Helping me, helping you: behavioral and neural development of social competence from childhood to adolescence

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CHAPTER 1

General Introduction

SOCIAL COMPETENCE IN CHILDHOOD AND ADOLESCENCE

What makes that some children find their way easily in social situations, are able to easily make new connections with peers, and are happy with their social lives, while others have more difficulties? One of the key components that may explain these successful social behaviors and outcomes is social competence: the ability to fulfill personal goals in social interaction while maintaining positive relationships with others over time and across situations (Rubin & Rose-Krasnor, 1992). One of the core qualities of socially competent children is that they adapt their behavior to different social situations in order to fulfill the goals of self and others, for example during social interactions.

The period between middle childhood and early adolescence is of particular interest for transitions in social interactions. It spans approximately the ages 7 to 13 years and it marks the time during which the social world of children expands, as children start to spent more time with peers, the first dyadic friendships are formed, and their social network increases, for example through social interactions at school or sport clubs (Berndt, 2004; Del Giudice et al., 2009). Towards adolescence, the quality and complexity of friendships further increase (Berndt, 2004) and peers start to play an even more important role in adolescents' social lives (Blakemore & Mills, 2014; Nickerson & Nagle, 2005), although parents continue to be important as well (Nickerson & Nagle, 2005). Early adolescence is characterized by increased sensitivity to social cues and peer opinions (Blakemore & Mills, 2014; Somerville, 2013), and behaviors in early adolescence are increasingly influenced by peers (Gardner & Steinberg, 2005; Large et al., 2019; Laursen & Veenstra, 2021; van Hoorn, Fuligni, et al., 2016).

In addition, the transition between middle childhood and early adolescence is a period of rapid development in cognitive and behavioral control skills. Basic cognitive functions, such as response inhibition, working memory and task switching, improve throughout this period and have been found to reach adult levels in late childhood or early adolescence (Crone & Steinbeis, 2017; Huizinga et al., 2006), whereas more complex, strategic cognitive control, such as choosing for a delayed reward, continues to improve throughout adolescence (Crone & Steinbeis, 2017; Prencipe et al., 2011; Zelazo & Carlson, 2012). Additionally, in middle childhood children learn to internalize and act following fairness principles (Chajes et al., 2022; McAuliffe et al., 2017; Smith et al., 2013), as is shown by increases in reciprocating behaviors (van den Bos et al., 2010). In adolescence perspective taking and mentalizing skills, i.e., the ability to think about the thoughts of others, continue to develop (Crone, 2013; Dumontheil et al., 2010; Guazzelli Williamson & Mills, 2023) and may underly increased other-oriented processing across development.

Interestingly, even though scientists have empathized the relatively large changes in the organization of the brain in early childhood and adolescence (Gilmore et al., 2018; Tamnes et al., 2017), much less research is devoted to neurodevelopmental changes in the transition from childhood to adolescence. The transition from middle childhood to early adolescence is an especially interesting period to study social development at the neural level, to understand the changes in socioaffective processes and cognitive development (Crone et al., 2020; Crone & Steinbeis, 2017; Pfeifer et al., 2011).

This aim of this thesis is to understand why some children more easily adapt their behavior across social contexts than others and how this adaptation develops from childhood to adolescence. Therefore, this thesis is focused on the development, neural mechanisms, environmental effects and developmental outcomes of social competence from childhood to adolescence. Studying individual differences and mechanisms underlying social competence contributes to our understanding of how youth grow up to become thriving individuals and how they may optimally be supported in their development.

Count to ten… Regulating aggression following social rejection

An important aspect of social competence is how children interact with peers, for example when receiving peer feedback. Receiving positive likes on social media can feel rewarding and make someone want to reciprocate the behavior towards others, whereas receiving a negative comment on your outfit can induce feelings of anger and wanting to retaliate to feel better. Specifically, receiving positive peer feedback can improve one's mood and self-esteem and may promote prosocial behaviors (Guyer et al., 2014; Thomaes et al., 2010; van Hoorn, van Dijk, et al., 2016; van Schie et al., 2018) whereas negative peer feedback can make one feel worse about themselves (Rodman et al., 2017), and lead to frustration and aggression (Achterberg et al., 2016; Quarmley et al., 2022). Even though displaying aggression to the person who rejected you can feel rewarding in the moment itself (Chester, 2017), it can also lead to a negative spiral of even more peer rejection on the long term (Lansford et al., 2010). Indeed, retaliation or aggression has been associated with behavioral and peer problems on the long term (Card & Little, 2006; Evans et al., 2021; Lansford et al., 2010). Thus, in order to intervene on this negative spiral, it is important to understand why some children are better able to regulate their aggression than others.

Aggression models

In the literature, several theories exist that try to explain the underlying components of aggression regulation. For example, the I^3 model suggests that aggression may result from a disbalance in the interaction of instigation, impellance and inhibition, where instigation refers to environmental stimuli that trigger aggression, such as provocation, impellance refers to situational or dispositional tendencies to aggress, such as proneness to aggression, and inhibition refers to situational or dispositional tendencies to refrain from aggression (Finkel & Hall, 2018). The Perfect Storm Theory, derived from this I^3 model, proposes that aggression may be the result of high instigation and impellance, and low inhibition (Finkel & Hall, 2018).

In addition, the social information processing theory proposes that aggression could stem from deviations in different steps of social information processing, such as in the encoding and interpretation of social cues, the clarification of goals, response access and evaluations, and the behavioral performance of the response (Crick & Dodge, 1994). For example, compared to non-aggressive children, aggressive children may more often believe that peers who provoke them have hostile intentions, they may be less able to choose non-aggressive responses and they may expect more favorable outcomes of aggression (Dodge & Crick, 1990). Later adaptations of the social information processing model also emphasized that each social information processing step may be affected by emotional processes (Lemerise & Arsenio, 2000). Possibly, the encoding and interpretation steps of the model may mostly be influenced by emotional experiences (e.g., being frustrated may alter how social cues are interpreted), whereas the response steps may mostly be influenced by emotional regulation (e.g., impairments in emotion regulation may interfere with which response is selected; Smeijers et al., 2020). Thus, together, these theories point toward both an affective and a regulation component underlying aggression. In other words, someone may respond aggressively because they are very sensitive to negative feedback, and/or because they have difficulties inhibiting their aggressive behavior. These components may rely on different neural networks (Nelson et al., 2005). In this thesis I used neuroimaging to study the neural processes related to the development of aggression regulation in childhood and adolescence.

Neurodevelopmental changes

Shedding light on neural mechanisms underlying behavioral responses to social feedback in childhood and on possible environmental influences, such as parenting effects, may aid in understanding shy some children have more difficulties regulating aggression following social feedback than others. Previously, it has been proposed that developmental changes in behavior may be explained by changes in neurodevelopmental processes towards adolescence. The social information processing steps presented by Crick and Dodge (1994) may be associated with different neural nodes of the Social Information Processing Network (SIPN; Nelson et al., 2005). According to SIPN, three brain networks are involved in processing social information. The detection node is activated when recognizing a social stimulus and includes regions such as the anterior temporal cortex, superior temporal sulcus and fusiform face area. The affective node is activated when assigning emotional significance to the stimulus and includes limbic regions such as the amygdala, ventral striatum, hypothalamus and orbitofrontal cortex. Finally, the cognitive-regulatory mode is activated when mentalizing, inhibiting responses and executing goal-directed behaviors and includes prefrontal regions such as the dorsomedial and ventrolateral prefrontal cortex (Nelson et al., 2005). These three neural nodes of the SIPN all show developmental changes in adolescence (Nelson et al., 2005).

For example, in the SIPN model, social cognitive processes such as perspective taking and mentalizing abilities have been found to rely on a network of brain areas including the dorsal medial prefrontal cortex (dmPFC), temporal parietal junction (TPJ), posterior superior temporal sulcus (pSTS) and anterior temporal cortex (Blakemore, 2008). Adolescents have been found to recruit this social brain network differently compared to adults during social cognitive processes such as mentalizing (Blakemore et al., 2007; Blakemore & Mills, 2014; Gunther Moor et al., 2012), which may reflect development of cognitive strategies when interpreting social situations (Crone & Fuligni, 2020). In addition, the imbalance model (Casey et al., 2008; Somerville & Casey, 2010) and dual systems theory (Steinberg, 2010) state that cortical brain regions (i.e., prefrontal cortex) that have been implicated in cognitive and impulse control show a protracted development in adolescence compared to more subcortical limbic brain regions (i.e., amygdala and ventral striatum) that have been implicated in emotional and reward sensitivity. The differentiation in developmental trajectories between the two regions peaks in adolescence, and lead to an imbalance favoring behaviors related to the relatively matured subcortical regions. Thus, this model is often used to explain increased risk-taking and impulsive behaviors in adolescence.

Together, the changes in social environment, behavior and neural functioning suggest that the transition towards adolescence is an important period to study the development of social adaptation. Although most neurodevelopmental models are based on adolescence, studying social development in the period leading up to adolescence may contribute to our understanding of individual differences that occur in adolescence and possibly help prevent mental health problems that often have an onset in adolescence (Rapee et al., 2019). Therefore, this thesis is focused on the behavioral and neural development of responses to social feedback from middle childhood to early adolescence.

Aggressive, prosocial, or both?

The leading theme of my thesis is that understanding the development of responding to social feedback requires a rich understanding of developmental processes and social context factors. This hypothesis is driven by recent findings showing that the experience of rejection as well as the observation of rejection may rely on a similar neural network. The medial prefrontal cortex has been found to be activating both when receiving negative (versus positive) feedback (Achterberg et al., 2018; Davis et al., 2022; Wikman et al., 2022), when experiencing exclusion (versus inclusion) in a ball-tossing game (van der Meulen et al., 2018), and when observing exclusion of another player in a ball-tossing game (Masten et al., 2011; Tousignant et al., 2018). Thus, receiving social feedback for self and others may be intertwined processes. Receiving rejection feedback for oneself may lead to aggression, whereas observing rejection or exclusion of someone else can result in helping behaviors towards the victim (Masten et al., 2011; van der Meulen et al., 2016, 2018; Will et al., 2013). Behaviors that benefit others are also referred to as prosocial behaviors (Eisenberg & Mussen, 1989). Children do not necessarily have to be either aggressive or prosocial but may also show both types of behavior in different situations (Hawley, 1999, 2003).

Still, developmental outcomes of aggression and prosocial behavior have mostly been studied separately. Aggression has often been linked to unfavorable developmental outcomes such as peer rejection and behavioral problems (Card & Little, 2006; Evans et al., 2021; Lansford et al., 2010), whereas showing prosocial behavior has been linked to favorable developmental outcomes such as peer inclusion, increased mental wellbeing, and protection against behavioral problems (Chávez et al., 2022; Flynn et al., 2015; Layous et al., 2012). However, whether someone acts aggressively or prosocially may depend on the social context, and mental health outcomes may be affected by a combination of behaviors. Previously, a subgroup of adolescents was identified who showed both aggressive and prosocial strategies to achieve social goals and who were well-adapted and socially skilled, suggesting that aggression may not always be maladaptive (Hartl et al., 2020; Hawley, 2003, 2014). Possibly, the co-occurrence of aggressive and prosocial responses in response to rejection of self and others may be a better predictor of developmental outcomes, such as behavioral problems or wellbeing, compared to studying aggression and prosocial behavior as separate constructs (e.g., Sunami et al., 2019).

Testing a bi-dimensional model of social responsivity

The theory that the co-occurrence of aggressive and prosocial behavior might be beneficial for wellbeing can be tested using the bi-dimensional model of social responsivity (Crone et al., 2020), a proposed framework for studying individual differences in behavioral responses to rejection of self and others. In this model, four subgroups were defined along the axes of aggressive and prosocial responses in response to rejection (Figure 1). First, individuals who were both aggressive following rejection of self and prosocial following rejection of others were labeled 'strong responders', as they may be particularly responsive to changes in the social environment (upper-right quadrant). Second, individuals who score low on aggression but high on prosocial behavior were labeled 'prosocial forgivers', and they may be mostly responsive to observing rejection of others (lower-right quadrant). Third, individuals who score high on aggression but low on prosocial behavior were labeled 'antisocial revenge-takers', and they may be mostly responsive to experiencing rejection themselves (upper-left quadrant). Finally, individuals who were neither aggressive nor prosocial were labeled 'passive bystanders', as they may show low responsivity to experiencing or observing rejection of self and others (lower-left quadrant). Thus, these subgroups differ in the degree of social responsivity in response to rejection.

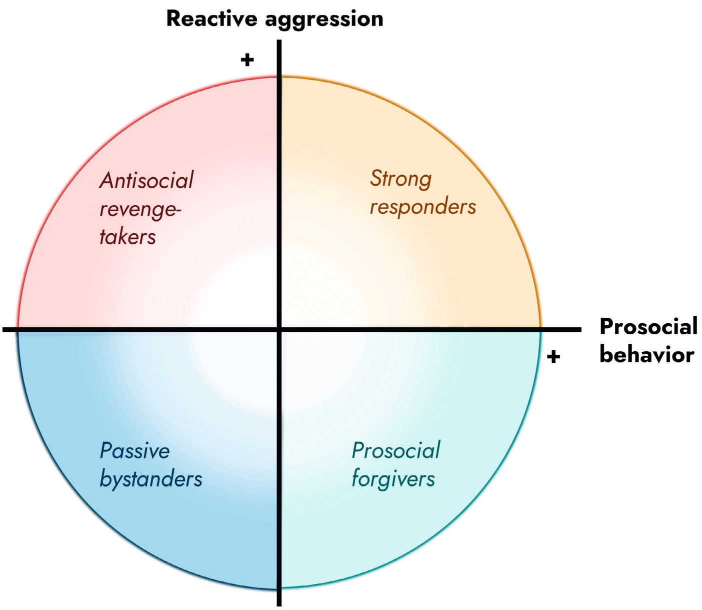

Figure 1. Bi-dimensional model of social responsivity as proposed by Crone et al. (2020). Subgroups of social responsivity were defined along the dimensions of reactive aggression and prosocial behavior.

In this thesis, I studied individual differences in social competence development and tested the bi-dimensional model of social responsivity in four steps. First, I methodologically tested the neural correlates of social feedback processing and aggression in childhood using a test-replication design (**chapter 2**). Second, I examined the longitudinal trajectories of neural and behavioral correlates of aggression following social feedback from middle childhood to early adolescence (**chapter 3**). Third, I examined whether parental influences were associated with the behavioral and neural development of aggression following social feedback (**chapter 3**). Finally, I used a longitudinal design to test whether the co-occurrence of aggression and prosocial behavior predicted developmental outcomes later in time (**chapter 4 and 5**).

The Leiden Consortium on Individual Development

The studies described in this thesis used data of the Leiden Consortium on Individual Development (L-CID; Crone et al., 2020; Euser et al., 2016). The L-CID study is a cohort-sequential longitudinal twin study that consists of two cohorts: an early childhood cohort (ECC), that was followed from 3 to 9 years of age, and a middle childhood cohort (MCC), that was followed from 7 to 13 years of age. Each cohort was followed for six consecutive years, with alternating annual home and laboratory (i.e., EEG/MRI) visits (see Figure 2). The two cohorts overlapped in age at two time points (i.e., the last two time points of the ECC and the first two time points of the MCC). The design of the L-CID study allowed me to examine compelling theoretical and methodological considerations that have been raised in the field of developmental neuroscience, such as replication of neuroscientific findings, the use of longitudinal designs to study development and the use of a multimodal approach to understand social processes.

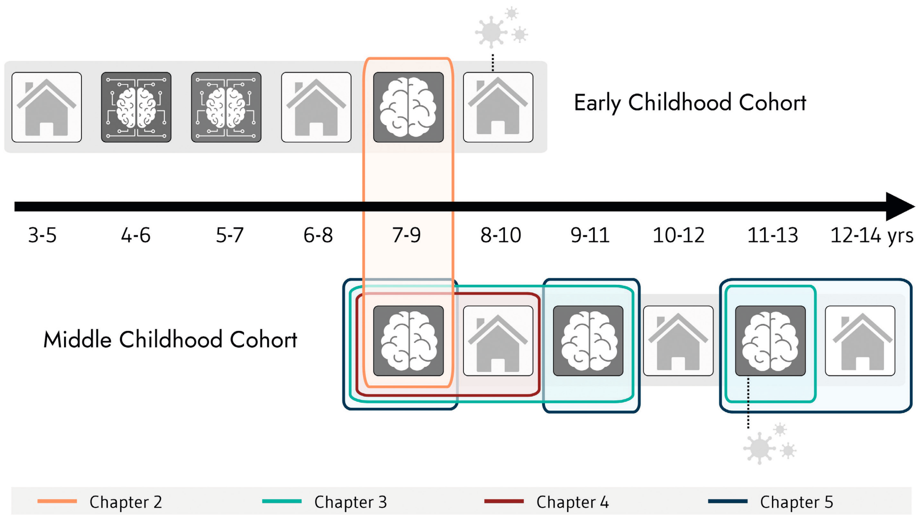

Figure 2. Design of the L-CID study. The L-CID study consists of an early childhood cohort (ECC; upper half) followed from 3-10 years, and a middle childhood cohort (MCC; lower half) followed from 7-14 years. Colored boxed indicate the waves of data collection used in each chapter: orange = chapter 2, green = chapter 3, red = chapter 4, blue = chapter 5.

Innovative scientific methods to study complex social behavior

Both aggression and prosocial behaviors are complex social behaviors that are affected by social context factors and that may be challenging to investigate. In the following sections I will introduce how using different types of scientific methods that each have its own advantages can aid our understanding of the development of responding to social feedback. For example, combining experimental tasks with functional magnetic resonance imaging (fMRI) can shed light on neural mechanisms underlying specific behaviors, self-reported questionnaires can give insight into more interoceptive processes, and parent-child observations can be used to study social interactions between parents and children in a more naturalistic way. As combining these measures can aid in creating a more complete view on social development, the studies described in this thesis incorporated a multimodal approach.

An experimental approach to study aggression following social feedback

One way to examine aggression following social feedback is by using experimental tasks, where specific conditions, such as the type of feedback someone receives, can be controlled. In laboratory settings, aggression following provocation can be measured using experimental tasks that include the delivery of noise blasts, that can differ in intensity or duration (Achterberg et al., 2016; Chester & DeWall, 2016; Reijntjes et al., 2011; Twenge et al., 2001). These tasks consistently show that receiving negative feedback results in longer noise blasts (i.e., aggression) compared to neutral or positive feedback, both in adults as well as in children (Achterberg et al., 2016, 2017, 2018; Reijntjes et al., 2011; Twenge et al., 2001; van de Groep et al., 2021, 2022).

An experimental paradigm that was recently developed to differentiate between experiencing and responding to social acceptance or rejection is the Social Network Aggression Task (SNAT; Achterberg et al., 2016). In the SNAT, participants first receive positive, neutral or negative peer feedback on a personal profile they filled out prior to the laboratory visit. Subsequently, they are instructed to respond to this peer feedback by sending a noise blast towards the peer who gave the feedback (Figure 3). Thus, within this task, it is possible to focus on neural processes related to the moment of receiving feedback (i.e., social feedback processing), and on neural processes related to the moment of the noise blast (i.e., (inhibition of) aggression). In general, aggression decreased between middle and late childhood, possibly indicating increased inhibitory control (Achterberg et al., 2020). Still, not all children are equally aggressive when receiving negative feedback, or show similar developmental trajectories. As such, an important question is what may drive individual differences in aggression regulation from childhood to adolescence.

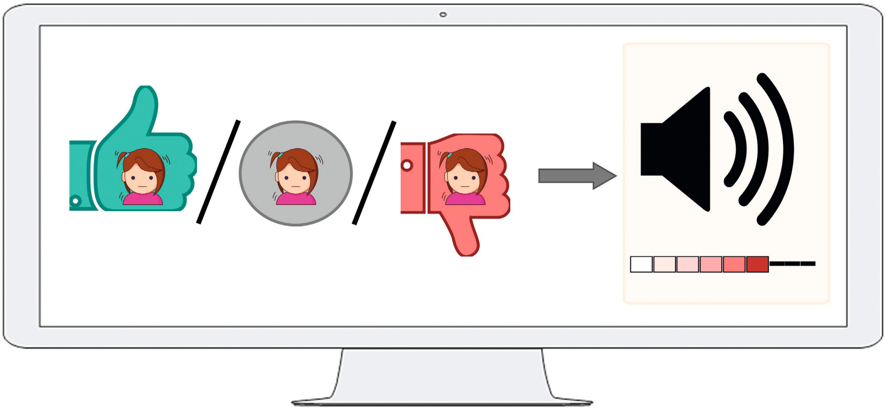

Figure 3. The Social Network Aggression Task. After receiving positive, neutral or negative peer feedback, participants were instructed to send a noise blast towards the peer who gave the feedback. Noise blast duration was used as measure of aggression.

Neural activation during social feedback processing

Previously, paradigms where participants received feedback, such as the SNAT, have been combined with neuroimaging to study the neural signature of social feedback processing (Achterberg et al., 2016; Davis et al., 2022; Gunther Moor et al., 2010; Guyer et al., 2012; Sequeira et al., 2021; see Figure 4). These studies showed that receiving positive feedback results in heightened activation in the dorsolateral prefrontal cortex (DLPFC), supplementary motor area and the ventral striatum in adults and adolescents (Achterberg et al., 2016; Gunther Moor et al., 2010; Guyer et al., 2012). The ventral striatum is often implicated as reward centrum of the brain (Daniel & Pollmann, 2014), suggesting that receiving positive feedback is indeed a rewarding feeling. In contrast, receiving negative feedback resulted in more activation in the superior medial prefrontal cortex (Achterberg et al., 2016; Crone et al., 2020; Davis et al., 2022). In adults, it was previously found that aggression was predicted by neural responsivity to rejection in the dorsal anterior cingulate cortex (dACC) and anterior insula (AI; i.e., high instigation/impellance) but only in adults with low executive functioning (i.e., inhibition; Chester et al., 2014).

The medial prefrontal cortex is considered a hub region for social processes, as it has been found to be involved in for example thinking about the self, social cognition and social feedback processing (Blakemore, 2008; Crone et al., 2020; Somerville, 2013). Together with the anterior insula, the medial prefrontal cortex was also found to be activated during both negative and positive feedback processing (compared to neutral feedback; Achterberg et al., 2016; Davis et al., 2022; van de Groep et al., 2021, 2022). As such, these regions may be responsive to signals that are socially salient rather than to signals with a specific negative or positive valence (Achterberg et al., 2016; Dalgleish et al., 2017). Interestingly, studies examining social feedback processing in children reported similar regions of activation as in adults (Achterberg et al., 2017, 2018, 2020). In other words, the neural foundation underlying social feedback processing may be already present in middle childhood.

To understand why some may be more aggressive following social feedback than others, individual differences in neural activation during social feedback processing have been linked to subsequent aggression. Several studies showed that adults with increased activation in the DLPFC during negative feedback processing showed less aggression (Achterberg et al., 2016; van de Groep et al., 2021). Relatedly, studies using transcranial direct current stimulation (tDCS) to increase activation of the lateral prefrontal cortex during social exclusion showed a reduction in behavioral aggression (Riva et al., 2015), thereby indicating an important role for the lateral prefrontal cortex in emotion regulation and cognitive control (Bertsch et al., 2020; Etkin et al., 2015; Zhao et al., 2021). In children, the association between increased DLPFC activation during negative feedback and decreased aggression has been found as well (Achterberg et al., 2018, 2020). However, compared to studies testing adults and adolescents, studies examining neural correlates of social feedback processing and aggression in children are scarce.

The replicability of neuroscientific findings, including fMRI, has been raised into question in the last few years. Specifically, fMRI has been found to have low test-retest reliability (Elliott et al., 2020; Herting et al., 2018), which might partly be explained by relatively small samples sizes in prior studies (Button et al., 2013; Turner et al., 2018). Notably, replicability of neuroscientific findings in childhood has received relatively little attention so far, possibly because it can be challenging to collect MRI data in large samples of young children. However, given that there can be large individual differences in development, it is a specifically important time period to study whether findings are not sample specific. To explore the robustness and generalizability of fMRI findings, I used the overlap between the two cohorts of the L-CID study to examine replicability of prior fMRI findings on social feedback processing and aggression in middle childhood (**chapter 2**).

Neural activation during behavioral responses to social feedback

Besides neural activation during social feedback processing, individual differences in aggression regulation can possibly also be explained by neural activation during the aggressive response itself. Neuroimaging studies that differentiated between threat or provocation processing and aggressive, retaliatory responses in adults found similar and distinct neural regions to be involved in both processes (Krämer et al., 2007; Lickley & Sebastian, 2018; Repple et al., 2017; Figure 4). That is, retaliation has been linked to activation in regions involved in emotional reactivity and cognitive control, such as the insula, anterior cingulate cortex, mPFC, orbitofrontal cortex (OFC) and lateral prefrontal cortex (Bertsch et al., 2020; Boccadoro et al., 2021; Dugré & Potvin, 2021; Fanning et al., 2017; Repple et al., 2017). In addition, in line with the idea that responding aggressively to rejection can also feel rewarding (at least in the short term), some studies also report ventral striatum activity during retaliation (Chester et al., 2018). However, neural activation in these regions is not reported consistently across studies (e.g., Fanning et al., 2017; Wong et al., 2019), probably because of differences between paradigms that have been used to evoke frustration and measure retaliatory behaviors. In the SNAT, most neural activation in lateral prefrontal areas and anterior cingulate cortex was found during aggressive responses following positive instead of negative feedback in adults. This possibly reflects inhibition processes as participants also showed most inhibition of aggressive responses in this condition (van de Groep et al., 2021, 2022).

Whether children similarly recruit these regions when inhibiting aggression following social feedback, and whether activation in these regions may also explain individual differences in aggression following feedback is still an open question. Across development, both increases and decreases in activation in regions involved in response inhibition and cognitive control, such as the DLPFC, have been reported (Crone & Dahl, 2012; Crone & Steinbeis, 2017; Luna et al., 2010). As inhibitory processes are still in development, children may use more diverse strategies to refrain from aggression (Crone & Steinbeis, 2017), that may differentially involve neural regions involved in emotion regulation and inhibition. Studying differences between participants with varying ages is a first step in understanding how behavior and neural processes changes with increasing age. However, longitudinal designs can help us additionally understand how behavior changes within participants over time and may therefore be used to capture true developmental change (Herting et al., 2018). This approach allows us to examine stability and change in individuals over time. Therefore, a second aim of this thesis was to study the neural correlates and neural development of behavioral responses to social feedback from childhood to adolescence. I investigated longitudinal development of aggression regulation following social feedback using the three longitudinal MRI waves of the middle childhood cohort of the L-CID study (**chapter 3**).

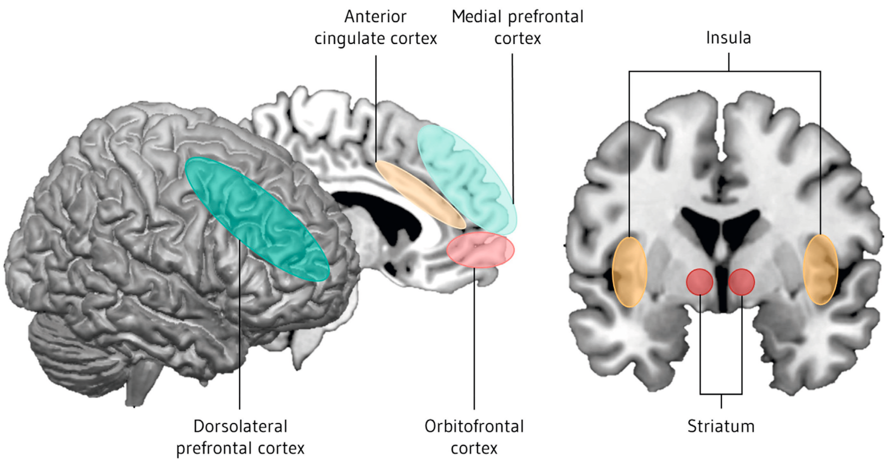

Figure 4. Brain regions implicated in social feedback processing and aggression following social rejection.

Environmental effects on aggression following social feedback

Understanding neural mechanisms may be one potential pathway to understanding differences in aggression regulation between children. However, social behaviors, such as responding to feedback, occur in interaction with others, and are also largely affected by influences in the social environment, such as by peers, friends or parents. Indeed, individual variation in aggression regulation following social feedback (as measured with the SNAT) is mostly explained by environmental, rather than genetic, influences (Achterberg et al., 2018). Parents are one the main social influences in childhood and continue to play a large role in adolescence, even though the opinion of peers and friends becomes increasingly important as well (Nickerson & Nagle, 2005). Parents may impact the regulation of emotions following social feedback and associated responses in several ways, such as through modeling of social behaviors, through parenting practices that may encourage or discourage certain behaviors, and through the emotional climate of the family, including factors such as attachment and parenting style (Morris et al., 2007, 2017). Positive parenting practices, such as parental warmth, sensitivity and support, have been associated with increased prosocial behaviors and effortful control and improved mental health (Day & Padilla-Walker, 2009; Eisenberg et al., 2005; Eshel et al., 2006). Recently, imaging studies have begun to suggest that parenting practices may also affect neural processes related to emotion regulation, although this is still an emerging field of research (Kerr et al., 2019; Tan et al., 2020). To shed light on environmental influences on responses to social feedback, I additionally studied how parents may affect the (neural) development of aggression regulation towards adolescence (**chapter 3**).

The co-occurrence of aggressive and prosocial responses

How one responds to feedback may not only depend on the valence of the feedback (i.e., positive or negative) but may also depend on the receiver of the feedback. Whereas receiving rejection feedback yourself can trigger aggression, observing rejection of others can also trigger prosocial helping behaviors towards the person who is excluded (Masten et al., 2011; van der Meulen et al., 2016, 2018; Will et al., 2013). Originally, aggression ('antisocial') and prosocial behaviors are often viewed as opposite constructs, such that children and adolescents who are aggressive are less prosocial and vice versa (Card & Little, 2006; Obsuth et al., 2015; Padilla-Walker, Memmott-Elison, et al., 2018). However, both aggressive and prosocial behaviors can be the result of rejection and may indicate a certain responsivity to the social environment (Crone et al., 2020). Some children may be more responsive to social feedback for themselves, some may be more responsive to social feedback for others, and others may be responsive to both types of social feedback. The final step in my thesis is to examine the neural responses to social feedback of self and others in combination with behavioral taxonomies, which may give a better view on social responsive behaviors across contexts, and predict developmental outcomes later in time (Crone et al., 2020; Sunami et al., 2019; **chapter 4 and 5**).

Outline of this thesis

The main aim of this thesis is to examine the development, neural mechanisms, environmental influences and developmental outcomes of social competence from childhood to adolescence. The first part of this thesis (**chapter 2 and 3**) is focused on the neural development of aggression regulation following social feedback from middle childhood to early adolescence.

In **chapter 2**, I tested and replicated neural correlates and brain-behavior associations related to both social feedback processing and aggressive responses following social feedback in middle childhood. Additionally, I examined age effects in behavioral and neural responses to social feedback to explore developmental differences in aggression regulation in the ages 7-9 years, the period where regulatory skills rapidly develop (Achterberg et al., 2020; Zelazo & Carlson, 2012). The cohort-sequential design of the L-CID study allowed me to test and replicate these questions in two age-matched cohort samples (test sample: N=512, replication sample: N=360).

In **chapter 3**, I followed up on the age effects reported in **chapter 2**, by investigating the longitudinal behavioral and neural development of aggression regulation from childhood to adolescence. In addition, I examined the effects of parental sensitivity on this development to further understand the role of the social environment in the development of socially responsive behaviors. Together, **chapter 2 and 3** help to shed light on 1) how children deal with social peer feedback in the important transition towards adolescence, 2) why some youth might be more prone to aggression than others, and 3) how parents may support children's adaptation to social feedback.

The second part of this thesis (**chapter 4 and 5**) is focused on individual differences in the co-occurrence of aggressive and prosocial responses following social rejection of self and others, respectively, from middle childhood to early adolescence. In the studies discussed in these chapters, data of two experimental fMRI tasks were combined following the bi-dimensional model of social responsivity (Crone et al., 2020), to test whether studying aggressive and prosocial responses to rejection in combination may be a suitable approach for understanding developmental outcomes, such as wellbeing.

In **chapter 4**, I tested the bi-dimensional model of social responsivity in middle childhood, by examining whether the combination of aggressive and prosocial behavior was a better predictor of internalizing and externalizing problems one year later compared to the separate constructs.

In **chapter 5,** I aimed to bring the forementioned aspects together by studying both development, neural correlates, and developmental outcomes of the co-occurrence of aggression and prosocial responses to rejection. Specifically, I examined stability of subgroups of social responsivity from childhood to adolescence, associations between social responsivity and mPFC activity to social rejection of self and others, and social responsivity as precursor for wellbeing later in adolescence. Together, **chapter 4 and 5** contribute to our understanding of 1) why some youth may be more responsive to social rejection of self and others; and 2) how social responsivity in childhood may promote or hinder developmental outcomes later in time.

Finally, in **chapter 6**, I summarize the main findings of the empirical chapters and discuss the implications and directions for future research.