 441-460.

Rothbart, M. K., Posner, M. I. & Kieras, J. (2006). Temperament, attention, and the development of self-regulation. In K. McCartney & D. Phillips (Eds.), *Blackwell handbook of early childhood development* (pp. 338–357). Malden: Blackwell Publishing

Rothbart, M. K., Sheese, B. E., Rueda, M. R., & Posner, M. I. (2011). Developing mechanisms of self-regulation in early life. Emotion Review : Journal of the International Society for Research on *Emotion, 3*(2), 207–213.

Rothbart, M. K., Ziaie, H., & O'Boyle, C. G. (1992). Self-regulation and emotion in infancy. In N. Eisenberg & R. A. Fabes (Eds.), *Emotion and its regulation in early development: New directions for child development* (pp. 7–23). No. 55: The Jossey-Bass education series. San Francisco: Jossey-Bass Publishers.

Sameroff, A. (2009). The transactional model of development: How children and contexts shape each other. Washington, DV: American Psychological Association.

Sameroff, A. (2010). A unified theory of development: A dialectic integration of nature and nurture. *Child Development, 81*, 6–22. https://doi.org/10.1111/j.1467- 8624.2009.01378.x

Sameroff, A. J., & Mackenzie, M. J. (2003). Research strategies for capturing transactional models of development: The limits of the possible. *Development and Psychopathology, 15*(3), 613-640.

Sameroff, A.J., & Chandler, M.J. (1975). Reproductive risk and the continuum of caretaking casualty. In Horowitz, F.D. (Ed). *Review of child development research, 4*, 187–244. Chicago: University of Chicago Press.

Sander, L. (1977). The regulation of exchange in the infant-caretaker system and some aspects of the context-content relationship. In M. Lewis & L. Rosenblum (Eds.), *Interaction, conversation, and the developoment of language* (pp. 133–156). New York: Wiley.

Sander, L. (1985). Toward a logic of organization in psycho-biological development. In K. Klar & L. Siever (Eds.), *Biologic response styles: Clinical implications* (pp. 20–36). Monographs of the American Psychiatric Association, Washington DC.

Scaramella, L.V., Sohr-Preston, S.L., Mirabile, S.P., Robison, S.D., & Callahan, K.L. (2008). Parenting and children's distress reactivity during toddlerhood: An examination of direction of effects. *Social Development, 17*, 578–595. doi: 10.1111/j.1467-9507.2007.00439.x.

Schoppe-Sullivan, S. J., Kotila, L. E., Jia, R., Lang, S. N., & Bower, D. J. (2013). Comparisons of levels and predictors of mothers' and fathers' engagement with their preschool aged children. *Early Child Development and Care, 1*(183), 498–514. https://doi.org/10.1080/03004430.2012.711596.Comparisons

Schueler, C. M., & Prinz, R. J. (2013). The Role of Caregiver Contingent Responsiveness in Promoting Compliance in Young Children. *Child Psychiatry and Human Development, 44*, 370–381. https://doi.org/10.1007/s10578-012-0331-0

Shapiro, A. F., & Gottman, J. M. (2004). The specific affect coding system. In *Couple observational coding systems* (pp. 205-222). Routledge.

Shields, A., & Cicchetti, D. (1997). Emotional regulation among school-age children: The development and validation of a new criterion Q-sort scale. *Developmental Psychology, 33*, 906–916.

Shoda, Y., Mischel, W., & Peake, P. K. (1990). Predicting adolescent cognitive and self-regulatory competencies from preschool delay of gratification: Identifying diagnostic conditions. *Developmental Psychology, 26*, 978–986

Shonkoff, J. P., Garner, A. S., Siegel, B. S., Dobbins, M.I., Earls, M.F., et al. (2012). The lifelong effects of early childhood adversity and toxic stress. *Pediatrics, 129*, 232–246.

Sigel, I. E., Stinson, E. T., & Kim, M. (1993). Socialization of cognition: The distancing model. In R. H. Wozniak, & K. W. Fischer (Eds.), *Development in context: Acting and thinking in specific environments* (pp. 211–224). Hillsdale, NJ: Erlbaum.

Skuban, E. M., Shaw, D. S., Gardner, F., Supplee, L. H., & Nichols, S. R. (2006). The correlates of dyadic synchrony in high-risk, low-income toddler boys. *Infant Behavior and Development, 29*, 423–434. doi:10.1016/ j.infbeh.2006.02.004

Smith, L. B., & Thelen, E. (1993). *A dynamic systems approach to development.* Cambridge, MA: MIT Press

Smith, L.B., & Thelen, E. (2003). Development as a dynamic system. *Trends in Cognitive Sciences, 7*, 343–348.

Stansbury, K., & Gunnar, M. R. (1994). Adrenocortical activity and emotion regulation. In N. A. Fox (Ed.), *The development of emotion regulation: Biological and behavioral considerations. Monographs of the Society for Research in Child Development, 59*(2-3, Serial No. 240), 108 – 134

Stern, D. N. (1985). *The interpersonal world of the infant: A view from psychoanalysis and developmental psychology*. New York: Basic Books

Stifter, C. A., & Braungart, J. M. (1995). The regulation of negative reactivity in infancy: Function and development. *Developmental Psychology, 31*, 448 – 455

Stifter, C. A., & Corey, J. M. (2001). Vagal regulation and observed social behavior in infancy. *Social Development, 10*(2), 189-201.

Stifter, C. A., & Spinrad, T. L. (2002). The effect of excessive crying on the development of emotion regulation. *Infancy, 3*(2), 133-152.

Strand, P. S. (2002). Coordination of maternal directives with pre- schoolers' behavior: Influence of maternal coordination training on dyadic activity and child compliance. *Journal of Clinical Child and Adolescent Psychology, 31*(1), 6–15. https://doi.org/10. 1207/s15374424jccp3101_03.

Suveg, C., Shaffer, A., & Davis, M. (2016). Family stress moderates relations between physiological and behavioral synchrony and child self-regulation in mother- preschooler dyads. Developmental Psychobiology, 58(1), 83–97. https://doi.org/10.1002/dev.21358.Family

Thelen, E., & Smith, L. B. (1994). *A dynamic systems approach to the development of cognition and action.* Cambridge, MA: Bradford/MIT Press

Thelen, E., & Ulrich, B.D. (1991). Hidden skills: A dynamic systems analysis of treadmill stepping during the first year. *Monographs of the Society for Research in Child Development, 56*(1, Serial No. 223)

Thomassin, K., & Suveg, C. (2014). Reciprocal positive affect and well-regulated, adjusted children: A unique contribution of fathers. *Parenting: Science and Practice, 14*(1), 28–46. https://doi.org/10.1080/15295192.2014.880017

Thompson, R. A., Virmani, E. A., Waters, S. F., Raikes, H. A., & Meyer, S. (2013). The Development of Emotion Self-Regulation: The Whole and the Sum of the Parts. In Handbook of self-regulatory processes in development (pp. 5-26). Psychology Press.

Thompson, R. A. (1994). Emotion regulation: A theme in search of definition. *Monographs of the Society for Research in Child Development*, 25-52.

Thorell, L. B. (2007). Do delay aversion and executive function deficits make distinct contributions to the functional impact of ADHD symptoms? A study of early academic skill deficits. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 48*(11), 1061–1070. https://doi.org/10.1111/j.1469-7610.2007.01777.x

Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner review: Do performance-based measures and ratings of executive function assess the same construct?. *Journal of child psychology and psychiatry, 54*(2), 131-143.

Tronick, E. (1989). Emotions and emotional communication in infants. *American Psychologist, 44*(2), 112–119. https://doi.org/10.1037//0003-066x.44.2.112

Tronick, E. (2005). Why is connection with others so critical? The formation of dyadic states of consciousness and the expansion of individuals' states of consciousness: Coherence governed selection and the co- creation of meaning out of messy meaning making. In *Emotional development: Recent research advances* (pp. 293– 315). Oxford University Press

Tronick, E. (2007). *The Neurobehavioral and Social-Emotional Development of Infants and Children* (Norton Series on Interpersonal Neurobiology). WW Norton & Co.

Tronick, E. Z., & Beeghly, M. (2011). Infants' meaning-making and the development of mental health problems. *American Psychologist, 66*, 107–119

Tronick, E. Z., & Gianino, A. (1986). Interactive mismatch and repair: Challenges to the coping infant. *Zero to Three, 6,* 1–6

Tronick, E. Z., Messinger, D. S., Weinberg, M. K., Lester, B. M., LaGasse, L., Seifer, R., Bauer, C. R., Shankaran, S., Bada, H., Wright, L. L., Poole, K., & Liu, J. (2005). Cocaine exposure is associated with subtle compromises of Infants' and Mothers' social- emotional behavior and dyadic features of their interaction in the face- to- face still- face paradigm. *Developmental Psychology, 41*(5), 711– 722. https://doi.org/10.1037/0012- 1649.41.5.711

Ursache, A., Blair, C., & Raver, C. C. (2012). The Promotion of Self-Regulation as a Means of Enhancing School Readiness and Early Achievement in Children at Risk for School Failure. *Child Development Perspectives, 6*(2), 122–128. doi:10.1111/j.1750-8606.2011.00209.x

U.S Department of Health and Human Services, Administration for Children and Families, Office of Head Start. (2015). *Head Start Early Learning Outcomes Framework: Ages Birth to Five*. Washington, DC.

Vallotton, C. D., & Ayoub, C. C. (2011). Use your words: The role of language in the development of toddlers' self-regulation. *Early Childhood Research Quarterly, 26*(2), 169–181. https://doi.org/10.1016/j.biotechadv.2011.08.021.Secreted

Van Egeren, L. A., Barratt, M. S., & Roach, M. A. (2001). Mother–infant responsiveness: Timing, mutual regulation, and interactional context. *Developmental Psychology, 37*(5), 684–697. https://doi.org/10.1037/0012-1649.37.5.684

Vandenbroucke, L., Spilt, J., Verschueren, K., Piccinin, C., & Baeyens, D. (2018). The classroom as a developmental context for cognitive development: A meta-analysis on the importance of teacher–student interactions for children's executive functions. *Review of Educational Research, 88*(1), 125-164.

Vaughn, B. E., Kopp, C. B., & Krakow, J. B. (1984). The emergence and consolidation of self-control from eighteen to thirty months of age: Normative trends and individual differences. *Child Development, 55*, 990–1004. doi:10.2307/1130151

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard Press.

Vohs K. D., Baumeister R. (Eds.). (2011). *Handbook of self-regulation: Research, theory, and applications* (2nd ed.). New York, NY: Guilford Press.

von Suchodoletz, A., Gestsdottir, S., Wanless, S. B., McClelland, M. M., Birgisdottir, F., Gunzenhauser, C., & Ragnarsdottir, H. (2013). Behavioral self-regulation and relations to emergent academic skills among children in Germany and Iceland. *Early Childhood Research Quarterly, 28*, 62–73.

Wanless, S.B., Kim, K.H., Zhang, C., Degol, J.L., Chen, J.L., & Chen, F.M. (2016). Trajectories of behavioral regulation for Taiwanese children from 3.5 to 6 years and relations to math and vocabulary outcomes. *Early Childhood Research Quarterly, 34*, 104–114. doi: 10.1016/j.ecresq.2015.10.001.

Welsh, M., & Peterson, E. (2014). Issues in the conceptualization and assessment of hot executive functions in childhood. *Journal of the International Neuropsychological Society, 20*(2), 152–156. https://doi.org/10.1017 /S1355617713001379

Wertsch, J. V. (1979). From Social Interaction to Higher Psychological Processes. A Clarification and Application of Vygotsky's Theory. *Human Development 1, 22* (1), 1–22. https://doi.org/10.1159/000272425

Willoughby, M. T., Wirth, R. J., & Blair, C. B. (2011). Contributions of modern measurement theory to measuring executive function in early childhood: An empirical demonstration. *Journal of Experimental Child Psychology, 108,* 414–435. doi:10.1016/j.jecp.2010.04.007

Wilson, B., & Gottman, J. (1996). Attention-the shuttle between emotion and cognition: Risk resiliency, and physiological bases. In E. Hetherington, & E. Blechman (Eds.), *Stress, coping and resiliency in children and families*. (pp. 3–22). Mahwah, NJ: Erlbaum

Woltering, S., & Lewis, M. D. (2009). Developmental pathways of emotion regulation in childhood: a neuropsychological perspective. *Mind, Brain, and Education, 3*(3), 160–169. doi:10.1111/j.1751- 228X.2009.01066.x.

Woltering, S., Lishak, V., Elliott, B., Ferraro, L., & Granic, I. (2015). Dyadic Attunement and Physiological Synchrony During Mother-Child Interactions : An Exploratory Study in Children With and Without Externalizing Behavior Problems. *Journal of Psychopathology and Behavioral Assessment, 37*, 624–633. https://doi.org/10.1007/s10862-015-9480-3

Zachariou, A., & Whitebread, D. (2019). Journal of Applied Developmental Psychology Developmental differences in young children ' s self-regulation. *Journal of Applied Developmental Psychology, 62*(May), 282–293. https://doi.org/10.1016/j.appdev.2019.02.002

Zelazo, P. D., Carlson, S. M., & Kesek, A. (2008). The development of executive function in childhood. In C. A. Nelson & M. Luciana (Eds.), *Handbook of developmental cognitive neuroscience* (pp. 553–574). Boston Review.

Zelazo, P. D. (2015). Executive function: Reflection, iterative reprocessing, complexity, and the developing brain. Developmental Review, 38, 55–68. https://doi.org/10.1016/j.dr.2015.07.001

Zelazo, P. D., & Müller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Handbook of childhood cognitive development* (pp. 445 – 469). Oxford, UK: Blackwell

Zelazo, P. D., Muller, U., Frye, D., & Marcovitch, S. (2003). The development of executive function. *Monographs of the Society for Research in Child Development, 68*, 11–27.

Zhou, Q., Chen, S. H., & Main, A. (2012). Commonalities and differences in the research on children's effortful control and executive function: A call for an integrated model of self-regulation. *Child Development Perspectives, 6*(2), 112–121. https://doi.org/10.1111/j.1750-8606.2011.00176.x