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## Abstract

To support at-risk families and interrupt the intergenerational transmission of adverse childhood experiences (ACEs; e.g., mental illness, abuse and neglect), it is essential to investigate the underlying mechanisms of these cycles. One mechanism of interest is emotion dysregulation (ED), a transdiagnostic marker of psychopathology that involves both intra- and interpersonal processes and develops within parent-child co-regulatory transactions. To explore these transactions, this dissertation extends the 'Tripartite Model of the Impact of the Family on Children's Emotion Regulation' by adding four variables: physiological factors, biobehavioral synchrony, social support, and environmental factors. The Revised Tripartite Model with its emphasis on dynamic, bidirectional influences offers a comprehensive framework to understand how children's emotion regulation and psychological adjustment is shaped. Particular focus in this dissertation is placed on borderline personality disorder (BPD), a condition marked by ED and interpersonal difficulties.

The aim of this dissertation was to investigate specific aspects of the model, explore their implications for the development of children's emotion regulation within a co-regulatory context, and outline directions for future research and clinical practice.

**Study 1** employed a longitudinal design with a community sample of mothers and their young infants. Maternal dissociative symptoms 5 months postpartum were related to higher self-reported parenting stress, bonding impairments, and increased risk of physical abuse 12 months postpartum. They also predicted impaired observed parenting behavior and mediated the relationship between maternal abuse history and self-reported parenting difficulties. **Study 2** and **3** investigated a clinical sample of mother-adolescent dyads and focused on individual behavior and physiology as well as biobehavioral synchrony in the context of adolescent borderline personality traits. For BPD dyads, reduced quality of maternal and adolescent behavior, and a lower adolescent resting state heart rate variability (HRV) were found. Only mothers in healthy dyads displayed concordant HRV and behavior. BPD dyads showed lower behavioral synchrony than HC dyads. Under stress, HC dyads increased their behavioral synchrony but did not show any HRV synchrony, while BPD dyads decreased their behavioral synchrony and were positively synchronized in HRV. **Study 4** highlights the protective role of social support, demonstrating its potential to buffer the negative impact of ACEs across generations.

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## **List of Scientific Publications for the Publication-Based Dissertation**

### Manuscript 1:

**Williams, K.**, Moehler, E., Kaess, M., Resch, F., & Fuchs, A. (2022). Dissociation links maternal history of childhood abuse to impaired parenting. *Journal of Trauma & Dissociation*, 23(1), 37–51. <https://doi.org/10.1080/15299732.2021.1934938>

### Manuscript 2:

**Williams, K.**, Fleck, L., Fuchs, A., Koenig, J., & Kaess, M. (2023). Mother-child interactions in adolescents with borderline personality disorder traits and the impact of early life maltreatment. *Child and Adolescent Psychiatry and Mental Health*, 17(1), 1-14. <https://doi.org/10.1186/s13034-023-00645-4>

### Manuscript 3:

**Williams, K.**, Fuchs, A., Kuehn, J., Fleck, L., Lerch, S., Cavelti, M., Koenig, J., & Kaess, M. (2025). Individual patterns and synchrony of heart rate variability in adolescent patients with borderline personality psychopathology and their mothers: a case-control study. *Borderline Personality Disorder and Emotion Dysregulation*, 12(1), 12. <https://doi.org/10.1186/s40479-025-00289-0>

### Manuscript 4:

Seeger, F. R., Neukel, C., **Williams, K.**, Wenigmann, M., Fleck, L., Georg, A. K., Bermpohl, F., Taubner, S., Kaess, M., & Herpertz, S. C. (2022). Parental mental illness, borderline personality disorder, and parenting behavior: the moderating role of social support. *Current Psychiatry Reports*, 24(11), 591–601. <https://doi.org/10.1007/s11920-022-01367-8>

## **Specification of the Contribution for Publications with Multiple Authors**

Manuscript 1: K. Williams developed the research question under the supervision of A. Fuchs and M. Kaess. She performed all statistical analyses independently and wrote the first and final version of the manuscript, incorporating the input of all co-authors. K. Williams revised the manuscript to enhance its intellectual content in collaboration with all co-authors.

Manuscript 2: K. Williams was critically involved in participant recruitment, data acquisition, and processing of the obtained data. Together with L. Fleck and A. Fuchs, she coded the videos of the study focusing on interactional parental, adolescent and dyadic behavior. K. Williams developed the research question under the supervision of M. Kaess and conducted all statistical analyses independently. She wrote the first and final version of the manuscript, incorporating the input of all co-authors. K. Williams revised the manuscript to enhance its intellectual content in collaboration with all co-authors.

Manuscript 3: K. Williams was critically involved in participant recruitment, data acquisition, and processing of obtained data (e.g., processing of the ECG raw data for further analyses). Together with L. Fleck and A. Fuchs, she coded the videos of the study focusing on behavioral synchrony. A. Fuchs and K. Williams conducted the statistical analyses supported by S. Lerch and J. Koenig. K. Williams wrote the first and final version of the manuscript supported by A. Fuchs. K. Williams revised the manuscript to enhance its intellectual content in collaboration with all co-authors.

Manuscript 4: K. Williams contributed to the conceptualization of the study, provided significant literature input, and assisted in writing the initial draft of the review. With the first author, F. Seeger, she reviewed feedback from other co-authors and helped integrate their input into the manuscript. She further revised the manuscript to enhance its intellectual content and approved the final version of the manuscript.

## **Further Publications That Are Not Part of the Present Dissertation**

Buczyłowska, D., Dittrich, K., von Schönfeld, J., Hindi-Attar, C., Bempohl, F., Herpertz, S., Neukel, C., Kaess, M., **Williams, K.**, Winter, S., & Bödeker, K. (under review). The german empathy questionnaire (EmQue) for preschool children: psychometric properties, associations with social cognition and psychopathology. *Early Education and Development*.

Fleck, L., Fuchs, A., Moehler, E., **Williams, K.**, Koenig, J., Resch, F., & Kaess, M. (2023). Child versus adolescent borderline personality disorder traits: frequency, psychosocial correlates, and observed mother-child interactions. *Personality Disorders: Theory, Research, and Treatment*, 14(2), 196. <https://doi.org/10.1037/per0000574>

Fleck, L., Fuchs, A., **Williams, K.**, Moehler, E., Resch, F., Koenig, J., & Kaess, M. (2024). Child temperament as a longitudinal predictor of mother-adolescent interaction quality: are effects independent of child and maternal health? *European Child and Adolescent Psychiatry*, 1-11. <https://doi.org/10.1007/s00787-023-02359-6>

Neukel, C., Bempohl, F., Kaess, M., Taubner, S., Boedeker, K., **Williams, K.**, Dempfle, A., & Herpertz, S. H. (2021). Understanding and breaking the intergenerational cycle of abuse in families enrolled in routine mental health services: study protocol for a randomized controlled trial and two non-interventional trials investigating mechanisms of change within the UBICA II consortium. *Trials*, 22, 749. doi: 10.1186/s13063-021-05653-3

**Williams, K.**, Georg, A., Kutsch, S., Wenigmann, M., Bödeker, K., Dempfle, A., Taubner, S., Kaess, M., Bempohl, F., Herpertz, S., & Neukel, C. (under review). The german version of the alabama parenting questionnaire (APQ): a validation study of the original APQ and an adapted version for parents of preschool children. *Journal of Child and Family Studies*.

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## 1. Introduction

Imagine being a mother who, after a long day at work, picks up her tired 5-year-old daughter from childcare. On the way home you have to run errands, and you rush through the supermarket, trying to stay focused on the task at hand while your daughter pulls on your arm, crying and begging for chocolate she is not supposed to have. When you finally get home (after enduring the children's special song edition CD in the car that you have listened to a thousand times before) you are greeted by your husband in the middle of an argument with your son, who is refusing to do his homework.

The next few hours are a whirlwind: cooking, eating, talking about the day, soothing, cleaning, helping the kids prepare for the next day and then bed, reading bedtime stories, and finally getting them to sleep and maybe, just maybe, you and your husband have a short moment of peace (and sleep) before the demands of the next morning again require your full attention.

The mother in this story represents millions of parents worldwide who face similar situations every day. These moments are demanding: parents have to suppress their own exhaustion and whatever stress they have experienced throughout the day, stay calm and composed while getting everything done (and let us be honest, "just" shopping and figuring out dinner after a long day at work can be challenging enough), and, the most difficult part, they are expected to stay tuned to their child's needs. Also, they are supposed to respond in just the right way: sensitive, empathetic, acknowledging, validating, soothing, maybe even offering some external emotion regulation like redirecting the child's attention. Basically, parents need to keep their own emotions in check while also managing their child's feelings, all while keeping daily life running smoothly. Sounds simple enough, right?

Now imagine that the mother in the story has severe difficulties with emotion regulation. Maybe she has experienced neglect or abuse in her childhood, leading to sudden overwhelming feelings in stressful situations she cannot manage. Or maybe she suffers from a mental illness that complicates her ability to cope. Factors on the child's side also influence the situation. For example, the daughter in the story might have impulsivity issues and a tendency to throw a tantrum, while the son could struggle with learning difficulties, making homework particularly tense and exhausting.

And it does not stop there: maybe the spouse is also emotionally dysregulated. Or perhaps the mother is a single parent without a partner or support system to lean on.

On top, critical environmental factors can exacerbate parenting stress: imagine the mother has to worry about money while being in the supermarket because it is the end of the month and her bank account is almost empty.

This scenario illustrates the complexity of everyday life and the immense demands on parents and their children, especially those who face additional challenges. All these factors (and more) play a role in how well parents can manage stressful situations and whether their children grow up to be physically and mentally healthy individuals.

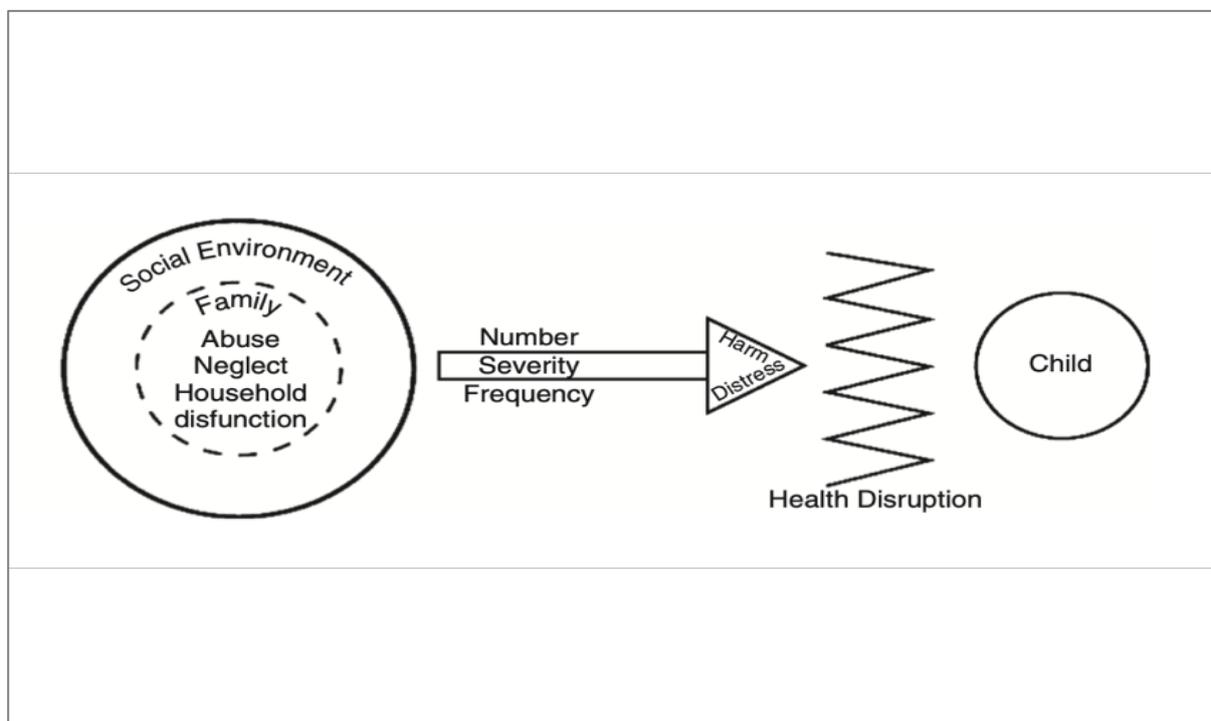
In Germany, approximately three million children each year experience one parent with a mental disorder (Markwort et al., 2015), and one in six children is affected by emotional or behavioral disorders themselves (Barkmann & Schulte-Markwort, 2012). Nearly 20% of adults aged 18 to 31 report having experienced a form of abuse or neglect in their childhood (Kasinger et al., 2024) – adverse experiences that both increase the risk of developing mental health problems (Badr et al., 2018; Baldwin et al., 2023), and are more likely to be inflicted on children of parents with mental disorders (Ben David, 2021) or emotion regulation difficulties (Lavi et al., 2021). Given these findings, it is essential to conduct research to better understand the development of mental disorders and intergenerational dynamics and to develop effective, evidence-based interventions aimed at prevention and early support.

This dissertation examines how specific parental, child, and social factors interact to shape the development of child mental health. Particular attention is given to emotion regulation (ER) or rather emotion dysregulation (ED) as a potential mechanism facilitating the transmission of adverse childhood experiences (ACEs) from one generation to the next and as a risk factor for adolescent psychopathology. The overall goal is to highlight the transactional nature of dyadic interactions within this context and to provide recommendations for interventions aimed at supporting families at risk. To provide a theoretical foundation for this dissertation, Chapter 2 will present a summary of literature about ACEs and their potential intergenerational effects, define ER and ED, outline a conceptual framework guiding this dissertation, and introduce borderline personality disorder (BPD) as an example of an ED disorder that develops in the context of maladaptive caregiver-child transactions. Chapter 3 will then outline the objectives of this dissertation and summarize the four included papers. Finally, in Chapter 4 a general discussion will synthesize the main findings, suggest directions for future research and highlight clinical implications.

## 2. Theoretical Framework

### 2.1 ACEs and their Impact on the Next Generation

ACEs are defined as “childhood events, varying in severity and often chronic, occurring within a child’s family or social environment that cause harm or distress, thereby disrupting the child’s physical or psychological health and development” (Kalmakis & Chandler, 2014, p.1495). ACEs include various forms of childhood maltreatment, such as physical, emotional, and sexual abuse, physical and emotional neglect (often referred to as “early life maltreatment”; ELM), and exposure to household dysfunctions, like growing up with a mentally ill parent or witnessing domestic violence. Kalmakis & Chandler (2014) emphasized that the family environment is situated within a broader social environment, which can either harm the child (e.g., through bullying) or serve as a protective factor (e.g., through social support). The impact of ACEs on the child’s health depends on their number, severity and frequency (Figure I; Kalmakis & Chandler, 2014).



**Figure I.** Model of adverse childhood experiences. Reprinted from “Adverse childhood experiences: towards a clear conceptual meaning” by K. A. Kalmakis & G. Chandler, 2014, *Journal of Advanced Nursing*, 70(7), 1489-1501. Copyright 2013 John Wiley & Sons Ltd. Reprinted with permission.

Experiencing ACEs can entail lifelong consequences for the victim's health. Individuals face a heightened risk for developing both physical illnesses (e.g., cardiovascular and respiratory diseases, cancer, sexually transmitted diseases) and mental disorders (e.g., depression, anxiety, alcohol/drug abuse, suicide attempts, psychotic symptoms); ACEs can also negatively affect psychosocial aspects and can lead to social isolation, impaired job performance, welfare dependence, decreased self-esteem and lower life satisfaction (Anda et al., 2004; Fergusson et al., 2013; Hughes et al., 2017, 2021; Tzouvara et al., 2023; Witt et al., 2019). Beyond the personal consequences for those affected, the associated costs for healthcare and social systems are substantial (Hughes et al., 2021; Loxton et al., 2019).

Furthermore, individuals who have suffered from ACEs have a higher risk to pass this experience on to the next generation: approximately 30% of parents who were maltreated in their childhood would later neglect and/or abuse their own children (Berlin et al., 2011; Kaufman & Zigler, 1987). Children of mentally ill parents are at risk to experience abuse or neglect and/or to develop a mental disorder themselves. Again, approximately 30% of these children would develop transient and another 30% severe long-term mental health issues (van Santvoort et al., 2015).

However, these numbers also provide us with a potential window for interventions: a good part of parents seems to be able to appropriately care for their children, despite ACEs and/or mental disorders they might have experienced or are still suffering from. Investigating the underlying mechanisms of these intergenerational transmissions is therefore essential. When we know how ACEs and mental disorders are passed on to the next generation and what factors could buffer or even prevent these cycles, we could develop specifically tailored interventions for parents and children at risk.

One intergenerational mechanism of interest is ED (Corso et al., 2025; Weissman et al., 2019; Zitzmann et al., 2024). ED contributes extensively to the development of most mental disorders and is considered a transdiagnostic marker (Beauchaine & Cicchetti, 2019; Paulus et al., 2021; Thompson, 2019).

## **2.2 Emotion Regulation and the (Revised) Tripartite Model**

Thompson (1994, pp. 27-28) defined ER as “the extrinsic and intrinsic processes responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensive and temporal features, to accomplish one's goals”. When these

processes fail and one's immediate or future (developmental) goals cannot be accomplished, we refer to this as ED (Cole et al., 2019). ED encompasses emotional responses characterized by prolonged emotions and ineffective regulatory efforts, emotions that disrupt appropriate behavior, emotional expressions or experiences that are contextually inappropriate, and emotions that shift either too fast or too slowly (Cole & Hall, 2008). It is important to note that ED is not the mere absence of ER, but a regulatory effort that does not lead to the desired outcome (Cole et al., 2019).

Both adaptive and maladaptive ER strategies can contribute to a regulated or dysregulated state of mind, and ED can manifest in various attempts – both adaptive and maladaptive – to regain emotional balance. For example, an individual may feel calm and content after consuming alcohol, perceiving this state as emotionally regulated. However, this would constitute a maladaptive ER strategy (i.e., suppression or avoidance), as it does not address the underlying problems that led to the urge to drink (and also poses long-term health risks). Should this individual display disinhibited behavior after consuming alcohol, such as heightened aggression, this would reflect an emotionally dysregulated state. Similarly, another individual might employ meditation during states of emotional distress. Although meditation is generally considered an adaptive ER strategy (i.e., mindfulness) that can reduce stress and enhance mental health (Chiesa et al., 2013), its use as a means of avoidance without engaging with or resolving the underlying conflict may undermine its regulatory efficacy and lead to a continuation of dysregulation over time. Adaptive ER strategies that have been negatively associated with the development of psychopathology include reappraisal, mindfulness (i.e., acceptance of emotions), and problem solving; maladaptive ER strategies typically include suppression, rumination and avoidance (Aldao et al., 2010).

Strategies for managing emotions can vary in their adaptiveness depending on context (Cole et al., 2019). For instance, children who have experienced physical abuse may develop an increased sensitivity to anger cues (i.e., an enhanced threat detection) in order to anticipate future harm and emotionally prepare for it (Thompson, 2019). This anticipation has been associated to the strategy of attention deployment, an antecedent-focused adaptive ER strategy (Weissman et al., 2019). However, such adaptations may become maladaptive over time: the same heightened sensitivity to threat may later contribute to ED, manifesting, for example, in a generalized physiological and psychological hypervigilance in social interactions and therefore

interactional difficulties. It is therefore not surprising that these patterns have been associated with an elevated risk for the development of mental health problems (Thompson, 2019).

These theoretical considerations are supported by a wide range of research suggesting that experiencing ACEs increase the risk of ED, which in turn has been linked to various psychiatric disorders such as mood disorders, eating disorders, psychosis/schizophrenia and personality disorders (Paulus et al., 2021; Thompson, 2019; Weissman et al., 2019).

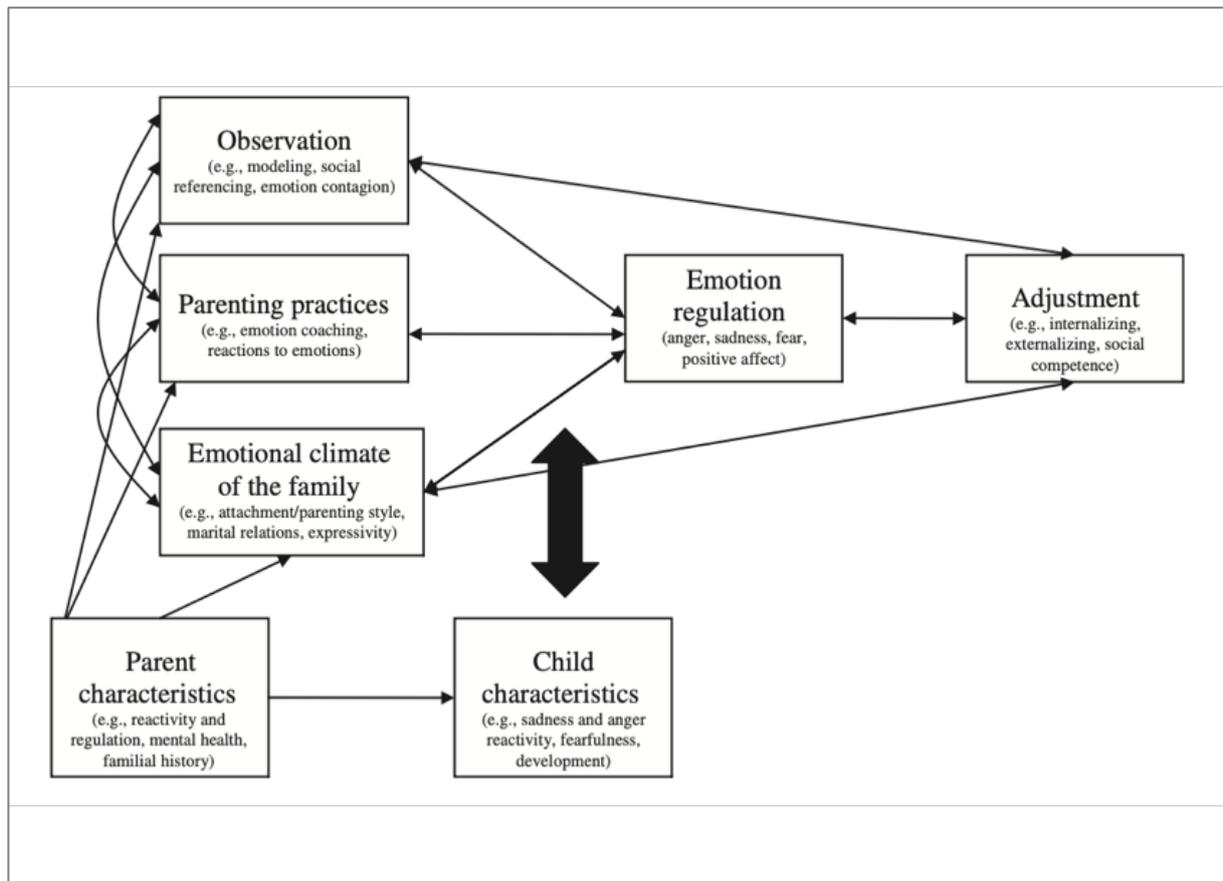
As ER is not only an intrapersonal but also (and some might argue mainly) an interpersonal process (Hughes et al., 2012), the development of ER in the context of caregiver-child relations – as the foundation of later ER skills and adult relationships – is of specific interest. Considering that, we have to explore both parent and child characteristics that may influence these interactions over time.

Historically, research on the intergenerational transmission of (dys)function has primarily focused on parent-driven effects. These include factors such as parenting behavior, parental mental health, and abusive or neglectful behavior towards the child, which have all been shown to significantly influence a child's emotional development and adjustment outcomes (see Chapter 2.1). However, research has increasingly adopted a transactional perspective, which emphasizes that both parent and child characteristics shape developmental outcomes in a reciprocal manner. Transactional approaches, such as those proposed by Hughes et al. (2012) or Sameroff (2009), suggest that cognitive, emotional and social child development is influenced by the environment (e.g., parenting behavior), while at the same time, the child's temperament and emotional reactivity influence and shape that environment. For instance, a stressed child with an impulsive temperament might especially challenge appropriate parenting behavior. (In)appropriate parenting behavior in response to the child's emotions and behaviors in these situations subsequently shapes future responses of the child, which in the long-term affects the development of ER and mental health of the child.

Morris et al. (2007) introduced the 'Tripartite Model of the Impact of the Family on Children's Emotion Regulation and Adjustment' (Figure II). The model states that children's ER develops within the family context through three primary mechanisms:

- 1) **Observation:** Children learn about emotions and regulatory strategies within the family through modeling, social referencing and emotional contagion.
- 2) **Parenting practices:** This entails parental emotion coaching, reaction to and encouragement of the child's emotions, and guidance on how to effectively regulate emotions.
- 3) **Emotional climate of the family:** Attachment style, parental attitudes and behavior towards the child, marital relations, emotional expressivity, and expressed emotion (i.e., criticism and overinvolvement of the parent) within the family further influence the child's ER development.

The Tripartite Model explicitly acknowledges the role of both parent and child characteristics in the socialization of ER. Parent characteristics in this model include mental health, their own familial history (ACEs), beliefs about emotions and emotional expressivity, and their emotional reactivity and ER abilities (Morris et al., 2007). On the child's side, temperament, emotional reactivity, and gender are key factors influencing emotional development (Morris et al., 2007). Therefore, the development of children's ER and their ability to adapt to life challenges are shaped not only by the family context but also by both the parent's and the child's characteristics. Moreover, ER has been proposed as a mediator in the relationship between family context and the child's adjustment (Morris et al., 2007).



**Figure II.** Tripartite Model of the Impact of the Family on Children’s Emotion Regulation and Adjustment. Reprinted from “The Role of the Family Context in the Development of Emotion Regulation” by A. S. Morris et al., 2007, *Social Development*, 16(2), 361-388. Copyright 2007 Blackwell Publishing Ltd. Reprinted with permission.

The Tripartite Model encompasses a wide range of research and mechanisms related to the development of ER within the context of transgenerational processes. However, in this dissertation I propose the inclusion of three additional variables in the model:

- 1) ***Physiological factors***
- 2) ***Biobehavioral synchrony***
- 3) ***Social support***

Each of these variables is crucial for a deeper understanding of how ER develops and is transmitted across generations. The following section will summarize existing

research on these variables within the context of the conceptual model. In Chapter 3, Studies 2 through 4 will further explore these variables and their interrelations.

***Physiological factors:*** In the last two decades, a growing body of research has been directed towards the investigation of the physiological foundations of ER and its relations to childhood adversities. ACEs have been linked to decreased volumes of the amygdala, the medial prefrontal cortex (mPFC), and the hippocampus in children (McLaughlin et al., 2019) - all critical regions of the emotional brain circuit responsible for, e.g., identifying emotional salience and generating emotional responses to stimuli (Callaghan & Tottenham, 2016; Zhu et al., 2019). There is also evidence for alterations in brain functions, e.g., increased amygdala reactivity in response to negative stimuli (e.g., angry or fearful faces) in children who have experienced violence (McLaughlin et al., 2019). Interestingly, amygdala reactivity during childhood can be buffered by a parent: the physical presence or availability of a parent can increase reactivity of the mPFC and decrease amygdala reactivity, cortisol levels and fear responses (Callaghan & Tottenham, 2016). Parental influence during this sensitive period of mPFC-amygdala plasticity may shape the connectivity within this network and therefore later regulatory abilities (Callaghan & Tottenham, 2016). Parenting behavior (e.g., inconsistent discipline, positive parenting) has also been associated with the development of child and adolescent heart rate variability (HRV), which is considered a transdiagnostic marker for ED (Alen et al., 2022; Beauchaine & Thayer, 2015; Graham et al., 2017). Exposure to stress as early as during pregnancy can affect the function of the child's hypothalamus-pituitary-adrenocortical (HPA) axis, leading to suppression of immune functioning, cortisol hypo- or hyperreactivity to stress, chronically heightened cortisol levels or enhanced cardiovascular tone (Thompson, 2014). A growing body of research has been investigating the transmission of trauma via epigenetic mechanisms, particularly via altered DNA methylation pathways (Zhou & Ryan, 2023). For instance, epigenetic modifications as a result of traumatic childhood experiences may contribute to a dysfunctional physiological stress response later in life (Megala et al., 2021). Taken together, there is growing evidence that ACEs, in the Tripartite Model represented by family context, influence physiological factors which in turn can have an effect on the development of ER skills.

**Biobehavioral synchrony:** Feldman (1998) postulates a biobehavioral approach for understanding the development of ER. Parents and their children adapt their neurobiological and behavioral rhythms to one another during the course of the first years of the child's life. It is important to emphasize that this concept does not refer to the behavior or physiological responses of either the parent or the child in isolation, but rather to the dynamic coordination between them during interactions, i.e., a moment-to-moment alignment of signals. This dyadic attunement lays the groundwork for attachment patterns and the child's ability to self-regulate (Bell, 2020; Feldman, 2012). For instance, when infants express distress and their mothers respond sensitively, i.e., promptly and appropriately to these signals, infants learn that their actions can influence the dynamics of dyadic interactions (Bell, 2020). Through these early back-and-forth interactions, children learn the basics of co-regulation, i.e., how to manage their own emotions with the help of another person. While mother-infant interactions in the early postnatal period are mostly parent-driven, they become increasingly mutually synchronous in the second half of the first year and extend to physiological measures, including cardiac, adrenocortical and brain functioning (Bell, 2020; Davis et al., 2018). As children acquire skills like speech or symbolic play, these dyadic exchanges become more reciprocal and social, further shaping the development of other abilities, such as social competences and Theory of Mind (Birk et al., 2022). During adolescence, biobehavioral synchrony is thought to be influenced by the adolescent's striving for autonomy and the rise of parent-child conflict (Birk et al., 2022). It has been proposed that physiological synchrony may decline during this period, while behavioral synchrony becomes more enhanced and loosely coordinated (Birk et al., 2022). However, empirical research on the development of biobehavioral synchrony during this period remains limited, and current understanding is still in its early stages.

In general, higher levels of parent-child synchrony have been associated with typical development and positive child outcomes (Leclère et al., 2014). Synchrony is influenced by family context and characteristics of both the parent and the child, with long-term implications for the child's and youth's self-regulation throughout development (Birk et al., 2022; Davis et al., 2017, 2018). For instance, intrusive maternal behavior, often observed in the context of maternal anxiety, may override the child's signals, while maternal withdrawal, which has been associated with maternal depression, can limit the child's opportunities for reciprocal, give-and-take interactions (Feldman, 2012). In such cases, synchrony cannot be adequately established, as the

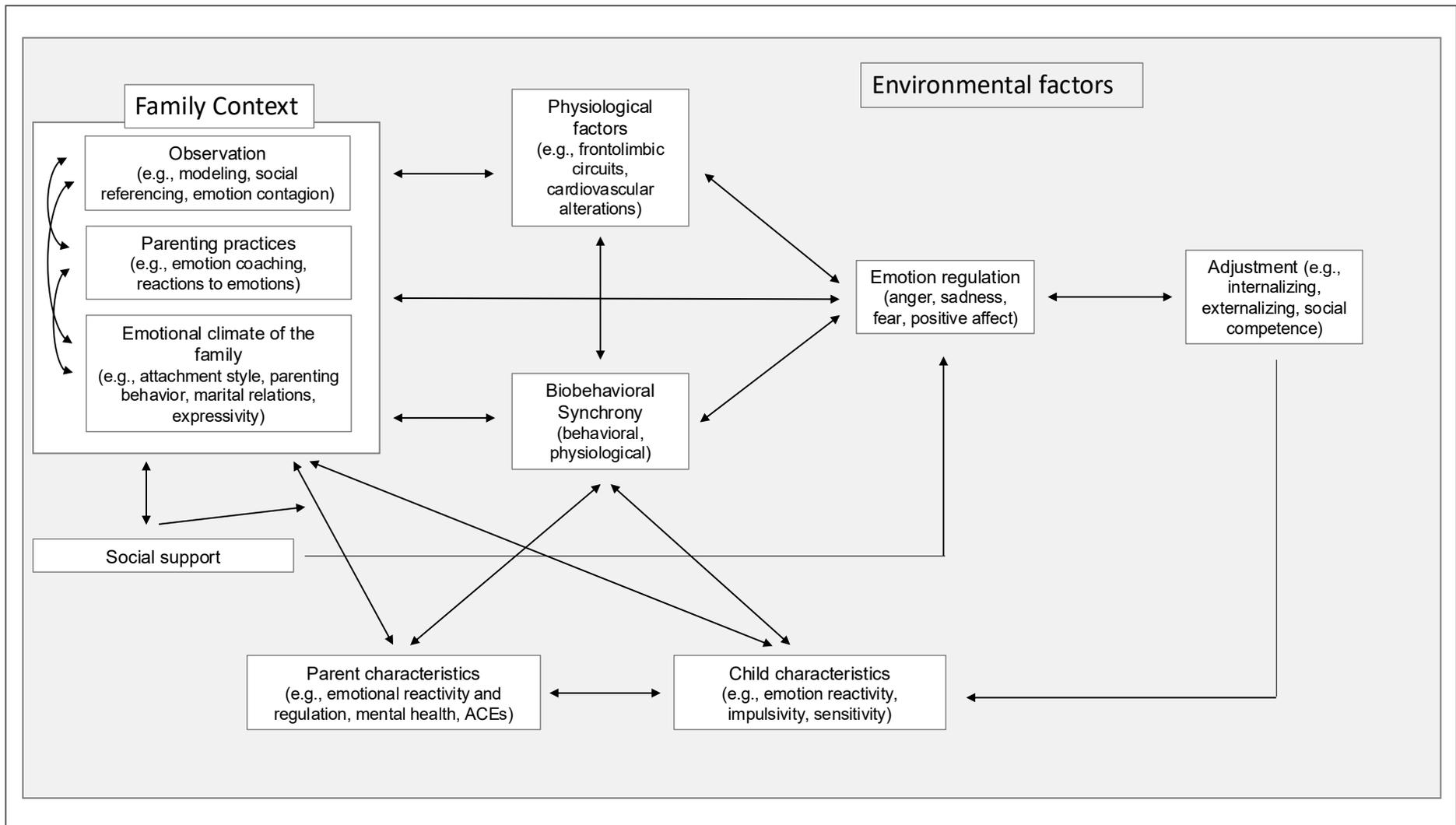
child's signals are either ignored or go unrecognized. Physiological synchrony, on the other hand, may become unfavorable when one interactional partner exhibits a stress response, potentially amplifying distress within the dyadic interaction (DePasquale, 2020). Overall, research on biobehavioral synchrony, especially during adolescence, and its relation to child development remains an emerging field, with many questions still unanswered. Advancing this area of research is essential, as social co-regulation later in life, e.g., in a romantic relationship, provides evolutionary advantages. By preserving regulatory resources, co-regulation enables more effective brain and body functioning within supportive social networks, as outlined in the Social Baseline Theory (Coan & Sbarra, 2015; Hughes et al., 2012; Saxbe et al., 2020).

**Social support.** Social co-regulation is deeply interconnected with the broader social environment (including peers, partners, extended family members or members of the community such as neighbors or healthcare providers) in shaping mental health outcomes. Social support, which encompasses emotional, informational and instrumental assistance (Barnett et al., 2015), can have a positive impact on well-being by enhancing psychosocial adjustment, coping behavior, ER, quality of life, well-being or health promoting behavior and by reducing stress and psychological symptoms (Azpiazu Izaguirre et al., 2021; Wang et al., 2003). Beyond its direct benefits, perceived social support also serves as a protective factor against the adverse effects of stressful life events, It reduces the risk of negative health outcomes and mitigates the intergenerational transmission of ACEs, which is in line with the buffering model (Cohen, 2004; Cohen & Wills, 1985; Ozbay et al., 2007; Van Wert et al., 2019). The Social Baseline Theory (Coan & Sbarra, 2015; Hughes et al., 2012; Saxbe et al., 2020) provides a neuroscientific explanation for these effects. It posits that the human brain is evolutionary adapted to function within a social context, relying on others for fundamental processes such as detection of danger and stress regulation. When individuals are socially connected, cognitive and physiological resources are conserved. In contrast, social isolation represents a deviation from this baseline, requiring greater cognitive effort to navigate challenges, which can contribute to poorer mental and physical health over time.

While this dissertation does not specifically focus on environmental factors, it is impossible to discuss child development without acknowledging the socioeconomic

context in which children are raised. Numerous studies have demonstrated links between family socioeconomic status (SES) and both cognitive and behavioral development in children (Bradley & Corwyn, 2002; Letourneau et al., 2013; Sabates & Dex, 2015). A recent meta-analysis highlights that SES influences positive and negative parenting behavior (Ayoub & Bachir, 2023). Additionally, both individual poverty and poverty of the community the family lives in have been associated with an increased risk and severity of child maltreatment (Imran et al., 2019). It is therefore not surprising that children of families with lower SES backgrounds face a higher likelihood of developing mental disorders and experiencing academic difficulties (Letourneau et al., 2013). Furthermore, individuals who have experienced childhood maltreatment are more likely to struggle with lower SES in adulthood (e.g., higher unemployment rates, reduced income, no health insurance coverage; (Bunting et al., 2018; Zielinski, 2009). This is particularly relevant as these individuals may go on to become parents themselves and continue cycles of adversity. Examples for other environmental factors that were found to influence the child's development are community noise (Raess et al., 2022) and air pollution (Ha, 2021). Environmental stressors can significantly challenge a family's ER capacities: families facing adversities need to self-regulate and co-regulate far more frequently than those with more secure life circumstances, while also lacking reliable external co-regulatory sources (e.g., community networks). Therefore, I suggest to add **environmental factors** to the model as a contextual variable that influences and is influenced by basically all components of the framework.

By incorporating these additional variables into the Revised Tripartite Model of Emotion Regulation (Figure III), the model emphasizes how family context influences the child's ER both directly and indirectly through physiological factors and biobehavioral synchrony. Also, in this model social support affects the family context and moderates the influence of parental characteristics on family context (representing the buffering hypothesis), but also directly influences the child's ER. The model emphasizes the transactional, bidirectional exchanges between basically all variables of the model.



**Figure III.** The Revised Tripartite Model of the Development of Children's Emotion Regulation and Adjustment.

With this model, I also introduce an important feedback loop when considering transgenerational dynamics: the one from child adjustment back to child characteristics. A well-adjusted child, for instance, is more likely to become a sensitive or empathetic individual and therefore experience more positive, rewarding social exchanges which further support their mental health. When this child becomes a parent, these characteristics will have an immense effect on how ER development in the next generation will be shaped.

The Revised Tripartite Model (Figure III) serves as the foundational framework for this dissertation, which examines specific parent and child factors, parent-child behavioral and physiological synchrony, and social support as influences on the development of ER in children.

### **2.3 Borderline Personality Disorder**

The present work places particular emphasis on BPD, as it is known to be associated with ACEs, is frequently conceptualized as an ED disorder (Bozzatello et al., 2020; Linehan, 1993), and is characterized by severe interpersonal dysfunction (American Psychiatric Association, 2013). As such, BPD serves as an illustrative case for examining how the variables in the Revised Tripartite Model may interact and influence one another.

The Biosocial Theory of Linehan (1993) describes the development of BPD as an interplay between the child's temperament (e.g., heightened emotional sensitivity) and the environment of the child (e.g., parenting behavior, SES, maltreatment, chronic stress). This framework is in accordance with the Revised Tripartite Model, as both emphasize the transactional processes between caregiver and child that seem to be central for understanding the developmental origins of ED and BPD symptomatology (Sharp & Fonagy, 2015).

BPD can be explored from both the parent's and the child's perspective, as symptomatology on either side may shape the development of child's ER and relational functioning. On the parent's side, BPD is a well-documented risk factor for the child's development (Petfield et al., 2015). Children of parents with BPD have a higher risk of suffering from emotional and behavioral problems than children of parents with other mental disorders (Abela et al., 2005; Barnow et al., 2006). Impaired maternal parenting, emotional dysfunction as well as child characteristics were previously

discussed as mediators or moderators between maternal BPD and child adjustment problems (Eyden et al., 2016). A recent systematic review summarized that ER deficits in parents with BPD are linked to negative parenting behaviors and non-supportive emotion socialization (Zitzmann et al., 2024), which may contribute to a cycle of emotional dysfunction across generations. These associations highlight a critical opportunity for early interventions aimed at preventing children of parents with BPD from experiencing ACEs and developing their own ER difficulties (Eyden et al., 2016). On the child's side, early BPD traits – which often manifest during adolescence, a particularly vulnerable time for the onset of mental disorders – have been associated with impaired dyadic behavior and interpersonal conflict (Fleck et al., 2023; Whalen et al., 2014). Prior research suggests alterations in caregiver-child transactions in the context of child or adolescent BPD traits, especially under stressful circumstances when ED might be elicited (e.g., Fleck et al., 2023). Despite a growing interest in interpersonal factors in the context of adolescent BPD, studies specifically examining parent-adolescent interactions and their implications for the development of BPD remain limited. However, BPD can (and should) be reliably diagnosed during adolescence: early identification provides a valuable (research) opportunity to deepen our understanding of the disorder, improve treatment approaches, and, most importantly, implement early, tailored interventions that may help to prevent life-long and severe psychosocial impairments (Álvarez-Tomás et al., 2019; Bozzatello et al., 2021; Chanen et al., 2017; Feurer et al., 2025; Sharp & Fonagy, 2015).

Taken together, by further investigating BPD we can examine the development of ER in the context of caregiver-child co-regulation, taking into account both the parent's and the child's characteristics. Considering both sides may help to identify potential windows for preventive as well as early intervention.

### 3. Contributions of the Present Work

The aim of this dissertation was to add specific knowledge about parental and child factors to the current body of research that might contribute to the intergenerational transmission of ACEs and mental disorders. A special focus was directed towards ED and co-regulatory behavioral and physiological processes (i.e., synchrony) in the context of parental and adolescent borderline personality traits. Finally, the role of social support was explored.

**Study 1** of this dissertation (Williams et al., 2022) focuses on parent characteristics. Specifically, it examines whether maternal dissociative symptoms, a maladaptive ER strategy, predict parenting variables longitudinally. These include parenting stress, parental physical abuse risk, bonding and observed parenting behavior during mother-infant interactions. Additionally, the study investigates whether maternal dissociative symptoms mediate the relationship between maternal childhood experiences of sexual or physical abuse and these parenting outcomes. Findings provide insights into how maternal dissociation might impact parent-child co-regulatory processes.

The case-control **studies 2 and 3** explore co-regulatory processes by examining a clinical sample of adolescent patients with borderline personality traits during two interactions with their mothers. **Study 2** (Williams et al., 2023) focuses on maternal, adolescent, and dyadic observed behavior during a fun day planning task versus a stress task and additionally considers potential effects of maternal and/or adolescent childhood experiences of abuse and neglect on behavior. **Study 3** (Williams et al., 2025) concentrates on the physiological (co-)regulation of mothers and their adolescent children during both interactions and during resting periods. The study investigates individual heart rate variability (HRV) as well as HRV synchrony and its relationship to behavioral data. Results of both studies are discussed with a focus on transactional exchanges in the light of child ED.

**Study 4** (Seeger et al., 2022) provides a narrative literature review focusing on social support as a moderating factor when parents suffer from a mental disorder. A specific focus was directed towards parental BPD. This literature overview also sheds light on the challenges the SARS-CoV-2 pandemic posed for parenting, and how social support may have buffered negative health outcomes for families.

In the following chapters, the four studies included in this dissertation will be outlined, summarizing relevant literature, existing research gaps, and the specific contributions each study makes to the field of child development.

### **3.1 Dissociation Links Maternal History of Abuse to Impaired Parenting**

**Williams, K., Moehler, E., Kaess, M., Resch, F., & Fuchs, A. (2022).** Dissociation links maternal history of childhood abuse to impaired parenting. *Journal of Trauma & Dissociation*, 23(1), 37–51.

The first study of this thesis focuses on parent characteristics, specifically on their history of sexual and/or physical abuse (early life maltreatment, ELM), parental dissociative symptoms as a form of ED and their effects on parenting-related variables. Parents who have experienced abuse or neglect during their own childhood are at increased risk for impaired parenting (e.g., more hostile-intrusive behavior and less sensitivity during interactions), report higher levels of parental stress, and perceive themselves more negatively in their parental role (Banyard, 1997; Douglas, 2000; Lang et al., 2010; Vaillancourt et al., 2017). When investigating how parental ELM might affect the next generation, ED symptoms caused by ELM are of specific interest as a potential mediating pathway. Dissociative symptoms, which may serve as a protective mechanism during acute stress (e.g. sexual or physical abuse; Chu & Dill, 1990), but can become maladaptive when generalized to non-threatening contexts (e.g., interpersonal conflict), were suggested to be associated with the intergenerational transmission of trauma and parenting behavior (Kim et al., 2010). Prior studies have identified the mediating role of parental dissociation in the pathway between parental ELM and parenting (Collin-Vézina et al., 2005; Mitkovic-Voncina et al., 2014; Narang & Contreras, 2000, 2005). However, these studies show methodological limitations (i.e., lack of non-maltreated control groups, mostly cross-sectional designs), did not compare self-report to behavior observations and neglected other parenting variables, such as parental stress.

Study 1 overcomes these limitations by applying a longitudinal design, several (self-report and objective) measures of parenting, and by including a non-maltreated control group. It focuses on maternal dissociation as a predictor of various parenting variables (parental stress, mother-child bonding, physical abuse potential, observed behavior in

mother-child interactions) and as a potential mediator in the link between maternal ELM and these parenting variables.

In a community sample of  $N = 119$  mothers with and without a history of ELM, both ELM and dissociative symptoms (measured 5 months postpartum; T1) predicted more self-reported parenting stress, parental bonding impairment, and a higher child abuse potential 12 months after birth (T2). This was also the case for observed behavior during mother-infant interactions at T2: maternal ELM and dissociative symptoms negatively predicted maternal sensitivity, non-intrusiveness, and their overall emotional availability. Maternal ELM also predicted less structuring and non-hostility during interactions, while their infants were less responsive and involved in the interaction. Finally, dissociative symptoms mediated the link between maternal ELM and self-reported parenting variables. However, dissociative symptoms did not mediate the relationship between maternal ELM and observed parenting behavior.

This study was the first to examine the associations of maternal ELM, dissociative symptoms, and parenting behavior with a combination of self-reported and observational methods within a healthy, low-risk community sample using a longitudinal design. Maternal ELM and dissociation not only affect the mother's ER but also shape her ability to engage with her infant in a sensitive and non-intrusive manner. From a transactional point of view, when a mother is confronted with stress (e.g., a crying infant) and begins to dissociate as a maladaptive stress response, the lack of availability to her child is likely to trigger emotional and behavioral reactions in the child (e.g., crying louder). These reactions, in turn, may increase parenting stress and the risk of physical abuse and, as a result of these dysfunctional interactional patterns, the mother might perceive her bonding with the child as impaired. Associations between maternal dissociation and observed behavior were generally weaker than between dissociation and self-report measures. Therefore, different aspects of parenting and different ways to measure it (self-report vs. observation) may influence findings in distinct ways.

The results of this study contribute to existing literature by highlighting the influence of parent characteristics (i.e., dissociative symptoms) in the context of the intergenerational transmission of ACEs, and the need for specific interventions targeted at trauma- and stress-related symptomatology that may (negatively) influence ER development in the next generation.

### **3.2 Mother-Child Interaction in Adolescents with Borderline Personality Disorder Traits and the Impact of Early Life Maltreatment**

**Williams, K.,** Fleck, L., Fuchs, A., Koenig, J., & Kaess, M. (2023). Mother-child interactions in adolescents with borderline personality disorder traits and the impact of early life maltreatment. *Child and adolescent psychiatry and mental health*, 17(1), 96.

The second study of this dissertation shifts the focus to child characteristics, specifically adolescent borderline personality symptomatology, and investigates how these traits are linked to mother-adolescent interactions. Additional effects of ELM experiences of both adolescents and their mothers were explored.

According to Linehan's Biosocial Theory (1993), both caregiver and child characteristics play a role in the development of adolescent and young adult BPD symptomatology. On the caregiver's side, research has identified problematic parenting behavior in community and clinical samples, based on self-reports (e.g., Armour et al., 2022; Ball Cooper et al., 2018; Vanwoerden et al., 2017) but also on observations of parent-child interactions (e.g., Brumariu et al., 2020; Fleck et al., 2023; Lyons-Ruth et al., 2013). On the child's side, an "unusually sensitive" temperament (Boucher et al., 2017) and behavioral alterations during mother-child interactions (e.g., disorganized-controlled, withdrawn or less engaged behavior; Fleck et al., 2023; Lyons-Ruth et al., 2013) have been reported in association with current and later BPD traits. The few studies that have investigated both parent and child behavior during the same interaction found that dysfunctional dyadic patterns, e.g., disoriented/role confused behavior, disorganized behavior, dyadic negative escalation, impaired reciprocity, and dyadic negative affect, were associated with adolescent BPD traits (Fleck et al., 2023; Khoury et al., 2020; Lyons-Ruth et al., 2015; Whalen et al., 2014). The association between ELM and the development of BPD has been covered by a wide body of research (e.g., Bozzatello et al., 2020; Porter et al., 2020) and parental ELM has been reported as having a negative effect on parenting behavior during mother-child interactions (Rowell & Neal-Barnett, 2022; Vaillancourt et al., 2017). Child or adolescent ELM as an influence on mother-child interactions, however, has rarely been considered in previous studies, although first studies could demonstrate effects on maternal and child behavior (Lyons-Ruth et al., 2013, 2015).

In general, studies examining parent-child interactions in the context of child and adolescent BPD traits are still scarce, particularly those focusing on parental, child/adolescent and dyadic behavior during the same interaction. Moreover, many existing findings are based on community samples, do not include a control group, or assess behavior in only one context (either positive or stress-related).

Study 2 overcomes these limitations by comparing interactional behavior across two different contexts in a sample of 38 adolescents with at least 3 BPD symptoms and their mothers (BPD-G) to a sample of 35 healthy mother-adolescent dyads (HC-G). Within the BPD-G, 50% of adolescents met the full diagnostic criteria of BPD, while the other 50% displayed subsyndromal symptomatology. Subsyndromal symptomatology during adolescence has been linked to serious mental health problems and alterations in psychosocial functioning and should therefore be treated in clinical settings and also considered in research studies (Chanen et al., 2020; Kaess et al., 2017).

Each mother-adolescent dyad participated in two 10-minute interactions: a positive interaction (planning a fun day with joyful activities) and a stress-inducing task (solving an unsolvable tangram under time and social pressure; see also Figure 1 on p. 129). All interactions were video-recorded and maternal, adolescent, and dyadic behavior were later coded by trained raters. Additionally, several self-report questionnaires (measuring e.g., general adolescent and maternal psychopathology, ELM, attachment security) were applied.

In our sample, adolescents in the BPD-G reported significantly more emotional and behavioral problems and ELM than those in the HC-G. Their mothers reported higher levels of psychopathology, interpersonal sensitivity, and attachment insecurity, though maternal ELM did not differ between groups.

Behavioral analyses indicated that BPD-G showed lower quality in maternal, adolescent, and dyadic behavior, with the exception of maternal intrusiveness, where no group differences emerged. Stress reduced maternal sensitivity, adolescent engagement and withdrawal (maybe representing different ER strategies, i.e., disengagement versus increased activity, used by those adolescents), and increased dyadic negativity. Notably, a significant group\*context interaction was observed for dyadic reciprocity: while HC-G dyads increased reciprocal behavior under stress, BPD-G dyads showed a decline.

General adolescent psychopathology (GAP) was associated with adolescent and dyadic behavior. When controlling analyses for GAP, group differences in adolescent

behavior remained robust, whereas differences in dyadic behavior were no longer significant. Maternal trauma was unrelated to behavior. Adolescent trauma scores correlated with behavioral outcomes but did not account for additional variance beyond group status.

This study confirms previous research findings of reduced quality in parental, adolescent, and dyadic behavior during mother-adolescent interactions in the context of adolescent BPD traits and extends these findings to a clinical adolescent sample across two different contexts (positive and stress-inducing). Results indicate that maternal sensitivity and structuring as means to externally co-regulate overwhelming emotions of the adolescent might be more relevant contributors to the development of BPD than maternal intrusiveness. An interesting result is the group difference in dyadic reciprocity (i.e., behavioral synchrony) during stress. While HC-G dyads may trust their interaction partner and their collective abilities to solve the issue at hand, BPD-G dyads tend to cease cooperation, probably reflecting a history of conflict-ridden interactions and mutual experiences (and therefore expectations) of frustration and escalation (Geiger & Crick, 2010; Lyons-Ruth et al., 2013). While impaired dyadic behavior seems linked to both BPD symptoms and GAP, adolescent behavior appears driven mainly by BPD, suggesting difficulties or limitations in social interaction skills. From a transactional point of view, the elevated levels of maternal psychopathology in the BPD-G could either have contributed to the development of BPD traits or result from the adolescent's BPD symptomatology. The lack of association between maternal ELM and behavior supports previous findings suggesting that parental ELM alone may not explain alterations in mother-child interactions, but only when accompanied by psychopathology (Kluczniok et al., 2016; Mielke et al., 2020).

Results of this study indicate that BPD specific treatments should place greater emphasis on parent-child interactions to foster interpersonal skills and, in the long run, improve long-term psychosocial functioning.

### **3.3 Individual Pattern and Synchrony of Heart Rate Variability in Adolescent Patients with Borderline Personality Psychopathology and their Mothers: A Case-Control Study**

**Williams, K.,** Fuchs, A., Kuehn, J., Fleck, L., Lerch, S., Cavelti, M., Koenig, J., & Kaess, M. (2025). Individual patterns and synchrony of heart rate variability in adolescent patients with borderline personality psychopathology and their mothers: a case-control study. *Borderline Personality disorder and Emotion Dysregulation*, 12(12).

Study 2 focused on interactional behavior and examined, amongst other variables, dyadic behavior which has previously been referred to as behavioral synchrony (Feldman, 2012). Study 3 focuses on physiological functioning and synchrony (i.e., physiological co-regulation) in the context of adolescent BPD traits before, during, and after the same mother-adolescent interactions examined in Study 2. Specifically, it investigates HRV, which has been described as a physiological marker of emotional and social regulation (Beauchaine & Thayer, 2015).

Lower resting state HRV has been associated to adolescent BPD (Hedinger et al., 2023; Weise et al., 2020) and ED in both children and adolescents (Bellato et al., 2023). HRV decrease (vagal withdrawal) is theorized to reflect attention and stress-related mobilization of resources, while a HRV increase (vagal augmentation) may indicate calmness and readiness for social engagement (Graziano & Derefinko, 2013; Lunkenheimer et al., 2019; Smith et al., 2020). Studies on HRV reactivity and recovery in parent-child interactions and associations to behavior during those interactions are scarce and findings are mixed, especially in the context of adolescent BPD traits (Amole et al., 2017; Bortolla et al., 2020; Crowell et al., 2017; Smith et al., 2020). Given the importance of interpersonal co-regulation in the context of the development and maintenance of BPD, research on HRV functioning of adolescents with BPD traits and their caregivers and associations to behavioral outcomes is needed.

HRV synchrony refers to the “dynamic, within-dyad coordination of [HRV] over time [...] that is directly tied to an interpersonal process” (DePasquale, 2020, p. 1755). Positive HRV synchrony describes simultaneous increases or decreases in both the mother’s and child’s HRV, whereas negative HRV synchrony reflects opposing patterns, such as an increase in the mother’s HRV accompanied by a decrease in the

child's HRV or vice versa. Studies on HRV synchrony indicate a link to positive behavioral interaction and a positive impact on child regulation, though they have mainly focused on early childhood (DePasquale, 2020). HRV synchrony is likely influenced by context and the dyad's risk for psychopathology (Lunkenheimer et al., 2018). It may become maladaptive when parents have mental health problems or difficulties with ER (Birk et al., 2022; Creavy et al., 2020), and as children grow older and are supposed to develop (and use) better self-regulation skills (Birk et al., 2022; Motsan et al., 2021). To the best of our knowledge, HRV has not been investigated before in the context of adolescent BPD traits. Regarding the association of HRV and behavioral synchrony, one study with a preadolescent sample found the strongest HRV synchrony in combination with the lowest behavioral synchrony in clinical dyads and the lowest HRV synchrony in combination with the highest behavioral synchrony in resilient dyads (Motsan et al., 2021). However, this has also never been investigated with an adolescent BPD sample.

To address the current lack of research, Study 3 focused on four dependent variables: 1) individual HRV for resting/reactivity/recovery, 2) intrapersonal concordance of HRV and behavior, 3) HRV synchrony between caregiver and child and 4) associations between HRV and behavioral synchrony. Additionally, the influence of GAP on individual HRV was explored.

To examine these research questions, chest belts were applied to the mothers (BPD-M/HC-M) and adolescents (BPD-A/HC-A) from Study 2. HRV was recorded before, during and after both interactions. HRV data were analyzed in one-minute segments across five conditions: *resting 1*, a *positive interaction* (fun day planning), *resting 2*, a *stress-inducing task* (unsolvable tangram), and *resting 3*. As described above, interactions were 10 minutes long and each resting period lasted five minutes (see also Figure 1 on p. 129).

In line with prior research and our hypotheses, BPD-A showed lower *resting* HRV in comparison to HC-A. For mothers no group differences were found (see also Figure 2 on p. 137 for visualization).

From *resting 1* to *positive interaction*, HRV increased in BPD-A and mothers of both groups and did not change for HC-A. This increase may represent calmness for mothers but a struggle to self-regulate and/or the suppression of emotions for BPD-A (Daros & Williams, 2019; Moore et al., 2009; Thayer et al., 2012). Given that controlling for GAP did not change these effects, they appear to be specific to BPD.

From *resting 2 to stress*, no HRV changes were found in neither of the groups. Different mechanisms may have played a role in the lack of adolescent HRV reactivity to stress, e.g., decreased autonomic flexibility for the BPD-A vs. presence of mothers/higher behavioral skills as a buffer for the HC-A (Shahrestani et al., 2014; Williams et al., 2023). When controlling these analyses for GAP, higher GAP was linked to higher HRV differences between contexts, i.e., lower HRV scores during stress. Therefore, GAP may have had a stronger influence on stress reactivity than BPD traits which highlights the need to include other clinical groups in future research.

In all groups, HRV increased from *stress to resting 3*, which may be explained by the anticipated end of our interactional paradigm.

Associations between behavior and HRV were not significant for either adolescent group or BPD-M in any of the interactions. In contrast, HC-M showed a significant positive behavior-HRV link during the positive interaction, suggesting a regulated physiological state. However, the negative link during stress was not significant. Visual inspection of the regression plots hint at altered autonomic regulation in BPD dyads; however, given the lack of statistical significance, interpretations must be made with considerable caution.

HC dyads and those with higher behavioral synchrony showed positive HRV synchrony during rest, whereas BPD dyads and those with lower behavioral synchrony exhibited HRV synchrony during stress. Study 2 found increased reciprocal behavior during stress in HC dyads, but a decrease in BPD dyads. Taken together, our data suggest that under stress, HC dyads may rely on their social competence, task-solving abilities, and self-regulation skills, reducing the need for physiological co-regulation. In contrast, BPD dyads may lack these resources and thus remain more dependent on physiological co-regulation, reflecting a more developmentally immature pattern. Future research will have to determine whether physiological synchrony in this context is adaptive (i.e., effective physiological co-regulation) or maladaptive (i.e., physiological stress escalation).

This study is the first to examine aberrations in HRV functioning and synchrony in the context of mother-child interaction and adolescent BPD traits. Findings highlight the need for further research, such as validating results with an established stress paradigm, comparison to other psychiatric conditions, or the exploration of treatment effects. Nevertheless, Study 3 underscores the importance of the caregiver-child

relationship and physiological co-regulation for the development of BPD, supporting the benefit of the biobehavioral synchrony framework.

When analyzing intergenerational processes, it is not only important to examine factors that may contribute to negative cycles, but also to identify those that might buffer the adverse effects of parental mental illness or ELM on the next generation. This is the focus of Study 4, which concludes this dissertation on a constructive note by exploring social support as a potential protective factor.

### **3.4 Parental Mental Illness, Borderline Personality Disorder, and Parenting Behavior: The Moderating Role of Social Support**

Seeger, F. R., Neukel, C., **Williams, K.**, Wenigmann, M., Fleck, L., Georg, A. K., Bempohl, F., Taubner, S., Kaess, M., & Herpertz, S. C. (2022). Parental mental illness, borderline personality disorder, and parenting behavior: the moderating role of social support. *Current Psychiatry Reports*, 24(11), 591–601.

The last paper of this dissertation returns to parental characteristics by reviewing existing literature on parental mental disorders, their influence on parenting behavior and on child functioning. It also introduces social support as moderating variable within these associations and therefore touches several components of the proposed Revised Tripartite Model.

The narrative review includes literature published between 2000 and 2021 and synthesizes findings on how parental mental illness (e.g., depression, anxiety, substance-abuse disorder) is associated with impairments in parenting behavior (e.g., low sensitivity, inconsistent discipline, affective dysregulation, difficulties in mentalization). These impairments seem to be amplified when mothers have experienced ELM, e.g., by further reducing sensitivity in parent-child interactions (Kluczniok et al., 2016). However, ELM alone and without the subsequent development of a mental disorder may not significantly impair parenting behavior (Mielke et al., 2020). Research has largely focused on parental BPD, demonstrating, for example, increased hostility towards the child or difficulties with serving as a role model for effective ER (Bartsch et al., 2015, 2016; Kluczniok et al., 2018).

In addition, the reviewed studies underline the bidirectional nature of parent-child interaction. Child attachment difficulties and the emergence of psychopathological

symptoms in response to problematic parenting may increase parental stress and further decrease the quality of parenting behavior (Evers et al., 2023).

Importantly, the review identifies both informal (e.g., from friends or extended family) and formal (e.g., from professionals and public health institutions) social support as a moderating factor. Several studies indicate that higher perceived social support can buffer the negative effects of parental psychopathology on parenting behavior, particularly in high-risk groups such as mothers with BPD (e.g., Álvarez et al., 2021; Armstrong et al., 2005). Social support benefits parents both indirectly, e.g., by enhancing their well-being through improved ER, and directly, e.g., by promoting more adaptive parenting behaviors. However, there are also studies suggesting that this is not always the case. For instance, in the context of parental depression, social support may reinforce parental withdrawal, as other family members step in to take over caregiving responsibilities (Taraban et al., 2017).

The importance of social support for family functioning became particularly evident during the SARS-CoV-2 pandemic, when social distancing measures – including home office and school closures – isolated many families from formal and informal support systems. Research showed that parental mental health declined during this period, children were more exposed to negative parenting behaviors, and exhibited higher rates of psychopathological symptoms (Racine et al., 2021; Sari et al., 2022; Seitz et al., 2021). However, social support appeared to mitigate some of the pandemic's adverse effects on mental health (Seitz et al., 2021; Yu et al., 2020).

Finally, the review introduces parenting programs as a promising approach to interrupt the transgenerational transmission of mental disorders. Although improvements in parental mental health can have a positive effect on parenting (Cuijpers et al., 2015), interventions that directly target parenting behavior may be more effective. Key components such as psychoeducation, peer exchange, and skills training in specific parenting strategies have proven particularly beneficial (Marston et al., 2016). These elements are integrated, for example, in the Lighthouse Parenting Program (Byrne et al., 2019), a mentalization-based intervention specifically designed for parents with mental illness. Such programs may be especially beneficial for at-risk families, not only by enhancing parenting skills but also by providing much-needed social support.

The review concludes that there is strong evidence for the importance of social support in the context of family dynamics. However, inconsistent conceptualizations of social support and the complex interplay between social support and other influencing

factors, such as SES, make it difficult to compare findings across studies. Surprisingly, studies on how social support could buffer effects of BPD on parenting behavior are scarce. Future studies could examine how supportive networks enhance ER in parents with BPD and reduce negative affect, potentially decreasing hostile behavior towards their children. Finally, parenting programs that include both informal and formal support should be offered additionally to standard clinical care to help prevent transgenerational transmissions.

#### **4. Discussion**

This dissertation comprises studies that investigated key variables of the Revised Tripartite Model (p. 21) to enhance our understanding of the development of ER in children. The model emphasizes the dynamic interplay between *parent* and *child characteristics*, *family context*, *physiological factors*, *biobehavioral synchrony*, and *social support* in shaping children's ER and subsequent adjustment.

The findings of Study 1 underscore the critical role of maternal ER (*parent characteristics*) in shaping early mother-infant interactions (*family context*) and specifically identify maternal dissociative symptoms, a maladaptive form of ER, as a potential mechanism in the intergenerational transmission of ACEs. Within the scope of my dissertation, I integrated four additional variables (*physiological factors*, *biobehavioral synchrony*, *social support*, and *environmental factors*) into the model, three of which I explored in Studies 2 through 4. The findings of Studies 2 and 3 point to the importance of *biobehavioral synchrony* during adolescence and its role in adolescent ER and mental health. Finally, Study 4 demonstrated the moderating role of *social support* in the relationship between *parent characteristics* and *family context*. The following section discusses the main findings of these studies in relation to one another, considers their potential implications for the development of child ER (4.1), addresses limitations of the included studies and outlines directions for future research (4.2) and clinical practice (4.3).

## 4.1 Caregiver-Child Co-Regulation and the Development of Emotion Regulation: Insights from the Revised Tripartite Model

Study 1 provides insight into one potential pathway through which maternal ELM and maladaptive ER strategies may have long-term effects on child development. The results indicate that maternal ELM not only predict maternal parenting behavior but also child behavior during mother-infant interactions. Furthermore, maternal dissociation emerged as a longitudinal predictor of several parenting-related variables and served as a mediator in the relationship between maternal ELM and parenting stress, bonding impairment, and the risk of physical child abuse. From a transactional point of view, maternal ELM appears to initiate a cycle: in stressful situations, the mother might display dissociative symptoms, initially developed as a mechanism to cope with her own childhood trauma. These dissociative states in turn might undermine her caregiving and co-regulatory abilities when her child is in need and the child's persisting distress might further increase the mother's stress and perpetuate dissociation. In Study 1, infants of mothers with ELM showed less responsive and involved behavior during interactions, possibly reflecting early signs of disrupted dyadic regulation resulting from maternal difficulties in coping with stress. When considering potential long-term implications of this scenario for the child, he or she may not only observe and later imitate a maladaptive ER strategy (i.e., *observation within the family context* as described in the Revised Tripartite Model) and therefore develop difficulties to self-regulate, but also fail to receive effective co-regulation, increasing his or her risk for ED. The child in this scenario might also learn that close others withdraw in moments of stress, possibly decreasing trust in future co-regulation. Given that children who experience ELM often exhibit heightened emotional reactivity (Weissman et al., 2019), the absence of adaptive co-regulation can raise the risk for ED and subsequent psychopathology. Dysregulated children are also at heightened risk to be rejected or victimized by peers, which in turn can further negatively influence social and affective functioning in adolescence (Bierman et al., 2015). This early message ('others won't help you to manage your emotions') might therefore have implications for long-term relational and emotional health.

As Study 4 outlines, social support can serve as a buffer in this cycle by supporting the parent, e.g., by promoting parenting skills or enhancing their well-being, and by providing effective co-regulation through external sources. However, social support

might also be helpful for the child's ER development independent of the parent: empathic co-regulation of preschoolers in their friendship group, for example, can promote ER of these children (Diebold et al., 2025). During adolescence, best friends, parents, and also teachers all contribute to ER development and therefore emotional adjustment of the adolescent (Azpiazu Izaguirre et al., 2021; Miller-Slough & Dunsmore, 2020; Reindl et al., 2016).

The fact that adolescent ER strategies are still malleable is important when considering the results of Study 2 and 3. Adolescents in these studies were already clinically affected in their ER and exhibited BPD symptoms. The findings suggest alterations in parent-adolescent behavioral and physiological co-regulation, especially during a stress condition. While healthy dyads were able to increase cooperative, reciprocal behavior during stress, clinical dyads might not have trusted in their behavioral co-regulation and therefore might have fallen into a presumably immature physiological co-regulative pattern. In the context of BPD, this result is particularly relevant given that interpersonal conflicts and disturbances affect not only current mental health (e.g., self-harm behavior) but also long-term psychosocial functioning of individuals with BPD (Howard et al., 2022; Miskewicz et al., 2015; Pagano et al., 2004; Perry et al., 1992; Powers et al., 2013). In studies with adult BPD patients, they exhibited impaired cooperation in economic games and, when cooperation was broken, were unable to repair it (King-Casas et al., 2008). Compared to healthy controls, patients with BPD tend to expect less from relationships and show lower trust in their interaction partners; they also struggle with resolving interpersonal problems, often generating less effective and more passive solutions (Lazarus et al., 2014). Such deficits can undermine the development of supportive social networks, fostering feelings of loneliness and social isolation in BPD patients (Liebke et al., 2017; Reinhard et al., 2022). In turn, loneliness has been linked to lower social functioning (i.e., social engagement, prosocial behavior, and social communication; Liebke et al., 2017).

Taken together, results suggest that early dysregulated mother-child interactions might lay the groundwork for later difficulties in self-regulation and interpersonal skills, and reduced trust in others as sources of co-regulation. In the long-term, this could lead to increased vulnerability to ED-related disorders such as BPD, as well as social isolation, which can further exacerbate mental health problems.

In line with the Revised Tripartite Model's feedback loop, these maladaptive patterns may continue across generations: a child growing up with ER deficits may later

replicate similar caregiving patterns as a parent and, without having learned effective self-regulation, will struggle to co-regulate their own children. This parent is also likely to be socially more isolated and therefore receive less social support, that could buffer potential problematic interactions with their child or help the child develop adaptive ER strategies outside of the caregiving environment.

Mental health issues have a profound impact not only on those directly affected and their families, but also impose a significant financial burden on society, particularly in the case of BPD (Wagner et al., 2022; Wiegand et al., 2025). While it is essential and unquestionable that those in need receive appropriate treatment, the critical question remains: how can we prevent the onset of psychopathology in the first place? Addressing this requires a twofold approach: firstly, we have to continue research to deepen our understanding of underlying mechanisms (4.2), and secondly, we have to intervene with effective clinical practice (4.3) when individuals and their support system are no longer able to cope.

## **4.2 Limitations and Directions for Future Research**

To better understand how trauma-related dissociative symptoms shape parenting and, in turn, the mental health of the next generation, future research should adopt longitudinal designs with clinical samples and a bidirectional approach. Even though Study 1 employed a longitudinal design, it was limited to the first year postpartum. Since we are interested in the long-term impact of such maladaptive parental ER strategies on the next generation, we have to follow up on the children and explore their ER development and related mental health. Ideally, this would also include an exploration of how these children navigate self- and co-regulation as future parents. As we did not investigate clinical samples, we cannot draw conclusions about how clinically relevant dissociative symptoms might affect the children of mentally ill parents. To confirm the hypothesis that dissociative states lead to child behaviors which then elevate parental stress and maintain dissociation, fine-grained, moment-by-moment bidirectional analysis of behavior are required. As previously discussed, and demonstrated in our study, studies should include different aspects of parenting and integrate both self-report and behavioral data.

While Study 2 and 3 are the first studies to investigate biobehavioral synchrony in a clinical adolescent BPD sample in two different contexts, the current findings on behavioral and physiological co-regulation offer only preliminary insights into altered dyadic processes. Considerably more research is needed, particularly regarding physiological co-regulation. Most importantly, longitudinal studies must clarify if dysregulated co-regulatory processes between caregiver and child are precursors or consequences of adolescent BPD traits. In our own study, maternal BPD traits were not assessed, even though earlier work has shown that children of BPD parents have an elevated risk of developing the disorder themselves (Flowers et al., 2018), with maladaptive mother-child interactions mediating this intergenerational transmission (Reinelt et al., 2014). This raises the possibility that parental characteristics shaped early co-regulatory experiences, preventing their child from acquiring effective self-regulation in the first place. Moreover, it remains unclear whether physiological synchrony in the absence of behavioral co-regulatory competence represents an adaptive or maladaptive mechanism. As stated before, synchrony may have different meanings depending on the presence of certain risk factors, particularly when parental ER difficulties or mental health problems are present. Physiological synchrony with a physiologically dysregulated caregiver may not be beneficial and could even reinforce maladaptive patterns. Therefore, it is essential that future research systematically includes parental characteristics such as ER skills, to better understand their role in these dyadic processes.

Assuming that biobehavioral synchrony affects children's ER development, it becomes essential to assess ER competencies in the child or adolescent involved in these studies. Depending on the developmental stage of the child, different co-regulatory abilities and requirements can be assumed (e.g., adolescents should have greater self-regulatory competencies and be therefore less dependent on caregivers). This further underscores the importance of longitudinal studies that can trace these developmental changes over time. Ideally, such studies would involve different diagnostic groups (e.g., BPD, depression, anxiety disorders) and integrate diverse physiological and behavioral measures (e.g., cortisol, HRV, and dyadic reciprocity) to investigate how these processes interact over time.

Another critical gap in the literature and limitation of our studies involves the role of fathers in the development of BPD. While maternal influences have been more thoroughly investigated, studies like the one from Reichl et al. (2017) suggest that

paternal contributions warrant greater attention. Equally underexplored is the question of whether social support can buffer the effects of parental BPD on parenting behavior and child-related outcomes. This is particularly relevant as existing findings suggest that support systems can play a protective role.

One shared limitation of the presented studies is the absence of a stress paradigm in Study 1 and the lack of a measurable physiological stress response to the stress paradigm in Studies 2 and 3. Given that dissociative symptoms and BPD-specific ER difficulties are more likely to be triggered under stress, future research should employ paradigms that reliably elicit stress responses (e.g., the Trier Social Stress Test, TSST; Kirschbaum et al., 1993).

Additionally, the samples in these studies were predominantly highly educated and of higher socioeconomic status. While this limits generalizability to the broader population, it also reduces the influence of contextual confounds (e.g., financial stress), enabling more focused conclusions about the effects of ELM and mental disorders.

In sum, future research should aim to implement longitudinal, multimethod designs, examine biobehavioral bidirectional processes in the context of both parental and child risk factors and investigate protective factors such as social support. Only when we truly understand how ED and psychopathology are transmitted across generations, we can develop effective interventions to disrupt these cycles.

### **4.3 Clinical Implications**

Each study of this dissertation has focused on a different component of the Revised Tripartite Model, highlighting multiple intervention points.

First of all and as a general note, any adult entering psychiatric or psychotherapeutic treatment should be asked: 'Do you have children?'. Despite clear evidence that parental mental illness is a risk factor for the next generation, clinicians often skip this step, likely due to limited awareness and knowledge about parenting and child development in adult psychiatric/psychotherapeutic care (Maybery & Reupert, 2018; Reedtz et al., 2019; Tabak et al., 2016; Zalewski et al., 2017). Parenting stress can worsen parental psychopathology but parenthood has also been described as a protective factor, e.g., preventing suicide attempts or increasing treatment engagement (Zalewski et al., 2017). Routine assessment of parenting stress, satisfaction and

quality benefits both parent and child (Zalewski et al., 2017). When additional stress related to parenthood becomes apparent, evidence-based parenting programs could be offered additionally to standard clinical care (e.g., Neukel et al., 2021; Rosenbach et al., 2022). Such programs have been shown to reduce child maltreatment, prevent or improve child mental health issues, and enhance maternal psychosocial well-being (Barlow et al., 2002; Chen & Chan, 2016; Jeong et al., 2021; Thanhäuser et al., 2017; Zalewski et al., 2017). There is also a considerable amount of online parenting programs available that have shown to increase positive parenting, reduce negative parent-child interactions, parenting stress, and psychopathology on both sides (Spencer et al., 2020).

Circling back to Study 1 of this dissertation, trauma-related symptoms such as dissociation, that are known to have an impact on the next generation, must be addressed both in individual adult therapy and in parenting programs. This requires routine screening for dissociative symptoms, followed by targeted psychoeducation on how dissociation can impair a parent's ability to protect their child. Indeed, mothers suffering from dissociative symptoms have been shown to struggle with recognizing potential threats to their children (Hulette et al., 2011).

Despite of frequent co-occurrence of parent and child psychopathology (Zalewski et al., 2017), adult and child services still rarely collaborate in their treatment efforts (Tabak et al., 2016). Approaches that simultaneously treat both interactive partners are needed.

When children or adolescents are in treatment, it remains unclear whether clinicians routinely assess parents' history of ELM or mental illness, even though child and adolescent health professionals are generally more inclined to include parents in care (Zalewski et al., 2017). For adolescents with BPD, current guidelines emphasize that treatment must address the adolescent within their broader social system with its daily challenges and interactions (Arbeitsgemeinschaft der Wissenschaftlich Medizinischen Fachgesellschaften (AWMF)-Ständige Kommission Leitlinien, 2012; National Health and Medical Research Council, 2012). Dialectic Behavior Therapy for Adolescents (DBT-A), for example, already invites parents into skills groups (Rathus & Miller, 2002). In general, evidence supports family-focused interventions (e.g., psychoeducation, family therapy sessions) for adolescents with full or subthreshold BPD (Pu et al., 2023). Building on the findings of Study 2 and 3, two targets emerge for intervention: enhancing maternal sensitivity and reciprocal mother-adolescent behaviors, especially

under stress, and strengthening adolescents' interpersonal and dyadic skills. Video-based feedback, for example, could be a valuable tool for the training of interactional skills in families (De Oliveira et al., 2024). Specifically, programs should train ER strategies not only to the adolescents but also their parents and cultivate cooperative interaction patterns so that adolescents learn to view others as potential sources of support rather than a threat. Indeed, positive maternal and dyadic affective behavior have been linked to reduced BPD symptom severity over time in adolescent girls with BPD (Whalen et al., 2014).

In addition to treating existing psychopathological symptoms, we should also foster resilience, e.g., by strengthening social support. Families facing isolation can benefit from evidence-based parenting programs that involve peer-to-peer exchange and peer-led self-help groups. As a low threshold, community-building option, regular playgroups or shared activities offer parents and children a positive setting to connect with and learn from other families.

It can be concluded that children, adolescents, and adults in psychotherapeutic or psychiatric treatment for ED are never isolated individuals. They exist within relational systems that profoundly influence their well-being through transactional co-regulatory processes. Personal relationships and their co-regulatory functions must be considered as essential to both the development and treatment of mental health difficulties. Achieving to assess and evaluate these dynamics means making use of a critical opportunity to enhance therapeutic outcomes and foster lasting change.

Overall, this dissertation emphasizes the central role of caregiver-child co-regulation in the development of child ER and the intergenerational transmission of adversity. By extending the Tripartite Model to include physiological factors, biobehavioral synchrony, social support, and environmental influences, it offers a more comprehensive framework for understanding the transactional dynamics involved. The presented studies show how maternal and adolescent trauma, maternal dissociative symptoms, adolescent borderline personality traits, and GAP of mothers and adolescents can disrupt these regulatory processes across developmental stages. Taken together, the findings highlight both risk and resilience factors, informing future research and intervention efforts aimed at supporting families at risk.

## 5. References

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## Original publications

### Manuscript 1. Dissociation Links Maternal History of Childhood Abuse to Impaired Parenting

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## **Abstract**

The present study investigated dissociation as a predictor of parenting and a potential mediator in the relationship between early life maltreatment (ELM) and impaired parenting. Mothers reporting moderate to severe sexual and/or physical abuse (assessed with the Childhood Trauma Questionnaire) formed the maltreatment group ( $n = 58$ ; MG) and were compared to a non-maltreated comparison group ( $n = 61$ ; CG) five months (T1) and twelve months (T2) postpartum. Dissociative symptoms were assessed with the Dissociative Experiences Scale (DES) at T1. Parenting was investigated by self-report questionnaires and behavior observation (Emotional Availability Scales; EA) at T2. Higher dissociation scores significantly predicted more self-reported parental bonding impairment and stress, higher physical abuse risk and less observed maternal sensitivity, non-intrusiveness and a lower total EA-score during mother-child interactions ( $p < .001$  to  $p < .05$ ). Dissociation mediated the associations between ELM and self-reported parenting, but not the associations between ELM and parenting as observed during mother-child interactions. Our results suggest that maternal dissociative symptoms play a distinct role in the intergenerational transmission of adverse childhood experiences and should therefore be targeted in therapeutic interventions provided for victims of physical/sexual childhood abuse and in preventive family programs.

**Keywords:** impact of trauma, intergenerational trauma, childhood abuse, dissociation, parenting

## **Introduction**

Early life maltreatment (ELM) is associated with serious consequences for the victims' health and psychosocial development, e.g. suffering from psychiatric disorders, decreased physical health and life satisfaction and lower socioeconomic wellbeing (e.g. Fergusson et al., 2013; Hughes et al., 2017; Witt et al., 2019). ELM not only affects the maltreated but also presents a risk factor for their children. Several research findings indicate that parents who have suffered from ELM are more likely to act abusively and/or negligently towards their own children (e.g. Berlin et al., 2011; Kaufman & Zigler, 1987). A review by Vaillancourt et al. (2017) found self-reported maternal sexual and physical abuse to be a risk factor for impaired parenting in observed mother-infant interactions: mothers were less involved with their children, showed less structuring, less sensitivity or more hostile-intrusive behavior during interaction. In studies using self-report questionnaires, maternal ELM was associated with more hostile behavior towards the offspring, a higher likelihood to use physical punishment, more parental stress and a more negative view of themselves as a parent (Banyard, 1997; Douglas, 2000, Lang et al., 2010). This transmission of ELM is often referred to as the "intergenerational cycle of abuse". Whereas transmission rates vary widely depending on maltreatment operationalization and sample characteristics (see Berlin et al., 2011), findings are consistent in that a large number of abused parents are able to appropriately care for their offspring. However, to be able to support those who are not, we need to identify mechanisms explaining the link between ELM and impaired parenting by investigating potential mediating pathways, such as mental health or altered cognitive and affective processes (Vaillancourt et al., 2017) that may facilitate the "cycle of abuse".

## **ELM, Dissociation and Parenting**

Dissociation, the "disruption of and/or discontinuity in the normal integration of consciousness, memory, identity, emotion, perception, body representation, motor control, and behavior" (DSM-5; American Psychiatric Association, 2013), is often described as a defense mechanism or an acute stress response to cope with otherwise unbearable experiences like physical or sexual abuse (e.g. Chu & Dill, 1990). While dissociation functions as a protective strategy when experiencing abuse, frequent and continued dissociation becomes a dysfunctional coping mechanism. It might then serve as an automated response to even minor stressful situations and prevent

adequate emotion regulation strategies (see Banyard et al., 2001b; Cole et al., 1996). Prior research has provided empirical support for the link between traumatic childhood experiences and dissociation (Dalenberg et al., 2012; Vonderlin et al., 2018). Further, there is preliminary evidence that dissociation in parents may be associated to parenting and the intergenerational transmission of childhood abuse (Egeland & Susman-Stillman, 1996; Kim et al., 2010). Studies have identified dissociation as a mediator in the link between different ELM experiences and self-reported physical child abuse potential in community samples (Mitkovic-Voncina et al., 2014; Narang and Contreras, 2000, 2005) as well as the link between ELM and inconsistent use of discipline in a sample of abusive mothers (Collin-Vézina et al., 2005). Lyons-Ruth and Block (1996) could not replicate these findings in their longitudinal study with low-income mothers, where dissociation was not related to trauma severity or observed parenting. However, behavioral observations took place 7 to 8 years prior to the assessment of maternal ELM and current dissociative symptoms. None of the described mediation studies combined self-report with behavioral observation or addressed other parenting variables, such as parental bonding and parental stress, both related to observed impaired parenting behavior (Muzik et al., 2013; Pereira et al., 2012). Also, none of the studies has included a non-maltreated control group. Additionally, only one study applied a longitudinal design. Still, despite of the methodological differences, all but one study found a significant mediating effect of dissociation in the link of ELM and parenting, suggesting that dissociation may in fact play a role in the intergenerational cycle of abuse.

### **Present Study**

Prior studies examining the same sample of mothers with a history of ELM (maltreatment group = MG) and a matched comparison group (CG) have highlighted associations between maternal ELM and both dissociation (Marysko et al., 2010) and observed parenting (Fuchs et al., 2015). We now extend these findings by focusing on maternal dissociation as a potential mechanism in the intergenerational cycle of abuse. This study contributes to the existing literature by using a longitudinal and CG design as well as a thorough assessment of parenting comprised of both behavioral observation and self-report questionnaires. Firstly, we hypothesized that higher levels of dissociative symptoms would be associated with lower levels of parenting such that

- a) Dissociation predicts more self-reported mother-child bonding impairment,

parenting stress and maternal physical abuse potential; b) Dissociation predicts lower observed sensitivity, structuring, non-intrusiveness and non-hostility as well as less child responsiveness and involvement; c) MG mothers will show more impaired parenting in self-report questionnaires and in mother-child interactions than CG mothers. Secondly, we expected dissociation to be a significant mediator for the pathways between ELM and parenting.

## **Methods**

### ***Recruitment and Participants***

Women giving birth to a child were contacted via email ( $N = 2001$ ) and asked to fill in the Childhood Trauma Questionnaire (CTQ-SF; Bernstein & Fink, 1999; German version by Driessen et al., 2000). 748 (37.4%) women completed the CTQ. 73 (9.8%) of these mothers reached the cut-off score for moderate to severe sexual abuse (score  $> 7$ ) and/or physical abuse (score  $> 9$ ). From these 73 women, 58 mother-child dyads were included in the MG. In the CG, only women with CTQ scores of no or minimal abuse were included ( $n = 258$ ). 61 mother-child dyads were matched to the MG by gender of infant, relationship status, education and number of children.

The total sample consisted of 119 mothers aged between 16;0 and 43;0 years ( $M = 32.45$ ;  $SD = 5.46$ ) and their infants. Mothers were mostly highly educated and in relationships. Groups did not differ in infant sex, age of mothers, relationship status, education and number of children ( $p > .05$ ). The demographic characteristics are presented in Table 1.

### ***Procedure***

At T1 (five months postpartum), we assessed maternal dissociative symptoms; at T2 (12 months postpartum), mother-child interactions were videotaped and parental bonding impairment, parental stress and physical abuse potential were evaluated via self-report.

The study was approved by the ethics commission of the Faculty of Medicine (University of Heidelberg). Subjects gave written informed consent and received financial compensation.

**Table 1***Sample characteristics*

	Maltreatment group ( <i>n</i> = 58)		Control group ( <i>n</i> = 61)		<i>t</i> value	<i>p</i> value
	<i>mean</i>	<i>sd</i>	<i>mean</i>	<i>sd</i>		
Demographics						
Age of mothers	32.45	5.94	32.44	5.02	.01	.996
Number of children	1.76	.82	1.82	.81	-.41	.684
	<i>n</i>	%	<i>n</i>	%	$\chi^2$ value	<i>p</i> value
Male infants	31	53.4	32	52.5	.01	.914
Mother's relationship status					4.35	.053
Relationship	54	93.1	61	100.0	-	-
No relationship	4	6.9	0	0.0	-	-
Mother's highest degree					3.07	.400
Intermediate school (or less)	15	26.8	13	21.3	-	-
A-Levels	23	41.1	26	42.6	-	-
University	18	32.1	22	36.1	-	-

## **Measures**

*Maternal history of abuse:* The CTQ (Bernstein & Fink, 1999; German version by Driessen et al., 2000) is a retrospective self-report inventory that comprises five subscales: emotional abuse, physical abuse, sexual abuse, emotional neglect and physical neglect; scores of the five subscales range from 5 (no history of abuse/neglect) to 25 (severe history of abuse/neglect). The German version of the CTQ has been found to be a valid and reliable instrument (e.g. Scher et al. 2001).

*Maternal dissociation:* The Dissociation Experience Scale (DES; Bernstein & Putnam, 1986; German version by Brunner et al., 1999), a self-report questionnaire that measures dissociation as a continuum from normal to pathological, was applied. Psychometric properties of the DES were found to be good to excellent (Brunner et al., 1999).

*Postpartum bonding:* The German version of the Postpartum Bonding Questionnaire (PBQ; Reck et al. 2006; original version by Brockington et al., 2001) is a validated screening instrument to determine bonding disorders within mother-child relationships. As the German version could not replicate the structure model of the original scale, only total scores were used (Reck et al., 2006).

*Parenting stress:* The self-report Parenting Stress Index (PSI-SF; Abidin, 1995) was translated into German for the purpose of this study; higher total values indicate more stress in the parent-child system. The PSI-SF shows good to excellent internal consistencies and high test-retest reliability (e.g. Haskett et al., 2006).

*Parental risk of physical child abuse:* The potential for physical child maltreatment was assessed with the Physical child abuse scale of the Child Abuse Potential Inventory (CAPI; Milner, 1986; German version by Globisch & Spangler, 2000). Validation studies could prove good reliability and validity of the instrument (Laulik et al., 2015).

*Observation of mother-child interactions:* 20 minutes of free play were videotaped. Mothers were instructed to play with their infant "as usual". The videos were independently coded by two previously trained raters (interrater reliability: .69 to .84), who were blinded to group membership of the dyads (MG vs. CG), using the Emotional Availability Scales (EAS, 3<sup>rd</sup> version; Biringen et al., 1998). The EAS are a well-established standardized instrument with good psychometric properties (Biringen et al., 2014) that assesses quality of mother-child interactions. The EAS allow ratings on four parental scales (sensitivity, structuring, non-intrusiveness, non-hostility) and two child scales (child responsiveness and child involvement).

## **Statistical analyses**

Sample characteristics were computed with independent samples *t*-tests and Fisher's  $\chi^2$ -Tests. Group differences were calculated with independent samples *t*-tests. 16 mothers of the CG (26.2%) and 17 mothers of the MG (29.3%) had missing data in self-report parental outcome measures [PBQ:  $n_{MG} = 11$  (19.0%),  $n_{CG} = 13$  (21.3%); PSI:  $n_{MG} = 5$  (8.6%),  $n_{CG} = 1$  (1.6%); CAPI:  $n_{MG} = 2$  (3.4%),  $n_{CG} = 2$  (3.3%)]. Subjects with missing data did not significantly differ in parental outcome or sociodemographic variables from those with full data sets ( $p = .251$  to  $p = .992$ ) and were therefore included in the analyses.

Age and education of mother were controlled for in subsequent analyses. To test if dissociation predicts parenting outcome measures, multiple linear regressions were computed; when homoscedasticity could not be assumed (Breusch & Pagan; 1979), the HC3 method for parameter estimates with robust standard errors was applied.

Mediation analyses were calculated using the bootstrapping-based approach by Hayes (2018); bootstrapping with 10000 samples together with heteroscedasticity consistent standard errors (HC3; Davidson & MacKinnon, 1993) were employed to compute the confidence intervals and inferential statistics. As recommended by Hayes and Rockwood (2017), mediation effects were assumed to be significant when the confidence interval did not include zero.

## **Results**

### ***Clinical characteristics of the sample***

Groups differed in the CTQ total score ( $t(59.24) = -11.03$ ,  $p < .001$ , Cohen's  $d = -2.07$ ), with the MG ( $m = 50.71$ ,  $sd = 15.85$ ) showing a higher overall trauma score than the CG ( $m = 27.52$ ,  $sd = 2.28$ ). The MG in our sample reported more dissociative symptoms 5 months postpartum than the CG ( $m_{MG} = 1.18$ ,  $sd_{MG} = .78$ ;  $m_{CG} = .67$ ,  $sd_{CG} = .46$ ;  $t(91.26) = 4.34$ ,  $p < .001$ , Cohen's  $d = -.80$ ).

### ***Associations Between Dissociation at 5 Months and Parenting at 12 Months***

As hypothesized, higher dissociation scores predicted more self-reported parenting stress ( $\beta = .34$ ,  $p < .001$ ) and bonding impairment ( $\beta = .40$ ,  $p < .001$ ) as well as higher child abuse potential ( $B = 31.80$ ,  $p < .01$ ). In mother-child interactions however, high dissociation only predicted lower maternal sensitivity ( $\beta = .22$ ,  $p < .05$ ), lower maternal non-intrusiveness ( $\beta = -.25$ ,  $p < .01$ ) and a lower EA total score ( $\beta = -.19$ ,  $p < .05$ ), but not the other EA subscales (see Table 2).

**Table 2***Dissociation predicts maternal self-report and behavior in mother-child interactions*

Dependent variable	<i>B</i> ( <i>SE</i> )	$\beta$	<i>t</i>	<i>p</i>	Adj. <i>R</i> <sup>2</sup>
Self-report questionnaires					
Bonding impairment (PBQ)	4.18 (.99)	.40	4.22	< .001	.172
Parental stress (PSI)	8.28 (2.190)	.34	3.78	< .001	.136
Child abuse potential (CAPI)	31.80 (10.76) <sup>1</sup>	-	2.95	.004	.115
Behavior observation (EA scales)					
Mother sensitivity	-.47 (.20)	-.22	-2.36	.020	.046
Mother structuring	-.12 (.12)	-.10	-1.02	.308	-.008
Mother non-intrusiveness	-.36 (.13)	-.25	-2.77	.007	.052
Mother non-hostility	-.13 (.12)	-.10	-1.08	.282	.008
Child responsiveness	-.12 (.13)	-.09	-1.00	.321	-.015
Child involvement	-.16 (.15)	-.10	-1.11	.268	.025
<i>Total</i>	-.23 (.11)	-.19	-2.07	.041	.038

*Note.* Multiple linear regressions with education and age of mother as covariates.

<sup>1</sup> HC3 method.

### ***Associations Between ELM and Parenting at 12 Months***

Mothers of the MG showed significantly more bonding impairment, more parental stress and higher physical child abuse potential in comparison to the CG ( $p < .01$  to  $p < .001$ ). On the EA scales, mothers of the MG showed less sensitivity, structuring, non-intrusiveness and non-hostility and children of the MG were observed to be less responsive and less involved in the interaction ( $p < .05$  to  $p < .01$ ; for details see Table 3).

### ***Maternal ELM, Dissociation and Parenting***

Mediation analyses revealed indirect and therefore mediating effects of dissociation on the association between group and self-reported parenting (PBQ: 95% *CI* .732; 3.662; PSI: 95% *CI* .444; 5.018; CAPI: 95% *CI* .9528; 21.7209) but not for the link between group and observed parenting behavior. For details of the mediation analyses see Table 4 and Figure 1.

**Table 3***Group differences in parenting 12 months postpartum*

Parenting measures	Maltreatment group		Control group		<i>t</i> value	<i>p</i> value	Cohen's <i>d</i> <sup>1</sup>
	<i>mean</i>	<i>sd</i>	<i>mean</i>	<i>sd</i>			
Self-report questionnaires							
Bonding impairment (PBQ) <sup>2</sup>	13.64	8.43	9.52	5.48	-2.82	.006	-.581
Parental stress (PSI) <sup>3</sup>	71.58	15.67	58.22	12.73	-5.00	< .001	-.942
Child abuse potential (CAPI) <sup>4</sup>	113.05	76.78	54.24	44.36	-4.99	< .001	-.944
Behavior observation (EA scales) <sup>5</sup>							
Mother sensitivity	5.66	1.32	7.13	1.30	6.15	< .001	1.122
Mother structuring	3.62	.90	4.14	.81	3.29	.001	.608
Mother non-intrusiveness	3.25	.93	4.30	.77	6.71	< .001	1.233
Mother non-hostility	3.61	.95	4.23	.77	3.88	< .001	.719
Child responsiveness	4.70	.81	5.43	.87	4.76	< .001	.868
Child involvement	4.46	1.14	4.93	1.00	2.38	.019	.439
<i>Total</i>	4.22	.78	5.03	.69	6.00	< .001	1.102

*Note.* <sup>1</sup>Cohen's *d* was corrected for different sample sizes; <sup>2</sup> $n_{MG} = 47$ ,  $n_{CG} = 48$ ; <sup>3</sup> $n_{MG} = 53$ ,  $n_{CG} = 60$ ; <sup>4</sup> $n_{MG} = 56$ ,  $n_{CG} = 59$ ; <sup>5</sup> $n_{MG} = 58$ ,  $n_{CG} = 61$ .

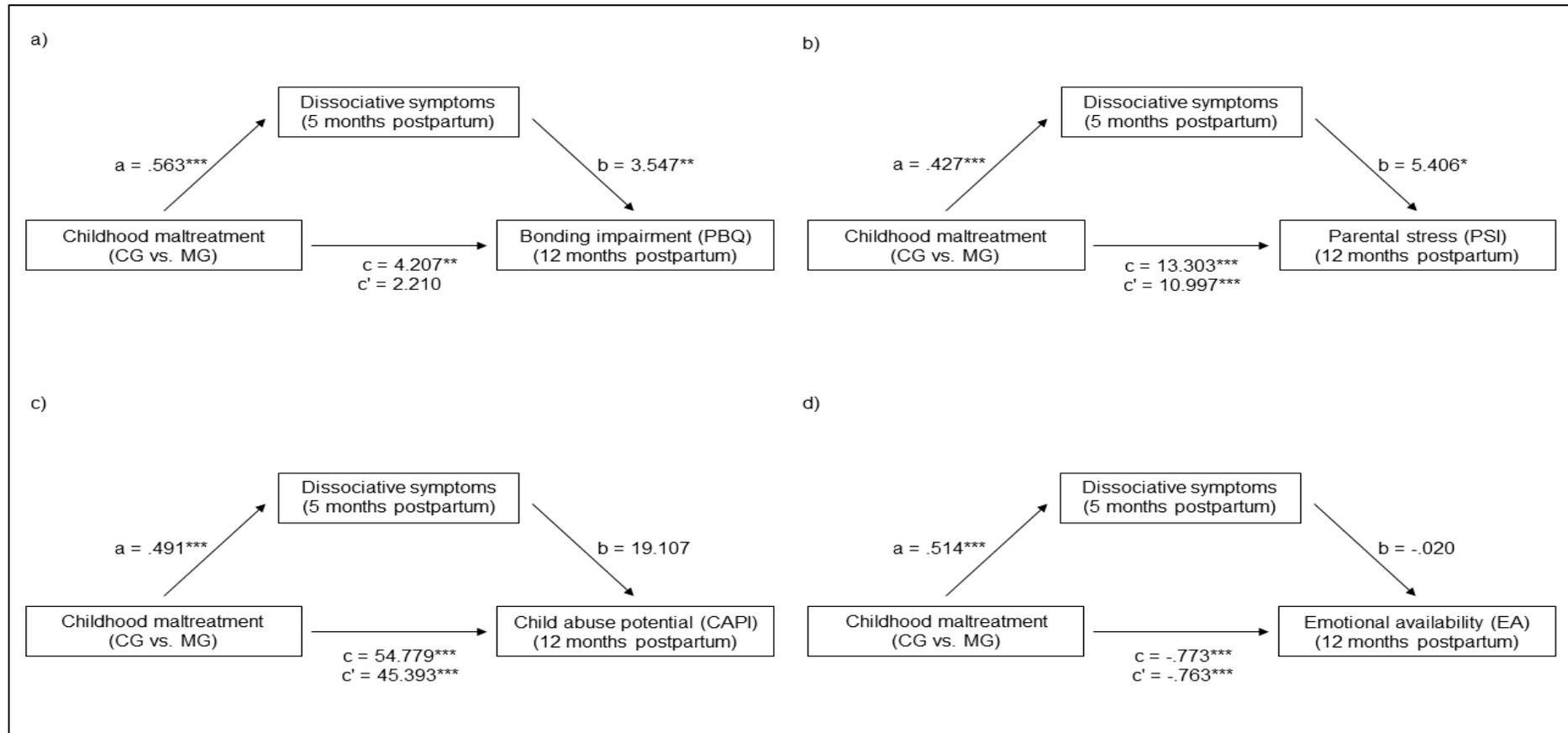
**Table 4**

*Mediation analyses: dissociation as a mediator of the association between group and parenting with age and education of mother as covariates*

Pathways	a		b		c		c'		ab	
	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>	<i>b</i>	95% <i>CI</i>
Self-report questionnaires										
Bonding impairment (PBQ)	.563	< .001	3.547	.002	4.207	.004	2.210	.144	1.997	[.732;3.662]
Parental stress (PSI)	.427	< .001	5.406	.020	13.303	< .001	10.997	< .001	2.306	[.444;5.018]
Child abuse potential (CAPI)	.491	< .001	19.107	.073	54.779	< .001	45.393	< .001	9.386	[.953;21.721]
Behavior observation (EA scales)										
Sensitivity <sup>1</sup>	.514	< .001	-.092	.615	-1.412	< .001	-1.365	< .001	-.048	[-.230;.142]
Structuring <sup>1</sup>	.514	< .001	.012	.928	-.4860	.004	-.492	.008	.006	[-.117;.150]
Nonintrusiveness <sup>1</sup>	.514	< .001	-.097	.494	-1.019	< .001	-.970	< .001	-.050	[-.183;.100]
Nonhostility <sup>1</sup>	.514	< .001	.032	.800	-.586	.001	-.602	.002	.016	[-.101;.161]
Responsiveness <sup>2</sup>	.514	< .001	.083	.536	-.713	< .001	-.756	< .001	.043	[-.082;.195]
Involvement <sup>2</sup>	.514	< .001	-.057	.736	-.420	.040	-.391	.098	-.029	[-.195;.145]
EA Total	.514	< .001	-.020	.856	-.773	< .001	-.763	< .001	-.010	[-.111;.109]

*Note.* a = effect of group on dissociation, b = effect of dissociation on parenting behavior, c = total effect of group on parenting behavior, c' = direct effect of group on parenting behavior, ab = indirect effect of group on parenting through dissociation (0 in confidence interval means indirect effect is not significant).

Figure 1. *Dissociation as a mediator of the association between group and parenting with age and education of mother as covariates*



Note. a) – d): a = effect of group on dissociation, b = effect of dissociation on parenting, c = total effect of group on parenting, c' = direct effect of group on parenting; indirect effects of group on parenting (0 in confidence interval means indirect effect is not significant): a)  $ab = 1.997$ , 95% *CI* [.732;3.662]; b)  $ab = 2.306$ , 95% *CI* [.444;5.018]; c)  $ab = 9.386$ , 95% *CI* [.953;21.721]; d) =  $-.010$ , 95% *CI* [-.111;.109].

\* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$

## Discussion

We examined dissociation as a predictor of self-reported and observed parenting and as a potential mediator of the association between maternal ELM and parenting. Higher dissociation scores predicted more self-reported parenting stress, more bonding impairment and higher physical child abuse potential as well as lower maternal sensitivity, non-intrusiveness and EA total scores in mother-child interactions. Further, dissociation significantly mediated the association between ELM and self-reported parenting, but not the association between ELM and observed parenting behavior.

Dissociation can be defined as a dysfunctional emotion regulation strategy, an “over-regulation of emotions” (Lanius et al., 2010), that occurs when no adaptive emotion regulation strategies are available (Banyard et al., 2001b; Hébert et al., 2018). The first year of parenthood poses challenges to all mothers (Cowan et al., 1991) and they go through an attunement process with their infant, learning how to read the child’s signals and adequately respond to them in order to foster the child’s emotional and cognitive development (see Biringen et al., 2014). Mothers’ self-regulatory skills support the child’s own emotion regulation development through modeling successful regulation and offering emotion socialization such as supportive responding or refocusing the child’s attention when being distressed (Morris et al., 2007; Rutherford et al., 2015). When being confronted with their distressed infant, mothers have to self-regulate while, at the same time, calm their child (Rutherford et al., 2015). As our results suggest, a dissociating mother might show lower emotional availability and sensitivity in mother-child interactions, as the mother is just “not fully there”; it could also lead to inappropriate overcompensating like showing intrusive behavior. Interpreting our results in the context of the transactional model by Sameroff (2009), the child might, as a consequence of the (lack of) maternal response, either show more negative behavior to provoke a maternal reaction or might stop expressing needs altogether. The child’s reaction might in turn influence the mother, by causing feelings of helplessness or insufficiency which could explain the higher levels of parental stress and physical child abuse potential. Feeling stressed and not able to appropriately care for their infant might also account for the higher levels of subjective bonding impairment in dissociating mothers. Future research should apply bidirectional approaches to further investigate these theoretical assumptions.

In our study, dissociation did not only predict decreased parenting abilities but did also mediate the association between ELM and self-reported parenting. It did not,

however, mediate the pathway between ELM and observed EA. We are, to the best of our knowledge, the first study to assess the link between ELM, dissociation and parenting using both self-report and observation. Our results show that the influence of dissociation on the association between ELM and parenting differs depending on the measure and, as objective and subjective measures explored different aspects of parenting, also on the assessed construct. However, caution is warranted regarding a generalization of these findings to other parenting contexts: As dissociation is considered a maladaptive response to stress, a stress paradigm may be more likely to evoke maternal dissociative responses (e.g. Banyard et al., 2001b) than a positive play paradigm. Also, even though we found significant direct effects between dissociation and EA scales, these effects were rather low in comparison to those with self-report questionnaires. When considering the self-report results, we must acknowledge the possibility that common method variance may be driving the effects. Future research should apply both positive and stress paradigms to further investigate these effects.

In order to distinguish clearly between maltreated and non-maltreated mothers, subjects with minimal to moderate abuse were excluded from the study. The selection of our sample was merely based on sexual and physical abuse scores and we did not differentiate between different types of abuse and/or neglect. CTQ subscales in our sample proved to be highly intercorrelated, confirming the often-described co-occurrence of maltreatment types found by other authors (e.g. Teicher et al., 2016). However, studies that analyzed different maltreatment types separately found that emotional abuse was the only significant predictor of child abuse potential (Mitkovic-Voncina et al., 2014) and of dissociation (Sar et al., 2009). Future studies could extend our findings by exploring the effects of different maltreatment and neglect types independently including the whole range of severity of trauma. As we only covered the first 12 months postpartum, we also recommend the examination of dissociative symptoms over time in relation to parenting behavior.

As groups were matched by sociodemographic variables, the only difference between MG and CG was the experience of ELM. Although we did not conduct clinical interviews to exclude psychiatric disorders, symptom severity in our sample was not elevated in comparison to the general population and there were no moderating or mediating effects of psychopathology on parenting (Fuchs et al., 2015). We examined a highly educated sample with relatively high levels of social support. Although it may not be representative for the general population, our low-risk sample therefore allowed

us to assess influences of ELM and dissociation on parenting without other possible confounding factors typically found in ELM survivors. The combination of questionnaires and observed parenting behavior allows us to differentiate between potentially biased self-report and assessment by trained professionals and different aspects of parenting. Lastly, we demonstrated that dissociation assessed five months postpartum affect parenting seven months later, which underlines the need for longitudinal designs in studies examining transgenerational processes.

## **Conclusion**

Our results emphasize the need to further investigate trauma-related symptomatology which may lead to inappropriate parenting even in healthy and low risk community samples. Maternal dissociation might not only contribute to the cycle of abuse by negatively influencing the mother-child interaction and maternal parenting abilities, it might also have an influence on whether or not a mother with ELM is able to detect other perpetrators in order to protect her child from experiencing interpersonal trauma (Hulette et al., 2011). Dysfunctional stress responses such as dissociation should therefore be specifically targeted in interventions provided for physical/sexual abuse victims and in preventive family programs.

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## **Declaration of interests**

The authors declare no conflicts of interest.

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## **Manuscript 2. Mother-Child Interactions in Adolescents with Borderline Personality Disorder Traits and the Impact of Early Life Maltreatment**

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## **Abstract**

**Background:** Early detection and intervention of borderline personality disorder (BPD) in adolescence has become a public health priority. Theoretical models emphasize the role of social interactions and transgenerational mechanisms in the development of the disorder suggesting a closer look at caregiver-child relationships.

**Methods:** The current study investigated mother-adolescent interactions and their association with adolescent BPD traits by using a case-control design. Thirty-eight adolescent patients with  $\geq 3$  BPD traits and their mothers (BPD-G) were investigated in contrast to 35 healthy control dyads (HC-G). Maternal, adolescent and dyadic behavior was coded using the Coding Interactive Behavior Manual (CIB) during two interactions: a fun day planning and a stress paradigm. Additional effects of maternal and/or adolescent early life maltreatment (ELM) on behavior were also explored.

**Results:** BPD-G displayed a significantly lower quality of maternal, adolescent and dyadic behavior than the HC-G during both interactions. Maternal and adolescent behavior was predicted by BPD traits alone, whilst dyadic behavior was also influenced by general adolescent psychopathology. Exploratory analyses of CIB subscales showed that whilst HC-G increased their reciprocal behavior during stress compared to the fun day planning, BPD-G dyads decreased it. Maternal ELM did not differ between groups or have any effect on behavior. Adolescent ELM was correlated with behavioral outcome variables, but did not explain behavioral outcomes above and beyond the effect of clinical status.

**Discussion/Conclusion:** Our data suggest a stronger focus on parent-child interactions in BPD-specific therapies to enhance long-term treatment outcomes in adolescent BPD patients. Further research employing study designs that allow the analyses of bidirectional transactions (e.g. longitudinal design, behavioral microcoding) is needed.

**Keywords:** borderline personality disorder, mother-child interaction, interpersonal dysfunction, early life maltreatment, BPD specific therapies

Borderline personality disorder (BPD) is a complex mental disorder characterized by severe impairments in interpersonal functioning, instability of self and emotion dysregulation (American Psychiatric Association, 2013a). It is associated with high suicide rates, serious self-harm, long-term occupational disabilities and poor physical health (Álvarez-Tomás et al., 2019; Bozzatello et al., 2021; Jacobi et al., 2021).

Although the diagnosis of BPD in adolescence is still controversially discussed in clinical practice (Cavelti et al., 2023), researchers in the field (Chanen et al., 2017; Chanen & Thompson, 2018; Winsper et al., 2016) as well as current international guidelines for BPD that are based on empirical data (Arbeitsgemeinschaft der Wissenschaftlich Medizinischen Fachgesellschaften AWMF-Ständige Kommission Leitlinien, 2012; National Health and Medical Research Council, 2012) strongly suggest diagnosing BPD and subthreshold BPD patterns in adolescence, a particularly sensitive period for the onset of mental disorders. An early diagnosis of BPD seems to be beneficial to the course of treatment (Álvarez-Tomás et al., 2019; Biskin et al., 2011; Gunderson, 2011; Kaess et al., 2014); adolescents receiving BPD specific therapy benefit from a short-term reduction of BPD symptoms and enhanced personality and psychosocial functioning (Álvarez-Tomás et al., 2019; Chanen & Thompson, 2018; Schmeck et al., 2023; Wong et al., 2020). In order to improve psychiatric and psychotherapeutic care and therefore treatment outcomes for BPD patients, a better understanding of underlying processes in adolescence distinguishing healthy from pathological development is necessary (Videler et al., 2019). Developmental theories of BPD (Fonagy & Bateman, 2008; Linehan, 1993; Sharp & Fonagy, 2015) emphasize the role of interpersonal relationships, specifically the caregiver-child relationship, in the etiology, expression and maintenance of BPD.

### ***Interpersonal functioning and BPD***

Although remission rates for BPD are promising with an average of 60% in the course of 5-15 years (Álvarez-Tomás et al., 2019), individuals with BPD often continue to suffer from severe interpersonal impairments (Gunderson, 2011; Lis & Bohus, 2013; Skodol et al., 2005; Videler et al., 2019). The cumulation of stressful interpersonal life events can further aggravate poor psychosocial functioning in adult BPD patients (Pagano et al., 2004). Also, acute BPD symptoms like self-harm behavior, intense anger or depressive symptoms often occur in interpersonal contexts (Howard et al., 2022; Miskewicz et al., 2015; Perry et al., 1992; Powers et al., 2013) and the perceived

quality of interpersonal relationships influences current BPD symptomatology and vice versa (Howard et al., 2022). Interpersonal experiences and processes therefore seem to influence present BPD symptoms but also the long-term psychosocial development of BPD individuals. As early relationship experiences form our later expectation of and behavior in social interactions (Agrawal et al., 2004; Fonagy et al., 2003; Geiger & Crick, 2010), a closer look at caregiver-child relationships and their dyadic interaction is warranted.

Many adolescent BPD patients still live at home and experience maladaptive relationships with their caregivers (Infurna et al., 2016). This becomes especially relevant when considering the role of transgenerational transmission of mental disorder and trauma in the development of the disorder (see Kaess, 2020). Several therapeutic approaches for adolescent BPD (e.g. Rathus & Miller, 2002: dialectic-behavioral therapy, DBT; Rossouw & Fonagy, 2012: mentalization-based treatment, MBT; Foelsch et al., 2014: adolescent identity training, AIT) have already addressed this fact by including caregivers in the treatment of the disorder. However, although first evidence from these treatments suggests an enhancement of psychosocial functioning for adolescent BPD patients (e.g. Schmeck et al., 2023), they still seem to profit less from these therapies than adult BPD patients (Storebø et al., 2020). More research is needed in order to understand familial interactional patterns, detect risk and protective factors and to identify potential windows for interventions.

### ***Caregiver-child interactions and BPD***

According to Linehan's Biosocial Theory (1993; see also Crowell et al., 2009), BPD develops as a result of child vulnerability (e.g. impulsivity, emotional sensitivity) interacting with an invalidating social environment. Important social risk factors include parental psychopathology, poor quality of the parent-child relationship, dysfunctional parenting practices and early life maltreatment (ELM; Belsky et al., 2012; Bozzatello et al., 2021; Steele et al., 2019).

Past research has mainly focused on the influence of parental caregiving, i.e. parent-driven effects, on the development of BPD pathology. In community samples, maladaptive parenting (e.g. chaotic parenting, physical maltreatment) was identified as predictive of adolescent BPD symptoms (Armour et al., 2022; Belsky et al., 2012); validating parenting (emotional support, involvement), on the other hand, could have a protective effect on developing BPD symptoms (Franssens et al., 2021). Also in clinical

samples, adolescents and young adults with BPD report that their parents displayed several problematic parenting practices (e.g. emotional withdrawal, parental inconsistencies, invalidation of thoughts and feelings; Ball Cooper et al., 2018; Bezirgianian et al., 1993; Boucher et al., 2017; Infurna et al., 2016; Macfie & Strimpfel, 2014; Schuppert et al., 2015; Vanwoerden et al., 2017; Whalen et al., 2015). Studies investigating child-driven effects have focused on temperament-related features: a review of Boucher et al. (2017) summarized that parents of children with BPD often describe their child as “unusually sensitive” or with a “difficult temperament” early on.

The studies reviewed above relied on the retrospective reports of BPD patients and/or their parents by applying self-report questionnaires and interviews. Self-reported experiences, however, may be influenced by recall bias and at least in parts by the BPD symptomatology itself (Carlson et al., 2009; Ebner-Priemer et al., 2006). The observation and professional coding of behavior during caregiver-child interactions offers a chance to address this problem. Regarding parent-driven effects, longitudinal studies using high-risk community samples showed that maternal withdrawal and hostility displayed during parent-toddler interactions predicted BPD symptoms in early adulthood (Carlson et al., 2009; Lyons-Ruth et al., 2013a). Maternal insensitivity during mother-child interactions at infancy, preschool and adolescence was associated with adolescent BPD traits (Brumariu et al., 2020). On the child’s side, disorganized-controlling behavior at age 8 was predictive of early adult BPD symptoms (Lyons-Ruth et al., 2013a).

Surprisingly few studies have observed (and reported) parent and child behavior at the same time in the context of current BPD symptomatology. It has also been suggested to observe behavior not only on an individual but also on a dyadic level, as mother and child are most likely influencing each other during interactions (Whalen et al., 2014). In at-risk community samples with adolescents, dyadic negative escalation and disoriented/role-confused behavior during a conflict discussion between mothers and their adolescent children were associated with more BPD traits (Lyons-Ruth et al., 2015; Whalen et al., 2014). Positive dyadic behavior, however, was related to decreases in adolescent girls’ BPD severity scores over time (Whalen et al., 2014). Dixon-Gordon et al. (2016) identified adolescent negative affect during interaction as a possible risk factor for BPD traits but only when mothers showed low support/validation and high problem solving during a conflict discussion task. In a clinical sample comparing young adults with BPD with healthy controls, BPD patients

and their mothers displayed more disorganized behavior during a conflict discussion task (Khoury et al., 2020). Whilst overall collaboration as a marker for dyadic behavior during conflict discussions did not predict adolescent BPD traits in a high-risk community sample (Lyons-Ruth et al., 2015), it contributed to a more secure attachment profile in the clinical sample of young adults (Khoury et al., 2020). Fleck et al. (2023) observed interactions in two community samples. At age 9, they found less maternal structuring and more child withdrawal during a conflict discussion task to be associated with BPD traits, but no relations during a fun day planning task. At age 14, less maternal sensitivity and structuring, more maternal intrusiveness and less child engagement during the conflict discussion task and more child withdrawal during the fun day planning was related to BPD traits. Associations between dyadic behavior and BPD traits in adolescents were significant during the conflict discussion task, but not during the fun day planning.

In summary, parental and child behavior in caregiver-child transactions seem to be altered and more conflict-driven when child or adolescent BPD traits are present. This seems to be especially relevant in stressful contexts (e.g. Fleck et al., 2023), when problems with emotion regulation would become noticeable. There is also first evidence that positive parental and dyadic behavior might mitigate the development of the disorder (Franssens et al., 2021; Whalen et al., 2014). Although many studies have identified specific maladaptive parenting practices that seem to foster the development of BPD, parental behavior was rarely investigated during actual mother-child interactions. Studies that have observed interactional behavior mainly focused on either parent- or child-driven effects in community samples.

To the best of our knowledge, only four studies have studied the influence of current BPD traits on parent, child and dyadic behavior during the same interaction (Fleck et al., 2023; Khoury et al., 2020; Lyons-Ruth et al., 2015; Whalen et al., 2014); the only study including a case-control design focused on young adults rather than adolescents (Khoury et al., 2020). Only one study compared observed mother-child interactions in a positive versus a stressful context (Fleck et al., 2023), although context seems to have an impact on relations between mother-child interactions and child behavioral problems (Dittrich et al., 2017).

The present study addresses these limitations by comparing a clinical adolescent sample with BPD symptoms and their mothers with healthy control dyads, observing

maternal, adolescent and dyadic behavior during a positive interaction and a stress paradigm.

### ***Early life maltreatment, BPD and parent-child interactions***

An overwhelming body of literature has identified ELM as a contributing factor to the development of BPD traits in children, adolescents and adults (Bozzatello et al., 2020; Ibrahim et al., 2018; Porter et al., 2020; Winsper et al., 2016). Lyons-Ruth et al. (2013) suggested that the assessment of parent-child interactions should include ELM as a possible influential factor. Previous research has focused mainly on maternal ELM and its influence on maternal behavior in mother-child interactions: mothers who have experienced ELM are more likely to show maladaptive parenting, including parental behavior that was previously associated with the development of BPD, such as psychological control, maternal hostility or harsh punishment (Rowell & Neal-Barnett, 2022; Vaillancourt et al., 2017).

Although some of the above-described studies have reported child or adolescent ELM and have shown associations with the development of BPD traits (e.g. Carlson et al., 2009), the influence of child ELM on behavior in mother-child interactions was rarely considered. Maternal withdrawal during a mother-toddler interaction, child disorganized-controlling behavior at age 8 and less collaborative, more mutual punitive and disoriented/out-of-context behavior during discussions between young adults and their parents seem to be influenced by the severity of the trauma the child/adolescent has experienced in the past (Lyons-Ruth et al., 2013a, 2015). Further research is needed to disentangle the effects of maternal/adolescent ELM and BPD pathology on caregiver-child interactions and how this may facilitate the development of BPD.

### ***The aim of the present study***

With the present study, we aimed at expanding prior research on the observation of caregiver-child transactions by using a case-control group design. Specifically, we wanted to know how a clinical group of adolescents with BPD traits (BPD-G) differs from a healthy control group (HC-G) in maternal, adolescent and dyadic behavior during mother-adolescent interactions in a positive versus a stress context. Additionally, we wanted to investigate the role of maternal and adolescent ELM and how it might independently or additionally to adolescent BPD symptomatology contribute to behavior in this context.

Firstly, and consistent with prior literature, we expected maternal, adolescent and dyadic behavior to be of less quality in the BPD-G than in the HC-G. During stress, we assumed this group difference to be larger than during the fun day planning, i.e. the BPD-G was expected to show more dysfunctional behavior during stress -when emotion regulation difficulties might come into play- than during fun day whilst we did not expect the HC-G to significantly change behavior between contexts. We were also interested in exploratory analyses on subscale level to identify specific behavior (e.g. maternal intrusiveness vs. maternal sensitivity), that might explain differences between groups and/or contexts.

Secondly, we assumed that BPD-G mothers and adolescents experienced more ELM than subjects in the HC-G. As a large body of research suggests (see Vaillancourt et al., 2017), we expected maternal ELM to influence maternal and dyadic behavior in both interactions; no specific assumptions were made for adolescent behavior. Regarding the influence of adolescent ELM on behavior we expected all behavioral outcomes to be affected, following indications of prior research (Lyons-Ruth et al., 2013a, 2015). Lastly, we explored whether adolescent ELM has an effect on interactional behavior above and beyond the effect of group membership.

## **Method**

### ***Recruitment and participants***

A-priori power analyses for group comparisons utilizing an anticipated effect size of  $d=.8$ , a desired statistical power level of 80% and a probability level of  $\alpha = .05$  revealed a minimum sample size of  $n=26$  per group. We therefore aimed at recruiting a total of 30 clinical dyads (BPD-G) and 30 healthy control dyads (HC-G). Recruitment took place from 06/2018-01/2021. BPD-G adolescents were recruited in our outpatient clinic for risk-taking and self-harm behavior (AtR!Sk; Kaess et al., 2017). Patients had to meet  $\geq 3$  criteria of BPD, which was assessed by trained clinical psychologists using the Structured Clinical Interview for DSM-5-Personality Disorders (SCID-5-PD; First et al., 2016). BPD-adolescents were also screened for other psychiatric disorders using the Mini International Neuropsychiatric Interview for Children and Adolescents (MINI-KID; Sheehan et al., 2010). HC-G were recruited via advertising and the local residents' registration office and matched to BPD-G according to adolescent sex and age, and adolescent and maternal education. HC-G dyads were excluded if adolescents fulfilled criteria for any current or lifetime disorder (assessed with the MINI-KID or if mothers

had received any psychotherapeutic/psychiatric treatment in the two years prior to the study. HC-G adolescents were also screened for BPD traits using the SCID-5-PD (First et al., 2016). Further exclusion criteria for all mothers and adolescents were a diagnosis of schizophrenia and/or autism. As the study included biological measures (not reported in this manuscript), exclusion criteria for both groups were serious somatic illness, neurological disorder or cardiac/hypothalamus-pituitary-adrenal system dysfunction. Also, mothers had to be the primary caregiver.

From a pool of 353 possible participants (BPD-G = 161, HC-G = 192), 294 (83.3%) were contacted and screened for exclusion criteria (reasons for not being contacted: no phone number/email available, BPD-G: still waiting for or in the process of the clinical assessment of AtR!Sk, HC-G: no match for BPD-G). 205 of the contacted dyads [BPD-G: 102(63.4%); HC-G: 103(53.6%)] could not be included due to lack of interest (BPD-G: 51, HC-G: 46), somatic illness (BPD-G: 12; HC-G: 17), lack of time (BPD-G: 11; HC-G: 10), being too young or too old (BPD-G: 11; HC-G: 5), mother not being the primary caregiver or not being available (BPD-G: 9), no match for BPD-G (HC-G: 5), insufficient language skills (BPD-G: 4; HC-G: 2), psychiatric illness according to exclusion criteria (BPD-G: 2; HC-G: 12) or giving wrong contact information (BPD-G: 2; HC-G: 6). From 89 (25.2%) included dyads, 16 (18%) became dropouts during the course of the study: One BPD-G turned 18, one BPD-G mother reported a somatic illness, 9 of HC-G adolescents reported psychopathology of any kind, and some dyads lost interest in the study in both groups (BPD-G: 3; HC-G: 2).

Finally, 38 adolescent patients between 12;0 and 17;0 years (*mean* = 15.6, *sd* = 1.13) and their mothers formed the BPD-G; 35 healthy dyads formed the HC-G (adolescents aged between 14;0 and 17;0, *mean* = 15.5, *sd* = 1.25). Adolescents were mostly female (BPD-G: 84.2%, HC-G: 80%) and on track for higher education. Mothers were well educated and the majority part-time or full-time employed. All participants were of European ancestry. For a detailed sample description see Table 1.

**Table 1****1 Sociodemographic Characteristics of the Sample**

	<b>HC-G</b> <b>(n=35)</b>	<b>BPD-G</b> <b>(n=38)</b>		
<b>Mothers</b>	mean(sd)	mean(sd)	t value	p value
Age	48.20 (5.43)	46.68 (6.15)	1.118	.267
	n(%)	n(%)	$\chi^2$ value	p value
Highest degree			2.107	.575 <sup>a</sup>
Lower secondary school	3 (8.57%)	5 (13.2%)		
Intermediate secondary school	7 (20.0%)	12 (31.6%)		
University entrance diploma	8 (22.9%)	6 (15.8%)		
University degree	17 (48.6%)	15 (39.5%)		
Employment			2.949	.400 <sup>a</sup>
Full-time at home <sup>1</sup>	3 (8.57%)	6 (15.8%)		
Part-time Employment	19 (54.3%)	18 (47.4%)		
Full-time Employment	13 (37.1%)	12 (31.6%)		
Other <sup>2</sup>	0 (0.00%)	2 (5.26%)		
<b>Children</b>	mean(sd)	mean(sd)	t value	p value
Age	15.49 (1.25)	15.61 (1.13)	-.429	0.670
	n(%)	n(%)	$\chi^2$ value	p value
Gender			.027	0.870
female	28 (80.0%)	32 (84.2%)		
male	7 (20.0%)	6 (15.8%)		
School form			3.925	0.159 <sup>a</sup>
Lower secondary school	1 (2.86%)	4 (10.5%)		
Intermediate secondary school	10 (28.6%)	16 (42.1%)		
University entrance diploma	24 (68.6%)	18 (47.4%)		

Note. HC-G = healthy control group; BPD-G = borderline personality disorder group.

<sup>a</sup>Fisher's Exact Test.

<sup>1</sup>e.g. housewife, retired, unemployed

<sup>2</sup>temporary leave of absence, work on minijob-basis

## **Procedure**

Dyads were invited to our laboratory in Heidelberg for two appointments (t1 and t2) over a three-week period. At t1, clinical assessment (interviews and questionnaires) and a computer task were performed. At t2, two 10-minute-long standardized mother-adolescent interactions (a positive interaction that was, after a resting period, followed by a stress task) were videotaped. During the positive interaction, dyads were asked to plan positive activities both individuals would benefit from and enjoy. The stress task was loosely based on the Parent-Child-Challenging Task (PCCT) by Lunkenheimer et al. (2017) and has, to the best of our knowledge, not been used before. During the stress task, the adolescent was presented with a tangram. The dyad was told that other adolescents were able to solve the tangram without any issues, when in fact it was too difficult to work out the tangram in the allotted timeframe. Additionally, the examiner would carefully observe their approach and make notes about their performance. Mothers were instructed to support their child but not to solve the puzzle for them. After 5 minutes, it was stated that the child was unsuccessful in completing the task and therefore an easier tangram would be presented (which was actually even more difficult to solve than the first one).

Preliminary analyses confirmed that mothers and adolescents reported significantly more negative affect [mothers:  $t(72) = -5.731, p < .001$ ; adolescents:  $t(72) = -6.706, p < .001$ ] and less positive affect (mothers:  $t(72) = 2.66, p < .01$ ; adolescents:  $t(72) = 3.15, p < .01$ ) in the stress task in comparison to the positive interaction.

Before, during and/or after interactions, physiological data (functional near-infrared spectroscopy, electrocardiography, saliva sampling) was retrieved. The physiological data as well as the computer task were not analyzed in the present study and will therefore not be described further.

## **Measures**

**Clinical assessment.** Adolescents of both groups filled in the Strength and Difficulties Questionnaire (SDQ; Goodman, 1997) to self-assess emotional and behavioral problems ( $\alpha = .89$ ). Mothers' psychopathology was screened in both groups with the Symptom Checklist 90-Revised (SCL-90-R; Derogatis, 1992; German version by Franke, 1995;  $\alpha = .98$ ). As our study focused on interpersonal behavior, we specifically investigated the SCL-90-R subscale *interpersonal sensitivity*. Additionally, we assessed attachment security of mothers with the Vulnerable Attachment Style

Questionnaire (VASQ; Bifulco et al., 2003; Reck et al., 2016) with higher values indicating higher attachment insecurity ( $\alpha = .77$ ).

**Childhood maltreatment.** The Childhood trauma questionnaire (CTQ, Bernstein & Fink, 1999; German version by Driessen et al., 2000) was used to assess traumatic childhood events of adolescents and their mothers in self-report. In the present study, only total CTQ scores were used, with higher scores indicating a more severe history of childhood abuse and/or neglect ( $\alpha_{mothers} = .94$ ;  $\alpha_{adolescents} = .92$ ). The psychometric properties of the German version were found to be satisfying (Scher et al., 2001).

**Quality of mother-adolescent interactions.** Mother-adolescent interactions were rated using the Coding Interactive Behavior Manual (CIB) by Feldman (1998). 56 behavioral codes were rated from 1 (low) to 5 (high). These codes form maternal, child and dyadic scales: Maternal sensitivity ( $\alpha = .89$ ), maternal structuring ( $\alpha = .78$ ), maternal intrusiveness ( $\alpha = .79$ ), child engagement ( $\alpha = .90$ ), child compliance ( $\alpha = .89$ ), child withdrawal ( $\alpha = .88$ ), dyadic reciprocity ( $\alpha = .91$ ) and dyadic negativity ( $\alpha = .83$ ; for details about scale-item assignment see Fleck et al., 2023). Additionally, total scales were built: the mother's total score was calculated by subtracting maternal intrusiveness from sensitivity and structuring ( $\alpha = .81$ ), the child's total score by subtracting child withdrawal from engagement and compliance ( $\alpha = .92$ ) and the dyadic total score by subtracting negativity from reciprocity ( $\alpha = .90$ ). Therefore, higher total scores represent higher quality of behavior. Two raters were trained and certified by the instrument's author, two additional trainers were trained and closely supervised by them. 41% of the videos were rated by at least two raters (interrater agreement 88%; Cohen's Kappa = .77).

### **Data analysis**

All analyses were carried out with R (v1.4.1717; R Core Team, 2021). Per group, one stress task was missing due to malfunction of the video camera [ $n = 2$  (2.74%)]. Welch's t-tests were applied to calculate group differences for continuous variables (Delacre et al., 2017), chi-square-tests for categorical variables.

For the analyses of the CIB data (BPD-G vs. HC-G and positive vs. stress context), robust two-way mixed Analyses of Variance (ANOVA) using 20% trimmed means were calculated via the *WRS2* package (Mair & Wilcox, 2010), as variance homogeneity could not be met. Although normal distribution could be assumed (sample sizes > 30),

it was visually verified and tested with the Shapiro-Wilk-Test. Greenhouse-Geisser corrections were made when the assumption of sphericity was violated. In our main analyses, Bonferroni-Holm correction for multiple testing was applied across effects that were applying to the same hypothesis (i.e. for group differences, context differences and group x context interactions we controlled for three comparisons per hypothesis).

To ensure that the group effect on behavior is not an effect of general psychopathology but specific to BPD traits, we transformed all values into z-values and then calculated Pearson correlation coefficients to determine the association between SDQ and the CIB scales. When significant correlations were found, we calculated regression analyses with group as a predictor and the respective CIB scale as an outcome variable, controlling for SDQ.

To determine how much additional variance in behavior could be explained by maternal and/or adolescent ELM, again all values were z-transformed and Pearson correlation coefficients were calculated. Significant correlations were further investigated in hierarchical linear regression models (step1: group as a single predictor, step2: group and CTQ as predictors).

When homoscedasticity could not be met in the above-described regression models, HC4-method for robust standard errors was applied.

## **Results**

### ***Psychopathology of adolescents and their mothers***

In the BPD-G (*range* = 3-8 BPD criteria), 19 (50%) adolescents fulfilled the BPD diagnosis. 9 (23.7%) BPD-G adolescents were diagnosed with F10-F19 diagnoses, 29 (76.3%) with F30-F39 diagnoses, 16 (42.10%) with F40-F49 diagnoses and 8 (21.05%) with F90-F99 diagnoses. 30 (78.95%) patients fulfilled at least two or more diagnoses. Adolescents of the BPD-G reported significantly more emotional and behavioral problems in the SDQ than the adolescents of the HC-G ( $p < .001$ ); BPD-G mothers reported significantly more psychopathology in the SCL-90-R ( $p = .001$ ), significantly more interpersonal sensitivity in the respective SCL-90-R subscale ( $p = .033$ ) and significantly more attachment insecurity in the VASQ ( $p = .028$ ) than HC-G mothers (for details see Table 2). However, on additional exploratory analyses we did not find any significant correlations between maternal interpersonal sensitivity and attachment insecurity and maternal, adolescent or dyadic behavior ( $r = .00$  to  $r = .14$ ).

**Table 2***Sample Psychopathology and Early Life Maltreatment*

	<b>HC-G</b> <b>(n=35)</b>	<b>BPD-G</b> <b>(n=38)</b>			
	<i>mean(sd)</i>	<i>mean(sd)</i>	<i>t value</i>	<i>p value</i>	<b>Cohen's d</b>
<b>Adolescents</b>					
BPD criteria	-	4.74 (1.41)	-	-	-
SDQ total	8.14 (3.84)	19.9 (5.98)	-10.084	<.001***	2.322
CTQ total	28.7 (4.06)	41.8 (10.8)	-6.931	<.001***	1.574
<b>Mothers</b>					
SCL-90-R	0.32 (0.26)	0.66 (0.54)	-3.432	.001**	.784
Interpersonal sensitivity	0.35 (0.32)	0.61(0.65)	2.169	.033*	.508
VASQ	53.69(6.94)	58.11(9.57)	2.242	.028*	.525
CTQ total	37.7 (12.0)	40.5 (13.9)	-.918	0.362	.214

*Note.* HC-G = healthy control group; BPD-G = borderline personality disorder group; BPD = borderline personality disorder; SDQ = Strengths and Difficulties Questionnaire; CTQ = Childhood Trauma Questionnaire; SCL-90-R = Symptom Checklist 90-Revised; VASQ = Vulnerable Attachment Style Questionnaire.

\*\* $p < .01$ . \*\*\* $p < .001$

**Early life maltreatment**

BPD-G adolescents reported a significantly higher CTQ total score in comparison to the HC-G ( $p < .001$ ). Mothers' CTQ, however, did not significantly differ between groups ( $p = .365$ ). Details can be obtained from Table 2.

**Quality of mother-adolescent interactions**

Means and standard deviations of CIB scores from both interactions can be obtained from Table 3. For our main analyses, robust two-way mixed-model ANOVAs revealed a significant group effect for maternal ( $p_{adj} = .003$ ), adolescent ( $p_{adj} = .003$ ) and dyadic behavior ( $p_{adj} = .003$ ): the BPD-G showed a significantly lower quality of maternal, adolescent and dyadic behavior in both interactions than the HC-G. For context, no significant main effects were found. Group x context interactions were also not significant (details can be obtained from table 4).

**Table 3**

*Descriptives of Maternal, Adolescent and Dyadic Behavior during Fun Day Planning and a Stress Paradigm*

	Fun Day Planning		Stress paradigm	
	HC-G ( <i>n</i> =35)	BPD-G ( <i>n</i> =38)	HC-G ( <i>n</i> =35)	BPD-G ( <i>n</i> =38)
	<i>mean</i> ( <i>sd</i> )			
Mothers: CIB total	2.33 (0.34)	2.05 (0.58)	2.24 (0.28)	1.98 (0.44)
Maternal sensitivity	3.57 (0.58)	3.29 (0.72)	3.28 (0.49)	2.86 (0.76)
Maternal intrusiveness	1.18 (0.22)	1.42 (0.63)	1.26 (0.37)	1.30 (0.38)
Maternal structuring	4.58 (0.41)	4.29 (0.66)	4.71 (0.33)	4.39 (0.48)
Adolescents: CIB total	2.37 (0.37)	1.95 (0.67)	2.32 (0.27)	1.89 (0.61)
Child engagement	3.83 (0.66)	3.43 (0.75)	3.60 (0.48)	3.15 (0.71)
Child compliance	4.63 (0.37)	4.17 (0.75)	4.61 (0.31)	4.08 (0.74)
Child withdrawal	1.35 (0.28)	1.75 (0.63)	1.26 (0.24)	1.57 (0.52)
Dyad: CIB total	1.31 (0.54)	0.86 (0.84)	1.20 (0.83)	0.51 (1.08)
Dyadic reciprocity	4.10 (0.57)	3.65 (0.78)	4.16 (0.79)	3.30 (1.07)
Dyadic negative states	1.48 (0.57)	1.93 (0.95)	1.76 (0.91)	2.28 (1.15)

*Note.* HC-G = healthy control group; BPD-G = borderline personality disorder group; CIB = Coding Interactive Behavior

In exploratory analyses on subscale level, significant main effects for group were found for maternal sensitivity ( $p = .003$ ) and maternal structuring ( $p = .004$ ) but not for maternal intrusiveness ( $p = .317$ ), all child scales [engagement:  $p = .002$ ; compliance:  $p = .002$ ; withdrawal:  $p = .006$ ] and both dyadic scales [reciprocity:  $p < .001$ ; negativity:  $p = .019$ ]: in the BPD-G, mothers were less sensitive and structuring; adolescents behaved less engaged and compliant and more withdrawn. BPD-G dyads showed less reciprocity and more negativity in comparison to the HC-G. Context effects were significant for maternal sensitivity ( $p < .001$ ), child engagement ( $p < .001$ ), child withdrawal ( $p = .025$ ) and dyadic negativity ( $p = .049$ ): in both groups, mothers behaved less sensitive in the stress task compared to the positive interaction whilst adolescents displayed less engagement and less withdrawal. Dyadic negativity scores were higher in the stress task than in the positive interaction task.

**Table 4**

*Robust Two-way Mixed Model Analyses of Variance: differences in maternal, adolescent and dyadic behavior depending on group and context*

<b>CIB scales</b>	<b>F</b>	<b>df</b>	<b>p value</b>	<b>ges</b>
<b>Main analyses</b>				
<b>Mothers: CIB total score</b>				
Group	12.054	1, 39.3	.001**a	.095
Context	2.593	1, 34.7	.116 <sup>a</sup>	.007
Group x context	0.006	1, 34.7	.941 <sup>a</sup>	.000
<b>Adolescents: CIB total score</b>				
Group	12.165	1, 28.2	.001**a	.152
Context	2.994	1, 32.1	.093 <sup>a</sup>	.003
Group x context	0.009	1, 32.1	.926 <sup>a</sup>	.000
<b>Dyad: CIB total score</b>				
Group	10.800	1, 29.3	.003**a	.106
Context	3.120	1, 32.4	.087 <sup>a</sup>	.016
Group x context	1.887	1, 32.4	.179 <sup>a</sup>	.004
<b>Exploratory analyses</b>				
Maternal sensitivity				
Group	10.231	1, 40.9	.003**	.076
Context	15.566	1, 40.7	< .001***	.069
Group x context	0.239	1, 40.7	.627	.002
Maternal structuring				
Group	9.555	1, 31.1	.004**	.099
Context	1.483	1, 32.6	.232	.016
Group x context	0.185	1, 32.6	.670	.000
Maternal intrusiveness				
Group	1.028	1, 36.9	.317	.027
Context	0.382	1, 37.4	.540	.000
Group x context	1.286	1, 37.4	.264	.015
Child engagement				
Group	11.546	1, 35.7	.002**	.099
Context	12.868	1, 40.3	< .001***	.037

Group x context	0.122	1, 40.3	.728	.000
<hr/>				
Child compliance				
Group	12.009	1, 29.1	.002**	.156
Context	2.215	1, 31.9	.146	.002
Group x context	0.311	1, 31.9	.581	.001
<hr/>				
Child withdrawal				
Group	8.728	1, 28	.006**	.137
Context	5.589	1, 30	.025*	.023
Group x context	0.549	1, 30	.464	.003
<hr/>				
Dyadic reciprocity				
Group	16.503	1, 32.8	< .001***	.144
Context	1.135	1, 37.8	.293	.007
Group x context	5.170	1, 37.8	.029*	.013
<hr/>				
Dyadic negative states				
Group	6.115	1, 30.0	.019*	.066
Context	4.203	1, 30.8	.049*	.026
Group x context	0.413	1, 30.8	.525	.000

Note.  $n_{HC-G} = 34$ ,  $n_{BPD-G} = 37$ ; CIB = Coding Interactive Behavior

<sup>a</sup>Bonferroni-Holm corrected for multiple testing

\* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$

Context effects for maternal structuring and intrusiveness, child compliance and dyadic reciprocity were not significant. For dyadic reciprocity a significant group x context interaction ( $p = .029$ ) was found: whilst HC-G dyads increased reciprocity under stress, BPD-G dyads decreased their reciprocal behavior. Details of all calculated ANOVAs are described in Table 4.

We next investigated, if SDQ total values were associated with CIB behavior. Exploratory analyses showed that SDQ was significantly negatively correlated with child and dyadic behavior during both interactions ( $r = -.24$  to  $r = -.36$ ) but not with maternal behavior. We then ran different regression analyses with group as a predictor and adolescent and dyadic behavior as outcome variables, controlling for SDQ total values. Whilst group still significantly predicted adolescent behavior during both tasks (positive interaction:  $p = .024$ , stress task:  $p = .044$ ), the significant effect of group to dyadic behavior disappeared (positive interaction:  $p = .108$ , stress task:  $p = .141$ ).

### ***The influence of childhood trauma on interactional behavior***

Maternal CTQ total scores did not significantly correlate with any of the CIB scales and were therefore not considered in further analyses. Adolescent CTQ total scores were significantly negatively correlated with all CIB total scales ( $r = -.24$  to  $r = -.40$ ). Hierarchical linear regressions revealed that adolescent CTQ did not significantly explain any additional variance in CIB scores above and beyond group as a predictor (changes in  $R^2$ :  $p = .078$  to  $p = .425$ ; see table 5).

**Table 5**

*Hierarchical linear regression models: adolescent early life maltreatment has no significant additional effect on maternal, adolescent or dyadic behavior*

Variables	<i>B</i>	<i>SE</i>	<i>t</i>	<i>p</i>	<i>F(df)</i>	<i>p</i>	<i>R</i> <sup>2</sup>	$\Delta R^2$	$p\Delta R^2$
DV1: maternal behavior pos. IA									
Step 1: group	.549	.227	2.419	.018*	5.851(1,71)	.018*	.076		
Step 2: group	.403	.291	1.387	.170					
CTQ adolescent	-.117	.146	-.802	.425	3.233 (2,70)	.045*	.085	.008	.425
DV2: maternal behavior stress task									
Step 1 <sup>a</sup> : group	.665	.222	3.001	.004**	8.695 (1, 69)	.004**	.112		
Step 2: group	.464	.294	1.582	.118					
CTQ adolescent	-.157	.147	-1.065	.290	4.923(2,68)	.010*	.126	.014	.290
DV3: adolescent behavior pos. IA									
Step 1 <sup>a</sup> : group	.718	.215	3.339	.001**	10.661 (1,	.002**	.131		
Step 2 <sup>a</sup> : group	.409	.269	1.524	.132	71)				
CTQ adolescent	-.249	.240	-1.040	.302	7.096 (2,70)	.002**	.169	.038	.078
DV4: adolescent behavior stress task									
task	.821	.212	3.879	< .001***	14.182(1,69)	<.001***	.170		

Step 1 <sup>a</sup> : group	.522	.251	2.082	.041*					
Step 2 <sup>a</sup> : group	-.234	.165	-1.421	.160	8.651(2,68)	<.001***	.203	.032	.101
CTQ adolescent									
<hr/>									
DV5: dyadic behavior pos. IA									
Step 1 <sup>a</sup> : group	.606	.221	2.743	.008**	7.261(1, 71)	.009**	.093		
Step 2: group	.377	.286	1.318	.192					
CTQ adolescent	-.184	.144	-1.280	.205	4.483(2,70)	.015*	.114	.021	.205
<hr/>									
DV5: dyadic behavior stress task									
Step 1 <sup>a</sup> : group	.670	.223	3.010	.004**	8.856(1.69)	.004**	.114		
Step 2: group	.479	.293	1.631	.108					
CTQ adolescent	-.150	.147	-1.018	.312	4.949(2,68)	.010*	.127	.013	.312

Note. positive interaction:  $n_{HC-G} = 35$ ,  $n_{BPD-G} = 38$ , stress task:  $n_{HC-G} = 34$ ,  $n_{BPD-G} = 37$ ; DV = dependent variable, pos. IA = positive interaction, CTQ = Childhood Trauma Questionnaire

<sup>a</sup>HC4 method for robust standard errors

\* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

## Discussion

This paper is, to the best of our knowledge, the first to report on how current adolescent BPD traits are related to observed parental, adolescent and dyadic behavior during two different interactional contexts in a clinical sample. We also explored if adolescent and/or maternal ELM explain variance in behavioral outcomes in addition to BPD psychopathology.

Consistent with our main hypothesis, our clinical sample showed less quality in maternal, adolescent and dyadic behavior. On the subscale level, BPD-G displayed less maternal sensitivity and structuring, less child engagement and compliance and more child withdrawal as well as less dyadic reciprocity and more dyadic negative states in comparison to the HC-G. We therefore confirm earlier research reporting negative associations between BPD traits and quality of behavior in mother-adolescent interactions (Fleck et al., 2023; Khoury et al., 2020) and extend these findings to an adolescent clinical sample in two different contexts.

Surprisingly, BPD-G mothers did not show significantly more intrusiveness than HC-G mothers. In adolescent community samples, increased maternal intrusiveness was found to be associated with BPD traits (Fleck et al., 2023) and poorer adolescent psychological adaptation (a score based on the child's externalizing, internalizing and depressive symptoms; Feldman, 2010). Lyons-Ruth & Yarger (2022), however, suggested that maternal withdrawal might play a more crucial role in the development of adolescent BPD symptomatology than maternal intrusiveness. Children at risk for BPD might need more external regulation in order to manage their emotions and prevent dysfunctional emotion regulation like self-harming behavior (Lyons-Ruth & Yarger, 2022). In the present study, maternal withdrawal would be represented by lower maternal sensitivity and structuring in BPD-G. Consistent with the studies reviewed by Lyons-Ruth & Yarger (2022), maternal sensitivity and structuring as protective factors might therefore be more relevant than the potential risk factor intrusiveness in the development of adolescent BPD.

Although maternal attachment style was previously shown to have an effect on parenting behavior in mother-child interactions (Biringen et al., 2000) and there is also proof for a strong linkage between BPD and insecure attachment (Agrawal et al., 2004), we did not find maternal interpersonal sensitivity and attachment insecurity to be associated with behavior during either of the interactions. Future studies should

explore if there are pathways through which maternal attachment styles and other maternal interpersonal relationship features contribute to the development of child or adolescent BPD traits.

We also wanted to know if adolescent general psychopathology has an effect on behavior, as most of our adolescent patients reported several comorbidities, a typical picture when assessing BPD samples (Zanarini et al., 2004). Adolescent psychopathology in our sample was not related to maternal behavior. Whilst, when controlling for general psychopathology, group still significantly predicted adolescent behavior during both tasks, the significant effect of group on dyadic behavior disappeared. We can therefore not conclude that BPD traits alone predicted dyadic behavior, it might rather be a combination of BPD traits and general adolescent psychopathology. However, adolescent behavior during interactions might be reflecting interpersonal dysfunction (as a core symptom of the disorder) and therefore be a promising target for future research and interventional approaches.

As to context, we did not find significant main effects in our main analyses. On the subscale level, mothers were less sensitive during stress while adolescents showed less engagement and also less withdrawal which - on first sight - seems somewhat contradictory. These effects might be driven by different sample subgroups: some adolescents might disengage and some might become more active when being confronted with our stress task, independent of clinical status. Further analyses would be needed to explore possible factors that might help differentiate between adolescents using different emotion regulation strategies. On the dyadic level, dyads showed more negative states in the stress task compared to the fun day planning task. Although effect sizes of these context effects were only small to moderate and should be interpreted with caution, our results emphasize the need to investigate caregiver-child transactions in different contexts. As interpersonal stress in combination with a lack of emotion regulation skills (one of the core features of BPD) can be a trigger for impulsive and/or self-harming behavior (e.g., Howard et al., 2022), a closer look at mother-child co-regulation under stress is warranted.

Another interesting result of our exploratory analyses was the fact that HC-G increased their reciprocal behavior during stress, i.e., their interaction became more fluent, compatible and interactive, whilst BPD-G decreased their reciprocal exchanges. Healthy dyads therefore seem to be able to rely on their abilities as a team to solve a potentially stressful situation by increasing their give-and-receive actions.

BPD-G dyads, on the other hand, might not have trust in their partner: interactions between adolescents with BPD and their caregivers often provoke dysregulation and exacerbate dysfunctional behavior (Geiger & Crick, 2010a; Lyons-Ruth et al., 2013a). Therefore, mothers might withdraw from the situation in expectation of a potential outburst of their child, and the child stops collaborating with their mother due to a lack of skills, overwhelming emotions they might feel and/or fear of an escalation of the situation. Research shows that adult BPD patients have problems with maintaining cooperation and repairing it when cooperation is ruptured (King-Casas et al., 2008). Maybe these impairments could be addressed in early interventions focusing on dyadic behavior during interactions. However, due to small effect size this result has to be interpreted with care.

It is worthwhile to note that we did not find a greater amount of significant interactions, therefore, and contrary to our hypothesis, most group differences did not increase during stress. Fleck et al. (2023) found BPD traits mostly associated with less behavioral quality during a stress paradigm but only few associations during a fun day planning task. Our results suggest that in a clinical sample, BPD-G dyads already struggle during tasks designed to elicit positive emotions (i.e. fun day planning), which might be reflecting the above-mentioned history of conflict-ridden interactions the BPD-G dyads have experienced in the past and a general lack of affiliative skills that are also needed in supposedly pleasant interactions.

Taken together, our results indicate that enhancing maternal sensitivity and reciprocal behavior during stress (which might increase maternal co-regulation when negative emotions are present) could be potential targets for BPD specific interventions in adolescence.

However, like most studies investigating parent-child interactions, we did not pursue a bidirectional and/or longitudinal approach, so we cannot determine how adolescents and mothers are influencing each other over time. Results of the Pittsburgh Girl study (Keenan et al., 2010) with an at-risk community sample indicate that reciprocal effects of parental harsh punishment and adolescent poor self-control contribute to the development of adolescent BPD symptoms (Hallquist et al., 2015). Longitudinally, maladaptive parental behavior caused increased adolescent BPD features which in turn led to worsening parental behavior (Stepp et al., 2014). Adolescent BPD symptoms at age 16 predicted greater parental BPD symptoms at age 17, whilst parental BPD symptoms did not influence adolescent BPD symptoms over time (E. A.

Kaufman et al., 2020). These results highlight the need to investigate both parent- and child-driven effects in reciprocal, longitudinal designs and during different developmental stages. During adolescence, for example, parental behavior might become less influential as achieving autonomy from parents and peer relationships become more important (E. A. Kaufman et al., 2020).

Our second research question was if and how maternal and/or adolescent ELM might influence behavior during mother-adolescent interactions. Maternal ELM was not correlated to behavioral outcomes during either of the interactions. Mothers of both groups showed similar levels of ELM, but BPD-G mothers reported higher levels of psychopathological symptoms than mothers of HC-G. Maternal psychopathology could be either a contributing factor for or a consequence of the offspring's psychopathology: Literature shows that mothers of adolescents with BPD are more likely to have BPD or other affective disorders themselves (White et al., 2003).

Also, resilience to trauma could be considered in this context: it has been previously discussed if maternal ELM alone or rather the combination with a mental disorder would negatively influence mother-child interactions (Kluczniok et al., 2016b; Mielke et al., 2020). Therefore, although in our study mothers of both groups reported similar levels of ELM, the combination of maternal ELM and ensuing psychopathology might be contributing to the development of child BPD traits. On the other hand, previous research shows that parents of mentally ill children report a decreased quality of life and more mental health problems than parents of healthy children (Dey et al., 2019); this was also found for carers of individuals who suffer from BPD (Bailey & Grenyer, 2013). In exploratory analyses, maternal psychopathology did not correlate with any of the CIB scales and therefore does not seem to have an impact on behavioral outcomes in our sample. Importantly, maternal psychopathology did not reach clinically relevant cut-off values and values of both groups stand representative for the general population which might explain their negligible effect in our sample. Additionally, during adolescence, maternal influences might not have the same impact as during infancy or childhood (E. A. Kaufman et al., 2020).

Adolescent ELM was elevated in the BPD-G in comparison to the HC-G and correlated to all behavioral scales. It did not, however, explain more variance of behavior than clinical status alone which confirms previous findings about the strong link between ELM and the development of BPD (e.g. (Kaess, 2020; Porter et al., 2020). It might be difficult to disentangle the effects of ELM and BPD traits as long as the

adolescent is potentially still experiencing neglectful or traumatic familial circumstances. It can be assumed that ELM has already affected behavior but its effect is not (yet) distinguishable from BPD symptomatology. Future research should address this issue in longitudinal designs.

### ***Limitations***

Although our study has several strengths (e.g. well characterized clinical sample, concurrent observation of maternal, adolescent and dyadic behavior), there are also limitations that should be discussed. As mentioned above, due to our cross-sectional design we could not investigate bidirectional transactions over time. In order to follow up on research questions that emerged during the discussion of our study results (e.g. the disentanglement of the influence of caregiver ELM, parental psychopathology and how this is related to parenting behavior and the occurrence of child psychopathology), bigger sample sizes would be needed.

Furthermore, only 50% of our clinical sample fulfilled full diagnostic criteria of BPD. Literature, however, suggests that even subthreshold BPD poses serious threats to mental health and psychosocial wellbeing and should therefore be treated in clinical settings and included in study designs (Chanen et al., 2020; Kaess et al., 2017; Thompson et al., 2019). In our study, general adolescent psychopathology had an effect on behavior, especially on dyadic behavior. Future studies should include a second clinical sample (e.g., adolescents with Major depressive disorder) and always assess general psychopathology to improve the possibility to distinguish better between effects of pathological symptoms of any kind and of BPD traits.

Like most studies, we did not include fathers, although fathers have to be considered as well as sources of transgenerational mechanisms in the development of the disorder (Reichl et al., 2017). Our sample did also mainly comprise female BPD adolescents [boys:  $n_{BPD-G} = 6$  (15.8%);  $n_{HC-G} = 7$  (20%)] which did not allow us to pursue gender specific analyses. Our sample is highly educated which impedes comparisons to at-risk families that are typically affected by psychopathology. However, this also offers the chance to investigate BPD related familial mechanisms without the often-confounding factor of low socioeconomic status. Future studies should focus on clinical and more diverse samples with larger samples sizes, either applying longitudinal designs or minute-by-minute microcoding of behavior that would also allow the investigation of bidirectional transactions.

## **Conclusion**

The current study contributes to existing literature by demonstrating in a clinical sample a decreased quality of observed parental, adolescent and dyadic behavior during mother-adolescent interactions in two different contexts when adolescent BPD traits are present. Maternal and adolescent behavior during interactions seemed to be BPD-specific, whereas effects of BPD and general adolescent psychopathology overlapped regarding the prediction of dyadic behavior. Maternal ELM by itself did not seem to be associated with interactional behavior. Adolescent ELM contributed to negative behavior but did not have an effect additional to clinical status. Our data suggest a stronger focus on parent-child interactions (e.g. maternal sensitivity, adolescent behavior in general and dyadic reciprocity) in BPD specific therapies in order to improve interpersonal skills (especially in the context of stress) which could in turn enhance long-term treatment outcomes and psychosocial functioning for adolescent BPD patients.

## **List of abbreviations**

BPD: Borderline Personality Disorder

BPD-G: adolescent patients with borderline personality traits and their mothers

HC-G: healthy control group

CIB: Coding Interactive Behavior

ELM: Early Life Maltreatment

SDQ: Strengths and Difficulties Questionnaire

CTQ: The childhood trauma questionnaire

VASQ: Vulnerable Attachment Style Questionnaire

## **Declarations**

Ethics approval and consent to participate: The study was approved by the Institutional Review Board of the Medical Faculty of Medicine, University of Heidelberg (S-593/2017). All mothers and adolescents gave written informed consent and received financial compensation.

Availability of data and materials: The study data are available from the corresponding author upon reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: AF, JK and MK conceptualized and designed the study, contributed to funding acquisition and allocation of resources. KW, LF and AF were involved in material preparation, participant recruitment, data acquisition and also conducted and supervised video coding (CIB). KW performed the data analyses and wrote the original draft of the manuscript. Review was performed by LF, JK and MK. All research was supervised by the principal investigator MK. All authors read and approved of the final manuscript.

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**Manuscript 3. Individual Patterns and Synchrony of Heart Rate Variability in Adolescent Patients with Borderline Personality Psychopathology and their Mothers: A Case-Control Study**

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## **Abstract**

**Background:** In adolescent Borderline Personality Disorder (BPD), interactions with caregivers often provoke dysregulation. Vagally-mediated heart rate variability (HRV), a physiological marker of regulatory capacities, shows alterations in BPD. Studies on individual and dyadic HRV in adolescents with BPD (BPD-A) and their mothers (BPD-M) are lacking. We examined 1) individual resting state -, reactivity- and recovery-HRV, 2) intrapersonal concordance of interactional quality with HRV, 3) mother-adolescent interpersonal HRV-synchrony and 4) the association of interpersonal HRV-synchrony with behavioral synchrony in a case-control design.

**Methods:** Thirty-eight (sub)syndromal BPD-A and BPD-M were compared to 35 healthy control adolescents and their mothers (HC-A/-M). HRV was assessed during a positive interaction, a stress task and resting before and after interactions (recovery). Behavior during interactions was observed and coded using the “Coding Interactive Behavior”- Manual. Data were analyzed using multilevel modeling.

**Results:** BPD-A showed a lower resting HRV than HC-A, while no group differences were found for mothers. From resting to positive interaction, BPD-A/BPD-M/HC-M showed a significant increase in HRV; this increase was not significant for HC-A. HRV-reactivity to stress was not significant in either group but influenced by general emotional and behavioral problems within both adolescent samples. Significant intrapersonal concordance of HRV and behavior could only be found for HC-M during the positive interaction (positive association). For BPD-M, a complete disconnect between behavior and HRV was observed. BPD-dyads and dyads lower in behavioral synchrony displayed HRV-synchrony during stress, in HC-dyads and dyads higher in behavioral synchrony during rest after dyadic interactions.

**Conclusions:** Our study is the first investigating altered HRV-reactivity, behavior-HRV-concordance and HRV-synchrony in adolescents with BPD traits and their mothers, adding new insight to physiological regulation and co-regulation in adolescent BPD pathology. Limitations and implications of these results are discussed.

**Keywords:** HRV, BPD, adolescents, mother-child interaction, physiological synchrony, behavioral synchrony

## **Background**

Individuals with Borderline Personality Disorder (BPD) often experience disturbances in emotion regulation (ER) which can lead to problematic behavior (e.g. self-harm, suicide attempts, substance abuse) and tumultuous interpersonal relationships (1, 2, 3, 4). Understanding how these difficulties in ER develop may be crucial to advance new treatment approaches. Etiological models of BPD suggest that insufficient caregiver-child co-regulatory processes during childhood hinder the development of secure attachment and the ability to self-regulate (e.g. 5, 6). A time period that is especially relevant for both the development of ER skills and the onset of mental disorders (including BPD) is adolescence (3). Therefore, studies with an interpersonal focus investigating both behavioral and physiological processes during caregiver-adolescent interactions are needed (7).

### **HRV: A Marker of Individual Regulation**

A physiological marker commonly associated with emotional and social regulation is vagally-mediated heart rate variability (HRV), i.e. beat-to-beat variability in a sequence of heartbeats (8). Higher levels of resting HRV indicate higher regulatory capacities (8, 9, 10). Lower resting HRV has been observed in several psychiatric populations - including adult (11) and adolescent BPD patients (12, 13, 14) – and has been associated with emotional dysregulation in children and adolescents (15).

Autonomic flexibility, i.e. HRV adjustment in response to environmental demands (8, 9, 10), is discussed as a foundation of social effectiveness (9, 16). While a decrease in HRV (i.e. vagal withdrawal) is suggested to indicate attention and (over)mobilization of resources in response to stressors, HRV-increase (i.e. vagal augmentation) may signal calmness, readiness for social engagement and disengagement from stressors (17, 18, 19).

As BPD is often characterized as a disorder of interpersonal functioning (6, 20), studies examining HRV-reactivity in different interpersonal contexts are needed. In healthy individuals, social interactions of negative valence seem to reduce HRV, while neutral or positive interactions may not induce HRV changes (16). In adolescents with psychopathology, hypo- and hyper-reactivity has been observed. While depressed adolescents did not show HRV-reactivity in response to parent-adolescent interaction in both positive interactions and a conflict discussion task (21, 22), female adolescents

with self-injuring behavior displayed hyper-reactivity in response to their mothers' aversive behavior during a conflict discussion (22). For individuals with BPD physiological hyper-reactivity expressed through an excessive decrease of HRV has been hypothesized but could not be confirmed by empirical data (23, 24). Due to a small number of primary studies that have almost exclusively focused on adults, current findings are still to be interpreted with caution (24).

Recovery or the degree of return to resting HRV levels has been neglected in prior research (19, 24). Similarly, an important but under-researched aspect of regulatory failures in BPD is a slower return to baseline (25). More studies on adolescent HRV during parent-adolescent interaction including a recovery condition are necessary.

In BPD, where failing parental co-regulation has been discussed as a developmental pathway and parent-adolescent conflicts seem to escalate symptoms and maintain the disorder, parent-adolescent regulation during interaction deserves more research attention (5, 22). Amole et al. (21) not only reported blunted HRV-reactivity (i.e. no significant changes in HRV) in depressed adolescent daughters but found the same blunted pattern in their depressed mothers, suggesting that there may be altered HRV in parents of mentally ill adolescents. However, there are no studies examining HRV functioning in parents of adolescents with BPD.

In sum, case-control studies focusing on dynamic HRV in both adolescent BPD patients and their parents during actual parent-adolescent interaction are needed. Ideally, these include not only resting conditions but reactivity to and recovery from pleasant and stressful events.

### **Intrapersonal concordance of HRV and Behavior**

Little is known about the relation between behavior and HRV during parent-child interactions, especially during adolescence. It seems to depend on the dyadic context, e.g. whether HRV is measured during a pleasant, collaborative or a stressful task, or whether participants belong to a clinical group or not (9, 10, 22). Concordance between HRV and behavior during mother-child interactions though has almost exclusively been highlighted in infancy and toddlerhood, with a strong focus on maternal functioning and community samples (27, 28). A study by Sturge-Apple et al. (26) investigated a preadolescent sample and found parents' blunted HRV reactivity to be associated with increased parental hostile behavior in a conflict discussion. Studies also suggest that maternal behavior-HRV associations vary when mothers are

maltreating their child (29, 30, 31). More data, especially focused on adolescence, is needed to illuminate associations of interactional quality and HRV during parent-child interaction.

### **Behavioral and HRV-synchrony in caregiver-child interactions**

Behavioral synchrony describes the coordination between a parent's and child's nonverbal behavior and communicative signals during social interactions in ways that enhance positivity, reciprocity, and mutual engagement (32). Parent-child synchrony in HRV is defined as a dynamic, within-dyad coordination of HRV over time that is directly tied to an interpersonal process (33). HRV synchrony can be positive (increase/decrease of mother's and child's HRV at the same timepoint) or negative (increase of mother's HRV and decrease of child's HRV at the same timepoint or vice versa). According to the biobehavioral framework put forward by Feldman (34), parents and children adjust their neurobiological and behavioral rhythms over time and daily experience. This dyadic adjustment then sets the stage for the formation of enduring attachment and provides a base for children's regulatory development (34). Similarly, Social Baseline Theory (35) postulates that homeostatic coregulation inherent in human nature serves the conservation of regulatory resources and thus provides evolutionary benefit. However, if coregulation goes awry, resources can deplete more rapidly, further disrupting regulation, social affiliation, and skills such as problem solving or attention allocation (6, 36).

HRV-synchrony has been found in parents and children of various developmental stages, yet, the number of studies focusing on adolescents is very limited and findings are mixed (21, 33). In early childhood, tasks demanding joint attention and simultaneous engagement in a dyad have been found to promote parent-child HRV-synchrony (37, 38). Some argue that HRV-synchrony can be induced simply by cognitive-emotional processing of a similar stimulus and does not necessarily require actual interaction or shared face-to-face experiences (39). Importantly, a number of studies suggest that both context and risk status of the dyad conjointly shape presence and nature of synchrony (38). In the context of maternal and child/adolescent depression, for example, negative synchrony during positive and stressful interactions was observed (as opposed to positive synchrony in healthy dyads; 21, 40). In the context of preadolescent Posttraumatic Stress Disorder (PTSD; and also increased maternal PTSD symptoms), tighter positive HRV-synchrony was found during a

positive interaction in comparison to war-exposed but resilient dyads (41). There are several indications in research suggesting HRV-synchrony to be maladaptive in the context of parental psychopathology or emotion regulation difficulties (42, 43). Finally, recent research also points out that as children grow up, strong physiological coupling might be less adaptive and hinder the child's abilities for self-regulation (41, 42).

As behavioral synchrony is a marker of healthy parent-child interaction not only in infancy but also adolescence (32, 34, 44), consistent co-occurrence of higher behavioral and HRV-synchrony may point to higher adaptiveness of the latter. However, the few studies examining these associations have shown that physiological and behavioral synchrony do not necessarily co-occur, and if they do, findings are inconsistent (37, 45). An early study examining infants and mothers suggested that cardiac synchrony was higher when affect and vocal synchrony was also higher (46). However, in another study during preadolescence, clinical dyads displayed the strongest HRV-synchrony combined with the lowest behavioral synchrony and resilient dyads displayed the lowest HRV-synchrony and the highest behavioral synchrony (41).

Dysregulated and unstable relationships with caregivers are common in adolescents with BPD (5, 47). Yet, the underlying mechanisms, e.g. how behavioral synchrony, context and BPD pathology shape individual and HRV-synchrony during interaction are still unclear. We aimed at closing this gap by implementing a case-control design which included adolescents with at least subthreshold BPD (BPD-A) and their mothers (BPD-M) and a healthy comparison group of adolescents (HC-A) and their mothers (HC-M). We included resting periods as well as two interactional contexts of different valence (positive interaction vs. stress task). Hopefully, our results will contribute to a better understanding of the development of emotion dysregulation and interactional difficulties in BPD.

### **Present study**

With our paper, we aimed at adding knowledge on 1) individual resting state -, reactivity- and recovery- HRV in both adolescents and mothers 2) intrapersonal concordance of interactional quality and HRV, 3) HRV-synchrony and 4) relations between HRV-synchrony and behavioral synchrony. These associations were examined depending on clinical status and assessment context, i.e. resting, reactivity to positive and stressful interactions and recovery after stress.

Regarding individual HRV as research question (RQ) 1, we first hypothesized that BPD-A/BPD-M would display lower *resting state HRV* than HC-A/HC-M. We further assumed that *HRV-reactivity and -recovery* of adolescents and mothers would depend on the interplay between context and clinical status. We hypothesized that HC-A/HC-M would not show significant phasic HRV changes from *resting to positive interaction* but exhibit a decrease in HRV from *resting to stress task*, indicating attention and mobilization of resources (16). As prior research has shown divergent results regarding HRV reactivity in adolescents with psychopathology, no specific hypotheses were made for BPD-A/BPD-M. For HRV-recovery we hypothesized that HC-A/HC-M would exhibit an increase in HRV (indicating disengagement from stressors and calmness) while BPD-A/BPD-M would not (based on the slower return-to-baseline findings). RQ2 zooms in on intrapersonal concordance, i.e. the link between interactional quality and HRV observed during mother-adolescent interaction. During *positive interaction*, we expected a positive link between individual interactional quality and HRV, suggesting that higher interactional quality supports higher HRV or the reverse. During *stress task*, we expected a negative link between individual interactional quality and HRV, suggesting that interactional quality supports effective regulation or effective regulation supports interactional quality. A moderating role of clinical status was examined exploratorily. Finally, we hypothesized that HRV-synchrony would be moderated by a) clinical status and context (RQ3) and b) behavioral synchrony and context (RQ4). In line with previous findings and theoretical considerations regarding interactional difficulties in BPD, we predicted that HC-M/HC-A show higher behavioral synchrony than BPD-M/BPD-A and that HC-M/HC-A and dyads higher in behavioral synchrony would not be HRV-synched during both interactions, while BPD-M/BPD-A and dyads lower in behavioral synchrony would be positively synched during both positive interaction and stress task.

## **Methods**

### **Recruitment and Participants**

For a detailed description of recruitment procedure and the sample see Williams et al. (48). In the present study, 38 adolescent patients (BPD-A;  $mean_{age} = 15.6$ ,  $sd_{age} = 1.13$ ) from a specialized outpatient clinic for self-harm and risk-taking behavior (AtR!Sk; 49) and their mothers (BPD-M) were included. Clinical assessment of BPD-A was conducted by trained psychotherapists. The German version of the Structured

Clinical Interview for DSM-5-Personality Disorders (SCID-5-PD; 50) was used to assess borderline personality disorder criteria. BPD-A were included if they fulfilled the diagnostic criteria for subsyndromal BPD ( $\geq 3$  BPD criteria) as adolescent subthreshold BPD is already associated with significant impairments in social and regulatory functioning (51). In our sample, BPD-A met a minimum of three and a maximum of eight BPD criteria [ $n(3)=8$ ,  $n(4)=11$ ,  $n(5)=9$ ,  $n(6)=7$ ,  $n(7)=2$ ,  $n(8)=2$ ;  $mean = 4.74$ ,  $sd = 1.41$ ]. The healthy comparison sample consisted of 35 adolescents (HC-A;  $mean_{age} = 15.5$ ,  $sd_{age} = 1.25$ ) and their mothers (HC-M) with a similar distribution of adolescent sex, age, education and maternal education as the BPD dyads (48). HC-A were excluded if they fulfilled criteria for any current or lifetime disorder according to the Mini International Neuropsychiatric Interview for Children and Adolescents (52); HC-M were excluded if they had been in treatment at any mental health facility during the past two years.

All mothers were primary caregivers of the target adolescent. The sample was of European ancestry and well educated (48). Most adolescents of both groups identified as female [(BPD-A:  $n = 32$  (84.2%), HC-A:  $n = 28$  (80.0%)]. Exclusion criteria for all participants were serious somatic illnesses, neurological disorders or dysfunctions of cardiac or hypothalamus-pituitary-adrenal systems.

## Procedure

The study was approved by the Institutional Review Board of the Medical Faculty, Heidelberg University.

Mothers and adolescents were invited to two laboratory visits. During the first visit, the clinical interviews were conducted. During the second visit, cardiac data was collected during a standardized procedure including two interaction paradigms. Dyads gave written informed consent and were compensated 60 Euro for participation.

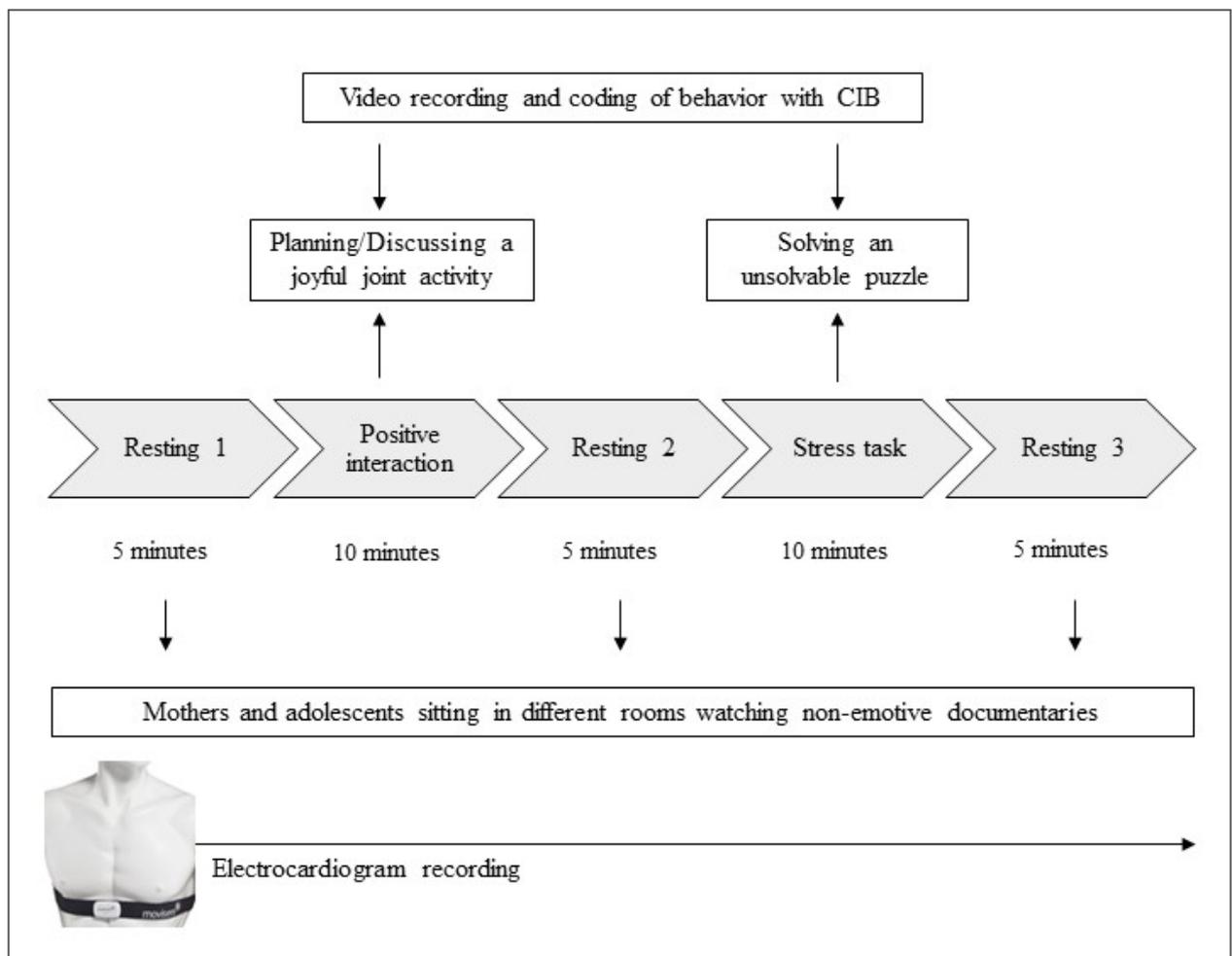
## Measures

**Experimental paradigm:** Participants completed five different segments in which continuous HRV was measured: resting 1, positive interaction, resting 2, stress task, and resting 3 (see Figure 1). During the 5-min resting periods, mothers and adolescents sat quietly in different rooms and watched segments of non-emotive documentaries. The documentaries were purely factual, focusing on topics such as the types of clouds and their formation processes. They did not include any themes

related to relationships, attachment, or emotions. During the 10-min long positive interaction, dyads were asked to plan and discuss a joyful joint activity. For the 10-min long stress task, adolescents were given a puzzle which was too difficult to solve in the provided timeframe. Additionally, they were informed that other participants their age had solved the task quickly and without any problems. Mothers were asked to support the adolescents, but not to solve the puzzle for them. For a more detailed description see also Williams et al. (48).

**Figure 1**

*Description of the paradigm*



Note. CIB = Coding interactive behavior manual

**HRV measurement:** Electrocardiogram recordings were collected using the ECGMove 3/4 sensors (movisens, Karlsruhe, Germany) which were attached to the sternum of participants using chest belts. Raw data were visually inspected in Kubios HRV premium (Version 3.1, Department of Applied Physics, University of Eastern Finland, Kuopio, Finland) and manually corrected. RHRV (53) was used to analyze the corrected interbeat interval time series data. Root mean square of successive RR interval differences (rMSSD in ms) was calculated for each of the 35 one-minute segments. Due to HRV device malfunction, HRV data were missing from 3 mothers (BPD-M:  $n = 1$ , HC-M:  $n = 2$ ) and 2 BPD-A. The HRV patterns of 2 BPD-M suggested supraventricular extrasystoles and were therefore excluded from the HRV analyses. Additionally, 2 adolescents ( $n = 1$  per group) were excluded from HRV analyses due to abnormal HRV (e.g.  $<50$  heart beats per minute). Hence, 137 participants (93,84%; BPD-A:  $n = 35$ , BPD-M:  $n = 35$ , HC-A:  $n = 34$ , HC-M:  $n = 33$ ) were included in individual HRV analyses. Due to moving artifacts, 199 (7.63%) of 2555 segments were missing for mothers and 195 (7.63%) were missing for adolescents.

**Quality of Interactional Behavior and Behavioral Synchrony:** Adolescent, maternal and dyadic behavior was observed during positive interaction and stress task and rated based on the Coding Interactive Behavior system (CIB; 54). The CIB version for parent-child conversational paradigms covers 56 behavioral codes which receive ratings from 1 (low) to 5 (high). Maternal CIB was calculated by subtracting maternal intrusiveness from maternal sensitivity and structuring (Cronbach's  $\alpha = .81$ ), adolescent CIB was calculated by subtracting adolescent withdrawal from engagement and compliance (Cronbach's  $\alpha = .92$ ) and dyadic CIB/behavioral synchrony was calculated by subtracting constriction and tension from dyadic reciprocity, compatibility, and fluency (Cronbach's  $\alpha = .90$ ). The combination of scales into a general score was guided by the following logic: scales have opposite directions; higher values on maternal sensitivity, for example, are considered 'positive' and higher values on maternal intrusiveness are considered 'negative'. Subtracting opposite oriented scales is mathematically equivalent (up to a constant term) to inverting one scale before adding them together. Thus, higher scores on maternal, adolescent, or dyadic CIB/behavioral synchrony represent higher interactional quality. Interrater reliability was checked continuously during the rating process. Overall, rater agreement was 88%. Cohen's Kappa was .77.

**General adolescent psychopathology:** The Strengths and Difficulties Questionnaire (SDQ; 55) is a self-report questionnaire and was applied to assess emotional and behavioral problems in both adolescent groups ( $\alpha = .89$ ).

**Covariates:** Participants age, sex, BMI, smoking habits (yes/no) and physical activity in minutes per week (The International Physical Activities Questionnaire (IPAQ; 56) were assessed through survey questions or interviews. Potentially cardioactive medication, such as certain antidepressants or beta-blockers, which are known to influence HRV, were documented.

### **Analytic Plan**

All analyzes were done in R version 4.3.2.; significance level was set at  $\alpha = 0.05$ . An rMSSD outlier analysis was performed ( $\geq 3SD$  from mean rMSSD) and all analyses were run with and without participants with outliers. To resolve skewness of raw rMSSD values, a natural log transformation was applied.

Given the nested structure of the data (individual analyses RQ1/2: rMSSD segment values nested within individuals, synchrony analyses RQ3/4: individuals nested within dyads) (57), RQs were investigated by implementing multilevel modeling (MLM; maximum likelihood estimation). Marginal means and contrasts were estimated using the emmeans package (58). Unstandardized estimates are reported. Random-intercept (RQ1) and random-intercept and -slope (RQ2, 3,4) models were estimated using the lme4 package (59).

Depending on the RQ, the contrast between different assessment contexts were investigated. To examine reactivity, the contrast between the task (positive interaction or stress task) and the preceding resting period was of interest; for recovery, the contrast between the task and the following resting period was of interest. Tukey method was applied for p-value adjustment of the contrasts.

Specifically, for the analyses of HRV baseline differences, HRV-reactivity and -recovery (RQ1), random-intercept models with group, context and group x context interaction were calculated. Time of lab visit, age, sex, BMI, smoking, physical activities and medication were included as covariates (in adolescent model adolescent age, sex, BMI, etc. and in maternal model maternal age, BMI, etc., respectively). To test whether our results were specifically related to borderline symptomatology rather than to general psychopathology, we included the total score of the SDQ and the interaction term with context (SDQ\*context) as predictors in the adolescent models.

For RQ2, two random-intercept, random-slope MLMs were set up: An adolescent model including a three-way interaction of adolescent CIB, clinical status and context predicting adolescent rMSSD (with time of lab visit, adolescent age, sex, BMI, smoking, physical activities and medication as covariates) and a maternal model including a three-way interaction of maternal CIB, clinical status and context predicting maternal rMSSD (with time of lab visit, maternal age, BMI, smoking, physical activities and medication as covariates). Each subject was allowed to have a different intercept and a random CIB slope.

For synchrony analyses (RQ3/4), multilevel state-trait modeling was applied, allowing for simultaneous estimation of between-dyad (BD) and within-dyad (WD) effects (37, 60). Thus, associations of maternal and adolescent rMSSD are parsed on “trait” and “state” levels. Average (trait) rMSSD was calculated by grand-mean centering (60). If mothers’ or adolescents’ average rMSSD across all one-minute segments was zero, this average was equivalent to the sample mean of mothers or adolescents, respectively. WD effects portray concurrent, in-the-moment associations (61) and capture whether mother and adolescent state rMSSD coordinate across the 35 one-minute measurements. State rMSSD was calculated by subtracting the individual’s average rMSSD from each of the 35 segment rMSSD values of that respective individual, thereby describing each individual’s fluctuations around their own average rMSSD. Thus, a state rMSSD value of zero represents the individual’s average rMSSD level (59), a positive state rMSSD value represents an increase in rMSSD with respect to an individual’s average rMSSD, and negative state rMSSD indexes a decrease. For a more detailed description of the method see e.g. Fuchs et al. (62).

For RQ3, two random-intercept, random-slope MLMs were run to establish presence or absence of HRV-synchrony across groups and contexts (Mother-to-Adolescent, MtA, including the covariates time of lab visit, adolescent age, sex, BMI, smoking, physical activities and medication; Adolescent-to-Mother, AtM, including the covariates time of lab visit, maternal age, BMI, smoking, physical activities and medication). Predictors were group, context, HRV state, HRV trait, and interaction terms were group x context, group x state, context x state, group x context x state. Observations were grouped by subject and each subject was allowed to have an individual state slope. To investigate RQ4, again two random-intercept, random-slope models were set up (AtM, MtA), controlling for covariates (following the logic of RQ3)

and group. The predictors were context, HRV state, HRV trait, dyadic CIB, and interactions were context x state, context x CIB, state x CIB, state x context x CIB. The three-way interaction was evaluated at discrete values for dyadic CIB given by the average value, minus (lower) and plus (higher) one standard deviation. For RQ3/4, observations were grouped by subject and each subject was allowed to have an individual HRV state slope.

In order to examine to what extent non-findings are related to limited power when testing the hypotheses, sensitivity analyses for RQ1 (two-way interaction) and RQ3 (three-way interaction) were calculated to identify the smallest effect the study was powered to find (see Supplement for further details).

## Results

### Individual HRV (RQ1)

**Resting state.** For adolescents, there was a significant effect of clinical status ( $t(81.5) = 3.898, p < .001$ ): BPD-A ( $m = 3.51, CI = 3.38 - 3.65$ ) had lower resting rMSSD than HC-A ( $m = 3.88, CI = 3.75 - 4.02$ ). For mothers, there was no significant difference ( $t(76.7) = 0.98, p = .329$ ) in resting rMSSD between BPD-M ( $m = 3.15, CI = 3.01 - 3.29$ ) and HC-M ( $m = 3.25, CI = 3.10 - 3.39$ ). Excluding outliers or including covariates did not change the results.

**Reactivity.** For adolescents, a significant clinical status x context interaction [ $F(4,2250.25) = 2.886, p = .021$ ] was found. Changes in rMSSD from *resting 1 to positive interaction* differed between groups: BPD-A showed a significant change of estimated marginal means (emm) from 3.55 ( $SE = 0.09$ ) to 3.67 ( $SE = 0.09$ ) (contrast:  $\beta = .12, p < .001$ ) whilst in HC-A the rMSSD remained constant [change from 3.87 ( $SE = 0.11$ ) to 3.89 ( $SE = 0.11$ ); contrast:  $\beta = .02, p = .999$ ]. Mothers showed a significant increase in rMSSD from *resting 1 to positive interaction* in both groups [BPD-M: changes from 3.10 ( $SE = .08$ ) to 3.22 ( $SE = .08$ ); contrast:  $\beta = .11, p < .001$ ; HC-M: changes from from 3.17 ( $SE = .10$ ) to 3.29 ( $SE = .10$ ); contrast:  $\beta = .12, p < .001$ ]. From *resting 2 to stress task*, no significant rMSSD changes or group differences could be observed (Table 1, Figure 2). Sensitivity analysis suggests that the response to the stress task would need to be about the same size as the observed significant response to the positive interaction to be detected with sufficient power (see Supplement “Sensitivity Analysis RQ1” and Figure S1). Since some observed responses in our sample meet the minimal resolvable effect size but the stress response is much smaller in

magnitude, we do not interpret the absence of a stress response as a sample size issue.

**Table 1***Clinical status and measurement context predicting individual rMSSD*

<i>Predictors</i>	<b>Adolescent rMSSD</b>			<b>Mother rMSSD</b>		
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>
(Intercept)	3.537	3.277 – 3.796	<b>&lt;0.001</b>	3.221	3.054 – 3.387	<b>&lt;0.001</b>
Context2	0.121	0.075 – 0.168	<b>&lt;0.001</b>	0.115	0.071 – 0.158	<b>&lt;0.001</b>
Context3	0.092	0.038 – 0.145	<b>0.001</b>	0.098	0.047 – 0.148	<b>&lt;0.001</b>
Context4	0.073	0.027 – 0.119	<b>0.002</b>	0.114	0.071 – 0.157	<b>&lt;0.001</b>
Context5	0.256	0.203 – 0.310	<b>&lt;0.001</b>	0.233	0.183 – 0.284	<b>&lt;0.001</b>
Group (BPD/HC)	0.321	0.112 – 0.530	<b>0.003</b>	0.066	-0.137 – 0.269	0.525
Time of day	-0.024	-0.062 – 0.014	0.212	-0.031	-0.071 – 0.009	0.131
Age	-0.066	-0.145 – 0.014	0.106	-0.010	-0.027 – 0.007	0.249
Medication yes/no	0.104	-0.180 – 0.389	0.472	-0.055	-0.309 – 0.198	0.669
Physical activity	0.000	-0.000 – 0.000	0.869	-0.000	-0.000 – 0.000	0.380
BMI	-0.008	-0.036 – 0.019	0.564	-0.000	-0.021 – 0.021	0.985

Sex	0.042	-0.183 – 0.266	0.717			
Smoking yes/no	-0.117	-0.346 – 0.112	0.316	-0.174	-0.394 – 0.046	0.120
Context2:HC	-0.102	-0.170 – -0.033	<b>0.004</b>	0.006	-0.057 – 0.070	0.844
Context3:HC	-0.084	-0.163 – -0.006	<b>0.035</b>	-0.030	-0.104 – 0.043	0.423
Context4:HC	-0.105	-0.174 – -0.037	<b>0.003</b>	-0.011	-0.074 – 0.053	0.744
Context5:HC	-0.114	-0.192 – -0.035	<b>0.005</b>	-0.052	-0.126 – 0.022	0.167

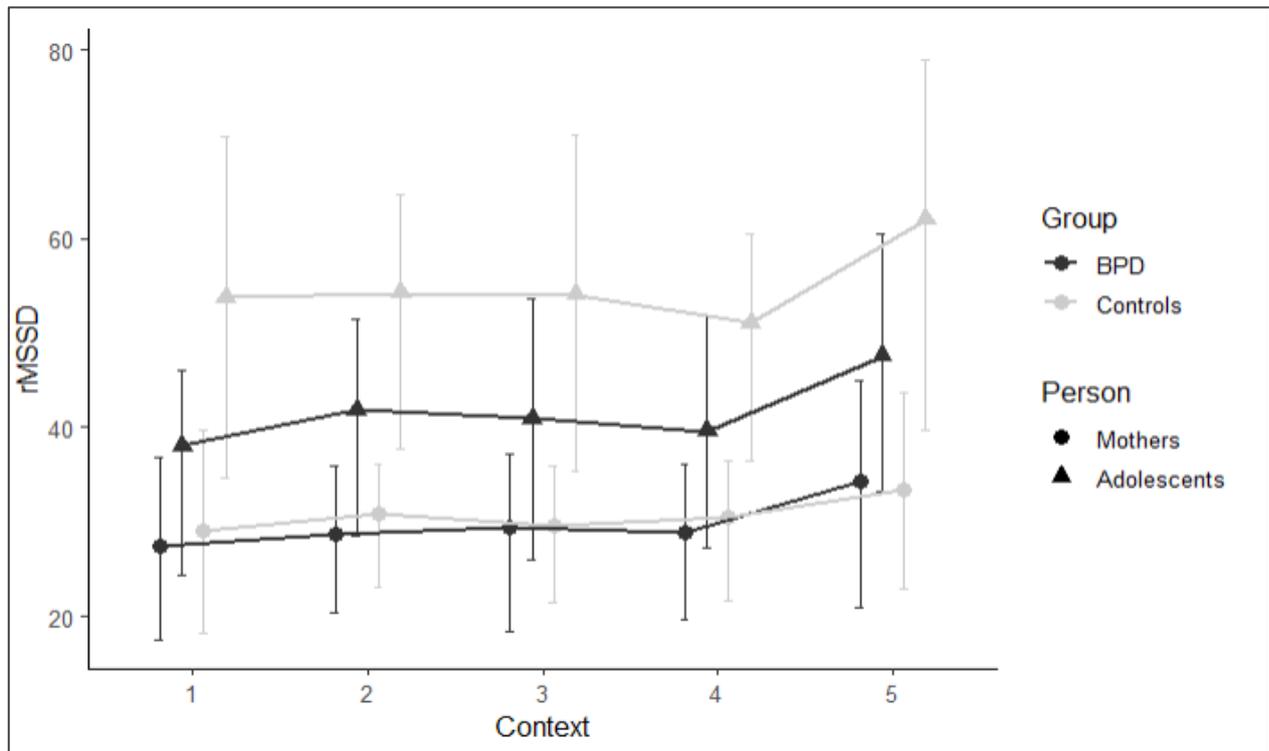
#### Random Effects

$\sigma^2$	0.06		0.06
T <sub>00</sub>	0.12 <sub>id</sub>		0.14 <sub>id</sub>
ICC	0.66		0.71
N	69 <sub>id</sub>		68 <sub>id</sub>
Observations	2318		2279
Marginal R <sup>2</sup> / Conditional R <sup>2</sup>	0.180 / 0.718		0.100 / 0.740

*Note.* Reference category: Context1=Resting 1. Context2=Positive Interaction, Context3 =Resting 2, Context4=Stress Task, Context5=Resting 3. BPD = clinical group; HC = healthy controls.

**Figure 2**

*rMSSD reactivity/recovery in mothers and adolescents by measurement context and group*



Note. Nontransformed rMSSD-values graphed. \*\*=significant changes,  $p < .01$ .

**Recovery.** Adolescents ( $\beta = .18$ ,  $SE = 0.02$ ,  $p < .001$ ) and mothers ( $\beta = .10$ ,  $SE = 0.02$ ,  $p < .001$ ) showed a significant increase in rMSSD from *stress task* to *resting 3*, irrespective of group [BPD-A: 3.62 ( $SE = .09$ ) to 3.80 ( $SE = .09$ ); HC-A: 3.84 ( $SE = .11$ ) to 4.01 ( $SE = .11$ ); BPD-M: 3.22 ( $SE = .08$ ) to 3.34 ( $SE = .08$ ); HC-M: 3.27 ( $SE = .10$ ) to 3.35 ( $SE = .10$ )].

Analyses controlling for SDQ and SDQ\*context interaction revealed that for resting state and recovery HRV, results remained robust. For HRV reactivity, results also stayed the same from resting 1 to positive interaction. From resting 2 to the stress task, however, significant differences were found within both groups dependent on the SDQ value: higher SDQ scores were associated with higher HRV differences between contexts ( $b = 0.01$ ,  $p = .002$ ). Specifically, HRV differences mainly represented lower HRV scores during stress. Plots for these additional calculations can be found in the supplement (Figures S2-S4).

### **Intrapersonal concordance of HRV and behavior (RQ2)**

In the adolescent model, plotted regression lines (see supplement Figure S5) suggested a negative CIB-rMSSD association for BPD-A and a positive CIB-rMSSD association for HC-A during the positive interaction (whilst both groups showed a negative regression line during stress). However, when outliers were excluded, the adolescent three-way interaction did not reach significance ( $F(3, 1415)=2.60, p=.051$ ). In the maternal model, a significant three-way interaction was found ( $F(3, 842)=3.37, p=.018$ ; see supplement Table S1 for results without outliers). For HC-M, plotting (Figure S5) suggested negative CIB-rMSSD associations during stress task and positive CIB-rMSSD associations during positive interaction. However, only the positive association between CIB and rMSSD during positive interaction turned out to be significant ( $\beta=0.13, p=.048$ ).

### **HRV-synchrony during caregiver-child interactions (RQ3)**

In MtA and AtM models, significant three-way interactions of state, clinical status and context were found (MtA:  $F(4, 1966)=5.61, p<.001$ ; AtM:  $F(4, 1963)=5.58, p<.001$ ; Table 2, Figure 3). In the MtA-model, significant positive associations between state rMSSD in HC-A/HC-M (meaning positive synchrony) were found during resting 2 ( $\beta=0.41, 95\% CI [0.19, 0.64]$ ) and 3 ( $\beta=0.31, 95\% CI [0.11, 0.52]$ ), while in BPD-A/BPD-M significant positive synchrony was observed during the stress task ( $\beta=0.18, 95\% CI [0.02, 0.34]$ ). Thus, when mothers increased or decreased their rMSSD at any given moment during resting 2 or 3 (CG) or during stress (BPD), adolescents also increased or decreased their rMSSD with respect to their average rMSSD. Sensitivity analysis shows that, in the positive interaction context, the minimal synchrony required to be detected with sufficient power is about 1.5 times the observed synchrony during the stress task (see Supplement “Sensitivity analysis RQ3” and Figure S6). Since the observed synchrony effects are of the same order as the minimal resolvable effect size but are 5.8 times smaller, we do not attribute the absence of synchrony during the positive interaction to a sample size issue. In the AtM-model, significant positive state rMSSD synchrony was found in HC-A/HC-M during resting 2 ( $\beta=0.37, 95\% CI [0.19, 0.56]$ ) and 3 ( $\beta=0.54, 95\% CI [0.34, 0.74]$ ), however, there was only trend-level significance of synchrony in BPD-A/BPD-M during stress task ( $\beta=0.13, 95\% CI [0.00, 0.26], p=0.06$ ). Again, there was no association between adolescent and maternal average rMSSD in either model.

**Table 2***Clinical status and measurement context shape HRV-synchrony*

<i>Predictors</i>	<b>Mother rMSSD -&gt; Adolescent rMSSD</b>			<b>Adolescent rMSSD -&gt; Mother rMSSD</b>		
	<i>Estimates</i>	<i>CI</i>	<i>p</i>	<i>Estimates</i>	<i>CI</i>	<i>p</i>
(Intercept)	3.566	3.323 – 3.808	<b>&lt;0.001</b>	3.224	3.051 – 3.396	<b>&lt;0.001</b>
Time of day	-0.020	-0.057 – 0.016	0.271	-0.014	-0.053 – 0.025	0.480
Age	-0.083	-0.162 – -0.003	<b>0.042</b>	-0.013	-0.030 – 0.004	0.130
Medication yes/no	0.047	-0.224 – 0.318	0.735	0.024	-0.221 – 0.269	0.847
Physical activity	0.000	-0.000 – 0.000	0.716	-0.000	-0.000 – 0.000	0.745
BMI	-0.002	-0.028 – 0.024	0.882	-0.006	-0.026 – 0.014	0.540
Smoking yes/no	-0.158	-0.377 – 0.060	0.156	-0.163	-0.385 – 0.059	0.150
Sex	0.067	-0.141 – 0.276	0.526			
Average rMSSD	0.123	-0.095 – 0.340	0.270	0.243	-0.017 – 0.502	0.067
State rMSSD	0.027	-0.170 – 0.224	0.786	-0.019	-0.166 – 0.128	0.798
Group (BPD/HC)	0.287	0.082 – 0.493	<b>0.006</b>	-0.000	-0.216 – 0.215	0.997

Context2	0.126	0.074 – 0.178	<b>&lt;0.001</b>	0.102	0.055 – 0.150	<b>&lt;0.001</b>
Context3	0.082	0.024 – 0.140	<b>0.006</b>	0.114	0.062 – 0.166	<b>&lt;0.001</b>
Context4	0.061	0.010 – 0.113	<b>0.020</b>	0.111	0.065 – 0.158	<b>&lt;0.001</b>
Context5	0.235	0.172 – 0.298	<b>&lt;0.001</b>	0.235	0.178 – 0.293	<b>&lt;0.001</b>
State:HC	0.048	-0.233 – 0.329	0.738	0.055	-0.208 – 0.319	0.680
State:Context2	0.031	-0.194 – 0.255	0.789	0.098	-0.071 – 0.267	0.256
State:Context3	-0.210	-0.467 – 0.047	0.110	-0.087	-0.275 – 0.102	0.368
State:Context4	0.154	-0.068 – 0.377	0.174	0.147	-0.018 – 0.312	0.081
State:Context5	0.073	-0.153 – 0.300	0.525	0.176	-0.019 – 0.371	0.076
HC:Context2	-0.151	-0.229 – -0.072	<b>&lt;0.001</b>	0.019	-0.050 – 0.088	0.582
HC:Context3	-0.075	-0.162 – 0.011	0.089	-0.042	-0.119 – 0.035	0.286
HC:Context4	-0.155	-0.233 – -0.077	<b>&lt;0.001</b>	0.001	-0.068 – 0.071	0.967
HC:Context5	-0.151	-0.244 – -0.058	<b>0.001</b>	-0.102	-0.186 – -0.018	<b>0.017</b>
State:HC:Context2	-0.058	-0.381 – 0.264	0.723	-0.111	-0.413 – 0.192	0.473

State:HC:Context3	0.549	0.172 – 0.926	<b>0.004</b>	0.424	0.106 – 0.742	<b>0.009</b>
State:HC:Context4	-0.224	-0.551 – 0.103	0.179	-0.171	-0.484 – 0.141	0.282
State:HC:Context5	0.166	-0.181 – 0.513	0.350	0.328	-0.003 – 0.660	0.052

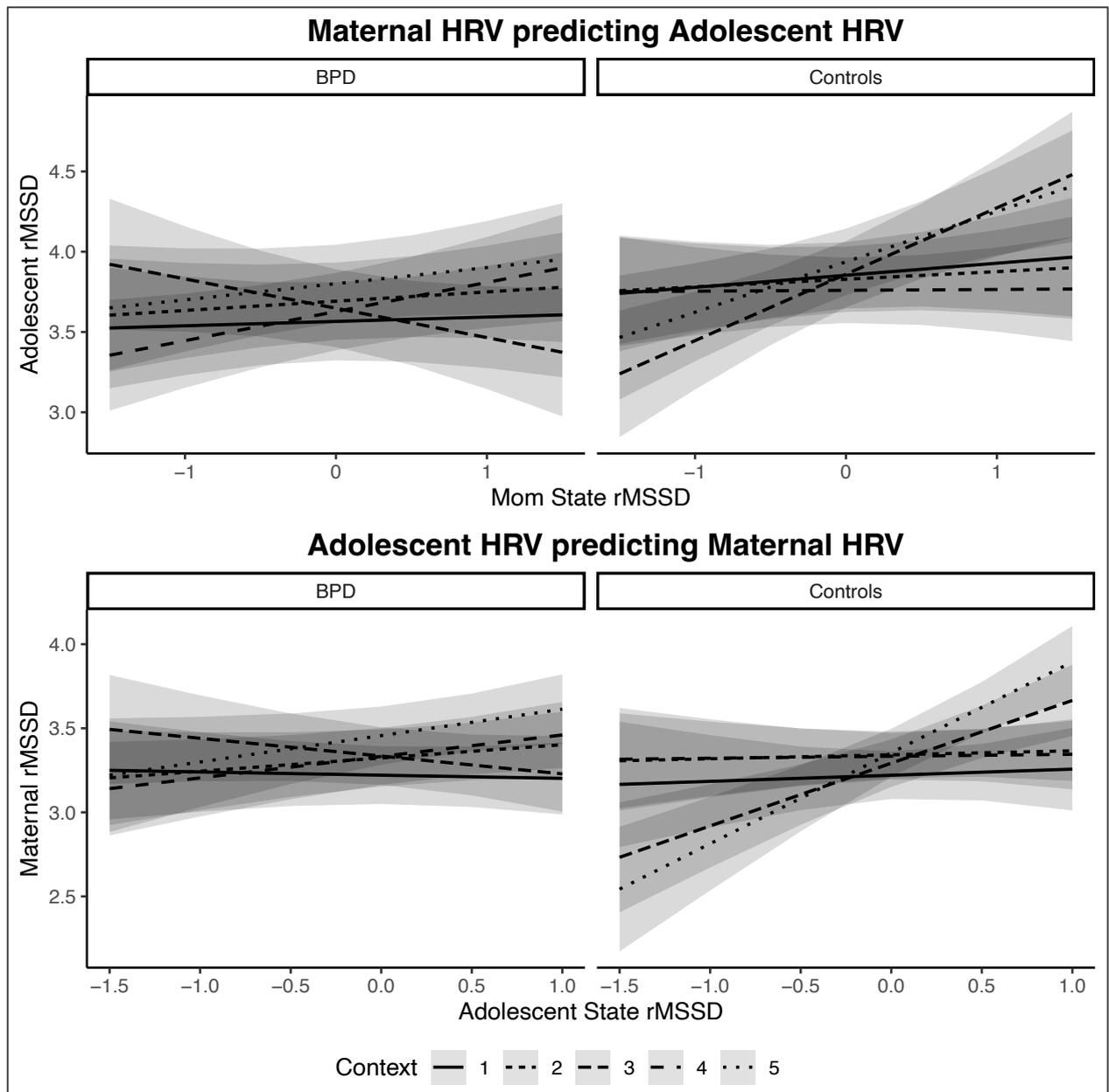
### Random Effects

$\sigma^2$	0.06			0.05		
T00	0.10 <sub>id</sub>			0.14 <sub>id</sub>		
T11	0.06 <sub>id.rMSSDIb_state</sub>			0.04 <sub>id.rMSSDIj_state</sub>		
$\rho_{01}$	-0.16 <sub>id</sub>			-0.42 <sub>id</sub>		
ICC	0.64			0.73		
N	64 <sub>id</sub>			64 <sub>id</sub>		
Observations	2049			2049		
Marginal R <sup>2</sup> / Conditional R <sup>2</sup>	0.227 / 0.720			0.107 / 0.758		

*Note.* Reference category: Context1=Resting 1. Context2=Positive Interaction, Context3 =Resting 2, Context4=Stress Task, Context5=Resting 3. 64 dyads, 2049 observations. BPD = clinical group; HC = healthy controls.

**Figure 3**

*Clinical status and measurement context shape HRV-synchrony*



*Note.* Context 1, 3, 5=Resting; Context 2=Positive interaction, Context 4=Stress task. Significant synchrony only in BPD dyads during stress task (maternal HRV to adolescent HRV model, trend level in adolescent HRV to maternal HRV model). In control dyads, significant state HRV associations during rest 3 and 5 in both models.

**Relations between interpersonal HRV- and behavioral synchrony (RQ4)**

In both models, significant three-way interactions of state rMSSD, dyadic CIB as an index of behavioral synchrony and context were found (MtA:  $F(3, 1561)=5.36, p=.001$ ;

AtM:  $F(3, 1565)=4.78, p=.003$ ). When dyadic CIB was observed to be *lower*, significant positive HRV-synchrony was found in both models during stress (MtA:  $\beta=0.16, p=.024$ ; AtM:  $\beta=0.15, p=.020$ ). In the MtA model, significant positive state rMSSD associations were also found during resting 2 and 3 when dyadic CIB was observed to be *average* (3:  $\beta=0.22, p<.001$ ) and *higher* (2:  $\beta=0.43, p<.001$ ; 3:  $\beta=0.33, p<.001$ ). In the AtM model, significant positive state rMSSD synchrony was found during resting 2 when dyadic CIB was *higher* ( $\beta=0.25, p=.010$ ), and during resting 3 across all levels of behavioral synchrony (*higher*:  $\beta=0.46, p<.001$ ; *average*:  $\beta=0.31, p<.001$ , *lower*:  $\beta=0.16, p=.040$ ). There was no association between adolescent and maternal average rMSSD in either model. See supplement Table S2 and Figure S7 for visualization.

The finding of positive HRV-synchrony during rest in CG-dyads and dyads average to higher in behavioral synchrony was surprising, given that synchrony is considered to be tied to a social process which should first and foremost be present when partners are concurrently interacting and not when they are sitting apart resting. To rule out the possibility that these synchrony findings emerged only because adolescents and mothers showed similar trajectories during rest independent from any dyad-specific social processes, we exploratively shuffled mothers and adolescents within clinical groups and randomly assigned mother-adolescent pairs. Again, two random intercept, random slope multilevel models including the covariates start time, age, sex adolescent, medication, physical activity, BMI, and smoking were run. Clinical status and context were added as moderators of HRV-Synchrony to both AtM and MtA-models. Contrary to findings from the original dataset, three-way interactions of state, clinical status and context were not significant (MtA:  $F(4, 1821)=0.47, p=.758$ ; AtM:  $F(4, 1947)=0.73, p=.571$ ; Table S3), suggesting that the reported effect was not significant in randomly assigned mother-adolescent pairs.

## Discussion

With our study, we aimed at examining physiological regulation and interactional behavior during rest and positive and stressful contexts in order to shed light on real-time individual and dyadic regulation in adolescents with BPD traits and their mothers. We examined 1) individual HRV -resting state, -reactivity and -recovery 2) intrapersonal concordance of interactional quality and HRV, 3) HRV-synchrony and 4) relations between HRV-synchrony and behavioral synchrony.

## Individual HRV (RQ1)

As hypothesized and in line with previous research, BPD-A showed a decreased *resting HRV* in comparison to HC-A. This result was not influenced by general psychopathology which is surprising given the fact that lower resting state HRV was found in a variety of mental disorders (e.g. 63). For mothers, no group differences were found. Regarding *HRV-reactivity*, we found significant HRV-changes over time, suggesting that the measurement of HRV was sensitive to environmental or contextual changes. BPD-A and mothers of both groups showed a significant increase in HRV from *resting to positive interaction*, suggesting a state of relaxation and calmness during social interaction. For the BPD group, there is also an alternative explanation: BPD-A/BPD-M may not have experienced their interaction as positive due to their history of conflict-ridden exchanges often observed in adolescents with BPD and their parents (5). Therefore, the HRV-increase may reflect heightened self-regulatory efforts or/and the use of emotion suppression as an emotion regulation strategy, two mechanisms that were previously associated with BPD and HRV-augmentation (28, 64, 65). The HRV-increase was not significant for the HC-A, a finding that would be in line with evidence from prior studies based mostly on community samples suggesting that neutral or positive social interactions may not induce changes in phasic HRV (16). However, the HRV-increase observed in BPD-A and BPD-M/HC-M may also simply be a consequence of lower resting HRV at the beginning of the visit and indicate a process of recuperation during dyadic interaction. Despite of having spent about 30 minutes at the laboratory prior to the first resting assessment, mothers and BPD-A may have still been influenced by a feeling of nervousness, whereas HC-A may have been rather undeterred by the assessment context. Effects were independent of general adolescent psychopathology and therefore appear to be specific to BPD symptomatology.

HRV-reactivity to the stress task did not reach significance in our sample. One obvious explanation may be that the task simply was not stressful enough, however, subjective reports from mothers and adolescents of positive and negative affect suggest otherwise: both reported significantly more negative affect [mothers:  $t(72)=-5.731$ ,  $p < 0.001$ ; adolescents:  $t(72)=-6.706$ ,  $p < 0.001$ ] and less positive affect (mothers:  $t(72)=2.66$ ,  $p < 0.01$ ; adolescents:  $t(72)=3.15$ ,  $p < 0.01$ ) immediately after the stress task compared to their reports immediately following the positive interaction. We also could find differences in behavior between the positive interaction and the

stress task (48). The lack of reactivity may be explained by different mechanisms. Prior studies suggest that while a decrease in HRV in response to stress seems to be normative in low-risk children, children at risk for psychopathology or with mental disorders may suffer from a lack of autonomic flexibility (66) which could have effected stress responding in BPD-A. These findings are consistent with prior research that could not confirm the hypothesis of physiological hyperreactivity in individuals with BPD (23, 24). In HC-A, supportive presence of mothers and/or higher behavioral skills (48) may have potentially dampened HRV stress reactivity. However, we did find differences in stress reactivity based on general psychopathology scores. This suggests that stress reactivity may be influenced more by general emotional and behavioral problems than by BPD-specific symptoms. Future research should include individuals with other mental disorders to further investigate this aspect. Regarding the mothers of our sample, a lack of HRV-reactivity could be explained by the task design, as the stress task mainly targeted adolescents and mothers were only asked to support their youth. Although maternal self-reports and behavioral observations suggest that stress was perceived, this did not manifest as a physiological stress response. However, as there is first evidence of significant associations between maternal HRV, maternal interactional quality and child and adolescent outcomes (26, 27, 28), more research is needed to disentangle processes of HRV-reactivity and their consequences for maternal behavior and adolescent outcome. Lastly, our hypothesis of group differences in *HRV-recovery* was not confirmed, as both BPD-A/-M and HC-A/-M demonstrated a significant HRV-increase from stress to resting (Shahrestani et al., 2015b) (which could also have been influenced by the anticipated near end of the experimental paradigm).

### **Intrapersonal Concordance of HRV and behavior (RQ2)**

HC-A/HC-M displayed the expected positive association of rMSSD and behavioral quality during positive interaction (indicating a regulated, relaxed state of mind) and the negative association of rMSSD and behavior quality during stress (indicating engagement with stress, adaptive coping and efficient self-regulation). Although only the HC-M result during positive interaction became significant, these (trend) findings are in line with previous considerations (9, 10). Behavior-rMSSD concordances in BPD-A/M were not significant. However, plotting suggested that a) BPD-A showed the same pattern during positive interaction as during stress (which could indicate that

even the positive caregiver-adolescent interaction requires active self-regulation) and b) rMSSD and behavior of BPD-M seem to be completely independent from each other, which is an interesting result considering the role of an invalidating environment in the development of BPD (2). During early childhood, children turn towards their parents to understand the nature of a situation (e.g. if the situation is stressful or potentially harmful) and how to appropriately regulate their upcoming emotions in this particular situation. However, perceiving diverging physiological and behavioral information from caregivers, which serve as a source of co-regulation, can disrupt the child's ability to develop effective self-regulatory skills, potentially leading to difficulties in self-regulation later in life.

Our findings on the individual concordance between behavior and HRV should be interpreted with caution. While plots suggest certain trends, statistical analyses in our study confirmed only one of these assumptions. More research is needed to illuminate links between behavior and physiology during parent-child interaction especially in adolescent clinical samples.

#### **HRV- and behavioral synchrony between Adolescents and their Parents (RQ3/4)**

In line with our hypothesis, we found that mother-to-adolescent (MtA) and adolescent-to-mother (AtM) HRV-synchrony were significantly moderated by the interplay of clinical status or behavioral synchrony, respectively, and context. Overall, CG-dyads or dyads higher in behavioral synchrony were positively synchronized during rest and BPD-dyads or dyads lower in behavioral synchrony during the stress task.

Behavioral synchrony has been hypothesized to be a sign for healthy parent-adolescent interactions (32, 34, 44). Motsan et al. (41) suggested that during adolescence, tight autonomic coupling might have to be replaced by more “loosely” coordinated behavioral exchanges, reflecting the growing importance of developing autonomy in this phase. In a healthy, age-appropriate development, the adolescent might have already developed the ability to self-regulate and self-confidence in own abilities to solve potentially stressful situations resulting in greater independence from parental physiology. The fact that we also did not find HRV-synchrony during interactions in dyads higher in behavioral synchrony would support this interpretation: if dyads are able to rely on their behavioral abilities, no physiological co-regulation might be necessary. A closer look at our behavioral data during interactions (48)

indicates an increase in reciprocal behavior during stress in our healthy dyads, which would also point towards co-regulating on a behavioral rather than a physiological level. HRV-synchrony in CG-dyads while resting in separate rooms right after having completed the interactional tasks appeared to be dyad-specific and the effect vanished when adolescents were randomly assigned to unfamiliar mothers: similar socio-emotional post-processing of the collective prior experience may allow for HRV-synchrony to emerge (39).

As for the BPD-dyads, a history of tumultuous and chaotic interactions might have decreased trust into their respective partner's ability to co-regulate on a behavioral level. Mothers might have experienced frequent anger outbursts and unpredictability in their adolescents which might cause hypervigilance and/or withdrawal on a behavioral level. Adolescents, on the other hand, might not have developed the abilities to emotionally or behaviorally self-regulate (a common symptom in BPD), which could throw them into a state of hypervigilance, despair and inability to access cognitive processes that would be helpful in solving the stressful situation (which could e.g. also involve asking the parent for help). BPD-dyads therefore might "fall back" into a more basic co-regulating system, the physiological co-regulation. Again, our behavioral data supports this line of thought by indicating a decrease in dyadic reciprocity during stress in BPD-dyads (48). These considerations are also supported by the fact that we found the same HRV-synchrony pattern in dyads low or medium in behavioral synchrony.

Future research has to determine if positive HRV-synchrony in this context is adaptive (maybe physiological attunement did in fact calm the adolescent) or maladaptive (leading to a physiological stress escalation). This research question could be explored by, for example, investigating how physiological synchrony and subjective reports of stress are related to each other. Also, longitudinal data should focus on the interplay of physiological and behavioral synchrony, how it develops over time and how disruptions in the normal process could add to clinical symptoms. This is especially important in disorders like BPD, that was repeatedly described as an emotion regulation disorder at its core (and also as a disorder of failed co-regulation; 6), as it might open potential windows for early interventions, preventing the development of emotion regulation disorders (e.g., by focusing on dyadic behavior in parent-child dyads).

## **Limitations**

While our study has several strengths such as the implementation of a case-control design, observed behavioral and physiological measures and a unique sample of adolescents with BPD traits and their mothers, there are some limitations to discuss (see also 48). First and as mentioned above, although subjective reports suggested that our stress task did induce negative emotions and stress, these may not have sufficed to trigger responses of the autonomous nervous system. Also, averaging rMSSD-values over one-minute segments and using a global behavior coding system may have masked more fine-grained patterns of behavior-physiology- or physiology-physiology-associations. It will be interesting to see whether present results can be replicated in datasets including micro-coded behavior and second-by-second HRV. Despite all its advantages, concurrent state-trait MLM does not allow for examination of mother-to-adolescent or adolescent-to-mother directionality. Furthermore, other operationalizations of synchrony, i.e. the definition of linkage between mother and adolescent HRV, can lead to different results. Since parent-adolescent interactional quality is often reduced in clinical dyads, larger and more diverse samples are needed to inform on these effects. Lastly, we did not assess maternal BPD symptomatology and therefore cannot exclude potential influences on maternal behavior and/or physiology.

## **Conclusions**

Our study is the first to suggest alterations in HRV-reactivity, behavior-HRV concordance and HRV-synchrony in adolescents with BPD traits and their mothers. While we were able to confirm some prior research findings (e.g., lower resting HRV in adolescents with BPD, no HRV change in HC-A from resting to positive interaction, dampened HRV response to stress in BPD-A), many questions remain and more data is needed to replicate current results. As our study cannot definitively determine whether the results are specific to BPD or applicable to various psychiatric disorders (or transdiagnostic symptoms like emotion dysregulation), future studies should include multiple diagnostic groups alongside a healthy control group. Future research should investigate HRV reactivity to stress with established stress tasks (for example the Trier Social Stress Test, TSST; 67) to ensure validity of results and eliminate concerns about whether stress was effectively induced. Especially our findings regarding the individual concordance of behavior and HRV warrant further exploration,

as most of our results did not reach statistical significance. Such studies could provide valuable insights into the development of emotion regulation difficulties during childhood and adolescence.

Moreover, our findings of physiological synchrony during stress - in BPD dyads and dyads with low behavioral synchrony, but not in healthy dyads and dyads with high behavioral synchrony - highlight the importance of exploring biobehavioral synchrony as a theoretical framework to advance our understanding of caregiver-child co-regulation processes in the context of a healthy versus pathological developmental pathways.

In order to establish whether the observed associations and their adaptiveness constitute a mechanism of BPD symptom development, further research should also investigate if and how existing BPD specific treatment options influence behavioral and physiological parent-adolescent synchrony. Of specific interest could be therapies focusing on the enhancement of interactional and emotion regulation skills (e.g., Dialectic Behavioral Therapy for Adolescents, DBT-A; 68). Furthermore, the current study aligns with existing guidelines (such as those of the German Association of the Scientific Medical Societies AWMF in Germany, 69; or the National Institute for Health and Care Excellence NICE in the UK, 70), as well as treatments like DBT-A (68) that address adolescent BPD pathology not in isolation but as part of a broader social system, recognizing the importance of daily dyadic interactions in which adolescents engage. In the long run, a thorough understanding of individual and dyadic biobehavioral regulation in the context of parent-adolescent interactions may support clinicians in working with BPD-adolescents and could help to conceptualize effective treatment approaches which specifically target interpersonal regulation.

**List of abbreviations:**

BPD = Borderline personality disorder

ER = Emotion regulation

HRV = Heart rate variability

BPD-A = Clinical group of adolescents

BPD\_M = Clinical group of mothers

HC-A = Healthy control group of adolescents

HC-M = Healthy control group of mothers

PTSD = Post traumatic stress disorder

RQ = Research question

SD = Standard deviation

SCID-5-PD = Structured clinical interview for DSM-5-Personality Disorders

CIB = Coding interactive behavior

rMSSD = Root mean square of successive RR interval differences

BMI = Body mass index

MLM = Multilevel modeling

WD = Within-dyad

MtA = Mother to adolescent

AtM = Adolescent to mother

## **Declarations**

### **Ethics approval and consent to participate**

The study was approved by the Institutional Review Board of the Medical Faculty, Heidelberg University. It was performed in accordance with the ethical standards of the Declaration of Helsinki and its later amendments. Written informed consent was obtained from all individual participants included in the study.

### **Consent for publication**

The publication does not include identifiable data.

### **Availability of data and materials**

The dataset used during the current study is available from the corresponding author on reasonable request.

### **Competing interests**

Not applicable.

### **Funding**

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financial interests to disclose.

### **Author contributions**

Anna Fuchs and Michael Kaess contributed to study conception, design, funding acquisition and allocation of resources. Material preparation, data collection and analyses were performed by Katharina Williams, Jana Kuehn, Anna Fuchs and Leonie Fleck. Formal analysis and investigation were conducted by Anna Fuchs and Katharina Williams and supported by Stefan Lerch and Julian Koenig. The first draft of the manuscript was written by Katharina Williams supported by Anna Fuchs, the manuscript was critically revised by Jana Kuehn, Anna Fuchs, Leonie Fleck, Stefan Lerch, Marialuisa Cavelti, Julian Koenig and Michael Kaess. All authors read and approved the final manuscript.

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## **Supplement Material**

### **Sensitivity analysis RQ1**

This study had a given sample size, including 35 control dyads and 38 clinical dyads. As we do not find a stress response in HC-A, we did a sensitivity analysis with a bootstrapped control sample. In order to calculate the smallest response the study was powered to find, we artificially tuned the stress response in RQ1 for adolescents, i.e. the two-way interaction Group x Context, by adding an outcome contribution for HC-A in the stress context. The effect sizes were thus not standardized but are reported in units of the outcome (logarithmized rMSSD). They are tuned in the direction of the observed effect.

We used 1000 bootstrapped samples to approximate the power for each effect size. An additional contribution to the log-transformed adolescents HRV was subtracted in each sample in the stress context for controls. Afterwards, the model was recalculated. Power corresponds to the proportion of significant stress responses (contrast between stress context and resting 2) within the 1000 analyses.

For a power of 0.8 at a significance level of  $\alpha=.05$ , analyses revealed an effect size of about 0.125 for the stress response in HC (Figure S1). This suggests that the stress response needs to be about the same size of the observed response to the positive interaction in the clinical group to be resolved with enough power. Since some observed responses in our sample meet the minimal resolvable effect size but measure a 3.2 times smaller effect, we do not attribute the absence of a stress response to a sample size issue.

### **Sensitivity analysis RQ3**

This study had a given sample size, including 35 control dyads and 38 clinical dyads. As we do not find synchrony in the positive interaction task for controls, we did a sensitivity analysis with a bootstrapped control sample. In order to calculate the smallest response the study was powered to find, we artificially tuned the synchrony in RQ 3 in the MtA model, i.e. the three-way interaction group x context x mothers state rMSSD, by adding an outcome contribution for the controls in the positive interaction context proportional to mothers state rMSSD. The effect sizes were thus not standardized but are reported in units of one. They are tuned in the direction of the observed effect.

We used 1000 bootstrapped samples to approximate the power for each effect size. An additional contribution to the log-transformed adolescents HRV was added in each sample in the stress context for controls. Afterwards, the model was recalculated. Power corresponds to the proportion of significant synchrony coefficients (dependency on mothers' state rMSSD for controls in the positive interaction) within the 1000 analyses.

For a power of 0.8 at a significance level of  $\alpha=.05$ , analyses revealed an effect size of about 0.275 (Figure S2). This suggests that the synchrony needs to be about 1.5 times the synchrony observed during stress task in the clinical group to be resolved with enough power. As we do see synchrony effects of the same order as the minimal resolvable effect size, but measure a 5.8 times smaller effect, we don't consider the missing synchrony during the positive interaction a sample size problem.

## Supplement Tables

**Table S1**

*Observed behavior during interaction, clinical status and context predicting individual HRV*

<i>Predictors</i>	<b>Adolescent RMSSD</b>			<b>Mother RMSSD</b>		
	<i>Estimates</i>	<i>Conf. Int. (95%)</i>	<i>P-Value</i>	<i>Estimates</i>	<i>Conf. Int. (95%)</i>	<i>P-Value</i>
Intercept	3.923	3.450 – 4.396	<b>&lt;0.001</b>	3.298	3.066 – 3.529	<b>&lt;0.001</b>
Time of day	-0.028	-0.071 – 0.014	0.187	-0.030	-0.069 – 0.010	0.137
Context3	-0.022	-0.160 – 0.116	0.755	-0.090	-0.240 – 0.060	0.240
Context4	-0.166	-0.301 – -0.032	<b>0.015</b>	-0.004	-0.177 – 0.169	0.962
Context5	-0.017	-0.1734– 0.140	0.833	0.096	-0.111 – 0.301	0.357
Group (BPD/HC)	-0.165	-0.838 – 0.507	0.623	-0.211	-0.620 – 0.199	0.309
Behavior	-0.136	-0.303 – 0.030	0.106	-0.002	-0.072 – 0.067	0.944
Age	-0.060	-0.152 – 0.031	0.193	-0.011	-0.027 – 0.006	0.190
Medication yes/no	0.070	-0.266 – 0.407	0.677	0.002	0.243 – 0.246	0.988

Physical activity	0.000	-0.000 – 0.000	0.444	-0.000	-0.000 – 0.000	0.167
BMI	-0.004	-0.035 – 0.026	0.779	-0.001	-0.021 – 0.020	0.940
Smoking yes/no	-0.103	-0.362 – 0.156	0.429	-0.116	-0.330 – 0.098	0.284
Sex	0.038	-0.215 – 0.291	0.766	-	-	-
Context3:HC	0.342	0.028 – 0.657	<b>0.033</b>	0.004	-0.331 – 0.340	0.980
Context4:HC	0.432	0.030 – 0.835	<b>0.035</b>	0.489	0.161 – 0.818	<b>0.004</b>
Context5:HC	0.500	0.015 – 0.984	<b>0.043</b>	0.084	-0.322 – 0.489	0.685
Context3:Behavior	-0.004	-0.069 – 0.062	0.916	0.036	-0.035 – 0.108	0.315
Context4:Behavior	0.048	-0.018 – 0.114	0.154	0.001	-0.083 – 0.085	0.979
Context5:Behavior	0.059	-0.018 – 0.136	0.134	0.002	-0.099– 0.103	0.962
HC:Behavior	0.193	-0.082– 0.468	0.165	0.135	-0.013 – 0.283	0.073
Context3:HC:Behavior	-0.135	-0.271 – 0.001	0.052	-0.025	-0.169 – 0.120	0.740
Context4:HC:Behavior	-0.192	-0.366 – -0.017	<b>0.031</b>	-0.230	-0.378 – -0.081	<b>0.002</b>
Context5:HC:Behavior	-0.225	-0.436– -0.0124	<b>0.037</b>	-0.057	-0.241 – 0.127	0.542

**Random Effects**

Intercept Variance	0.84 <sub>id</sub>	0.22 <sub>id</sub>
Behavior Variance	0.14 <sub>id/behavior</sub>	0.00 <sub>id/behavior</sub>
ICC	0.77	0.72
N	69 <sub>id</sub>	68 <sub>id</sub>
<hr/>		
Observations	1944	1899
Marginal / Conditional R <sup>2</sup>	0.145 / 0.805	0.094 / 0.750

*Note.* Reference category: Context2=Positive Interaction, Context3 =Resting 2, Context4=Stress Task, Context5=Resting 3. Behavior=Total CIB score: Maternal positive behavior predicting maternal vmHRV, Adolescent positive behavior predicting adolescent vmHRV. BPD = clinical group; HC = healthy controls.

**Table S2***Behavioral synchrony and measurement context shape vmHRV synchrony*

<i>Predictors</i>	<b>Mother RMSSD -&gt; Adolescent RMSSD</b>			<b>Adolescent RMSSD -&gt; Mother RMSSD</b>		
	<i>Estimates</i>	<i>Conf. Int. (95%)</i>	<i>P-Value</i>	<i>Estimates</i>	<i>Conf. Int. (95%)</i>	<i>P-Value</i>
Intercept	3.739	3.481 – 3.997	<b>&lt;0.001</b>	3.304	3.130 – 3.477	<b>&lt;0.001</b>
Average rMSSD	0.094	-0.137 – 0.325	0.419	0.263	-0.000 – 0.526	0.050
Group(BPD/HC)	0.187	-0.023 – 0.397	0.080	0.001	-0.204 – 0.205	0.994
State rMSSD	0.063	-0.152 – 0.278	0.566	0.089	-0.071 – 0.249	0.274
Context3	-0.031	-0.091 – 0.028	0.298	0.035	-0.021 – 0.092	0.220
Context4	-0.071	-0.116 – -0.025	<b>0.003</b>	0.021	-0.022 – 0.064	0.347
Context5	0.104	0.047 – 0.161	<b>&lt;0.001</b>	0.130	0.075 – 0.185	<b>&lt;0.001</b>
Dyadic CIB	-0.045	-0.087 – -0.002	<b>0.038</b>	0.031	-0.009 – 0.071	0.127
Time of day	-0.022	-0.060 – 0.016	0.258	-0.020	-0.060 – 0.019	0.306
Age	-0.060	-0.144 – 0.025	0.163	-0.015	-0.033 – 0.002	0.091
Sex	0.044	-0.179 – 0.266	0.696			

Medication yes/no	0.033	-0.255 – 0.320	0.822	0.016	-0.233 – 0.265	0.900
Physical activity	0.000	-0.000 – 0.000	0.914	-0.000	-0.000 – 0.000	0.518
BMI	-0.007	-0.034 – 0.021	0.631	-0.004	-0.025 – 0.016	0.667
Smoking yes/no	-0.155	-0.389 – 0.080	0.192	-0.166	-0.392 – 0.060	0.147
State:Context3	-0.199	-0.481 – 0.083	0.167	-0.212	-0.460 – 0.035	0.093
State:Context4	0.103	-0.124 – 0.329	0.373	0.059	-0.121 – 0.239	0.519
State:Context5	0.050	-0.208 – 0.308	0.703	0.069	-0.150 – 0.287	0.537
State rMSSD:Dyadic CIB	-0.007	-0.165 – 0.151	0.933	-0.017	-0.138 – 0.104	0.781
Context3:Dyadic CIB	0.023	-0.024 – 0.069	0.337	-0.048	-0.092 – -0.004	<b>0.033</b>
Context4:Dyadic CIB	0.005	-0.032 – 0.041	0.797	-0.025	-0.059 – 0.008	0.137
Context5:Dyadic CIB	-0.007	-0.051 – 0.036	0.743	-0.052	-0.093 – -0.010	<b>0.014</b>
State:Context3:Dyadic CIB	0.311	0.083 – 0.538	<b>0.007</b>	0.219	0.024 – 0.414	<b>0.028</b>
State:Context4:Dyadic CIB	-0.066	-0.239 – 0.107	0.454	-0.049	-0.184 – 0.086	0.477
State:Context5:Dyadic CIB	0.124	-0.064 – 0.312	0.195	0.180	0.014 – 0.346	<b>0.033</b>

**Random Effects**

Intercept Variance	0.11 <sub>id</sub>	0.13 <sub>id</sub>
State Variance	0.06 <sub>id/state</sub>	0.03 <sub>id/state</sub>
ICC	0.67	0.73
N	64 <sub>id</sub>	64 <sub>id</sub>
<hr/>		
Observations	1728	1728
Marginal R <sup>2</sup> / Conditional R <sup>2</sup>	0.217 / 0.739	0.127 / 0.760

*Note.* Reference category: Context1=Resting 1. Context2=Positive Interaction, Context3 =Resting 2, Context4=Stress Task, Context5=Resting 3. BPD = clinical group; HC = healthy controls.

**Table S3***Clinical status and context do not shape vmHRV-Synchrony in randomly assigned mother-adolescent dyads*

<i>Predictors</i>	<b>Mother RMSSD -&gt; Adolescent RMSSD</b>			<b>Adolescent RMSSD -&gt; Mother RMSSD</b>		
	<i>Estimates</i>	<i>Conf. Int. (95%)</i>	<i>P-Value</i>	<i>Estimates</i>	<i>Conf. Int. (95%)</i>	<i>P-Value</i>
Intercept	3.547	3.287 – 3.808	<b>&lt;0.001</b>	3.249	3.069 – 3.430	<b>&lt;0.001</b>
Time of day	-0.018	-0.055 – 0.019	0.343	-0.025	-0.069 – 0.018	0.251
Age	-0.052	-0.131 – 0.027	0.190	-0.010	-0.027 – 0.008	0.284
Medication yes/no	0.082	-0.209 – 0.372	0.577	-0.043	-0.311 – 0.225	0.750
Physical activity	0.000	-0.000 – 0.000	0.976	-0.000	-0.000 – 0.000	0.381
BMI	0.003	-0.024 – 0.031	0.811	0.000	-0.023 – 0.023	0.979
Smoking yes/no	-0.170	-0.408 – 0.068	0.157	-0.178	-0.412 – 0.057	0.136
Sex	0.085	-0.135 – 0.305	0.443			
Average rMSSD	0.149	-0.072 – 0.370	0.182	0.088	-0.186 – 0.361	0.525
State rMSSD	0.172	-0.021 – 0.366	0.081	0.112	-0.031 – 0.256	0.123
Group(BPD/HC)	0.325	0.110 – 0.539	<b>0.004</b>	0.051	-0.175 – 0.278	0.652

Context2	0.101	0.048 – 0.154	<b>&lt;0.001</b>	0.112	0.064 – 0.161	<b>&lt;0.001</b>
Context3	0.089	0.029 – 0.148	<b>0.004</b>	0.090	0.036 – 0.144	<b>0.001</b>
Context4	0.061	0.008 – 0.114	<b>0.024</b>	0.111	0.063 – 0.160	<b>&lt;0.001</b>
Context5	0.260	0.196 – 0.323	<b>&lt;0.001</b>	0.237	0.177 – 0.297	<b>&lt;0.001</b>
State:CG	0.006	-0.255 – 0.266	0.965	0.079	-0.167 – 0.326	0.528
State:Context2	-0.200	-0.429 – 0.029	0.087	-0.145	-0.319 – 0.029	0.102
State:Context3	-0.192	-0.452 – 0.067	0.146	-0.109	-0.303 – 0.084	0.267
State:Context4	-0.152	-0.377 – 0.073	0.184	-0.081	-0.250 – 0.088	0.347
State:Context5	-0.220	-0.452 – 0.012	0.063	-0.163	-0.365 – 0.038	0.112
HC:Context2	-0.102	-0.180 – -0.024	<b>0.010</b>	-0.055	-0.126 – 0.017	0.133
HC:Context3	-0.106	-0.194 – -0.017	<b>0.019</b>	-0.031	-0.110 – 0.049	0.449
HC:Context4	-0.115	-0.193 – -0.036	<b>0.004</b>	-0.038	-0.110 – 0.034	0.302
HC:Context5	-0.092	-0.186 – 0.001	0.052	-0.021	-0.111 – 0.068	0.638
State:HC:Context2	0.034	-0.286 – 0.354	0.834	-0.079	-0.371 – 0.213	0.597

State:HC:Context3	-0.055	-0.426 – 0.317	0.773	-0.153	-0.467 – 0.160	0.337
State:HC:Context4	-0.040	-0.361 – 0.281	0.808	-0.117	-0.416 – 0.181	0.441
State:HC:Context5	-0.185	-0.531 – 0.160	0.292	-0.282	-0.622 – 0.058	0.104

### Random Effects

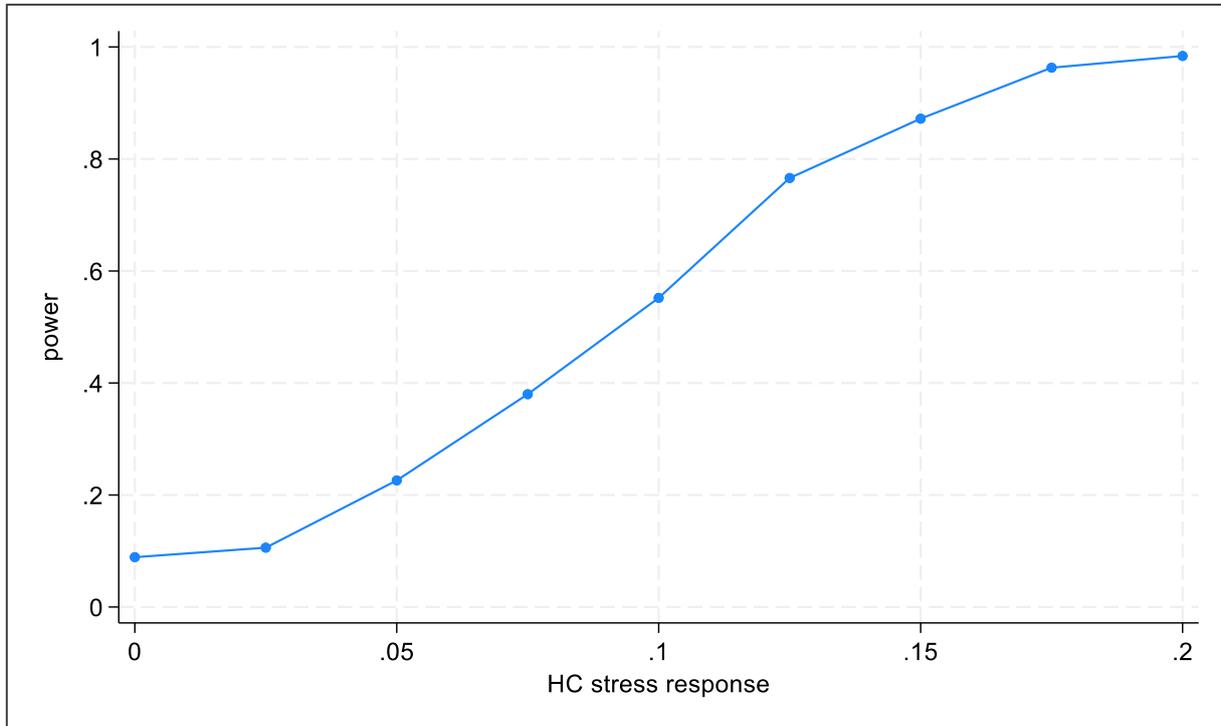
Intercept Variance	0.11	shuffle_id	0.14	shuffle_id
State Variance	0.03	shuffle_id/state	0.03	shuffle_id/state
ICC	0.63		0.72	
N	64	shuffle_id	64	shuffle_id
Observations	2050		2050	
Marginal R <sup>2</sup> /Conditional R <sup>2</sup>	0.225 / 0.713		0.107 / 0.752	

*Note.* Reference category: Context1=Resting 1. Context2=Positive Interaction, Context3 =Resting 2, Context4=Stress Task, Context5=Resting 3. BPD = clinical group; HC = healthy controls.

## Supplement Figures

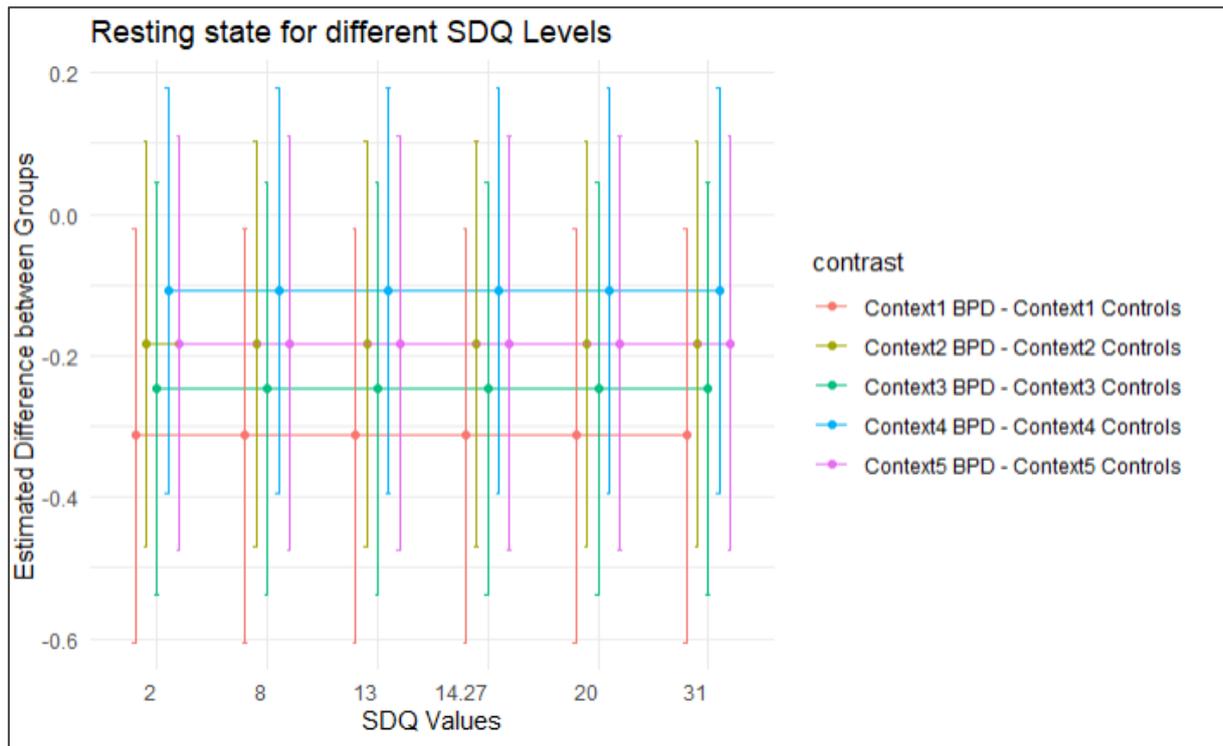
**Figure S1**

Sensitivity Analysis for RQ1



**Note.** Effect sizes of the two-way interaction Context\*Group were changed by artificially adding a contribution to the stress task for healthy control (HC). Power was calculated via bootstrapping.

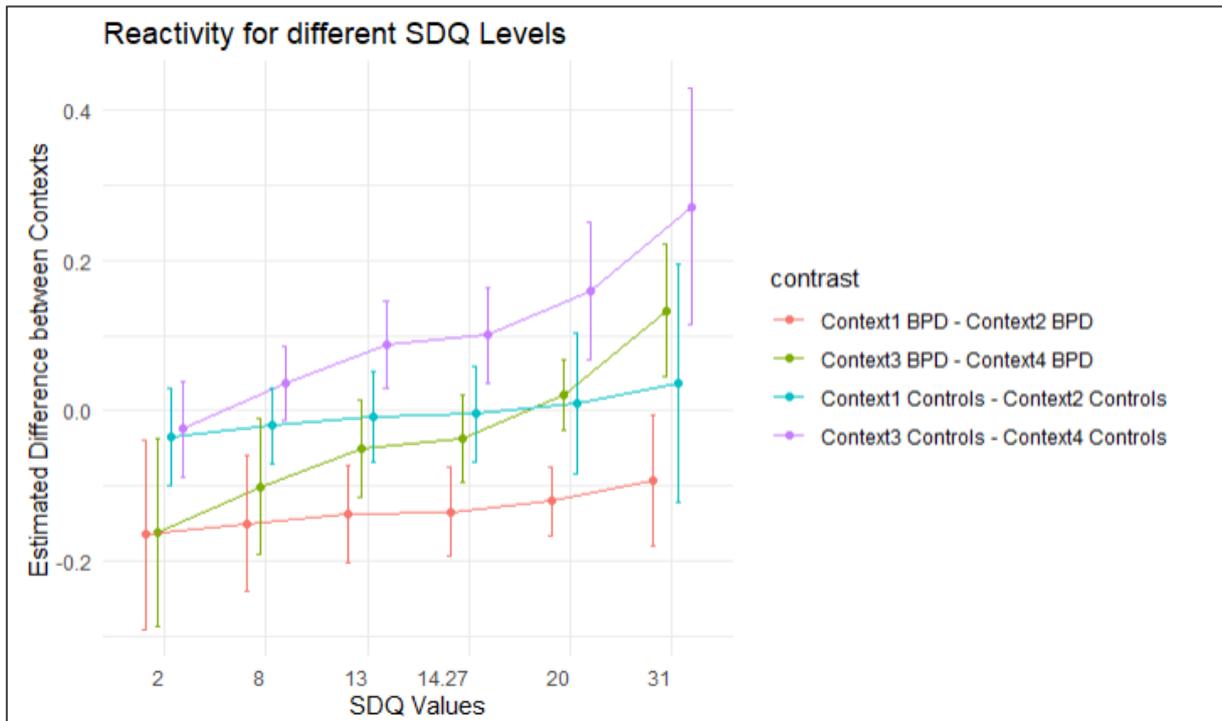
**Figure S2** Adolescent resting state HRV for different levels of general psychopathology (assessed with the Strength and Difficulties Questionnaire, SDQ).



**Note.** Context 1 = Resting 1, Context 2 = Positive interaction, Context 3 = Resting 2, Context 4 = Stress task, Context 5 = Resting 3. SDQ values correspond to Min, Max, Quartiles, and Mean = 14.27. Results for resting state HRV remain robust for adolescents.

### Figure S3

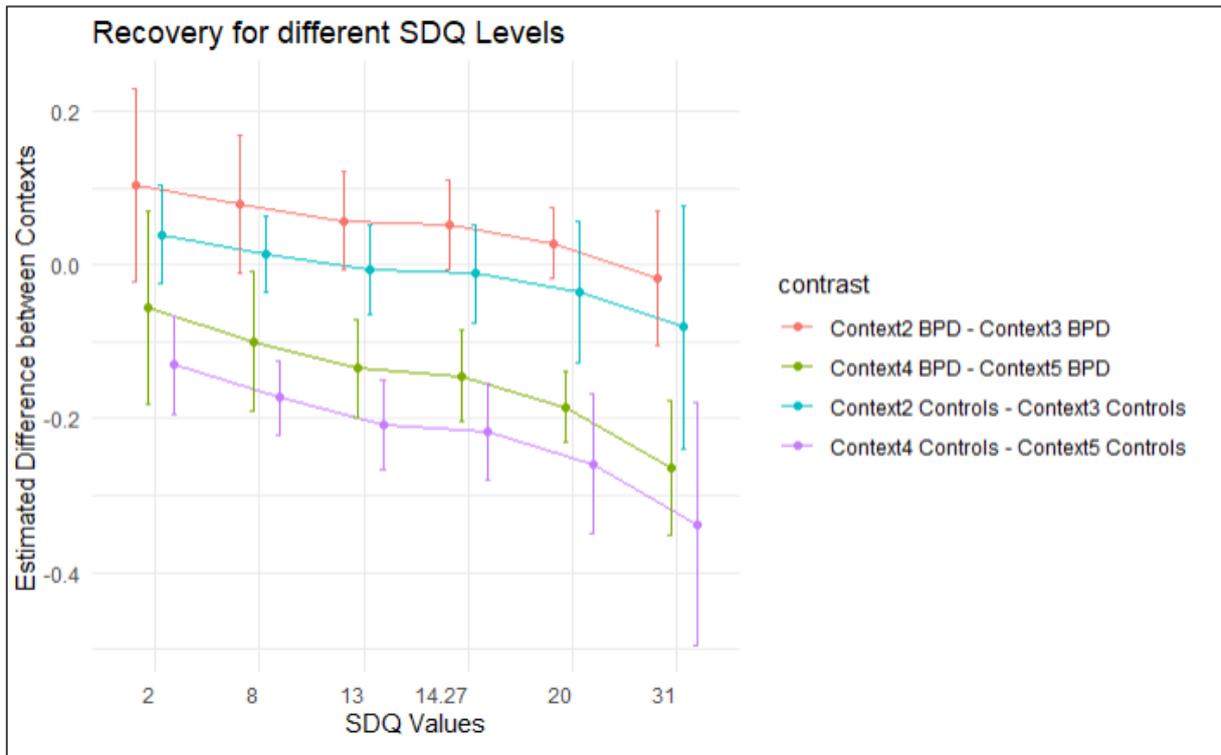
Adolescent HRV reactivity for different levels of general psychopathology (assessed with the Strength and Difficulties Questionnaire, SDQ).



**Note.** Context 1 = Resting 1, Context 2 = Positive interaction, Context 3 = Resting 2, Context 4 = Stress task, Context 5 = Resting 3. SDQ values correspond to Min, Max, Quartiles, and Mean = 14.27. Results for HRV reactivity remain robust for the difference between Resting 1 to positive interaction. Results for HRV reactivity change for the difference between Resting 2 and the stress task: in both groups, higher SDQ values were associated with higher HRV differences between contexts.

### Figure S4

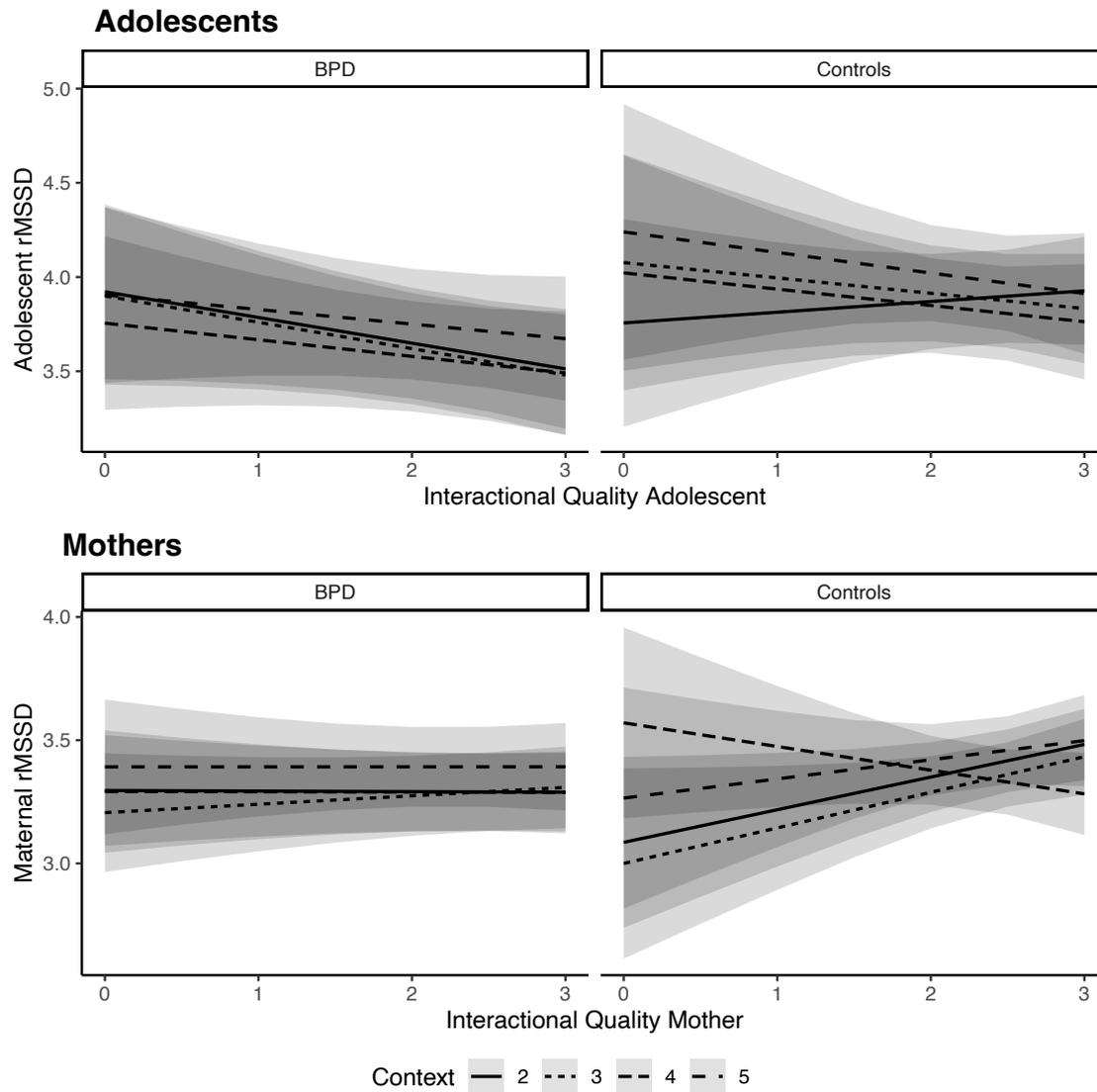
Adolescent HRV recovery for different levels of general psychopathology (assessed with the Strength and Difficulties Questionnaire, SDQ).



**Note.** Context 1 = Resting 1, Context 2 = Positive interaction, Context 3 = Resting 2, Context 4 = Stress task, Context 5 = Resting 3. SDQ values correspond to Min, Max, Quartiles, and Mean = 14.27. Results for HRV recovery remain robust for adolescents.

**Figure S5**

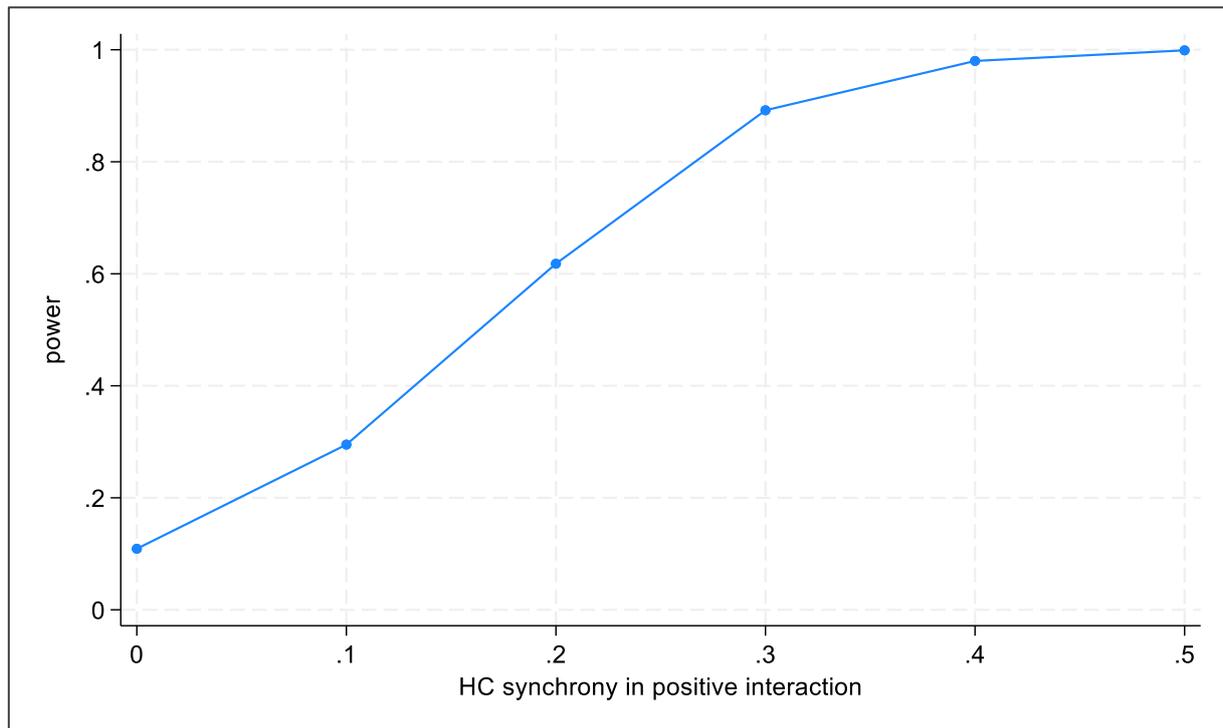
*Intrapersonal concordance of HRV and behavior.*



*Note.* Context 3, 5=Resting: Context 2=Positive interaction, Context 4=Stress task. The adolescent model was not significant; in the maternal model a significant positive HRV-behavior association during the positive interaction was found.

## Figure S6

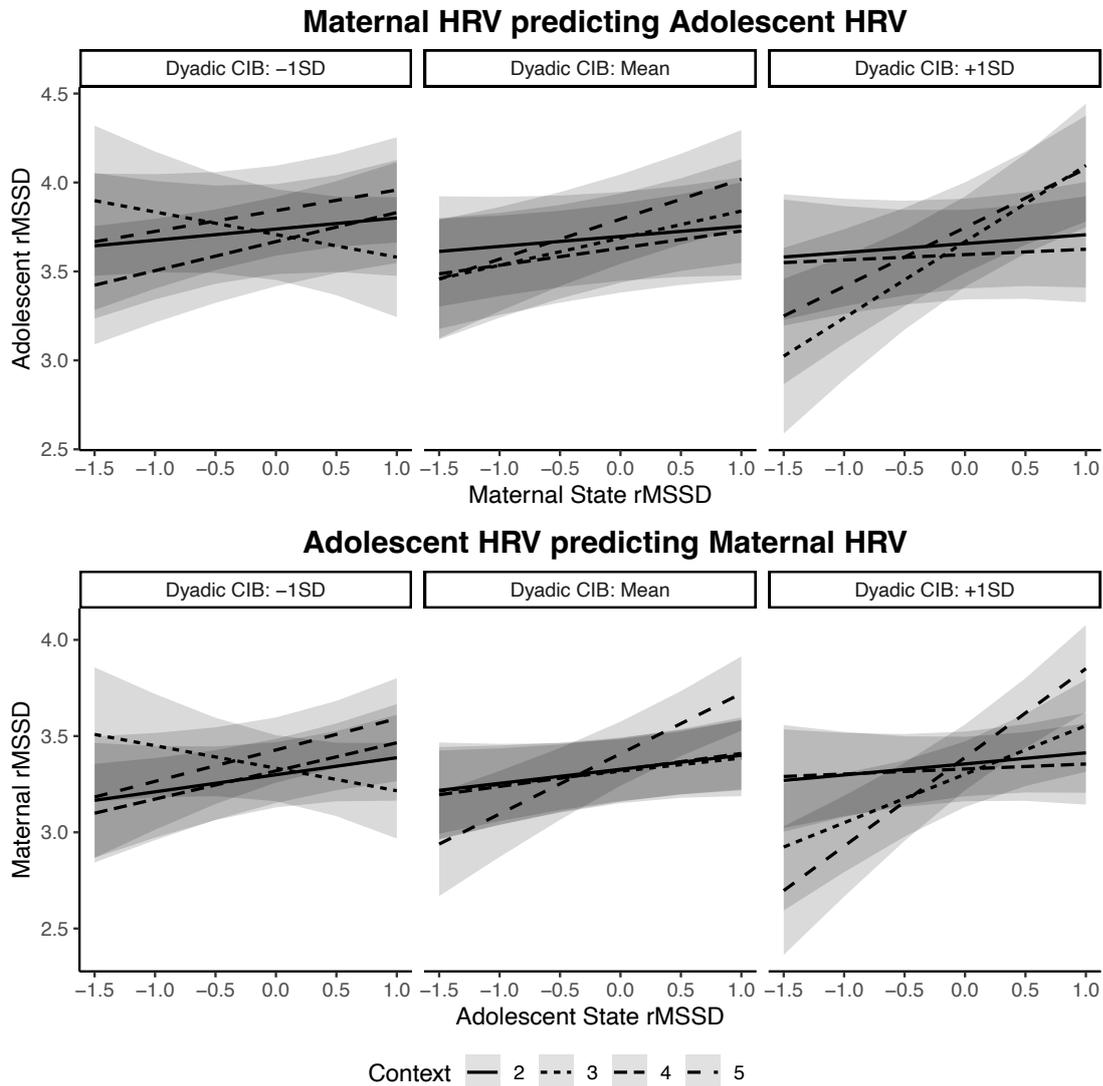
### Sensitivity Analysis for RQ3



**Notes.** Effect sizes of the three-way interaction Context\*Group\*state rMSSD were changed by artificially adding a dependency on state rMSSD to the positive interactionstress task for healthy control (HC). Power was calculated via bootstrapping.

**Figure S7**

*Dyadic CIB and context shape vmHRV synchrony.*



*Note.* Context 3, 5=Resting: Context 2=Positive interaction, Context 4=Stress task. When behavioral synchrony is lower, significant positive vmHRV-Synchrony during stress task in both models. When behavioral synchrony is average, significant state vmHRV associations during resting after stress (Context 5) in both models. When behavioral synchrony is higher, significant vmHRV-Synchrony during resting after stress and after positive interaction in both models (Context 3).

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## **Manuscript 4. Parental Mental Illness, Borderline Personality Disorder, and Parenting Behavior: The Moderating Role of Social Support**

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## **Abstract**

**Purpose of review:** Parental mental disorders, particularly borderline personality disorder (BPD), impair parenting behavior. Consequently, the children exhibit an elevated risk for psychopathology across their lifespan. Social support for parents is thought to moderate the relationship between parental mental illness and parenting behavior. It may dampen negative effects and serve as starting point for preventive interventions. This paper provides a literature overview regarding the impact of social support on the sequelae of parental mental illness and BPD for parenting behavior.

**Recent findings:** Current literature highlights the increased burden of families with a mentally ill parent and associated changes in parenting behavior like increased hostility and affective dysregulation, especially in the context of parental BPD. Literature further demonstrates the powerful impact of social support in buffering such negative outcomes. The effect of social support seems to be moderated itself by further factors like socioeconomic status, gender or characteristics of the social network.

**Summary:** Social support facilitates positive parenting in mentally ill parents and may be particularly important in parents with BPD. However, social support is embedded within a framework of influencing factors, which need consideration when interpreting scientific results.

## 1. Introduction

The quality of parenting behavior is frequently reported as the most influential environmental factor with regard to a child's development [1, 2]. According to the widely referenced and scientifically supported process model of parenting by Belsky [3], parental personality and developmental history, social network, marital relations, work, and child characteristics jointly impact on parenting behavior. Taraban and Shaw [4•] recently updated the model by adding gender, cognitions and affect, stress response, genetics, emotion regulation, family structure, and culture as further factors and clustering them into the three domains, namely parent characteristics, child characteristics, as well as family and social environment. Overall, the model considers parenting as a buffered system, in which a risk factor might be compensated for by another positive or supportive influencing factor (i.e. resilience factor) across domains. Therefore, e.g. a challenging temperament of the child does not necessarily lead to impaired parenting quality if it is counterbalanced e.g. by a supportive relationship between the parents [3, 4•]. On the other hand, a predominance of risk factors as well as the absence of sufficient resilience factors is thought to facilitate harsh, neglectful or even abusive parenting [3, 4•].

In line with the process model, a highly influential risk factor with respect to negative parenting behavior is parental psychopathology, particularly BPD [4•, 5-7]. They relate to almost every influencing factor proposed within the model: e.g. parental personality [7], parental developmental history [8], social relationships [9], work ability, and socioeconomic status [9], as well as cognition, affect, stress response, and emotion regulation [10]. More specifically, important cognitive, emotional or social prerequisites for positive parenting behavior such as attention, emotion regulation, or impulse control are often restricted in the presence of a personality disorder but also mental disorders in general [7, 11-13]. As a result, parents suffering from a mental disorder have been shown to exhibit greater difficulties in establishing authoritative parenting (the careful equilibrium of parental warmth and regulatory control; [14]). In contrast, parental psychopathology is thought to tip the balance towards permissive, rejecting-neglecting, or authoritarian parenting [14, 15]. Furthermore, our work group demonstrated in a previous study (UBICA-I) that mothers with a history of depression and severe early life maltreatment (ELM) show reduced maternal sensitivity, i.e. a less accurate and timed responsiveness to and perception of the child's signals [16], when

interacting with their child [17]. As maternal sensitivity appears to be especially diminished when mothers had experienced ELM and additionally suffered from a mental disorder in contrast to mothers who had experienced ELM but did not develop a mental disorder, parental psychopathology seems to be of special relevance when it comes to negatively altered parenting behavior [18]. With respect to personality disorders, maternal BPD has been associated with increased hostility towards the child, which further mediated the relationship between maternal BPD and behavioral problems in the child [19]. Additionally, parents with personality disorders like BPD report difficulties in establishing empathetic responsiveness towards the child, managing the child's behavior, and being a role model for emotional regulation [20, 21].

These negative effects of parental mental illness on parenting behavior have been demonstrated across a variety of parental diagnoses like depression [4•], bipolar disorder [22], anxiety disorders [23], substance-use disorders [24] personality disorders in general [7], and BPD in particular [25-27]. Regardless of the exact underlying psychopathology, a reduced ability to correctly infer the child's mental states such as emotions or psychological needs may additionally aggravate negative parenting behavior [6] and further heighten the risk for neglect, maltreatment, and abuse [28, 29].

For the child, the changes in parenting behavior might confer e.g. to an increase in externalizing and internalizing problems [30-32], the development of insecure or disorganized attachment [33], depressive mood [32, 34] or dysfunctional social behavior [35], which in turn promote the risk for child psychopathology (for reviews see [36, 37] and [38]). Changes in child functioning may in turn lead to parenting stress and altered parenting behavior due to transactional relations between child and parent variables [Evers et al., in press]. In BPD, the formation of a healthy parent-child relationship as well as offspring emotional development have been shown to be impaired [33]. This results in a heightened risk for the children to develop a BPD themselves [33].

Taken together, parental mental illness e.g. parental personality disorders such as BPD and the related changes in parenting behavior constitute an important factor in the intergenerational continuity of mental disorders besides genetic heritability of the individual diagnostic entities [36, 40]. Thirty-eight percent of physicians in German psychiatric hospitals report their patients to exhibit deficits in parenting behavior, and

roughly every second physician considers children's mental health at risk due to those deficits [41]. As approximately three million German children live in families with at least one mentally ill parent, there is a high number of parents who may require additional support in dealing with their parental role [42].

This review aims to give an overview of the current literature on the sequelae of parental mental illness, specifically parental BPD, for parenting behavior as well as the moderating role of social support regarding this influence.

Literature search has been conducted between May 2021 and December 2021 via PubMed and Google Scholar. The following search terms were entered separately or in conjunction (respective manuscript section in parentheses): parental mental illness (1,2,4), parental mental disorder (1,2,4), personality disorder (1,2), borderline personality disorder (1,2), affective disorders (1,2), parenting (1,2,3,4), parenting behavior (1,2,3,4), social support (2,3,4), pandemic (3), SARS-CoV-2 (3), COVID-19 (3), preventive intervention (4), parenting intervention (4), parenting program (4). Literature was subsequently selected according to the year of publication (2000-2021).

## **2. Social support as a moderator between parental mental illness, parental BPD and parenting behavior**

In line with the process model [3], the accumulated stress of coping with a mental disorder and caring for a child simultaneously may impede symptom amelioration and positive parenting behavior [43, 44]. In turn, factors reducing parental stress have been observed to decrease severity of parental psychopathology as well as to promote positive parenting behavior [45•]. Social support may serve as such a factor of resilience [4•].

Moak and Agrawal [46] broadly defined social support as a psychosocial resource accessible in the context of the individual's social network and interpersonal contacts. With respect to parenting, one may differentiate emotional, informational, and instrumental social support [47]. Emotional support mainly affects parenting behaviors indirectly via its effect on parental well-being, e.g. through the reduction of parental stress [45•, 48], the provision of a sense of social integration or the aid in emotion regulation. Instead, informational and instrumental support also directly impact on parenting behaviors, e.g. by promoting problem solving skills, providing advice or concrete aid in the accomplishment of everyday family requirements [49, 50]. Social

support may therefore reduce the risk for child maltreatment via a decrease in parental stress and symptom severity as well as an increase in positive parenting behavior [45, 51]. Furthermore, social support may reduce the negative effect of parental mental illness on child well-being [52] and promote service-use in at-risk caregivers [53]. The results of Álvarez et al. [45] further suggest a differential impact of social support obtained by professionals and institutions (formal support, [54]) and social support delivered by family members or friends (informal support): whereas informal support was more effective in changing child-rearing attitudes, formal support predicted a reduction in parental stress.

Research further highlights beneficial effects across different diagnoses, while the majority of studies focuses on parental depression: social support is associated with reduced parenting stress and lower levels of depression among parents [55, 56]. This effect has been demonstrated even before [57] as well as shortly after child birth [58], thus serving as a protective factor against postpartum depression and bonding-failure [57]. Social support also seems to attenuate negative effects of parental depression on confidence in own parenting skills [59]. Within a longitudinal study spanning three generations, Abraham et al. [60] found parental major depression to be a key factor accounting for the transmission of negative parenting behavior towards the next generation. This was mainly due to a parenting behavior characterized by reduced parental care to be transmitted to the children. However, individuals within the second generation did not carry on this behavior themselves if social support was present. Thus, social support aided in breaking the intergenerational cycle of negative parenting and parental depression.

Similar positive effects were described for patients with BPD, who often lack social support [21, 61]. Accordingly, social support has been demonstrated to moderate the influence of severity of several BPD symptoms like affective instability or identity problems on mothers' emotional availability and thus a key feature of positive parenting [62].

However, there are also studies questioning that social support can be consistently regarded as having positive effects on parenting. For example, in BPD, the beneficial effect of social support on parental emotional availability was shown to mitigate with increasing BPD severity in parents [62]. Taraban et al. [63] found the negative effect of maternal depression on parenting quality to be strongest in mothers reporting high levels of social support. Similarly, a recent study by Lee et al. [64]

reported young mothers suffering from depression to be less able to benefit from social support. The authors of these studies speculated their findings might be due to depressed mothers with high social support delegating their parental responsibilities more often to their social network, which may prevent them from learning to keep high parenting quality in case of depressed mood [63•]. Alternatively, social support might provoke feelings of inadequacy due to prevalent cognitive biases in depressed mothers [64]. The findings were further supported by Taraban et al. [65•], who found the association between maternal depression and overreactive parenting to be unaffected by own satisfaction with social support. In contrast, the higher the partner's satisfaction with social support was, the weaker the association between each parent's depressive symptoms and overreactive parenting behavior. This finding further highlights a potential inability to take advantage of social support if parental depression is present. In substance-use disorders, increased parental social support has even been associated with more frequent physical abuse of the children by their parents [66].

However, social support does not only moderate the influence of parental mental illness on parenting behavior, but its effect is moderated itself by further influencing factors: in a study by Ceballo and McLoyd [67], the positive effects of social support on parenting behavior were attenuated with decreasing socioeconomic status in the environment of the participating mothers. Furthermore, there seem to be gender differences: Leinonen et al. [68] reported single fathers to be unable to benefit from emotional support by friends or relatives with respect to parenting behavior when facing economic strain. In contrast, single mothers were able to benefit from various sources of social support.

These findings emphasize the high complexity of influences with respect to parenting and social support as proposed by the process model of Belsky [3]. Additionally, the findings shed light on the methodological problem of a lacking consistent conceptualization of social support within science [69]. This leads to findings that seem to be contradictory at first, but emerge from different aspects or types of social support that have been studied (e.g. formal vs. informal support; support by relatives vs. support by friends). Therefore, there is a high need for a precise and generally acknowledged concept of social support in future studies [69].

In summary, the majority of literature (for an overview see Table 1) points to substantial positive effects of social support on parenting behavior in the context of parental mental illness and across diagnostic categories. Unfortunately, we had to

realize that research on social support particularly for parents with BPD is scarce, although parenting is severely affected in parents with BPD. Overall, social support may directly promote changes in parenting behavior or facilitate positive parenting via its effect on parental abilities and symptom severity (see Figure 1). Therefore, it effectively hinders parental psychopathology from being forwarded to the child. However, the effects of social support may be moderated themselves by further (environmental) factors like socioeconomic status, characteristics of the social network, gender, or severity of symptomatology.

**Table 1**

*Overview of reported studies on social support as a moderator of parenting behavior*

<b>Study</b>	<b>Type(s) of social support</b>	<b>Sample characteristics</b>	<b>Sample Size</b>	<b>Results</b>
Abraham et al., 2021	Family & Partner	Outpatients with MDD or HCs + their children & grandchildren	N=498	Social support may break the continuity of negative MDD-associated parenting styles
Álvarez et al., 2021	Formal & informal	mainly at-risk families referred by municipal social services	N=256	Informal support is associated with changes in child-rearing attitudes; Formal support predicts reduction in parental stress.
Armstrong et al., 2005	N/A	N/A	N/A	Social support as resilience factor with respect to parenting quality
Barnett et al., 2015	Perceived social-emotional support	Low-income Mother-child dyads	N=59	parenting support is inversely related to parenting efficacy in mothers with stronger depressive symptoms

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Ceballo & McLoyd, 2002	Emotional & instrumental	Mother-child dyads from poor, high-crime environments	N=262	Positive effects of social support on parenting behavior are attenuated in poor, high-crime environments
Cox et al., 2008	Affective	Adolescent mothers	N=168	Depression is associated with decreased parenting confidence and decreased perceived social support
Crockenberg et al., 1988	N/A	N/A	N/A	Social support as buffer for stress and generator of active coping
Dunn et al., 2020	N/A	Parents with BPD Practitioners	N=12 N=21	High need for parenting-focused support in BPD patients
Freisthler et al., 2014	Social companionship	Telephone interviews on parenting and alcohol consumption in californian parents	N=3023	Social support may have negative effects: increased rates of physical abuse with increasing social companionship
Huang et al., 2014	Family/friends/significant other	African american or latino/hispanic adolescent mothers	N=180	Lack of social support associated with negative mental health status and negative impacts on child development
Kang, 2012	Affective & instrumental	Caregivers (incl. Grand and stepparents)	N=1000	Social support indirectly supports service use in at-risk caregivers

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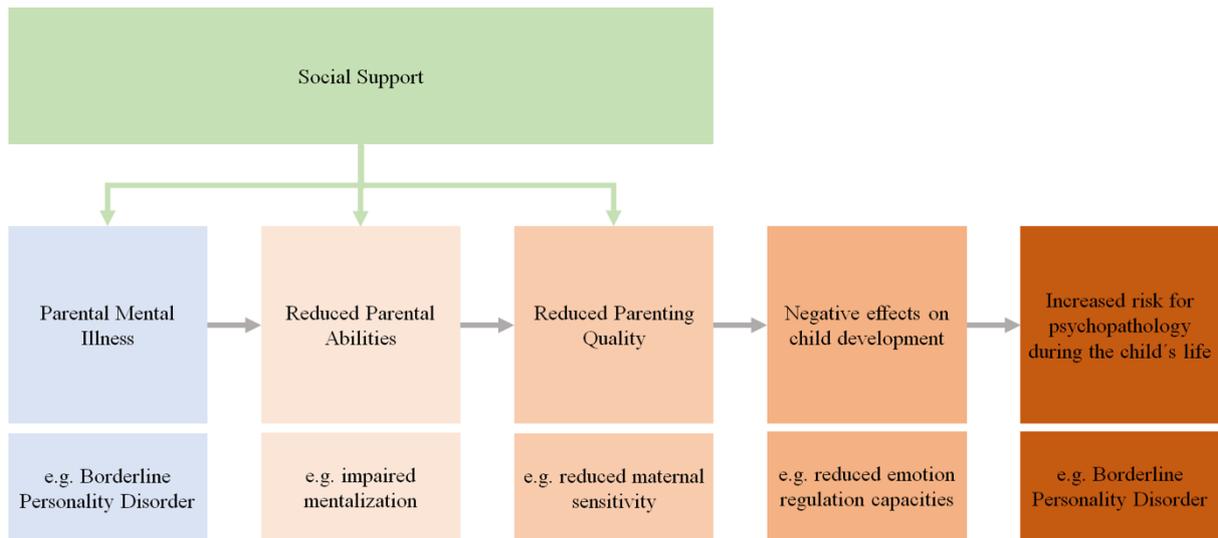
Leahy-Warren et al., 2012	Informational, instrumental, emotional, appraisal	First-time mothers shortly after childbirth	N=410	Social support by family and friends substantially reduces maternal postpartum depressive symptomatology
Lee et al., 2020	Parent figure, partner	Young, low-income african american mothers	N=192	Young mothers with depression have difficulties taking advantage of social support
Leinonen et al., 2003	Instrumental, emotional	Mothers/Fathers	N=1415	Mothers are able to benefit from various sources of social support, fathers only from instrumental support
Li et al., 2011	Confidant, affective, instrumental	Elementary school children	N=405	Social support reduces the risk for child maltreatment
Liu et al., 2020	Family/friends/significant other	Wuhan medical staff and average citizens	N=506	Depression and anxiety symptoms were inversely correlated with perceived social support during the pandemic
Maguire-Jack & Wang, 2016	Friends/neighbors	Families	N=1045	The higher neighborhood cohesion and social support, the lower parenting stress and levels of neglect
Milgrom et al., 2019	Attachment, social integration, opportunity for nurturance, reassurance of worth, reliable	Depressed women	N=54	Social support in late pregnancy as protective factor against postpartum depression

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	alliance, guidance relationships			
Nunes et al., 2021	Confidant, affective, instrumental	Parents	N=409	Parental affective support is predictive for child psychological adjustment
Ohara et al., 2017	Quantity of supportive persons + satisfaction with support	Mothers shortly after childbirth	N=494	Social support aids in preventing depression and bonding-failure
Taraban et al., 2017	Intimate relationships , friends, neighborhood /community	Mothers	N=1096	Association between maternal depressive symptomatology and reduced parenting quality was strongest in the context of high social support
Taraban et al., 2019	Intimate relationships , friends, neighborhood /community	Adoptive families	N=519	Social support satisfaction of the partner reduces the strength of association between each parent's depressive symptoms and overreactive parenting
Thomps on et al., 2015	Formal, informal	N/A	N/A	informal support was more effective in changing child- rearing attitudes, formal support predicted a reduction in parental stress
Trupe, 2013	Not specified	Mother-child dyads with and without maternal BPD	N=70	The beneficial effect of social support on emotional availability was shown to mitigate with increasing BPD severity

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**Figure 1.** Exemplary model on the moderating role of social support on parenting behavior in mentally ill parents. The model illustrates a hypothesized pathway for the intergenerational continuity of mental disorders and potential starting points for the effects of social support.

### 3. The SARS-CoV-2 pandemic and its influences on social support and parenting

Since SARS-CoV-2 has emerged in the end of 2019, the following pandemic and the related public health restrictions have fundamentally impacted on every individual's social networks. Especially regulations demanding social distancing have reduced possibilities for social support, thus withdrawing an important resource for families, especially those with at least one mentally ill parent. Studies point to long-lasting detrimental effects of the pandemic and related restrictions on mental health [72].

The loss of social support seems to be the crucial element in the exacerbated mental health burden of parents during the pandemic [73]. Correspondingly, there is already some evidence that the more social support was present, the less psychopathology increased during COVID-related lockdowns [74-76]. Social support may therefore constitute a starting point for interventions aiming at reducing the negative mental health impacts of the pandemic like a generally heightened level of psychological distress [76].

In line with the process model, this aggravation of parental symptomatology has facilitated negative parenting behaviors [77-79]. Accordingly, Sari et al. [80] reported heightened levels of harsh parenting during the pandemic and several studies have shown child mental health to decrease due in part to negatively altered parenting behaviors [81-84]. During COVID-19, parental depression has been determined to be a risk factor of negative parenting behaviors [85] which further aggravates in parents with a history of childhood maltreatment and a lack of compensatory resources such as social support [86].

As a result, Perks and Cluver [87] call for a “parenting vaccine” encompassing professional and scientifically evaluated parenting programs to buffer the negative effects of the pandemic on parental mental health, parenting behavior and child wellbeing. Such programs might not only be beneficial for the individual who is participating, but may further aid in preventing negative and long-lasting socioeconomic and societal effects. The positive effects of parenting programs are further highlighted when considering the social support they implicate: if the interventions comprise formal support e.g. via the teaching of parenting skills as well as informal support e.g. by peer-to-peer exchange, their effects might be strengthened.

#### **4. Preventive interventions targeting parenting behavior**

Parenting interventions enable the dissemination of positive parenting skills and thus allow for a direct impact on parenting behaviors of mentally ill parents [88••]. Besides, they may constitute an important source of social support for mentally ill parents. On the one hand, such interventions may provide formal social support via their association to specialized institutions and health care professionals. On the other hand, group programs may enable the exchange of experiences among parents and thus provide a valuable source of informal social support (see e.g. [89]).

While the sole treatment of parental psychopathology has been shown to improve parenting behavior and child mental health, those interventions have only reached medium effect sizes (see e.g. [90]). Directly targeting parenting behavior may be more effective due to its role as a mediator between parental and child mental health. Accordingly, numerous parenting programs aiming at improving parenting behavior have been developed in order to break the intergenerational continuity of mental disorders. Meta-analyses on such parenting programs have shown these

interventions to effectively improve parenting behavior and child outcomes (see e.g. [91-93]). Moreover, parenting programs also seem to prevent child maltreatment [94].

Recently, a meta-analysis by Everett et al. [88••] again highlighted that interventions targeting parenting behavior of mentally ill parents are successful in promoting positive parenting, but are especially effective in reducing child psychopathology. Furthermore, an improvement of parenting behavior diminished severity of parental psychopathology. The latter is thought to result from an improvement of parent-child interactions which account for reduced parental stress and thus facilitate symptom amelioration. The authors concluded that prevention programs not only need to address parenting behavior but also parental as well as child symptomatology to reach maximum efficacy [88••]. However, the exact pathways leading to the observed outcomes often remain unclear [95] and there is evidence that the efficacy of the programs varies significantly [96].

This variation might depend on the exact content of the parenting interventions: with respect to specific interventions, parental mentalization capabilities have been proposed to be a relevant prerequisite for positive parent-child interactions and positive parenting behavior [97]. Mentalization is defined as the ability to infer mental states within oneself and others [98]. Further, maternal sensitivity has been demonstrated to be a promising starting point for parenting interventions [99].

Irrespective of the exact content of the intervention Marston et al. [100] found psychoeducation, peer-to-peer exchange of own experiences (an important source of informal social support), and skills for positive interactions within the family to be the three crucial elements of parenting interventions. Within this context, social support and peer-to-peer exchange may be also provided via online interventions [89], which gains special relevance during the pandemic. Furthermore, the use of video feedback may facilitate the observation of the child's as well as one's own behavior and thus provides a vital element to enhance preventive parenting programs [101]. Even though most preventive programs comprise psychoeducation elements, only few additionally provide opportunities for peer-to-peer exchange, specific interventions targeting parent-child interactions, and the use of video feedback.

A program that combines the three elements recommended by Marston et al. [100], incorporates video feedback and thereby focuses on parental mentalization capabilities is the lighthouse parenting program [28] which is currently conducted and investigated in a study of our work group that aims to understand and break the

intergenerational cycle of abuse (UBICA) in mentally ill parents [102]. The group program specifically focuses on social support via peer-to-peer exchange (informal social support) and further incorporates social counselling (formal social support). We test for superiority of this prevention program against pure psychoeducation and aim to identify potential mechanisms of change mediating the effects of the mentalization-based intervention on parenting behavior (for details see [102]).

## **5. Conclusion**

Parental mental illness and parental BPD influence parenting behavior in many ways with serious consequences for the offspring. The association between parental mental illness and problematic parenting behaviour seems to be moderated by social support. Via its positive effect on parenting behavior, social support may also effectively aid in buffering or even preventing negative consequences for the children of mentally ill parents, and thus supports the discontinuation of mental illnesses and child maltreatment across generations. However, social support is embedded within a complex framework of influences on parenting behavior such as socioeconomic status, gender or characteristics of the social network, that in turn moderate the effect of social support. Adding the lack of a generally acknowledged scientific conceptualization of social support, this leads to difficulties in comparing and interpreting research on social support in mentally ill parents. Future research should specify the type of social support that was investigated and consider potentially confounding factors, which may have moderated the influence of social support on their part.

In addition, specific research is needed to study the moderating role of social support within parents with BPD who seem to face aggravated problems in the context of parenting due to characteristics of their symptomatology. Especially the increased hostility which is reported within the literature suggests a heightened need for (formal) support in those parents to improve emotion regulation and reduce negative effects on the children. This hypothesis crucially needs scientific evaluation.

Importantly, the majority of literature points to substantial positive effects of social support for families with a mentally ill parent. As the SARS-CoV-2 pandemic has isolated many families from social support, the need for structured and evidence-based parenting interventions has substantially increased. Optimally, such programs should comprise a combination of informal and formal support and should be broadly applied

within standard clinical care of mentally ill parents to buffer long-term negative effects of the pandemic on parent and child mental health.

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