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I see you: insights into the neural and affective signatures of connectedness between parents and adolescents

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Chapter 1

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General introduction

"The interaction between a parent and child can be like a dance. There are routines, standards and missteps, there is give and take, there is unparalleled intimacy, there are often vast differences in skill level and motivation, there is learning. A parent must learn to be an adept partner, being sensitive to the needs of their offspring while ultimately guiding the quality and nature of care to ensure normal growth and development.

*This dance can be beautiful.
It can be tender.
It can be awkward.
It can be difficult.
And sometimes it just does not occur."*

(Barrett & Fleming, 2011)

Parental caregiving is one of the most fascinating and best-preserved behaviors throughout evolution of mammalian species, humans included. It facilitates parents to perceive and appropriately respond to physiological and emotional cues from their offspring, signaling hunger, pain, or distress, therewith serving as an innate parental protection system (De Waal, 2008). As previously phrased by Barrett and Fleming (2011), parental caregiving can be described as a beautiful dance between a parent and child during which a parent learns to be adaptive and sensitive to the needs of their offspring. Concurrently, parents need to guide the quality and nature of this care to ensure normal growth and development of their offspring. Although this can be a challenge throughout all stages of development, adolescence is thought to be a specifically challenging period for parent-child dyads. This is due to the tremendous social, emotional, behavioral, and environmental changes adolescents encounter, which demands a different parental skillset compared to childhood. Parents need to adapt to these changes and need to find a new balance between being sensitive and responsive to the changing needs and emotional states of their adolescent child, while also giving appropriate guidance, and support their child's ability to make autonomous decisions (Kobak et al., 2017). When all goes well, this will lead to a strong socio-emotional connection between a parent and child and a securely attached relationship, which fosters healthy socio-emotional development in the transition from childhood to adulthood (George & Solomon, 1999). However, flourishing in this task turns out to be a bigger challenge for some parent-child dyads than for others and several inter-individual factors are thought to affect this parent-child dance, demanding for an adjustment of the "dance steps" or the "rhythm".

During adolescence, parent-child dyads find themselves in a complex emotional landscape and, although not in every family, increases in the frequency and intensity of conflicts are more likely in this period than in others (Arnett, 1999; de Gelder et al., 2011; Restifo & Bögels, 2009; Shanahan et al., 2007). A factor likely contributing to these changes in family dynamics is the enhanced sensitivity to social evaluation in adolescents (Somerville, 2013), which gives rise to higher levels of affect lability and irritability (Steinberg & Silk, 2002). In addition, adolescents become more autonomous in this period and the relationship with their parents starts to take on a new, more egalitarian, form (Crone & Dahl, 2012). Altogether, the parent-adolescent relationship is put under pressure during this developmental period and parents and adolescents need to find a new balance in connecting with each other on a social and emotional level. This is important as, despite adolescents starting to spend more time with peers, they still perceive their parents as their most important advisors. This is in line with the fact that parental support remains a strong predictor of adolescents' wellbeing and mental health (Baumrind, 1991; Yap et al., 2014), showing the ongoing importance of a strong parent-child bond during adolescence.

Feeling connected with others on a socio-emotional level can be defined as a deep bond that is formed between people, which made them feel loved, cared for, and valued by the other

(Eisenberger & Cole, 2012). Strong social connections with others are crucial for one's mental and physical well-being, and are thought to be even more important for a strong parent-child bond (Ainsworth et al., 1978; Bowlby, 1969). As such, it is hardly surprising that negative social experiences (e.g., childhood emotional maltreatment) or circumstances that negatively affect (the perception of) these social connections (e.g., adolescent depression) may cause disturbances in the ability to interact with others, both within and outside the parent-child context. Extending our knowledge about neural and affective processes underlying this socio-emotional connection between parents and adolescents in well-functioning families may serve as a strong foundation for the understanding of difficulties and disturbances in this connectedness in dysfunctional family systems in which the parent-child bond may be at stake. Moreover, this will pave the way for the development of suitable interventions focusing on repairing this connection between parents and adolescents, which will potentially limit further harm due to family dysfunction.

This thesis aimed to elucidate the neural and affective signatures of socio-emotional connectedness between parents and their adolescent child. This was operationalized by the assessment of two key processes in parent-child interactions: Eye contact and empathy. These two processes are highly important for the parent-child bond. Moreover, I further aimed to investigate two inter-individual characteristics that may explain differences in parents' and adolescents' ability to connect with each other on a socio-emotional level: A history of childhood emotional maltreatment in parents and adolescent depression. In order to do this, several behavioral and functional magnetic resonance imaging (fMRI) paradigms were used with a multimethod approach, including self-report measures of affective responses, functional neuroimaging assessed by blood-oxygen-level-dependent (BOLD-)activation in the brain, and gaze responses assessed with eye-tracking. This not only enabled us to examine how parents and adolescents feel, but also how they respond at the level of their gaze and brain when connecting with each other (see Figure 1.1 for a schematic overview of the chapters in this thesis). The remainder of this chapter introduces a conceptual framework for the empirical studies described in this thesis and the RE-PAIR (Relations and Emotions in Parent-Adolescent Interaction Research) study within which the data collection took place.

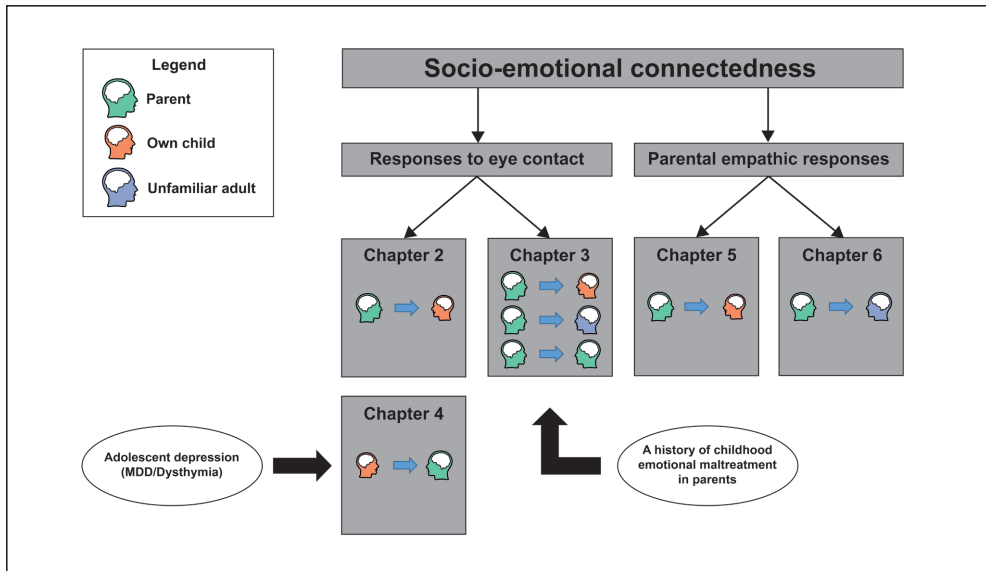


Figure 1.1 Schematic overview of the theoretical framework and concepts examined in this thesis. MDD = Major depressive disorder.

THE SIGNIFICANCE OF AFFILIATIVE BONDS

As human beings, we are intrinsically social and have a deeply ingrained need to belong to others. This innate psychological drive to participate and invest in meaningful affiliative bonds is thought to be a heritage of our primal ancestors, who needed to cooperate in a group to gain access to food, shelter, and protection for attack (Allen, 2020). Although nowadays depending on others is no longer a case of life or death, the desire for social connection with others has remained and is reflected in our need to be (literally and figuratively) seen by others and its impact if this desire goes unanswered (Allen, 2020). From this perspective, the longing for social interactions is not merely a desire, but a fundamental need.

Attachment theory proposes that the fundament of an individual's ability to form and maintain social bonds with others is based on the attachment bond with one's primary caregivers: The attachment figures (Ainsworth et al., 1978; Bowlby, 1969). This theory states that an infant's early interactions with their attachment figure(s) shapes their attachment bond, and with that their ability to form and engage in other meaningful and satisfying relationships with those around them. One of the main reasons to think that this parent-child attachment bond is of paramount importance is that early positive experiences in the parent-child rearing context have a positive impact on how the socio-emotional pathways in the brain are wired and give a secure base from

which a child can explore the (social) world around them (Feldman, 2017; Schore, 2013). As such, the parent-child attachment bond is a foundation for future relationships into adulthood (e.g., romantic relationships, friendships) and a starting point for the development of a child's social competences (Pratt et al., 2017).

NEURAL SYSTEMS OF ATTACHMENT AND AFFILIATIVE BONDING

Studies on neural signatures of the parent-child bond seem to agree on an “attachment network” in the brain (Abraham et al., 2018; Atzil et al., 2011; Barrett et al., 2012; Elmadih et al., 2016; Feldman, 2017; Kuo et al., 2012; Leibenluft et al., 2004; Lenzi et al., 2009; Shimon-Raz et al., 2021; Swain et al., 2014; Wan et al., 2014). In response to the sight of one's own child (versus an unfamiliar child) parents typically show increased activation in neural networks supporting complex social functions that are important for parental caregiving, such as resonating with other's mental states and emotions in the anterior insula, anterior cingulate cortex, inferior frontal gyrus, inferior parietal lobule, and supplementary motor area (i.e., embodied simulation network, including the affective empathy network) and social cognition, mental-state understanding, and social goal interpretation in the medial prefrontal cortex, temporoparietal junction, temporal pole, posterior cingulate gyrus, superior temporal sulcus (i.e., mentalizing network, including the cognitive empathy network) (Feldman, 2017). See Figure 1.2 for a schematic overview of this “attachment network”. Moreover, these brain regions have been consistently linked to subjective (self-report) and objective (behavioral observations) measures of parental caregiving and parent-child bonding. It is of note, however, that the lion's share of these studies has been conducted in parents of infants and young children. Interestingly though, a recent study has found that these attachment-related patterns of activation were independent of a child's age, representing a parent's and child's attachment relationship throughout life from infancy to adulthood (Ulmer-Yaniv et al., 2021). Less is known about neural signatures of socio-emotional connectedness between a parent and a child during adolescence. This thesis therefore investigated neural signatures of two meaningful processes common within the parent-child relationship during adolescence: Socio-emotional connectedness of parents and adolescents when making eye contact with each other and parental empathic responses during the imagined suffering of their child.

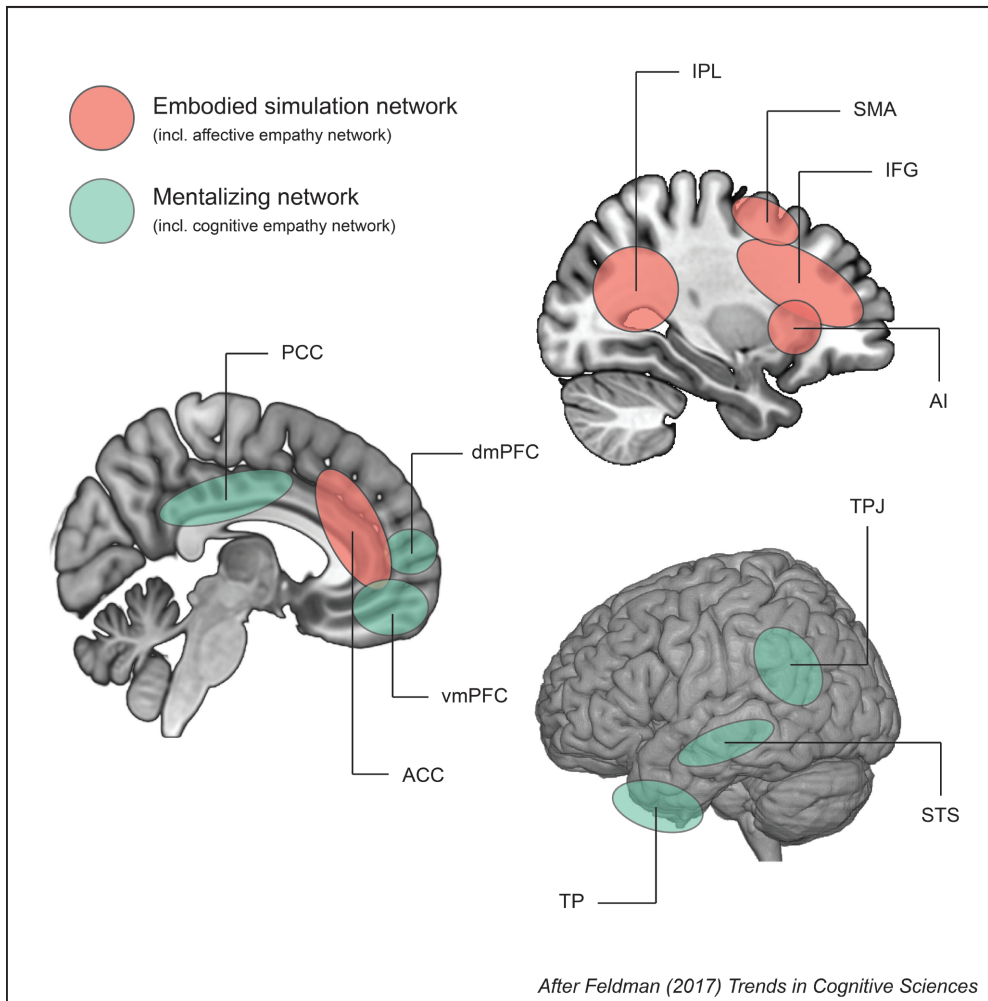


Figure 1.2 Schematic overview of brain regions involved in the “attachment network” (after Feldman (2017)), including the embodied simulation/affective empathy network (red) involved in resonating with others’ mental states and emotions and the mentalizing/cognitive empathy network (green) involved in social cognition, mental-state understanding, and social goal interpretation. ACC = Anterior cingulate cortex, AI = Anterior insula, dmPFC = Dorsomedial prefrontal cortex, IFG = Inferior frontal gyrus, IPL = Inferior parietal lobule, PCC = Posterior cingulate cortex, SMA = Supplementary motor area, STS = Superior temporal sulcus, TP = Temporal pole, TPJ = Temporoparietal junction, vmPFC = Ventromedial prefrontal gyrus.

EYE CONTACT

Eye contact is a social cue that initiates and regulates social interaction and facilitates the formation and maintenance of social ties between people (Emery, 2000; Hietanen, 2018). Although the attentional and cognitive processes related to eye contact have been extensively

studied in the literature, the affective component of eye contact is a road less explored (Hietanen (2018), for a review). Interestingly, it is this affective component of eye contact that is specifically associated with social bond formation and maintenance, and thus highly relevant to study in the context of socio-emotional connectedness between parents and adolescents.

The importance of eye contact in social interaction has also been emphasized by the finding that receiving a direct gaze from others signals social inclusion and usually induces positive feelings in people, as it resonates with our intrinsic need to belong and literally be 'seen' (Hietanen, 2018; Kobayashi & Hashiya, 2011). It may also serve as a way to gain information about others' mental states and conveys signals of empathy and social intimacy to others (Cowan, 2015; Cowan et al., 2014; Kleinke, 1986). Moreover, it is known that prolonged eye contact results in stronger affective responses and can elicit higher order socio-emotional processes, such as theory of mind processing and mentalizing, that are important for its communicative intent (Cavallo et al., 2015; Kuzmanovic et al., 2009).

In addition to its importance in social bond formation in general, eye contact may also serve as an important form of communication within the parent-child bond. It constitutes one of the first acts of reciprocity between a parent and its newborn baby and is thought to be an important facilitator for a strong parent-child bond and a secure attachment (Robson, 1967). Moreover, it has been shown that our tendency to make eye contact is innately driven as 2-5 days old newborns already show a preference for eye contact versus an averted gaze and 4-months-old infants show enhanced neural processing of faces with a direct versus averted gaze (Farroni et al., 2002). Being able to get the attention of one's parent by making eye contact enables infants to signal their physical and emotional needs for food and comfort of the parent. At the same time, the rewarding impact of positive affect in response to eye contact with their child is thought to reinforce sensitive caregiving behavior in parents towards the child (Robson, 1967).

Since affective responses to eye contact seem to be an innately driven adaptation to our complex social surroundings (Kobayashi & Hashiya, 2011), it does not come as a surprise that this is also reflected in our neural responses. Most neuroimaging studies conducted on eye contact have focused on neural responses to the detection and recognition of a direct versus averted gaze of others, using short stimuli of <2 seconds. These studies have broadly distinguished two networks: A subcortical pathway (i.e., superior colliculi/periaqueductal grey, pulvinar nuclei and amygdala) for a 'quick and dirty' detection of gaze direction and a more reflective cortical pathway (i.e., fusiform gyrus, superior temporal sulcus, medial prefrontal cortex and orbitofrontal cortex) for the evaluation of eye contact (Hietanen, 2018; Senju & Johnson, 2009). Only a small number of studies have focused more specifically on the affective and affiliative responses to prolonged eye contact during interpersonal contact with others, using stimuli with a longer presentation duration. These studies investigated higher-order processes, i.e., theory of mind

processing and mentalizing, that most likely come into play as the duration of eye contact increases (Cavallo et al., 2015; Kuzmanovic et al., 2009). These studies found that prolonged eye contact (i.e., 2-30 seconds) resulted in differential neural responses in orbitofrontal gyrus, inferior frontal gyrus, dorsomedial prefrontal cortex, paracingulate regions, anterior insula, premotor and supplementary motor area compared to short stimuli of <2 seconds. These brain regions are, amongst other things, involved in the preparation of a communicative response and the initiation of social interaction.

To assess parents' and adolescents' responses to eye contact with one another, we designed a fMRI paradigm and compared these responses to eye contact with unknown others (i.e., an unfamiliar peer or adult). This allows for a better understanding of neural and affective processes in response to prolonged eye contact during warm and affectionate interactions between parents and adolescents of well-functioning families. Moreover, this will function as a solid baseline that helps to investigate potential alterations in these processes in situations in which parents and adolescents have difficulties to connect with each other.

INTER-INDIVIDUAL DIFFERENCES IN CONNECTEDNESS

Two inter-individual factors that are known to be associated with difficulties in social interactions and are found to have a negative impact on family dynamics, are childhood emotional maltreatment and depression. What these factors have in common is that they are linked to altered (more negative) cognitive schemas about others and the self, which may affect one's ability to engage in interpersonal contact. As these processes might be strongly ingrained in one's way of responding to social cues, it is of interest to examine whether parents with a history of childhood emotional maltreatment and depressed adolescents show altered responses to gazing into the eyes of their child or parent, respectively, and of unknown others.

Childhood emotional maltreatment is common and includes situations in which parents fail to accurately perceive and appropriately respond to the emotional and psychological needs of their child. It encompasses both emotional abuse (i.e., verbal assaults and demeaning behaviors directed towards children by adults that are harmful for a child's self-worth) and emotional neglect (i.e., caregivers' irresponsibility or failure in satisfying children's basic psychological needs for love, belonging, nurturance, and support) (Bernstein et al., 1994; Bernstein et al., 2003). Childhood emotional maltreatment can give rise to long-term negative consequences far into adulthood, including the development of negative cognitions about the self and others, possibly due to the perceived betrayal of trust during childhood by a primary caregiver (Baugh et al., 2019; Reyome, 2010; van Harmelen et al., 2010). People who have experienced childhood emotional maltreatment might on the one hand generalize distrust to others, believing that

everyone has bad intentions (maladaptive other-schemas), while on the other hand it may lead them to believe that they are unloved, worthless, or unwanted (maladaptive self-schemas) (Baugh et al., 2019; Gobin & Freyd, 2014). These beliefs put them at risk for the development of internalizing disorders, such as anxiety and depression, and can contribute to interpersonal difficulties and problems in affiliative bond formation and maintenance (Reyome, 2010; Riggs, 2010; Wright et al., 2009). Moreover, there is evidence for the intergenerational transmission of childhood emotional maltreatment, showing that having a history of childhood emotional maltreatment as a parent raises the risk of maltreating one's own children (Lotto et al., 2023; Madigan et al., 2019). It is of note, however, that this relationship is far from deterministic in a way that people who have been maltreated as a child not always become a perpetrator of emotional maltreatment towards their own children (Madigan et al., 2019).

Depression is common during adolescence. This is thought to be linked to the enhanced sensitivity to social evaluation during adolescence, which may make adolescents especially vulnerable to develop depression in response to negative social experiences (e.g., bullying, exclusion, and rejection) (Crone & Dahl, 2012; Dahl, 2004; Giedd & Rapoport, 2010; Hankin & Abramson, 2001; Wilson et al., 2015). Adolescent depression is characterized by difficulties in the social domain, including social isolation and dysfunctional interpersonal relationships, putting a strain on their relationship with others, including peers and parents (Babore et al., 2016; Branje et al., 2010; Heaven et al., 2004; Sheeber et al., 2001). The latter is also reflected in studies who found that depressed adolescents reported lower levels of relationship satisfaction with their parents compared to non-depressed adolescents, although it is unsure whether this is related to an altered *perception* due to their depressed state or to an actually worse relationship with their parents (Branje et al., 2010; Restifo & Bögels, 2009; Sheeber et al., 2001; Yap et al., 2014).

PARENTAL EMPATHY

Empathy can generally be defined as the capacity to share an emotional state with another individual, assess the reasons for the other's state, and identify with the other by adopting his or her perspective (De Waal & Preston, 2017). Although the capacity to empathically respond to others is essential to the regulation of social interactions in general, it is thought to be evolved in the context of caregiving. Parental empathy is deemed fundamental for sensitive caregiving (Abraham et al., 2018; De Waal, 2008; Decety, 2011). As our social lives became increasingly complex across human evolution, caregiving behavior became more complex too. Consequently, human caregiving slowly transitioned from mainly protecting offspring from potential physical threats into preparing them for successfully navigating in our complex social worlds. Empathic parents provide more attuned care for their children, resulting in securely attached and stable

parent-child bonds (Kochanska, 1997), which fosters a child's socio-emotional development (Abraham et al., 2018; Manczak et al., 2018; Richaud et al., 2013; Soenens et al., 2007).

The neural correlates of empathy have been extensively studied and broadly two neural systems can be distinguished. The core of empathic responses is the *affective empathy network*, including bilateral anterior insula (AI) and anterior mid-cingulate cortex (aMCC) (De Waal & Preston, 2017; Shamay-Tsoory, 2011). This network supports the vicarious experience of affect and thereby facilitates emotion contagion and affect sharing. It may help parents to appropriately “feel” the emotions and needs of their children, which could then promote carrying out adequate caregiving responses needed for sensitive parenting (Abraham et al., 2018; Ainsworth et al., 1978; Fan et al., 2011; Feldman, 2017; Turpyn, 2018). In addition, a more recently evolved *cognitive empathy network* has been identified that includes regions in temporal, parietal and prefrontal cortex (De Waal, 2008; De Waal & Preston, 2017; Decety, 2011; Decety & Jackson, 2004; Shamay-Tsoory et al., 2009; Zaki & Ochsner, 2012). More specifically, this network includes the dorsomedial prefrontal cortex (dmPFC), ventromedial prefrontal cortex (vmPFC), temporoparietal junction (TPJ), temporal pole, superior temporal sulcus, and frontopolar cortex (Abraham et al., 2018; Feldman, 2017; Shamay-Tsoory, 2011), and facilitates understanding of another's point of view by making inferences of others' mental states (Shamay-Tsoory, 2011). In the context of parenting, this cognitive empathy network may promote a better understanding of the feelings, actions, and intentions of the child (Abraham et al., 2018). As parental empathy is, in fact, an important pillar of the attachment bond between a parent and child, it is no surprise that there is extensive overlap between the neural correlates of the affective and cognitive empathy networks and the “attachment network” presented in Figure 1.2.

Although parents' empathic responses towards babies and young children have been studied extensively (Abraham et al., 2018; Atzil et al., 2011; Barrett et al., 2012; Elmadih et al., 2016; Kuo et al., 2012; Leibenluft et al., 2004; Lenzi et al., 2009; Wan et al., 2014), less is known about these responses when parenting an adolescent child. This is remarkable, as the increasing autonomy of adolescents and more time spend outside adult supervision creates situations where parents are not involved in. When a child, in turn, verbally shares their distress about an unpleasant situation (e.g., being excluded from a peer group) it might be more difficult for parents to imagine how their child would feel and might place higher demands on their socio-cognitive capacities needed for an appropriate empathic response. One of the pillars of this thesis was to examine the neural and psychological signatures of parental empathic responses to the imagined suffering of their adolescent child. Moreover, we additionally investigated to what extent inter-individual differences in parental warmth are related to parents' neural responses to their child's suffering to examine whether these neural responses can serve as a marker for the parent-child bond.

Another facet of empathic behavior that is of interest to social interactions between people, both within and outside the parent-child bond, is the ability of people to accurately infer others' feelings, also referred to as empathic accuracy (Ickes & Hodges, 2013; Zaki et al., 2008; Zaki et al., 2009). Several studies have emphasized that the eye region is an important source of social cues that contribute to one's ability to be empathically accurate about others' internal state (Baron-Cohen et al., 1997; Buchan et al., 2007; Eisenbarth & Alpers, 2011; Hall et al., 2010; Zaki et al., 2009). However, the lion's share of these studies included paradigms in which empathic accuracy was assessed in response to static pictures of others, which limits generalizability to real life social situations. A hand full of studies that did make use of close-to-real life dynamic video stimuli found a positive link between people's trait empathy levels and the amount of eye contact they made with others, especially under emotionally valenced circumstances (Cowan et al., 2014; Martínez-Velázquez et al., 2020). However, these studies did not include whether gazing into the eyes contributes also to being more empathically accurate about others' feelings. To bridge this gap, we adapted an already existing empathic accuracy task by simultaneously measuring participants gaze using eye tracking. The task includes emotionally valenced target stories, including both visual and verbal (speech) informational cues, closely mimicking real life social settings. As little is known about the role of eye contact in empathic accuracy this study focused on this relationship in adults towards unknown other adults.

THE RE-PAIR STUDY

The empirical studies in this thesis take place in the context of the RE-PAIR study: "Relations and Emotions in Parent-Adolescent Interaction Research". This study uses a multi-method and multi-informant approach to examine the relation between parent-adolescent interactions and adolescent well-being by comparing adolescents with a current diagnosis of a major depressive disorder (MDD) or dysthymia and their parents to adolescents without psychopathology and their parents (i.e., healthy control families). Moreover, we included both mothers and fathers in the study, which allows for the assessment of potential gender differences in the socio-emotional connection between parents and their adolescent child. The RE-PAIR study consists of four parts: An online questionnaire battery, a research day in the lab, two weeks of ecological momentary assessment (EMA), and an MRI scan session in which we focus on concepts relevant for the parent-child relationship during adolescence and adolescent depression (e.g., parental empathy, eye contact, responses to feedback of parents, peers and unfamiliar others, and autobiographical memory processing). See Figure 1.3 for an overview of the RE-PAIR study and the specific parts used to answer the research questions in the present thesis.

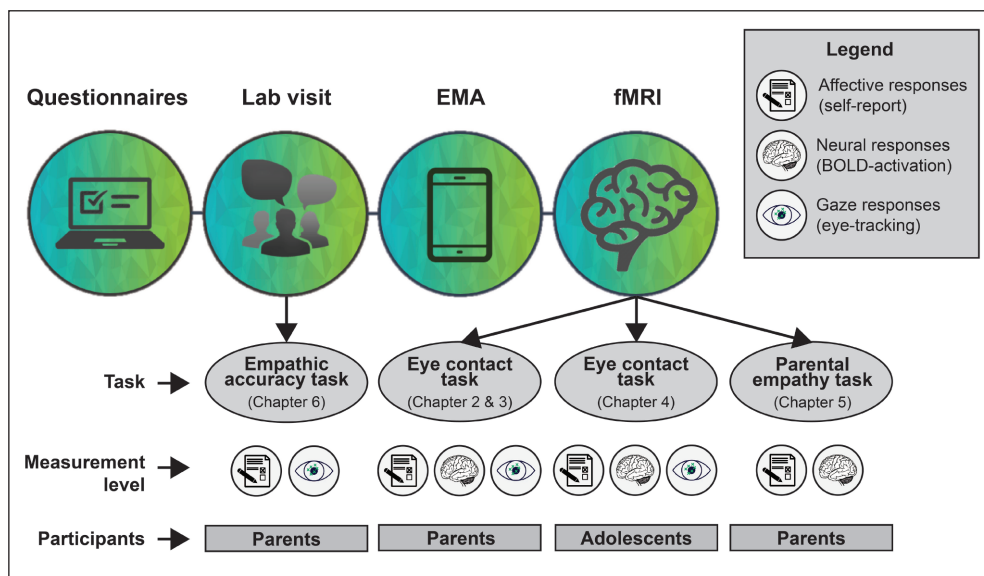


Figure 1.3 Schematic overview of the RE-PAIR study and specific tasks that have been used to answer the research questions in the present thesis. EMA = Ecological momentary assessment, fMRI = Functional magnetic resonance imaging.

OUTLINE OF THIS THESIS

The research described in this thesis investigated the neural and affective signatures of connectedness between parents and adolescents, which was operationalized by the assessment of parents' and adolescents' responses to making eye contact with each other and parental empathy. To assess this, we developed two novel fMRI paradigms to study the neural correlates of these processes in the brains of parents and adolescents. In addition, we examined the uniqueness of these responses to the parent-child bond by comparing these responses to how parents and adolescents respond to unknown others in similar situations. We examined these processes first in parent-adolescent dyads in well-functioning families in order to gain more insight in these processes under 'normal' conditions. In addition, we studied the impact of a history of childhood emotional maltreatment in parents and adolescent depression on parents' and adolescents' neural and affective responses to their mutual connectedness.

Chapter 2 examined parents' neural and affective responses to prolonged eye contact with one's own child versus unfamiliar others. **Chapter 3** examined the impact of a history of childhood emotional maltreatment in parents on their neural and affective responses to gazing into their own and others' eyes. **Chapter 4** investigated adolescents' neural and affective responses

when making prolonged eye contact with their parent and unknown others. In addition, differences in these responses between depressed and non-depressed adolescents were examined. **Chapter 5** examined parents' empathic responses to the imagined suffering of their adolescent child. In addition, it was examined whether these empathic responses may function as a marker for the parent-child bond by relating these responses to measures of parental care as reported by the adolescent child. **Chapter 6** examined the contributing role of eye contact to parents' empathic accuracy and to their individual state and trait levels of perspective taking and empathic concern towards unknown others in an emotionally valenced social setting. Lastly, **Chapter 7** summarized the findings of this thesis and discussed them in the context of connectedness between a parent and adolescent child, the uniqueness of the findings to the parent-adolescent bond, and whether a history of childhood emotional maltreatment in parents and adolescent depression are associated with altered responses to connectedness between parents and adolescents and with unknown others.