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**The Interplay of Parent-Adolescent Relationship and Adolescent
Self-Esteem Levels: The Mediating Role of the Neural Self-
Concept Evaluation**

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ABSTRACT

This study examines the relationship between secure parent-adolescent relationships and self-esteem in adolescents, considering the potential mediating role of medial prefrontal cortex (mPFC) activation during domain-specific self-concept evaluations. Secure parent-adolescent attachment is known to contribute positively to self-esteem in adolescents. However, this study delves deeper by exploring the influence of family interaction and mPFC activation on self-esteem during self-concept evaluations of prosocial traits, physical appearance, and academic domains. The results confirm a direct positive link between secure parent-adolescent attachments and high self-esteem, consistent with prior research. Secure attachment equips individuals with stress-coping and emotion regulation skills, supporting positive self-esteem during adolescence. Emotional support from parents alone did not significantly impact self-esteem, suggesting the importance of considering other factors such as peer relationships. Regarding mPFC activation, the findings are nuanced. mPFC activation did not mediate the relationship between attachment or parenting style and self-esteem during prosocial self-concept evaluations. Positive correlation was observed between mPFC activation during prosocial behaviour and overall self-esteem, expanding our understanding of neural mechanisms in self-concept evaluation in the context of prosocial behaviour and its impact on adolescent self-esteem. Similarly, mPFC did not mediate the relationship between attachment or parenting style and self-esteem during academic or physical self-concept evaluations, prompting further exploration of neural mechanisms and external influences. This study enhances our understanding of attachment, self-concept neural processes, and self-esteem in adolescence, emphasizing secure parent-adolescent attachments and shedding light on emotional support dynamics.

Keywords: Adolescence, parent-adolescent, self-esteem, neural self-evaluation, mediating factors

Chapter 1: INTRODUCTION

Adolescence, spanning from 10 to 24 years of age, is a phase of life characterised by significant emotional, hormonal, and cognitive challenges (Blackmore et al., 2010; Moretti & Peled, 2004; Sebastian et al., 2008; Weil et al., 2013). These challenges encompass a broad spectrum, ranging from emotional and cognitive development to hormonal changes. The transition from childhood to adulthood is a critical phase in the formation of one's identity, as well as a time of change (Wu, 2009). It is at this period that some health-related issues such as depression (Twenge & Nolen-Hoeksema, 2002), body image issues (Voelker et al., 2015), antisocial and delinquent behaviour (Moffitt, 1993, 2003), and school dropout (Choi, 2005) may emerge or worsen. Past and current research has consistently shown that higher levels of self-esteem across adolescents are associated with more positive developmental outcomes, such as being a healthy and positive adult (Povedano-Diaz et al., 2020). While some studies suggest that self-esteem increases during adolescence (Chiam, 1987; O'Malley & Bachman, 1983), others concur that self-esteem falls during this time (Robins & Trzesniewski, 2005; Casale, 2020). Recent evidence suggests that self-esteem, the perception of one's self-worth, is a multifaceted construct with both stable and dynamic components (Harter, 2006). Trait self-esteem represents an individual's enduring and relatively constant assessment of their self-worth over time (Brown & Marshal, 2006). It serves as the foundational baseline upon which a person's self-concept is built and tends to remain consistent across various life stages. In contrast, state self-esteem reflects the transient fluctuations in self-esteem that individuals experience in response to specific situations or events. State self-esteem is highly context-dependent and can rise or fall based on how a person perceives their performance or social interactions in each moment (Brown & Marshal, 2006; Pyszczynski & Cox, 2004). Notably, research, such as Birkeland et al. (2012) and Hank & Baltes-Gotz (2019), has highlighted that overall self-esteem remains relatively stable throughout adolescence, suggesting that trait self-

esteem plays a central role during this developmental stage, while changes in state self-esteem are primarily influenced by individual differences in self-esteem traits (Brown & Marshal, 2006; Hank & Baltes-Gotz, 2019). Different factors have been proposed as predictors of an individual's variability of self-esteem levels, including attachment types (Harter, 1990; Allen et al. 1998; Jamil et al., 2020) and self-concept development (Baudson et al., 2016). Attachment is the affective relationships that individuals form with their caregivers in the early stages of their life, and attachment theory aims to explain these relationships (Bowlby, 1982, Ainsworth, 1969). Attachment can be secure or insecure, and it is suggested to influence how individuals come to form the concept of the self (Emery et al., 2008; Kawamoto, 2020). The concept of the self, otherwise known as self-concept, is the understanding and convictions about all the characteristics that form a person's identity (Baumeister, 1999). The effective development of self-concept is important during adolescence since it forms the base of an individual sense of self-esteem, and therefore the foundation for mental well-being development in adolescents (Yang & Brown, 2016; Wilkinson & Parry, 2004).

Despite the reported evidence on the influence of attachment and parenting styles on adolescent self-esteem, research has not provided a clear explanation for what could mediate this relationship. There is still a need to understand how adolescent-parent relationships evolve to lead to higher or lower self-esteem levels during adolescence. Based on attachment theory and studies on self-esteem and self-concept, it could be predicted that securely attached adolescents may have better self-esteem due to their positive self-concept evaluation than insecure-attached adolescents. On the other hand, research is still trying to understand when and how changes in self-concept occur during adolescence, what factors promote good self-concept development, and how self-concept may lead to self-esteem levels in adolescents.

While most studies on self-concept have been behavioural, recent developmental neuroimaging research has begun to investigate the brain underpinnings of self-evaluation in

adolescents. According to these findings, adolescence is a time of ongoing self-development and a maturing mental state (Sebastian et al., 2008; Pfeifer et al., 2009; Harter, 2012; Fuhrmann, et al., 2015). Research has found increasing activity in prefrontal cortex (hereafter PFC), such as the medial prefrontal cortex (hereafter mPFC), a significant brain area for self-evaluation, that may lead to increased emotional worth and self-relevance in adolescence (Pfeifer et al., 2009; Roy et al., 2012; Denny et al., 2012; Somerville et al., 2013; Van der Aar et al., 2019). The mPFC may therefore play a crucial role in the development of adolescents' self-concepts as it appears to be linked to self-referential emotional processes (Sebastian et al., 2008; Roy et al., 2012; Crone et al., 2022; van der Crujisen et al 2023; Levorsen et al., 2003). The current study expands on these findings by examining whether higher or lower mPFC activation during functional magnetic resonance imaging (hereafter fMRI) tasks-related positive or negative self-concept evaluation may act as a mediation effect explaining the link between adolescent-parent relationships and adolescent self-esteem levels.

1.1. Attachment and Parenting Styles

One of the foundations and models upon which we build future relationships with others and with ourselves is constituted by the nature of our primary attachment to our caregivers in our initial years of life (Bowlby, 1982, Ainsworth, 1969). According to Bowlby (1982), attachment relationships are crucial for survival, physical, and emotional development, allowing a child to establish their way of being and related to their surroundings throughout development. The parent's sensitivity and availability, as well as their ability to respond to the child's demands and regulate their emotions, will be decisive in establishing a bond with their child (Ainsworth, 1963; Zeegers et al., 2017). Security is increased when a child believes that their attachment figure will be there for them and that they will respond appropriately if a threat arises (such as separation) (Ainsworth, 1963; Bowlby, 1982; Zeegers et al., 2017). By contrast, early contacts with inaccessible, unresponsive, and/or inconsistent attachment figures increase

a child's risk of developing an insecure attachment (Debbane et al., 2017; Ainsworth, 1978). The security or insecurity of the attachment relation is an enduring factor that maintains its influence over time, persistently affecting an individual's socio-emotional, behavioural, and cognitive development throughout their life span (Debbane et al., 2017).

Parent-child interactions are organised in terms of goal-oriented collaboration that begin in childhood and continue through adolescence, as adolescents continue to use their parents as a solid platform to increase their growing autonomy (Allen, 2008; Shumaker et al., 2009). Studies demonstrate that a well-established relationship based on communication and understanding between adolescents and their attachment figures is vital for the adolescent's free exploration (Allen et al., 2003; Bernier et al., 2005; Allen et al., 2003; Moretti & Peled, 2004; Doyle & Moretti, 2000). A stable link formed between parent-child at an early age and maintained throughout the adolescent period, facilitates the development of cognitive, social, and emotional competence in adolescents, just as it does in early childhood (Allen et al., 2003; Allen et al., 1998; Bernier et al., 2005; Moretti & Peled, 2004). When adolescents experience nurturing and positive caregiving, emotional accessibility from their caregivers, and receive clear and well-informed communication, they tend to develop a more favourable self-image (Gniewosz et al., 2015; Babore et al., 2016). However, stress-related improvements or declines in the parent-adolescent relationship can cause attachment status to change (Waters et al., 2000; Weinfield et al., 2004). If attachment figures reject or fail to comprehend and provide comfort in stressful moments for their children during their adolescence period, the adolescent develops an internal processing model of the parent as rejecting as well as an image of themselves as unworthy of support and comfort (Bretherton, 1985). As a result, the adolescent would seek to create distance from their parents and from those around them through avoidance and ambivalent behaviours (Moretti & Peled, 2004). A recent study found that avoidance and ambivalence behaviours, which are aspects of insecure attachment style, led to the dissociation

of the self, and this in consequence predicted lower self-esteem (Borondo & Oliver, 2021). Other studies have found that positive changes in the relationship between parents and their children may also contribute to a change in self-perception (Nezlek & Plesko 2001). Compared to those who have an insecure attachment style, those who have a secure attachment style are more likely to have a better self-concept, higher self-esteem, and fewer psychiatric issues (Nishikawa et al., 2010).

Since attachment can update itself to adapt to changing environmental demands and to generate more functional or adaptive behaviours for the child (Lewis et al., 2000; Allen et al., 2004), adolescents' security can be linked to actual caregiver-adolescent relationship features, which can provide insight into the proper functioning of the attachment system in crucial interactions during adolescence (Allen et al., 2003; Allen et al., 2004). In turn, this window may aid in illuminating the mechanisms by which adolescents' security is transformed into the many functional outcomes with which it has been associated, such as developing a good sense of self-esteem (Allen et al., 2003).

1.2. Self-Esteem in Adolescence

Self-esteem reflects an individual's understanding and perceptions of themselves, as well as their feelings of acceptance and worth (Rosenberg, 1965; Baumeister, 1993). For adolescents to know themselves, feel secure in who they are, and recognise their values, a good sense of self-esteem is essential. Self-esteem has historically been thought of as being universal, unidirectional, and unaffected by sources of influence such as a person's personality or the environment in which they live, especially the influence of close connections. Prior research, however, has shown that a solid attachment to parents may act as a stress-relief mechanism, promote social skills, and increase self-esteem (Harter, 1990; Wilkinson & Parry, 2004).

According to studies, one-third to half of adolescents experience low self-esteem, especially in the first few years of adolescence (Harter, 1990; Hirsch & DuBois, 1991). Low self-esteem can result in an array of issues, such as depression, anorexia nervosa, criminality, self-inflicted injuries, and even suicide (Twenge & Nolen-Hoeksema, 2002; Gillon et al., 2003; Donnellan et al., 2005; Trzesniewski et al., 2006). Some of these issues may be transient. Low self-esteem in adolescents may also increase the likelihood of poor academic performance (Birkeland et al., 2012; Noronha et al., 2018). The directionality of causation, however, is unclear, and researchers are still working to discover the key variables that lead to low self-esteem while also aiming at identifying the domains of competence that are crucial to adolescents (Harter, 2012; Hassan et al., 2016). The quality of adolescent interactions with their parents and friends can have a substantial impact on how confident they feel in themselves and how they behave (Raja et al., 1992; Luke et al., 2004; Keizer, 2019), especially as they work to become independent of their attachment sources (Rosenberg, 2015). According to previous literature reviews, adolescents feel safe when they have a positive parental connection, and this is highly correlated with how much they value themselves (Sim & Yow, 2011). Adolescents' perceptions of parental alienation have been suggested to lead to a more insecure attachment style and decreased self-esteem (Ben-Ami & Baker, 2012). In a study of 213 adolescents between the ages of 12 and 19, it was found that the effectiveness of the connections that the adolescents had with their parents strongly influenced the levels of life satisfaction and self-esteem that they experienced (Greenberg et al., 1983). Later studies also reported similar findings (Dhal et al., 2007; Lee & Hankin, 2009; Parker & Benson, 2005). Furthermore, past research has suggested that identifying the domains that adolescents care about is crucial for heightening their self-esteem (Wild et al., 2004). Academic achievement (Virtanen et al., 2016), physical appearance (Harter, 2006), and social interactions (Harter,

1990) have been indicated to have a significant impact on self-esteem and having a positive self-concept in these domains may be important for high self-esteem levels during adolescence.

1.3. Self-Concept in Adolescence

Attachment style, in addition to self-esteem, is crucial for the development of self-concept. Self-concept is defined as a complex and dynamic system of conscious and unconscious cognitive, behavioural, and social beliefs that a person holds to be true about themselves, each belief having a corresponding value (Massenzana et al., 2017; Harter, 2012). Self-concept has a differential aspect in that it primarily uses the elements that each individual thinks to be distinct and serves to identify oneself in front of others, and it is in this sense that it plays a critical role in daily life (Moreno, 2007), as well as being critical for the development of personality and identity (Crone & Fuligni, 2020), as it is socially tied to how the individual feels. Self-concept develops naturally in individuals as a result of the pervasive and natural process of self-awareness and self-evaluation (Gecas, 1982; Turner & Onorato, 1999). From the self-concept that a person has, the level of self-esteem is derived (Marsh & O'Mara, 2008; Manning et al., 2006). These two factors interact but the key distinction between self-esteem and self-concept is that self-esteem is an evaluation of one's self-concept, or what one already knows about oneself, and is thus a component or aspect of self-concept (Marsh et al., 2006; Massenzana et al., 2017). These judgments—descriptive and evaluative—about oneself are developed through experiences and constant interactions with the environment (Cardenal & Fierro, 2003; Marsh et al., 2006), as well as through one's reactions and those of others (family, society, and peers) (Manning et al., 2006). Reactions to events are generalised with the main identity verb, the verb to be. Once a belief system is formed, the experiences are translated into: "I am..." or "I am not..." It also assumes absolute adverbs: "always...", and "never". Different longitudinal studies have found that those various aspects of self-concept (such as

academic self-concept: “I am a good student”) can contribute to subsequent self-esteem (Marsh et al., 2006; Trautwein et al., 2006; Arens et al., 2019).

In the development of the self-concept, adolescence in particular marks a turning point. The basic attachment to significant caregivers is fundamental in the formation of the adolescents’ self-concept and in the detection of the level of self-esteem, as well as in the methodology to develop it (Wu, 2009; Kawamoto, 2020). The way adolescents keep developing knowledge of themselves and their qualities will be influenced by their relationship with their attachment figures and have an impact on the adolescent's behaviour, attitudes, and attempts (Bretherton & Munholland, 2008; Nie et al., 2016). It has been suggested that different attachment styles lead to differences in self-perception and evaluation (Wu, 2009; Kawamoto, 2020). Earlier research found that positive parenting, which is an effective parent-adolescent relationship, may positively influence the adolescent’s personal development in terms of both a more positive self-representation (that is, a stronger positive self-concept) and a more positive model of others (i.e., stronger positivity of interpersonal relations (Moretti & Peled, 2004; Brumariu, 2015; Mikulincer & Shaver, 2004; Allen et al., 2003). In contrast, it was found that people with an insecure type of attachment (avoidant or ambivalent) had a distorted sense of who they were (Dozier & Lee, 1995). Therefore, understanding the intricate interplay between attachment, self-concept, and self-esteem is vital for fostering healthy development during adolescence.

1.4. Neural Correlates of Self-evaluation in Adolescence

In the last 10 to 20 years, there has been a rising interest in understanding the physical, behavioural, and cognitive changes that occur during adolescence (Blackmore, 2012; Steinberg, 2010; Crone & Dahl, 2012) and how these changes are related to the development of self-evaluation in adolescence (Elder et al., 2023; Crone et al., 2020). Adolescence marks the onset of diverse physical attribute development (Crujisen et al., 2023; Crone & Fuligni,

2020). Previous cross-sectional studies revealed that a positive self-evaluation of one's own physical traits was positively correlated with growing children and early adolescents' good sense of self-esteem, suggesting that physical self-concept may be a crucial element in adolescents' self-esteem (Dishma et al., 2006; Martin-Albo et al., 2012; Lu et al., 2015). In addition to physical changes, adolescence is also marked by changes in social environment (Fuhrmann et al., 2015; Crone & Dahl, 2012). As previously discussed, adolescents' relationship with their attachment figures remains important during this transition from childhood to adulthood, starting from birth (or even during prenatal development). However, at the same time, other social influences, such as peer relationships, also become important for the adolescent's construction of their own (self) identity and comparison with others concerning their self-perceptions (Debanne et al., 2017; Crone & Dahl, 2012). One specific characteristic that has been studied among adolescents is the notion of prosocial behaviours, which is fundamental in adolescents when it comes to building relationships with other people outside the confines of the home environment (Pakaslahti et al., 2002; van Hoorn et al., 2016). Adolescent prosocial behaviour is defined as any behaviour that benefits other young people through acts of assistance, cooperation, and solidarity (van Hoorn et al., 2016; Fuligni, 2019). Young people go through their first social experiences at this age, which impacts how they develop as individuals as adolescents (van Hoorn et al., 2016; Fuligni, 2019). Prosocial behaviour has a key part in the emotional, and physical well-being, and academic success of adolescents as it is tightly linked to positive self-evaluation, which in turn influences the adolescent's levels of self-esteem (van Hoorn et al., 2016).

According to past and recent studies, major changes in brain structure and function occur during this period of life as well. The neural correlates of self-evaluation in adolescence have garnered considerable attention from researchers seeking to unravel the intricacies of the adolescent brain. This exploration delves into the neural structures and networks associated

with self-evaluation during adolescence, shedding light on how the brain processes self-related information. In doing so, research has illustrated that the PFC is one of the last parts of the brain to mature (Blackmore, 2012). Recent developmental studies have shown that part of the PFC namely the mPFC undergoes dynamic changes in both its structural components and connectivity, particularly during adolescence (Shaw et al., 2008). Furthermore, research has also revealed that the mPFC plays a pivotal role in processes related to social cognition and emotional appraisal (Blakemore, 2008; Araujo et al., 2013; Wagner et al., 2012). Although the mPFC is commonly thought of as specialised for social cognition, developing theoretical approaches have identified common recruitment of the mPFC during situations that depend on affective appraisal and assessment of relevance to the self (Denny et al., 2012; Murray et al., 2012), in response to both direct and reflected evaluation in children (Chen et al., 2021), adolescents, and adults (Pfeifer et al., 2009). These studies have looked at self-concept attitudes that are grounded in subjective descriptions of a person's traits, such as "being attentive or collaborative," rather than objective realities, like "having brown eyes" (Pfeifer et al., 2009). Typically, self-evaluation attitudes are examined by asking people to rate how well positive and negative attributes match them (Crone et al., 2022; Van der Crujisen et al., 2018; Van der Crujisen et al., 2023). These assessments of one's qualities can be viewed from one's point of view (direct self-evaluations; "I am attentive,") or from another's perspective (reflected self-evaluations; "others think I am attentive,") respectively (Pfeifer et al. 2009; Van der Crujisen et al., 2018;). Substantial associations between self-evaluation appraisal and increased activity in the mPFC have been regularly found in fMRI studies where participants were asked to evaluate their traits (Denny et al., 2012; Murray et al., 2012; Crone et al., 2022). However, it has been observed that the mPFC activity seems to have a different pattern of activation across participants. Some studies found stronger activation of the mPFC in children than in young adults concerning direct and self-reflected evaluations (Pfeifer et al., 2009). Indeed, it has been

predicted that self-evaluations change and become less positive during adolescence age (Harter, 2012). While children are more positive about their academic and physical traits (Cole et al., 2001), adolescents tend to be less positive about their school performance but increasingly positive about their prosocial abilities (Cole et al., 2001; Van der Cruijen et al., 2017).

Different studies on adolescents' neural correlates of self-concept evaluation have found that the mPFC is a neural signature of adolescents' self-concept development (van der Cruijssen et al., 2018; Sebastian et al., 2008; Blakemore, 2008). By looking at direct self-evaluation in three different domains, including physical, academic, and prosocial, these studies have found greater activity of the mPFC when adolescents judged themselves and those who were like them on these aspects (van de Aar et al., 2022; Van der Cruijssen et al., 2018). Furthermore, these studies also illustrated that the mPFC was more frequently activated when adolescents positively rated themselves in these three domains (Van der Cruijssen et al., 2018), suggesting that the mPFC may be positively correlated with positive self-evaluation of one's academic, physical, and prosocial traits (D'Argembeau, 2013; Moran et al., 2006; Van der Cruijssen et al., 2018). Thus, mPFC is an important area of individuals' self-concept development. In addition to these findings, other research has suggested that the development of brain areas such as the mPFC may be influenced by positive vs negative feedback from the environment and/or from parenting styles (Vrticka et al., 2014; Sullivan, 2012), implying that the brain may anticipate experience, and attachment is one of the primary experiential forces shaping individuation and self-definitions in the growing brain (Siegel, 1999; Sullivan, 2012; Newman et al., 2015).

While it is well-established that attachment style has a significant impact on an individual's self-esteem, as demonstrated by numerous previous studies (Greenberg et al., 1983; Parker & Benson, 2005; Dhal et al., 2007; Wu, 2009; Lee & Hankin, 2009; Jamil et al., 2020), there

remains a critical gap in our understanding of the underlying mechanisms of this relationship. Prior research has not explored the potential mediating role of self-concept evaluation in elucidating this connection, particularly when considering the neural aspects involved. The present study aims to address this gap by investigating how adolescents' self-concept evaluation may serve as a mediator in the parent-adolescent relationship's influence on self-esteem. By delving into the neural processes associated with this mediation, we seek to shed light on the intricate dynamics that underlie the development of self-esteem during adolescence. The significance of this research lies in its potential to enhance our comprehension of the factors contributing to a positive sense of self-esteem among adolescents. In a world where mental health and well-being are of paramount importance, understanding the role of neural underpinning of self-concept evaluation as a mediator can offer valuable insights into interventions and strategies that may foster healthier self-esteem among this age group. Therefore, this study seeks to explore how the neural processes involved in self-concept evaluation contribute to our comprehension of the mechanisms underlying the development of self-esteem in adolescents.

Chapter 2: RATIONALE OF THE PRESENT STUDY

This study is situated within the broader framework of the Leiden Self-Concept project, an ongoing inquiry into various facets of adolescent self-concept development and its neural substrates, with prior research findings reported and published (Van der Crujisen et al., 2017; Van der Crujisen et al., 2018; Van der Aar et al., 2019; Van der Crujisen et al., 2019). Therefore, all the data needed to test the aims of this study has already been gathered. The specific data used in the present study was taken from three time points separated by 1-year intervals.

The primary objective of this investigation is to scrutinize specific relationships within the intricate matrix of factors contributing to adolescent self-esteem. Our particular focus is on the dynamics of parent-adolescent relationships, encompassing attachment and interaction patterns, and their potential mediation by neural activity within the mPFC during self-concept evaluation processes. Our rationale for focusing on these aspects is grounded in their theoretical significance, as we aim to empirically substantiate the pivotal role of parent-adolescent relationships in shaping self-concept and self-esteem during adolescence. As previously explored, understanding how parent-adolescent relationships influence self-esteem has practical relevance for bolstering adolescents' development. The use of advanced neuroimaging techniques, such as MRI (Magnetic Resonance Imaging), aims to provide insights into the neural basis of self-evaluation processes, particularly emphasising the exploration of how the mPFC's activation during self-concept evaluation might serve as a mediator for the influence of adolescents' relationships with their parents on their self-esteem. The study looks at adolescents' self-concept evaluation in three domains: prosocial, physical, and academic. The aims and hypothesis of the present study are:

Aim and hypothesis 1a (H1a): While it is true that previous research has examined the influence of attachment to parents during adolescence on adolescents' self-esteem levels, the novelty of the current study lies in its focus on a specific population and its potential to uncover nuances or variations in this relationship. By examining this relationship within our unique sample, we aim to shed light on whether there are any distinctive factors or patterns that may differentiate it from previous findings. Thus, the first aim serves as both an exploration of this well-established relationship within our specific context and a potential avenue for uncovering new insights or confirming the robustness of existing research. We therefore hypothesise that adolescents who have more secure attachments with their parents during their adolescent years will exhibit higher levels of self-esteem.

Aim and hypothesis 1b (H1b): Examine whether the interaction patterns between parents and adolescents during adolescence itself influence adolescents' self-esteem levels. We hypothesise that adolescents with more warm and supportive interactions will show higher levels of self-esteem.

Aim and hypothesis 2: To further examine whether adolescents' lower or higher mPFC activity in response to positive or negative self-concept evaluation in prosocial, academic, and physical, mediates the association between parent-adolescent relationships and adolescents' self-esteem. We hypothesize that a positive association between adolescents-parents' relationships and self-esteem levels is mediated by higher mPFC activity when evaluating the self positively on prosocial (**H2a**), academic (**H2b**), and physical appearance (**H2c**) related traits.

Chapter 3: METHODS

3.1. Participants

One hundred and sixty healthy adolescent participants took part in the Leiden Self-Concept study. Participants were all right-handed, reported normal or corrected-to-normal eyesight, and had no diagnosed neurological or psychological conditions. The study primarily aimed at investigating self-esteem and attachment in healthy adolescents specifically, as individuals with diagnosed conditions might exhibit unique patterns or confounding factors that we wanted to avoid in the data analysis.

Due to excessive head movements during the fMRI scans and technical issues, 10 of the 160-participants were excluded from the experiment, resulting in a final sample of 150 participants ranging in age from 11 to 21 (mean age: 15.7, SD: 2.9). However, in the present study, only the data of 116 participants also ranging in age from 11 to 21 (Mean age:16.1, SD: 3.1), with 59 females and 57 males, was analysed after running the mediation analysis due to the missing data of some participants from the variables measured in this study. Participation inclusion criteria included being fluent in the Dutch language. About 95.3% of the included participants in this study (N=116) were born in the Netherlands. The other participants were not born in the Netherlands but reported to be of Dutch or European descent.

In this study, family socioeconomic status (SES) data was collected, including information on the participants' parents' gross annual income. Before being included in the study, each participant and their caregivers signed an informed consent form. The Self-Concept project obtained ethical approval from the Leiden University Medical Centre's Medical Ethics Committee. Participants were checked for MRI contraindications, self-reported psychiatric

diagnoses, and use of psychotropic medication before the scan session. A radiologist reviewed each scan, and no clinically significant issues were found.

3.2. Study Procedure

During the starting point of the Leiden Self-Concept project, adolescents' attachment styles was measured (Time 1). One year later, MRI scans were collected (Time 2). Another year later, adolescents' self-esteem was measured (Time 3). This sequential approach allowed us to examine how the relationship between parents and adolescents at Time 1 influenced self-esteem at Time 3 while considering MRI findings at Time 2.

3.3. Measures

3.3.1. Parent-adolescent relationship

The Experiences in Close Relationships Scale: In this study, we assessed the attachment style between adolescents and their parents using the Experiences in Close Relationships Scale (ECR: Fraley et al., 2011). The ECR is a comprehensive tool designed to measure attachment dimensions in various contexts, including the parent and adolescent relationship. For the purposes of this research, we specifically examined the attachment data obtained during the initial assessment at T1, which marks the beginning of the Self-Concept project. During this assessment, participants were asked to express their level of agreement with statements (such as "I'm afraid that I will lose my parent's love" OR "I often worry that my parents don't really love me") pertaining to their attachment figures (i.e., their parents). Responses were given on a seven-point Likert scale, with 1 representing "strongly disagree" and 7 representing "strongly agree."

Family Interaction Task (FIT: Allen et al., 2003) was used to investigate the interaction patterns between parents and adolescents. The FIT is effective in assessing the behaviours of mother-adolescent relationships (Eisenberg et al., 2008). Adolescents and their mothers selected themes that often created conflict between them. The researcher chose two of these

topics that received the greatest ratings from both the mother and the adolescent. Then, adolescents and their parents were given 10 minutes to discuss these topics and come to an agreement. Both parents and adolescents were instructed to talk about one issue first, and if having enough time, to move on to the second issue. The three most frequently brought up subjects were bedtime, laundry, and homework. Parents and adolescents were rated on their negative and emotional support behaviours. Expressions of tension, anger, disagreement, or antagonism towards the other were categorised as negative behaviour and included actions like sighing aloud, interrupting the other person's thoughts, and rolling one's eyes. The scale for rating negativity ranged from 1 (no indications of negativity) to 9 (extreme negativity; "The negativity endures throughout the discussion and is disruptive to the interaction"). A score for emotional support, a measure of how well a person empathises with and acknowledges the emotions of others, involving naming emotions, showing sympathy, or acknowledging their feelings, was also included. Participants were assessed using a 9-point scale, where a rating of 1 denoted a lack of emotional support (indicating no attempts to provide emotional support), and a rating of 9 signified strong emotional support (reflecting clear efforts to acknowledge and assist with emotional distress).

3.3.2. The Rosenberg Self-Esteem Scale (RSES; Rosenberg, 1965) is a 10-item self-report measure to assess self-esteem levels. The RSES is the most used scale for measuring self-esteem in psychological studies. The scale offers a quick, easy, and practical way to gauge overall self-esteem. Since the proposed mediation model of this study looks at the influence of parent-adolescent attachment on adolescents' self-esteem, the RSES measure for this study is taken at T3 from the Self-Concept project. Participants were instructed to indicate the degree of agreement on each item (e.g., 'I feel that I have many good qualities'). All items were scored on a four-point Likert scale ranging from 1 (disagree strongly) to 4 (agree strongly). In our analysis, higher total scores indicated higher levels of self-esteem. It is important to note that

the RSES includes both positively and negatively worded items. To ensure that higher scores consistently reflect higher self-esteem, we employed a common practice in psychological measurement, which involves reverse-scoring the negatively worded items. This practice, while introducing a level of complexity compared to scales with only positively worded items, is a standard procedure in self-esteem assessment and is implemented to maintain the validity and reliability of the scale's results (Martín-Albo et al., 2007).

3.3.3. Self-concept task (fMRI)

Before conducting the MRI scan, clear instructions were provided. Participants practiced the task on a separate computer and had the opportunity to seek clarification as needed. During the fMRI self-concept assessments, participants responded to 60 sentences, one per trial. These sentences included 10 positive and 10 negative statements for each of the three domains: physical, academic, and prosocial. Examples of these sentences included traits like 'I am intelligent' and 'I help others.' Participants were instructed to rate these statements on a scale of 1 (meaning 'not at all') to 4 (meaning 'completely'). Trials were presented in a domain-specific pseudorandomized order.

Each trial lasted for 5000 milliseconds and followed a fixed sequence: Fixation Cross > Response Time > Confirmation of Response > Jitter (as depicted in Figure 1). A 400-millisecond fixation cross marked the beginning of each trial. The stimulus, consisting of the trait statement and response options (1 to 4), was displayed for 4600 milliseconds. Participants had this time to respond using predefined response buttons for selecting option 1, 2, 3, or 4 (See Van der Crujisen et al., 2017, 2018, 2019). When a response was registered, the selected number turned yellow. If participants did not respond within the 4600-millisecond window, they saw "Too late!" displayed for 1000 milliseconds.



Fig. 1. An illustration of a trial (images taken from Van der Crujisen et al., 2017, 2019). Each trial began with a jittered black screen lasting between 0 and 6600ms. A fixation cross was then displayed for 400 milliseconds before the stimulus was presented. On a scale of 1 to 4, participants were asked to indicate how well the attributes applied to them. The selected number turned yellow to notify participants that their choice had been recorded.

3.3.4. *fMRI Data Acquisition*

In the context of fMRI data acquisition (of the section 3.3.3), a Philips 3T MRI scanner equipped with a standard whole-head coil was employed. Functional images were acquired through two runs using a T2*-weighted echo-planar imaging (EPI) sequence, with parameters set as follows: a repetition time (TR) of 2200 milliseconds, an echo time (TE) of 30 milliseconds, sequential slice acquisition involving 38 slices, each having a thickness of 2.75 millimetres, and a field of view (FOV) measuring 220 x 220 x 114.68 millimetres. To account for T1 saturation, the first two volumes of data were eliminated. After the functional scans, a high-resolution 3D T1-FFE (T1 fast field echo) scan was obtained for anatomical reference. This scan comprised 140 slices with a voxel size of 0.875 millimetres and an FOV of 224 x 177.33 x 168 millimetres. During the scans, sentences were displayed on a screen positioned behind the scanner and were made visible to the participants via a mirror affixed to the head coil. The coil was equipped with foam inserts to restrict head movement.

3.3.5. *fMRI Pre-processing and Statistical Analysis*

The data was analysed utilizing SPM8, with adjustments made for slice-timing errors and variations in rigid body movement in the functional scans (*See* Van der Crujisen et al., 2017, 2018, 2019). Spatial normalization to T1 templates was carried out on all structural and functional volumes, employing a normalization approach that combined a 12-parameter affine

transformation with a nonlinear transformation using cosine basis functions. The volumes were subsequently resampled to 3mm cubic voxels utilizing the algorithm. The creation of the templates utilized the stereotaxic space MNI305 (Cocosco et al., 1997). A 6mm FWHM isotropic Gaussian kernel was employed for spatially smoothing the functional volumes. Within SPM8, the general linear model was employed to assess task effects for each participant, with the fMRI time series described as a collection of zero-duration events using the hemodynamic response function (HRF). The events of interest, namely "Direct-Academic-Positive," "Direct-Academic-Negative," "Direct-Physical-Positive," "Direct-Physical-Negative," "Direct-Prosocial-Positive," and "Direct-Prosocial-Negative," were modelled. In addition to a fundamental set of cosine functions used for high pass filtering the data, the events were integrated as covariates in a general linear model. The model also included six motion regressors. Group analyses were performed on the contrast images generated following the computation of contrasts on a subject-by-subject basis.

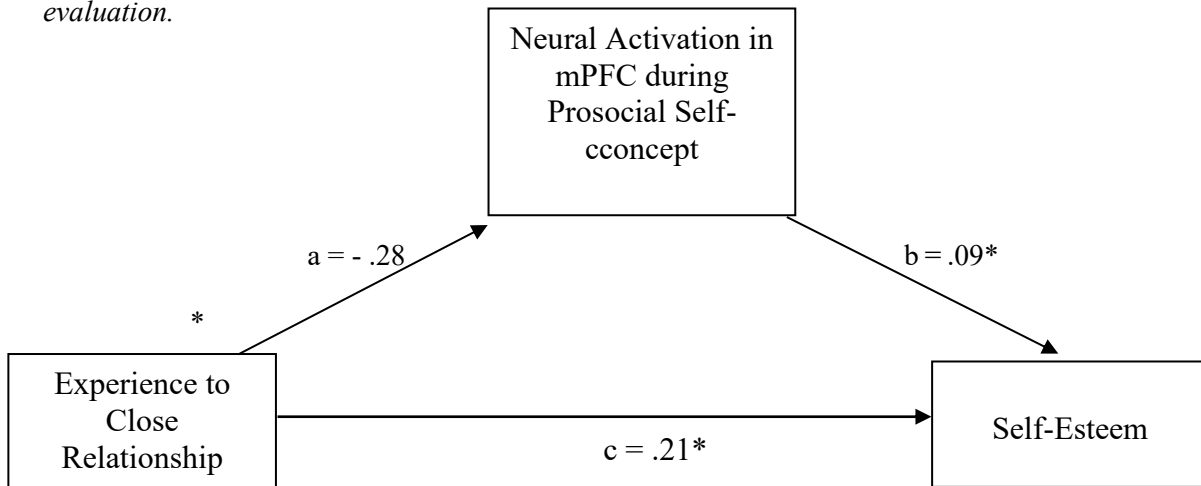
Chapter 4: RESULTS

To investigate the potential connection between secure and positive parent-adolescent relationships and higher self-esteem during adolescence, as well as to examine whether this relationship could be explained through neural activity in the mPFC during self-concept assessment, we conducted nine mediation analyses using the PROCESS tool in SPSS (Hayes, 2012). These analyses included bias-corrected 95% confidence intervals and were based on a sample size of 10,000. We hypothesised that a secure attachment and positive family interactions between parents and adolescents would be associated with higher levels of self-esteem in adolescents. Furthermore, we postulated that mPFC activity during self-evaluations of physical appearance, prosocial traits, and academic skills would mediate these associations. Each mediator was analysed separately to discern their individual contributions to self-esteem.

Firstly, we examined the mediating effect of mPFC activity during prosocial self-evaluations on the association between secure parent-adolescent attachment and self-esteem. The outcome variable was RSES. The predictor variable was ECR, while the mediation variable was neural activation in the mPFC during self-concept evaluation in prosocial. Participants' sex and age were included as covariates. As can be seen in Figure 2, we found that secure parent-adolescent attachment was not significantly related to mPFC neural activation during prosocial self-concept evaluation (*a* path, $\beta = -.28$, standard error (SE) = .15, $p = .068$, with 95% CI [-.59; .02]). However, mPFC activity during prosocial self-evaluations was positively associated with higher self-esteem, (*b* path, $\beta = .09$, SE = .04, $p = .034$, at 95% CI [.01; .16]). Individuals with more mPFC activity during prosocial self-evaluations were more likely to report higher self-esteem. Similarly, the total effect of secure attachment style on self-esteem was significant (*c* path, $\beta = .21$, SE = .07, $p = .002$, 95% CI [.07; .34]) suggesting that adolescents with more secure parent-adolescent attachment reported higher self-esteem,

however this relationship was not mediated by mPFC activation during prosocial self-concept evaluation (c' path, $\beta = .02$, $SE = .02$ at a 95%CI [-.08; .00]).

Fig. 2. The standardized mediation coefficients for the relationship between experience to close relationship and self-esteem as mediated by neural activation in mPFC during prosocial self-concept evaluation.

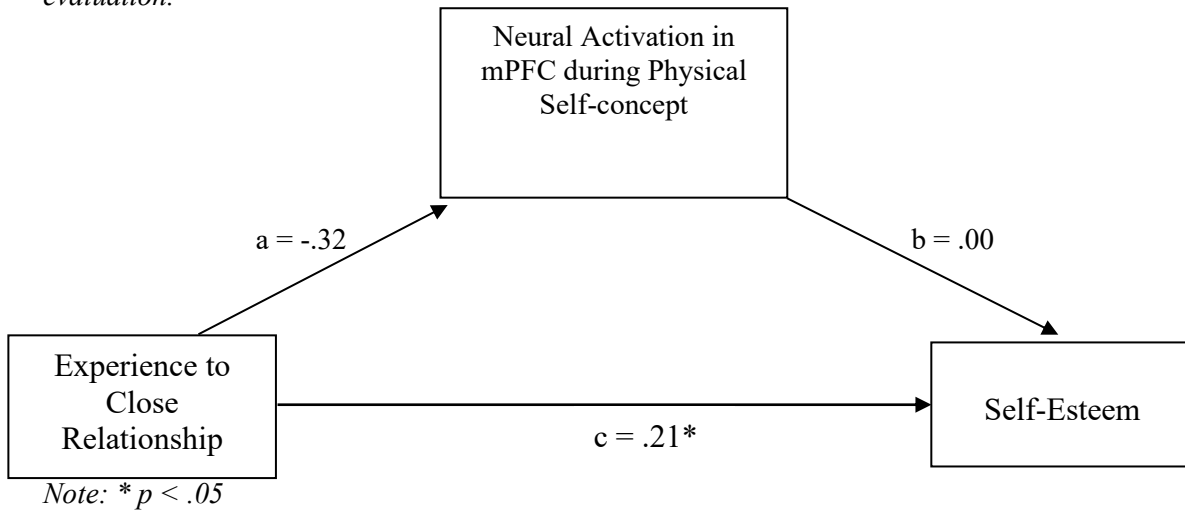


Note: All statistical significance is represented with * ($p < .05$)

In the second mediation model, we looked at the relationship between secure attachment style and self-esteem levels mediated by mPFC activation during physical self-concept evaluation, as shown in Figure 2. The analysis showed that although ECR had a negative influence on mPFC neural activation during physical self-concept evaluation, this influence did not reach statistically significant results (a path, $\beta = -.32$, $SE = .17$, $p = .055$, 95% CI [-.64, .01]). Furthermore, neural activation during physical self-concept evaluation did not appear to influence adolescents' overall self-esteem levels (b path, $\beta = .00$, $SE = .04$, $p = .954$, 95% CI [-.07; .07]). The total effect (c path) of early attachment style on self-esteem levels ($\beta = .21$, $p = .002$, 95% CI [.07; .34]) was statistically significant. But the influence of attachment on self-esteem levels was not mediated by mPFC activation during physical self-concept evaluation, as no significant indirect effect was observed, (c' path, $\beta = .00$, $SE = .01$ at a 95%CI [-.04, .03]), even after controlling for participants' sex and age. These findings suggest that quality of attachment experiences can shape adolescents' self-esteem levels independently of the

mPFC activation during physical self-concept evaluation, even when controlling for the effects of sex and age.

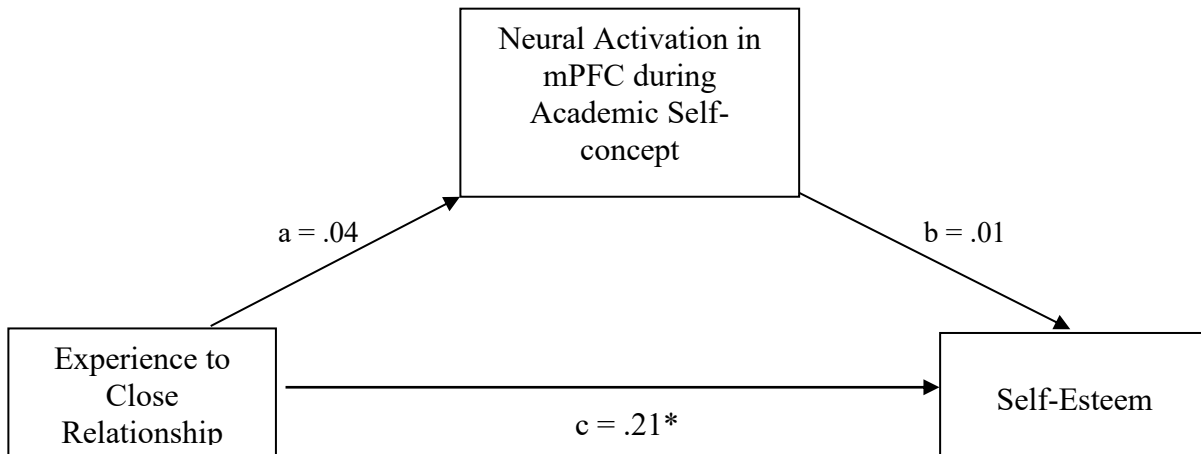
Fig. 3. The standardized mediation coefficients for the relationship between experience to close relationship and self-Esteem as mediated by neural activation in mPFC during physical self-concept evaluation.



The third analysis examined the role of secure attachment on self-esteem levels with the potential mediating role of mPFC neural activation during academic self-concept evaluation (Figure 3). Experience to close relationship was not significantly related to mPFC activation during academic self-concept evaluation (a path, $\beta = .04$, $SE = .15$, $p = .777$ at a 95% CI [.08, .34]), suggesting that attachment style did not predict activation of the mPFC during academic self-concept in adolescents. Furthermore, mPFC activation was not significantly related to self-esteem levels in adolescents, (b path, $\beta = .01$, $SE = .04$, 95% CI [-.07, .09], $p = .78$). Likewise, there was not a significant indirect effect of experience to close relationship on self-esteem levels through mPFC neural activation during academic self-concept, (c' path, $\beta = .00$, $SE = .01$ at a 95% CI [-.01, .01]). However, the total effect of attachment style on self-esteem was found to be statistically significant (c path, $\beta = .21$, $SE = .07$, $p = .002$, with 95% CI [.07, .34]), after accounting for the mediator variable. All relationships with the covariates sex and age were not statistically

significant. This model also showed that secure attachment with parents has a direct impact on adolescents' self-esteem, independent of the influence on the neural activation of mPFC during academic self-concept evaluation.

Fig. 4. *The standardized mediation coefficients for the relationship between experience to close relationship and self-Esteem as mediated by neural activation in mPFC during academic self-concept evaluation.*

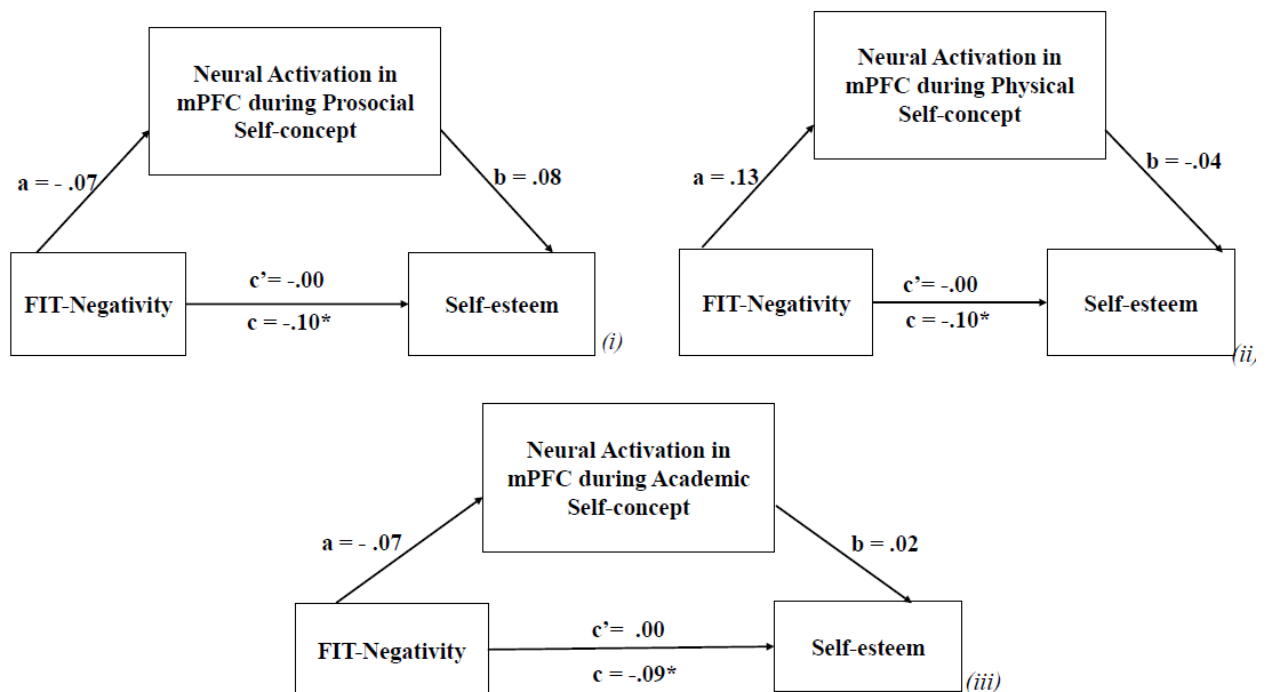


Note: * $p < .05$

The next series of mediation analyses examined the impact of family interaction (FIT) as measured by levels of negativity on self-esteem, mediated by the mPFC activation during prosocial, physical, and academic self-concept evaluation, as shown in the Figure 5 A total of 85 participants were included in these analyses due to missing data from other participants. Results revealed that overall, levels of negativity between adolescents and their parents showed a significant negative relationship with self-esteem levels in adolescents $\beta = -.24$, $SE = .02$, $p = .024$, with 95% CI $[-.17, -.01]$), suggesting that high levels of negativity between adolescents and their parents leads to lower self-esteem in adolescents. No significant indirect effects of parents-adolescents' levels of negativity on self-esteem through neural activation of mPFC during academic self-concept ($\beta = .00$, $SE = .00$, at a 95% CI $[-.01; .01]$), physical self-concept ($\beta = .10$, $SE = .00$, at a 95% CI $[-.02; .01]$) or prosocial ($\beta = .00$, $SE = .00$ at a 95% CI $[-.01; .01]$) were found. Likewise, levels of negativity did not significantly relate to mPFC neural

activation during academic ($\beta = .07$, $SE = .10$, $p = .509$, 95% CI [-.13; .26]) physical ($\beta = .13$, $SE = .11$, $p = .246$, with 95% CI [-.09; .33]), or prosocial self-concept evaluation ($\beta = -.02$, $SE = .10$, $p = .835$, 95% CI [-0.22, 0.18]). Similarly, mPFC neural activation during physical ($\beta = -.04$, $SE = .04$, $p = .71$, 95% CI [-.10; .07]), academic ($\beta = .02$, $SE = .04$, $p = .698$, 95% CI [-.07; .11]) and prosocial ($\beta = .08$, $SE = .04$, $p = .06$, 95% CI [-.00; .17]) self-concept evaluation did not show a significant effect on self-esteem. In other words, levels of negativity between adolescents and their parents may be associated with lower self-esteem in adolescents, even after controlling for sex and age. However, this relationship was not shown to be mediated by activation of mPFC during self-concept evaluations in prosocial, physical, and academic domains.

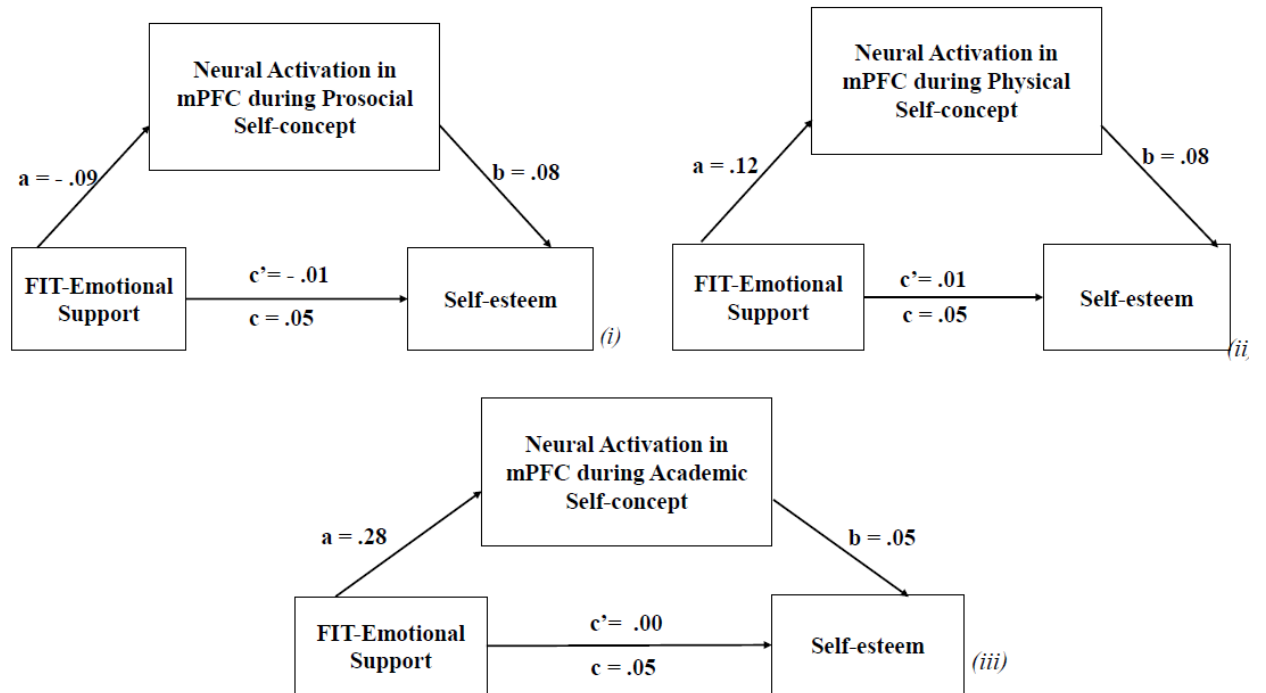
Fig. 5. The standardized mediation coefficients for the relationship between Family interaction (FIT-Negativity) and self-Esteem as mediated by neural activation in mPFC during self-concept evaluation (in Prosocial(i), Physical domains (ii), and Academic (iii) domains).



Note: * $p < .05$

The last three mediation analyses looked at the relationship between family interaction, measured by the level of emotional support (LES) and self-esteem levels mediated by mPFC activation during prosocial, academic, and physical self-concept (see Figure 6). Controlling for age and sex as covariates, the analysis involved 85 participants, due to missing data from the other participants of the present study. The results indicated no significant direct effects of LES on self-esteem in any of the three domains. Levels of emotional support had no significant effect on the mPFC activation during prosocial ($\beta = -.09$, $SE = .19$, $p = .623$, with 96% CI [-.47, .28]), academic ($\beta = .17$, $SE = .19$, $p = .147$, 95% CI [-.10 to .65]), and physical ($\beta = .12$, $SE = .11$, $p = .246$, with 95% CI [-.14; .66]) self-concept evaluation. Neural activation of mPFC did not significantly affect self-esteem levels during prosocial ($\beta = -.09$, $SE = .19$, $p = .626$, 95% CI [-.47; .28]), academic ($\beta = .05$, $SE = .08$, $p = .529$, 95% CI [-.11 to .21]) or physical ($\beta = .26$, $SE = .20$, $p = .198$, 95% CI [-.14 to .66]) self-concept evaluation. Furthermore, no significant total effect was found between LES and self-esteem levels in the three analyses ($\beta = .05$, $SE = .08$, $p = .529$, 95% CI [-.11 to .21]) suggesting that adolescents perceived emotional support from their parents did not have a significant impact of their self-esteem. Likewise, the relationship between LES and self-esteem levels in adolescents was not mediated by mPFC neural activation during academic ($\beta = .00$, $SE = .01$, 95% CI [-.03, .04]), physical ($\beta = .00$, $SE = .00$, 95% CI [.02, .01]), or prosocial self-concept evaluation ($\beta = -.01$, $SE = .01$, 95% CI [-.06, .03]). The covariates, age, and sex did not significantly influence the relationships.

Fig. 6. The standardized mediation coefficients for the relationship between Family interaction (FIT-emotional support) and self-esteem as mediated by neural activation in mPFC during self-concept evaluation (in Prosocial(i), Physical domains (ii), and Academic (iii) domains).



Note: * $p < .05$

Chapter 5: DISCUSSION

Numerous studies have so far examined the relationship between secure parent-adolescent attachment and self-esteem levels in adolescents (Harter, 1990; Allen et al. 1998; Moretti & Peled, 2004; Bretherton & Munholland, 2008; Nie et al., 2016; Jamil et al., 2020). However, to the best of our knowledge, none of these studies have considered the possibility that the relationship between these two variables may be mediated by neural activation of mPFC during domain specific self-evaluations (i.e., when evaluating the self on prosocial traits, physical appearance, and academic performance). Given the importance of self-esteem during adolescence (Moretti & Peled, 2004; Bernier et al., 2005; Birkeland et al., 2012; Noronha et al., 2018; Povedano-Diaz et al., 2020) it is critical to understand which factors may further explain the development of self-esteem. Hence, the present study aimed to investigate the influence of secure parent-adolescent attachment style and family interaction, on self-esteem levels in adolescents, while also exploring the potential mediating role of mPFC activation during domain specific self-concept evaluations. The first hypothesis of the present study was that adolescents with more secure attachments with their parents will show higher levels of self-esteem (**H1a**) and that adolescents with more warm and supportive interactions will show higher levels of self-esteem (**H1b**). Furthermore, we hypothesised that a positive association between adolescents-parents' relationships and self-esteem levels would be mediated by higher mPFC activity when evaluating the self positively on prosocial (**H2a**), academic (**H2b**), and physical (**H2c**) appearance-related traits. The results of this study demonstrated a positive correlation between secure parent-adolescent relationships and elevated self-esteem levels, whereas the neural mediation aspect yielded inconclusive evidence. These results shed lights into the factors that contribute to adolescent self-esteem and the complex interplay between attachment, family interaction, neural processes of self-concept, and self-esteem, which will be discussed below in more detail.

5.1. Main Effect of Parent-Adolescents Relationship on Self-esteem

As hypothesised (H1a), our results demonstrated a significant direct impact of secure attachment to caregivers during adolescence and high self-esteem levels. This finding is consistent with prior research (Arbona & Power, 2003; Wilkinson, 2004; Sim & Yow, 2011) and underscore the importance of secure attachment in fostering positive self-esteem during adolescence, as securely attached individuals are better equipped to cope with stress and employ adaptive emotion regulation strategies (Sim & Yow, 2010; Karreman & Vingerhoets, 2012; Palmer & Gentzler, 2018). The present study also investigated whether warmer and more supportive interactions with parents during adolescence had a positive impact on adolescents' self-esteem levels (H1b). Contrary to the findings on attachment, emotional support from parents alone did not significantly impact adolescents' self-esteem levels, but consistent with some previous research (Amato & Fowler, 2002). This suggests that emotional support may interact with other factors, such as peer relationships and overall negativity within parent-adolescent interactions, in influencing self-esteem during adolescence (Keizer et al., 2019). Our results did, however, reveal that negative interaction between parents and adolescents was associated with lower self-esteem levels (thus, partially supporting H1b). This aligns with prior research indicating that negative family dynamics can have enduring negative effects on self-esteem, potentially persisting from childhood into adolescence and adulthood (Heaven & Ciarrochi, 2008; Khaleque, 2017; Orth, 2018).

5.2. Role of mPFC Activation in Prosocial, Academic, and Physical Self-Concept

In this study, we investigated the potential mediating role of mPFC activation during domain-specific self-concept evaluations (i.e., prosocial, academic, and physical appearance) on the relationship between attachment/parenting style and self-esteem. Our findings revealed mixed results across these domains.

Contrary to our expectations, our analysis did not reveal a mediating role of mPFC activation during prosocial self-concept evaluations in explaining the relationship between attachment or parenting style and self-esteem (H2a). This surprising finding challenges the initial hypothesis that neural activation in the mPFC during prosocial self-evaluations would serve as a mediator of the link between secure parent-adolescent attachment and higher self-esteem in adolescents. However, in one mediation model (ECR > mPFC during prosocial self-concept evaluation > self-esteem), our analysis revealed a positive correlation between mPFC activation during prosocial behaviour and adolescents' overall self-esteem levels. This discovery contributes to the limited body of research on the neural underpinnings of self-concept evaluation in the context of prosocial behaviour and its influence on adolescent self-esteem. In a related study, Hein et al. (2010) conducted research where participants observed distressing situations involving ingroup and outgroup members while undergoing fMRI scanning. Their findings revealed that individuals with higher self-esteem displayed a stronger association between neural responses in the anterior insula and their willingness to assist distressed ingroup members. Essentially, those with higher self-esteem were more inclined to aid members of their social group when witnessing their distress, and this inclination was associated with specific brain activity patterns. While our study primarily focused on the mPFC brain region, it is conceivable that other brain regions, such as the anterior insula, may also become active during prosocial behaviour and may play a role in explaining self-esteem levels among adolescents, as demonstrated in Hein et al.'s (2010) study. Therefore, future research should explore these additional brain areas to comprehensively understand how neural processes contribute to prosocial self-concept and its impact on self-esteem.

Similarly, we did not find support for the mediating role of mPFC activation during academic self-concept evaluations in explaining the relationship between attachment or parenting style and self-esteem (H2b). These null findings suggest that mPFC activation may

not be the primary neural mechanism underlying the connection between attachment, academic self-concept, and self-esteem during adolescence. The absence of mediation in the academic domain raises intriguing questions about the factors that shape adolescents' academic self-concept and its subsequent impact on self-esteem. One possibility is that academic self-concept becomes less central during adolescence compared to earlier developmental stages (Shapka & Keating, 2005; Arshad et al., 2015; Van der Cruijen et al., 2018). As adolescents transition into adolescence, they may begin to derive their self-esteem from a broader range of experiences, including peer interactions, extracurricular activities, and personal achievements. Therefore, adolescents' academic self-perception may be intertwined with their social identity and peer comparisons, making it a complex construct shaped by multiple factors. Future research could explore the role of peer relationships and social comparisons in the development of academic self-concept and self-esteem during adolescence.

Our analysis did not support H2c, as it did not demonstrate a mediating role of mPFC activation during physical self-concept evaluations in explaining the relationship between attachment or parenting style and self-esteem. The absence of mediation in the physical domain prompts consideration of alternative neural regions involved in processing physical self-concept, apart from mPFC. Research has highlighted the potential role of other brain areas, in the evaluation of physical appearance. According to these studies, while mPFC seems to be more active during character self-evaluation, the posterior cingulate cortex (pCC) shows more engagement for appearance evaluations (Moran et al., 2011). Additionally, it has been suggested that the inferior parietal lobule (IPL) may have a role in discerning the differences between one's own preferences and those of others, as highlighted in the study conducted by Janowski et al. (2013). These results potentially indicate that when people assess physical characteristics, they tend to think more from the standpoint of others, in contrast to their approach when evaluating academic and prosocial qualities. Furthermore, other previous

research has observed that when individuals assessed their physical traits, there was an observed increase in dlPFC activation, suggesting that dlPFC activity may also serve as a neural indicator of physical self-concept (van der Crujisen et al., 2018; van der Crujisen et al., 2019). Consequently, the dlPFC appears to play a vital role in the development of positive self-concept in adolescence. Therefore, physical self-concept may recruit additional brain areas which may be implicated in the neural mechanisms associated with physical self-concept and self-referential processing. Future research may delve further into the specific contributions of different prefrontal regions in addition to the mPFC, such as IPL area, and the pCC to various aspects of self-concept.

On the other hand, factors beyond attachment and parenting style may also play significant roles in adolescents' physical self-concept and self-esteem. Peer influence and societal beauty standards are known to impact adolescents' perceptions of physical appearance and their self-esteem (Daniali et al., 2013; Oktan & Şahin, 2010; Calado et al., 2011). These external factors may interact with attachment and parenting style to collectively shape adolescents' self-esteem, emphasizing the need for a comprehensive understanding of the multifaceted influences on physical self-concept and self-esteem during this developmental stage.

5.3. Strengths, Limitations, and Direction for Future

This study makes a valuable contribution to the existing literature by investigating the mediating role of mPFC activation in the connection between secure parent-adolescent attachment and self-esteem. This approach fills a notable gap in understanding the complex interplay between attachment, neural processes, and self-esteem during the crucial developmental stage of adolescence. The empirical evidence generated by this study supports a positive association between secure parent-adolescent relationships and elevated self-esteem

levels in adolescents. These findings are consistent with previous research and emphasize the pivotal role of secure attachments in nurturing positive self-esteem during adolescence, as previously discussed. Moreover, this study offers a nuanced understanding of emotional support within parent-adolescent relationships. While emotional support alone did not exhibit a significant impact on self-esteem levels, the study highlights the potential interactions of emotional support with other factors, such as peer relationships and overall negativity within parent-adolescent interactions. This nuanced perspective contributes to our overall understanding of the complex and multifaceted relationship between emotional support, attachment, and self-esteem in adolescents.

The investigation of mPFC activation during domain-specific self-concept evaluations, including prosocial, academic, and physical appearance domains, provides valuable insights into the neural underpinnings of self-esteem in adolescents. It raises intriguing questions about how neural processes may contribute to self-esteem within specific domains, shedding light on the multifaceted nature of self-esteem development. Furthermore, the study effectively integrates previous research, particularly drawing on Hein et al.'s (2010) work. This integration suggests that other brain regions, such as the anterior insula, might also play a role in explaining self-esteem levels among adolescents, especially in the context of prosocial behaviour. This integrative approach enriches the discussion and offers potential directions for future research.

However, it is important to acknowledge an epistemological challenge associated with this study. The choice of a neural correlate as a mediator raises questions about whether mPFC activation and self-esteem are distinct constructs or simply different levels of the same phenomenon. This epistemological issue should be recognised, as it has implications for the interpretation of the study's findings. Additionally, the complexity in the study's findings regarding the mediation of the relationship between secure parent-adolescent attachment,

neural activation in the mPFC, and self-esteem in adolescents can be attributed to several interrelated factors.

Firstly, self-esteem is a multifaceted construct influenced by a multitude of variables, encompassing family dynamics, peer interactions, cultural norms, and individual personality traits (Bosson et al., 2000). While the study focuses on the potential mediating role of mPFC activation, it represents only one facet of the intricate self-esteem paradigm. It is essential to recognise that self-esteem is a complex construct with many dimensions and contributors. Secondly, adolescents exhibit considerable individual differences in their psychological and neural responses, resulting in a diverse range of reactions to secure attachment and varying patterns of neural activation. This heterogeneity introduces complexity as the study may not fully account for these individual variations. Thirdly, the period of adolescence is characterised by significant psychological and neural development. As the brain undergoes structural and functional changes, self-esteem also evolves (Blackmore, 2012). This developmental aspect may contribute to the complexity of the relationship, as neural mechanisms influencing self-esteem in adolescents may differ within this specific age group. Furthermore, the measurement of neural activation, reliant on techniques such as MRI, is subject to inherent limitations, including potential noise in the data, individual variability in brain structure, and challenges in precisely pinpointing specific neural regions involved in complex cognitive processes like domain specific self-concept evaluation. Moreover, the study's focus on mPFC activation as a mediator might not account for potential additional mediators or moderators, such as individual personality traits, coping strategies, or social support networks. Neglecting these factors can lead to inconclusive results. Furthermore, intricate interaction effects may be at play, where mPFC activation could mediate the relationship between attachment and self-esteem under specific conditions or for particular subgroups of adolescents. Finally, the sample characteristics, including size, demographic selection criteria, may have exerted an influence

on the findings. Most of the participants in this study were of Dutch descent. Addressing these complexities necessitates further research, diverse sample sizes, and refined methodologies to attain a comprehensive understanding of how neural processes, attachment, and self-esteem intersect during adolescence. Therefore, acknowledging and addressing these limitations, along with the epistemological challenge of mixing behavioural and neural levels, can further refine and enhance the robustness of the study's findings in future research.

CONCLUSION

This study conducted a comprehensive exploration of the complex relationship among secure parent-adolescent attachment, family interactions, medial prefrontal cortex (mPFC) activation, and adolescent self-esteem. Our findings affirmed the positive association between secure attachment and elevated self-esteem in adolescents. While emotional support alone did not exert a significant impact on self-esteem, our study did reveal that negative parent-adolescent interactions were associated with lower self-esteem, underscoring the enduring consequences of adverse family dynamics. However, our analyses did not provide conclusive evidence for the mediation effect of mPFC activation during prosocial, academic, or physical self-concept evaluations in explaining the relationship between attachment to parents during adolescence, family interactions, and self-esteem.

In our investigation of mPFC activation during prosocial, academic, and physical self-concept evaluations, we did not find consistent evidence of mediation in any of these domains. It is noteworthy to mention that we observed a positive correlation between mPFC activation during prosocial self-concept evaluations and adolescents' self-esteem levels, despite the absence of a mediation effect. This intriguing finding underscores the complex interplay between neural processes and self-esteem, particularly in the context of prosocial behaviour.

In conclusion, this study advances our understanding of attachment, family dynamics, neural processes, and self-esteem in adolescence. While our initial hypotheses regarding the mediation effect were not supported, our findings highlight the intricate nature of self-esteem development in adolescents and the potential role of mPFC activation in specific self-concept domains. Future research should continue to explore alternative neural regions, external influences, and contextual factors shaping self-esteem during this pivotal developmental stage, recognising the multitude of factors influencing adolescent self-esteem. This knowledge carries

clinical implications for therapists and counsellors working with adolescents, emphasising the importance of fostering secure parent-adolescent attachments and addressing negative family interactions for promoting healthy self-esteem. Additionally, educators and policymakers can use this research to inform educational programs and policies aimed at supporting positive self-esteem in adolescents.

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