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

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CHAPTER 6

General Discussion

SUMMARY

The main goal of this thesis was 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, in this thesis I examined this question by empirically examining contextual, environmental and neural factors affecting the development of social competence in several steps. First, I studied the neural correlates of social feedback processing and behavioral responses to feedback in middle childhood using a test-replication design including two independent fMRI samples of N > 195 (**chapter 2**). Second, I examined the longitudinal development of neural and behavioral responses to social feedback from childhood to adolescence (**chapter 3**). Third, I examined parental influences on the development of responding to social feedback (**chapter 3**). Finally, I studied whether individual differences in the co-occurrence of aggressive and prosocial responses to social rejection were predictive of behavioral problems (**chapter 4**) and wellbeing (**chapter 5**) one, three and five years later, and whether aggressive and prosocial responses may be reflected in neural activation during social rejection of self and others (**chapter 5**). In this final chapter of the thesis, the main findings of these studies are summarized, followed by a general discussion including implications and directions for future research.

Neural correlates of social feedback processing and aggression regulation in childhood

In **chapter 2**, I aimed to examine the neural correlates of both social feedback processing as well as of behavioral responses to social feedback in childhood. To disentangle these two processes, I used the Social Network Aggression Task (SNAT; Achterberg et al., 2016), where participants first received positive, neutral or negative peer feedback and subsequently responded to this feedback by sending a noise blast towards the peer. The duration of the noise blast was used as measure of aggression. Consistent with prior behavioral findings (Achterberg et al., 2016, 2017, 2018, 2020; van de Groep et al., 2021, 2022), children were most aggressive following negative feedback, less so following neutral feedback and least following positive feedback. Given that the replicability of fMRI findings has been an ongoing discussion (e.g., Elliott et al., 2020; Turner et al., 2018) and replicability of fMRI findings in childhood is an important direction in developmental neuroscience, I assessed the robustness of neural findings using a test-replication design in two large independent fMRI samples (7-9 years old; test sample: N = 385, replication sample: N = 195).

First, I investigated the replicability of neural activation during social feedback processing in childhood. Replicating prior work by Achterberg et al. (2018, 2020),

results showed that receiving positive and negative feedback compared to neutral feedback resulted in activation in the anterior insula (AI) and medial prefrontal cortex (mPFC). These findings support the notion that these regions signal for feedback that is socially salient, rather than positive or negative. Receiving positive (compared to negative) feedback additionally resulted in activation in the dorsolateral prefrontal cortex (dlPFC). Individual differences in this dlPFC activation during social feedback processing were related to subsequent aggression, such that children with more dlPFC activation during negative feedback showed less aggression following negative feedback. These findings confirm that social feedback processing in the dlPFC plays an important role in aggression regulation in childhood.

Second, the SNAT paradigm does not only allow for an analysis of the immediate neural response to social feedback, but also to the subsequent delivery of aggressive noise blasts. Therefore, a novel question was to test and replicate the neural correlates of aggressive responses following social feedback in childhood. For this question we focused on the noise blast event of the SNAT. In both the test and replication sample, the medial prefrontal regions, i.e., the mPFC and orbitofrontal cortex (OFC), again showed social saliency effects with increased activation during responses following positive and negative feedback compared to neutral feedback. On the other hand, the lateral prefrontal regions, i.e., vlPFC and dlPFC, and insula showed strongest activation during responses following positive feedback and lowest during responses following negative feedback, suggesting that these regions were involved in the inhibition of aggression (e.g., Bertsch et al., 2020; Knehans et al., 2022; van de Groep et al., 2021). Children with stronger dlPFC activation during aggressive responses showed less aggression, and this association was found irrespective of the valence of the feedback. These findings suggest that the neural architecture underlying aggression regulation can be found already in childhood, where the dlPFC might play a regulating role both during social feedback processing and subsequent behavioral responses.

Finally, age analyses revealed that between 7 and 9 years, aggression following negative feedback increased and following positive feedback decreased with age, signaling increased differentiation in responses following negative and positive feedback. Relatedly, DLPFC activation during behavioral responses following feedback increased with age. Interestingly, there were no age effects on neural activation during social feedback processing. Thus, the neural underpinnings of social feedback processing may already largely be present in childhood, whereas the neural underpinnings of the regulation of aggressive responses, especially following positive feedback, are still in development (Casey et al., 2008).

Development of neural and behavioral correlates of aggression from childhood to adolescence

To further increase our understanding of the development of responding to social feedback, in **chapter 3** I followed-up on the age effects reported in **chapter 2**, by investigating longitudinal trajectories of behavioral and neural responses in the SNAT in a three-wave longitudinal fMRI sample spanning middle childhood to early adolescence (7-13 years). Behaviorally, the longitudinal trajectories of aggressive responses differed depending on the valence of the social feedback. Inhibition of responses following positive feedback showed the largest development between middle and late childhood, whereas inhibition of responses to negative feedback showed the largest development between late childhood and early adolescence. In childhood, this inhibition was strongly associated with a large network of neural activation, including the dlPFC, such that children who showed more activation were less aggressive following social feedback. However, the association between inhibition of aggression and neural activation was considerably stronger in middle and late childhood than in early adolescence, indicating changing neural mechanisms in the transition towards adolescence (Crone & Steinbeis, 2017; Luna, 2009; Luna et al., 2015; Ordaz et al., 2013). Thus, these findings highlight the importance of the period between childhood and adolescence for the behavioral and neural development of responding to social feedback.

Parental influences

An additional aim of **chapter 3** was to examine environmental influences, in particular of parental sensitivity, on the development of responses to social feedback. Parental sensitivity is the ability to notice, correctly interpret and adequately respond to a child's signals (Ainsworth et al., 1974), and has been linked to increased prosocial behaviors and effortful control (Day & Padilla-Walker, 2009; Eisenberg et al., 2005; Neppl et al., 2020). I used the Etch-a-Sketch, an observational parent-child interaction task, to assess parental sensitivity in childhood (Cents et al., 2014). Parental sensitivity was stable from middle to late childhood. Moreover, in middle childhood (7-9 years), children of more sensitive parents showed more inhibition of aggressive responses following positive feedback, suggesting that parent and child behaviors affect each other in this developmental phase. However, parental sensitivity was not associated with neural activation, nor was it predictive of aggression regulation later in early adolescence. Possibly, other environmental influences, such as peers, friends and the interplay between different sources of influence, may become of increasing importance in

predicting behavior across development (Blakemore & Mills, 2014; Brown & Larson, 2009; Molleman et al., 2022).

Co-occurrence of aggression and prosocial behavior as precursor for wellbeing

Finally, in **chapter 4** and **chapter 5**, I studied social competence by examining whether children and early adolescents differed in aggression in response to rejection of self and prosocial behaviors in response to rejection of others. Prosocial behaviors are behaviors that benefit others (Eisenberg & Mussen, 1989), such as helping or sharing. I used the SNAT to study aggression in response to rejection and the Prosocial Cyberball Game (PCG; Riem et al., 2013; van der Meulen et al., 2016) to study prosocial behaviors following exclusion of others. The PCG is a four-player ball-tossing game, where each player first received the ball an equal number of times and subsequently one player was excluded by the other two players. The participant could compensate for this exclusion by tossing the ball more often to the excluded player, which was used as measure of prosocial behavior following observed rejection.

In **chapter 4**, I assessed the co-occurrence of aggression and prosocial behavior following rejection of self and others in middle childhood (7-9 years old). Although both behaviors may indicate a certain responsivity to social situations (Crone et al., 2020), aggression following rejection and prosocial behavior following observed exclusion were not associated. Rather, I observed individual differences in whether aggression and prosocial behavior co-occurred, such that some children showed both aggression and prosocial behavior, others only showed one of the two behaviors, and some children were relatively passive in responding to social rejection. When studied separately, aggression and prosocial behavior were not predictive of behavioral problems, but the co-occurrence of both behaviors were. That is, children who were more responsive to rejection of self and others (i.e., who showed more aggressive and/or prosocial) developed fewer externalizing behaviors over a one-year period compared to children who were less responsive. These findings emphasize the importance of studying social competence as an interplay of behaviors across different social contexts.

As a follow-up on **chapter 4**, in **chapter 5**, I studied the co-occurrence of aggression and prosocial behavior as responses to rejection in the transition from childhood to adolescence. On a neural level, we hypothesized that the mPFC might be involved in both behaviors, as it has been related to experiencing social rejection and exclusion (Achterberg et al., 2018; Crone et al., 2020; Davis et al., 2022; van der Meulen et al., 2018) and observing social exclusion of others (Masten et al., 2011; Tousignant et al., 2018). The aims of **chapter 5** were three-fold: 1) examining stability of subgroups

of social responsivity (i.e., the co-occurrence of aggression and prosocial behavior) across childhood and early adolescence; 2) examining whether neural activation during social rejection of self and others was related to social responsivity; and 3) examining whether social responsivity in childhood and early adolescence was predictive of wellbeing later in adolescence. First, there were large transitions between subgroups of social responsivity, indicating low stability of subgroups of aggressive and/or prosocial responses over time. Thus, behavior in middle childhood did not necessarily define behavior in late childhood or early adolescence. Second, I found that children with higher social responsivity in middle childhood showed decreased mPFC activation during social rejection of self, but increased mPFC activation during observed exclusion of others. These findings suggest that responding to social rejection of self and others in childhood is associated with increased neural sensitivity to other-focused processes. Finally, early adolescents who showed higher social responsivity reported higher wellbeing one year later compared to adolescents who showed lower social responsivity. Thus, in addition to being a possible protective factor for behavioral problems in middle childhood (**chapter 4**), social responsivity may also be a promotive factor for wellbeing in adolescence (e.g., Hartl et al., 2020; Hawley, 2003; Rodman et al., 2017).

GENERAL DISCUSSION

To understand why some children more easily adapt their behavior in social situations, social competence should be viewed as a complex interplay between contextual factors, neural mechanisms, developmental processes and social environmental influences (Figure 1). In other words, to understand social competence, it should be studied across multiple dimensions of behavior, across different contexts, in longitudinal designs and using multiple levels of explanation. This thesis aimed to contribute to this understanding by 1) studying the combination of aggression in response to social rejection of self and prosocial behaviors in response to social rejection of others; 2) studying longitudinal development of (inhibition of) responding to positive, neutral and negative social feedback; 3) studying the role of the social environment by examining associations with parenting; 4) using a multi-method approach including experimental tasks, neuroimaging, observational tasks and parent- and self-reported questionnaires.

The studies described in this thesis confirm the complexity of responding to social feedback in three main findings. First, I found that in middle childhood there is a robust neural signature of social feedback processing and aggression regulation, with some neural regions being differentially involved in both processes. Second, I

found that the phase between childhood and adolescence is an important period for the development of responding to social feedback, where regulation of responses following positive, neutral and negative feedback are developing at a different rate. That is, inhibition of aggressive responses following positive feedback showed an earlier development than inhibition of aggressive responses following negative feedback. Third, I found that aggression following social rejection and prosocial behaviors following observed rejection were predictive of behavioral problems and wellbeing one year later, but only when studied as co-occurring behaviors within individuals. Therefore, I argue that to understand mental health outcomes of social competence, it is important to take into account a combination of behaviors across different social contexts (Figure 1). In the following sections, I discuss these three main findings in further detail, and provide directions for future research.

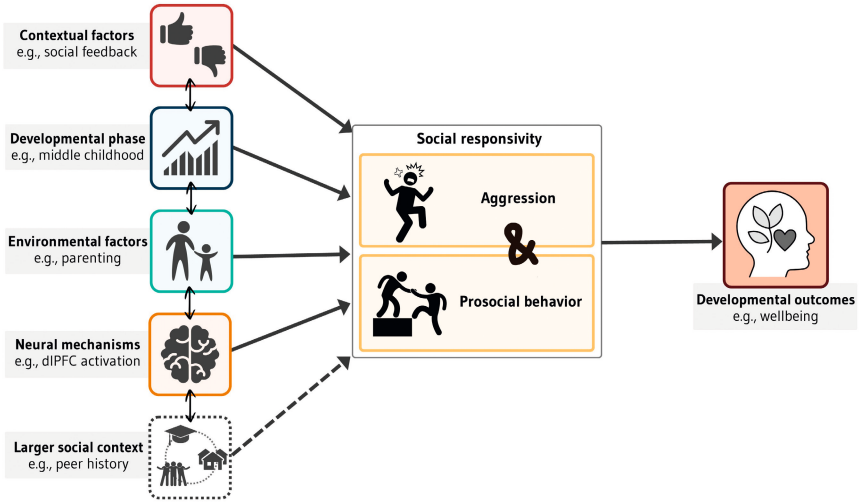

Figure 1. To understand social behaviors such as aggression and prosocial behaviors in childhood and adolescence, it is important to take into account contextual, developmental, environmental and neural factors underlying these behaviors. The combination of these factors and behaviors may explain developmental outcomes later in time, such as wellbeing. Note that even though not displayed, relations can be bi-directional and contextual, developmental, environmental and neural factors may possibly also directly influence developmental outcomes such as wellbeing.

Neural signature of social feedback processing and aggression regulation in childhood

First, by replicating neural findings in an independent sample of 7–9-year-olds, I showed that on a group level there is a robust neural network related to social feedback processing and aggression regulation in middle childhood (**chapter 2**). During social feedback processing, I replicated prior findings indicating the existence of a specific network of mPFC and AI/anterior cingulate cortex (ACC) signaling for socially salient events (Achterberg et al., 2018, 2020; Dalgleish et al., 2017; Davis et al., 2022). The AI/ACC has previously been found to respond to expectancy violations (Somerville et al., 2006) and behaviorally relevant signals (Han et al., 2019), and the mPFC has been implicated in thinking about the thoughts of others (Blakemore, 2008; Blakemore et al., 2007; Frith & Frith, 2006). Possibly, receiving both positive and negative feedback could feel surprising, elicit a response tendency and make children wonder about the other's thoughts or reasoning. During behavioral responses to feedback, medial prefrontal regions (i.e., mPFC and OFC) still showed social saliency effects during responses to positive and negative feedback. In contrast, and in line with prior findings in adults (van de Groep et al., 2021, 2022), lateral prefrontal regions (i.e., vlPFC and dlPFC) showed most activation during responses to positive feedback. Given that in general noise blast durations were shortest following positive feedback, increased lateral prefrontal activation may be indicative of inhibition or cognitive control processes, a function often reported in non-social tasks (Blasi et al., 2006; Cai et al., 2016; Jacobson et al., 2011). This distinction between medial and lateral prefrontal activation corresponds to prior models suggesting that the medial prefrontal regions may be involved in internalized processes, such as the monitoring of negative feedback, surprise or rewards, and the lateral prefrontal regions subsequently implements specific regulation or control of responses (Crone & Steinbeis, 2017; Shenhav et al., 2016). The findings in this thesis support the presence of a similar distinction during aggression regulation in childhood.

Second, the findings of **chapter 2** also underscore the importance of studying neural correlates of social feedback processing and behavioral responses as separate components of aggression regulation. For instance, whereas the anterior insula showed social saliency effects during positive and negative feedback processing (Achterberg et al., 2018, 2020; Dalgleish et al., 2017; van de Groep et al., 2021), during behavioral responses it showed most activation following positive feedback, possibly indicating a role in inhibition processes (Brass & Haggard, 2007; Swick et al., 2011). Because of its flexible function, the AI has also been labeled the 'gatekeeper' of executive control (Molnar-Szakacs & Uddin, 2022). The foundations for this gatekeeper function have

been found in childhood, as the AI has been linked to global executive functioning in non-social contexts, especially in situations that are more cognitively demanding (Cai et al., 2019; Engelhardt et al., 2019; Molnar-Szakacs & Uddin, 2022). This thesis extends this work by suggesting a similar role in social contexts, specifically when inhibiting aggressive responses following positive feedback.

A difference between social feedback processing and behavioral responses was also observed in brain-behavior analyses on individual differences between children. In line with the view that the lateral prefrontal cortex works as a key region for response regulation by directing attention and selecting strategies from working memory (Bertsch et al., 2020; Silvers & Guassi Moreira, 2019), children with stronger dlPFC activation consistently showed less aggression. However, the specificity of the function of the dlPFC may depend on the specific event of aggression regulation. For dlPFC activation during social feedback processing the relation with noise blast duration was found only when receiving negative feedback, whereas during behavioral responses the relation was found irrespective of the type of feedback children received. This suggests that in childhood, at the moment of receiving negative feedback, the dlPFC might be involved in emotion regulation strategies, such as distraction (Zhao et al., 2021) or the capacity to reappraise an emotional stimulus (Dörfel et al., 2014; Golkar et al., 2012; Silvers & Guassi Moreira, 2019), but when subsequently responding to the feedback the dlPFC might be involved in more general inhibition strategies, or effortful tasks (Bertsch et al., 2020; Blasi et al., 2006). Because the SNAT does not differentiate between different emotion regulation strategies or motives, including a manipulation involving specific emotion regulation strategies in future research may further shed light on the specific role of the dlPFC when children receive and respond to social feedback (Bertsch et al., 2020). Together, this thesis emphasizes the existence of a robust neural mechanism underlying aggression regulation following social feedback already in middle childhood, as well as the importance of studying neural correlates of different components of aggression regulation separately.

The transition between childhood and adolescence as important period for the development of social competence

Although neurodevelopmental models often focus on neural, social and behavioral changes in adolescence (Blakemore, 2008; Casey et al., 2008; Nelson et al., 2005), I argue that the period leading up to adolescence is important for the behavioral and neural development of social competence. Even in a small age range of two years (7-9-year-olds), we observed developmental effects indicating inhibition of aggressive responses and concurrent neural activation in medial and lateral prefrontal cortex increased with age (**chapter 2**), highlighting the rapid development of responding to

social feedback already in childhood (Achterberg et al., 2020; Zelazo & Carlson, 2012). This inhibitory development following social feedback continued in adolescence, in line with general inhibitory control development (Luna et al., 2010; Zelazo & Carlson, 2012). However, developmental trajectories were distinctive for responses to positive, neutral and negative feedback, with inhibition following positive feedback developing earlier than inhibition following negative feedback (**chapter 3**). Interestingly, the largest differentiation in behavioral responses to positive and negative feedback was observed in late childhood, the period when children learn to internalize fairness principles (House, 2018; McAuliffe et al., 2017; Smith et al., 2013). In this period, it may feel fair to respond aggressively to rejection, but not to acceptance feedback. Indeed, prior research shows that behavior of children around ages 8 years are strongly influenced by fairness norms (Meuwese et al., 2015). When transitioning into adolescence, aggressive responses following negative feedback decreased (Cui et al., 2016; Fite et al., 2008), possibly accompanied by socio-cognitive development such as perspective taking skills (Blakemore & Mills, 2014; Crone, 2013) and an increased need for social belonging to the peer group (Blakemore & Mills, 2014). These findings again stress the importance of taking contextual factors into account when studying social development.

Together, the studies in this thesis show that it is important to focus on the period between childhood and adolescence in future neurodevelopmental models of social behaviors, as this is the period where the role of the dlPFC when responding to social feedback may change. In middle and late childhood, children with more dlPFC activation during behavioral responses were less aggressive, but this relation became considerably smaller towards adolescence. This is consistent with studies showing decreased recruitment during cognitive tasks across development (Booth et al., 2003; Crone & Dahl, 2012; Ordaz et al., 2013) and with adult studies where neural activation was also not related to behavior (van de Groep et al., 2021). It is possible that inhibition becomes less effortful over development (Ordaz et al., 2013) and inhibition strategies may become more goal-directed and localized in the brain (Crone & Steinbeis, 2017). Interestingly, these findings tentatively suggest that already in early adolescence the dlPFC may play a similar role in inhibition following social feedback as in adulthood, a finding often reported for more basic non-social cognitive functions instead of complex strategic cognitive control (Crone & Steinbeis, 2017; Zelazo & Carlson, 2012). Given that neurodevelopmental models such as the imbalance model (Casey et al., 2008) emphasize that prefrontal regions implicated in cognitive control show a protracted development in adolescence, future studies may aid the interpretation of the role of the dlPFC by following the participants in this study as they develop through adolescence.

Predicting mental health outcomes by a combination of behaviors across contexts

My final goal was to investigate whether mental health outcomes in childhood and adolescence could be predicted by the co-occurrence of aggression following social rejection of self and prosocial behavior following social rejection of others. This was inspired by a leading model suggesting that developmental outcomes can be predicted on the basis of co-occurring developmental processes (Blankenstein et al., 2020; Crone et al., 2020; Do et al., 2017). The combined occurrence of aggression and prosocial behaviors in response to rejection is referred to as social responsivity. Results revealed that in middle childhood, children with higher social responsivity showed decreased externalizing behaviors one year later compared to children with lower social responsivity (**chapter 4**). Interestingly, this effect was not found when studying aggression and prosocial behavior separately, indicating that it is important to investigate social behaviors across different contexts in order to understand developmental outcomes. In early adolescence, higher social responsivity was associated with higher personal wellbeing one year later (**chapter 5**). These findings suggest that in addition to being a possibly protective factor against the development of behavioral problems in childhood, social responsivity may also be a promotive factor for wellbeing in adolescence. Thus, in contrast to prior findings highlighting more problematic outcomes of reactive aggression (Card & Little, 2006; Evans et al., 2021), I found that in response to social rejection, aggression may not always be maladaptive, as long as it is combined with prosocial behaviors in other contexts. These findings add to prior work showing that aggressive and prosocial strategies can both be used to achieve social goals (Hawley, 1999, 2014), and that children and adolescents who show both type of behaviors are well-adapted among peers (Hartl et al., 2020; Hawley, 2003). Possibly, both aggressive and prosocial responses to rejection can contribute to positive self-views (Grant & Sonnentag, 2010; Rodman et al., 2017) and flexibly adapting responses depending on the social context may help build social relations.

It is important to note that wellbeing in adolescence was only predicted by social responsivity in early adolescence (i.e., on a one-year period), but not by social responsivity in middle or late childhood. This may possibly be explained by the low stability of responsivity between childhood and adolescence, which indicated that behavior in childhood was not necessarily predictive of behavior in adolescence. For instance, between childhood and adolescence, more than 80% of participants changed subgroups of social responsivity at least once (**chapter 5**). In addition, relatively low stability was also observed in the intraclass correlation coefficients of

neural and behavioral responses to feedback in the longitudinal sample (**chapter 3**). Both findings may at least partly be explained by developmental changes across time (Herting et al., 2018). In addition, functional MRI and experimental tasks such as the SNAT generally show lower test-retest reliability than brain structure and trait-like measures such as questionnaires (Elliott et al., 2020; Enkavi et al., 2019; Heckendorf et al., 2019; Herting et al., 2018; Zondervan-Zwijnenburg et al., 2022), but are also more suitable to study context-dependent behaviors such as responses to different types of feedback. Although for a subgroup of children, aggression may develop early in life and remain stable across development (e.g., Campbell et al., 2006; Harachi et al., 2006), this thesis supports the notion that for most children, responses to social feedback are still in development and not fixed yet and these behaviors may possibly be promoted through environmental influences, such as parenting behaviors (**chapter 3**).

FUTURE DIRECTIONS

Based on the main findings in this thesis, I address three important considerations for future research on social competence development in childhood and adolescence.

Social motivations and internalizing behaviors following social feedback

First, this thesis was focused on aggressive and prosocial responses to social feedback, which are behaviors that are directed outwards. However, receiving negative feedback can also result in withdrawal or internalizing behaviors. Prior research showed that early adolescents internalized peer rejection more and showed higher levels of anxiety following exclusion than adults (Rodman et al., 2017; Sebastian et al., 2010). Moreover, both increased neural activation to rejection and reduced neural activation to social reward have been linked to depressive symptoms and internalizing disorders (Kujawa et al., 2017; Rappaport & Barch, 2020; Sequeira, Silk, Hutchinson, et al., 2021; Silk et al., 2014). In this thesis, the finding that higher mPFC sensitivity to social rejection was associated with less social responsivity also suggests that neural sensitivity to social rejection may be associated with more passive, possibly internalizing behaviors (**chapter 5**). However, internalizing or withdrawing behaviors were difficult to assess with the experimental tasks used in this thesis, because participants were instructed to always respond, either by sending a noise blast or tossing the ball to another player. Given that adolescence is a sensitive period for the onset of socio-emotional disorders (Kessler et al., 2001; Rapee et al., 2019) and internalizing symptoms may have even increased during the Covid-19 pandemic (e.g., Achterberg et al., 2021; Green, Becht, et al., 2023), it is important in future studies to address differences in responses

that are directed outwards (e.g., aggression and prosocial behaviors) and inwards (e.g., withdrawal or decreased mood) when receiving social feedback. Additionally, future studies may include measures of social motivations underlying aggression and prosocial responses to feedback. Similar behavioral responses may rely on different motivations. For instance, refraining from prosocial compensating behavior in the PCG may be due to a lack of noticing the exclusion of the other player, due to the feeling that the exclusion was deserved or due to not wanting to risk getting rejected yourself. Understanding these social motivations for responding aggressively or prosocial to feedback may be helpful in further explaining individual differences and mental health outcomes.

Larger social context of responding to social feedback

Second, in this thesis I took a first step in predicting mental health outcomes by studying a combination of social behaviors in different contexts, such as when receiving feedback for oneself or for others. To further increase our understanding of why some children are more responsive to feedback, and how this relates to wellbeing, it is important that future studies take into account prior experiences and larger social contextual influences. Prior peer experiences such as a history of peer victimization have been linked to rejection sensitivity (e.g., Calleja & Rapee, 2020; Kellij et al., 2023) and may alter behavioral and neural responses to social feedback (Kiefer et al., 2021; Rudolph et al., 2021). Furthermore, sociometric approaches can be used to study how social peer status and friendships may be related to aggressive or prosocial responses to social feedback (Cillessen & Rose, 2005; Güroğlu & Veenstra, 2021). Finally, aggressive and prosocial behaviors may be viewed in social networks (e.g., Pinho et al., 2021; van den Bos et al., 2018) or the larger socioeconomic context in which a child grows up (Bukowski et al., 2020; Chen et al., 2021; Greitemeyer & Sagioglou, 2018; Sheridan et al., 2017). Possibly, aggression may be considered a more adaptive coping strategy (at least on the short term) in harsh or adverse environment compared to more supportive environments. Besides parenting behaviors, future studies may integrate measures of socioeconomic hardship, early life adversity and prior peer experiences to shed light on what may be most adaptive behaviors for whom (e.g., Ellis et al., 2022; Ellis & Del Giudice, 2019).

Bridging science and society: transdisciplinary research to answer broader societal questions

In this thesis I argue that understanding social competence requires a rich understanding of social contextual, developmental, neural and environmental processes. Laboratory settings provide an important set-up to study these processes, for example in experimental tasks and longitudinal neuroimaging designs. However, to address large societal questions such as how children grow up to become thriving individuals, in the future we may have to look further than the laboratory setting. Taking a transdisciplinary approach, by combining scientific knowledge with knowledge from society to approach a socially relevant issue (Pohl, 2011), can be an important step forward to answer these questions (Vandenbroucke et al., 2021). For example, in the school context, where many peer interactions take place in childhood, teachers are experts on social development (Farmer et al., 2011). Teachers' perspectives on social development and child wellbeing can be integrated with scientific research by involving them throughout the scientific research cycle. This may include exploring teachers' perspectives on factors influencing social competence, involving teachers in the data collection, interpreting results together and thinking about implementation of scientific findings. In this way, societal partners such as teachers may be able to enrich scientific knowledge with knowledge observed in daily life that is difficult to capture in experiments, which may in turn help the implementation of scientific knowledge into daily practice. Similarly, the involvement of youth in scientific research may help researchers ask and answer the right questions regarding social development and wellbeing, while similarly providing youth with opportunities to contribute (Fuligni, 2018; Green, van de Groep, et al., 2023; te Brinke et al., 2022; Whitmore & Mills, 2022). Thus, future studies can incorporate a citizen science approach, where societal partners are involved throughout the research process, in order to integrate knowledge from science and society on social development (Figure 2).

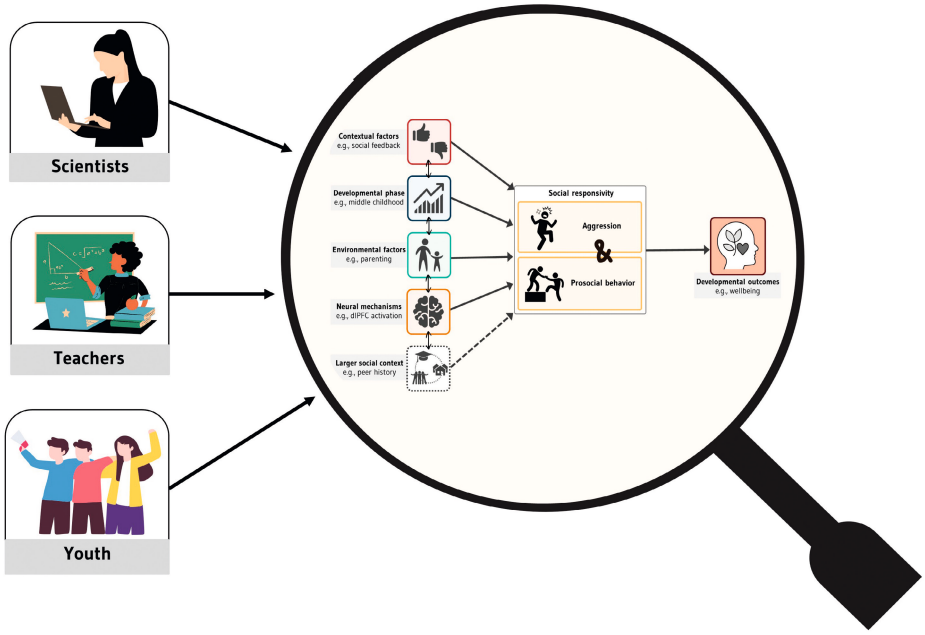

Figure 2. Combining perspectives of scientists and societal partners, such as (but not limited to) teachers or youth, on social competence and developmental outcomes can aid in broadening our knowledge and answering large societal questions.

CONCLUSION

This thesis focused on individual differences in social competence from middle childhood to early adolescence by integrating contextual, developmental, neurobiological and environmental influences on aggressive and prosocial responses to social feedback. I showed that robust neural processes related to social feedback processing and to behavioral responses to social feedback are present already in middle childhood (7-9 years). Moreover, this thesis revealed that between middle childhood and early adolescence, inhibitory responses following positive, neutral and negative feedback follow differential longitudinal trajectories. On a neural level, involvement of the dlPFC in this inhibitory development was strong in childhood, but decreased over time. These findings highlight the importance of the transitional period between childhood and adolescence for social competence development and suggest that future research and neurodevelopmental models on social development (e.g., Casey et al., 2008; Nelson et al., 2005) should include an additional focus on the period leading up to adolescence. Finally, this thesis showed that the co-occurrence

of aggressive behaviors in response to rejection and prosocial behaviors in response to rejection of others may possibly aid in protecting against externalizing behaviors in childhood and in promoting wellbeing in adolescence. Therefore, I propose that in order to understand individual differences in mental health outcomes across development, it is important to not only focus on separate psychological constructs but to take into account the interplay of developmental processes across different social contexts. Unraveling the complexity of social behaviors by understanding the interplay of developmental, biological and environmental processes can be a starting point for supporting children and adolescents in becoming social and resilient members of society.