Title
Empathy development in adolescence and associated neural processing

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Publication Date
2023

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFNORNIA

Los Angeles

Empathy development in adolescence and associated neural processing

A dissertation submitted in partial satisfaction of the requirements for the degree of

Doctor of Philosophy in Psychology

by

Maira Fatima Karan

2023

ABSTRACT OF THE DISSERTATION

Empathy development in adolescence and associated neural processing

by

Maira Fatima Karan

Doctor of Philosophy in Psychology

University of California, Los Angeles, 2023

Professor Andrew J Fuligni, Chair

Given previously established links with physical and psychosocial health, there has been renewed scientific interest in investigating the behavioral and neural development underlying prosocial behavior. It has been proposed that empathy is critical to the maturation of prosocial behavior during adolescence; however, there are missing gaps in our understanding of the behavioral and neural development underlying empathy in adolescence. Research is needed to clarify how processes constituting empathy, such as perspective-taking (understanding another's emotional state), empathic concern (feeling another's emotional state), and empathic responses such as personal distress, differ by age and relate to neural processing. This dissertation sought to examine age differences in the development of empathy and its associated neural activation during adolescence. Specifically, this dissertation had 3 primary aims 1) examine age-related differences in empathy (i.e., empathic concern, perspective-taking, personal distress) during adolescence, 2) investigate age-differences in neural activation among brain regions linked with pain processing, social cognition, and emotion regulation that are associated with empathy, and

3) assess the moderating role of brain regions linked with emotion regulation in the association between personal distress and prosocial behaviors. This research was accomplished by examining a sample (N_{Total} = 147) of human adolescent responses to a validated empathy task that youth (aged 11-17 years old) completed while undergoing a functional magnetic resonance imaging (fMRI) scan. Findings from this dissertation demonstrated age-differences in self-reported state empathy, but not trait empathy, as a function of gender. Neuroimaging findings did not replicate the age by gender association in empathy. Youth, irrespective of age and gender, showed positive neural activation to empathy in the bilateral anterior insula, dACC, dmPFC, and vlPFC, intimating the involvement of brain regions linked with pain processing, social cognition, and emotion regulation in empathy during adolescence. While the neural correlates of empathic concern and perspective-taking were not as clear, there was evidence of an association between lower personal distress and higher activation in the dlPFC, vlPFC, and OFC. Furthermore, preliminary evidence emerged to suggest that the bilateral OFC moderates the association between personal distress and prosocial behavior. Suggestions for future research and implications for behavioral interventions are discussed.

The dissertation of Maira Fatima Karan is approved.

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University of California, Los Angeles

2023

This dissertation is dedicated to my mother – my first teacher in love and empathy.

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The research presented in this dissertation was generously funded by the Eunice Kennedy Shriver National Institute of Child Health and Human Development (PIs: Eisenberger, Galván, Fuligni; R01 HD093823). My graduate training was funded by the Pritzker Graduate Scholar Award funded by the Anthony & Jeanne Pritzker Family Foundation, a T32 Training Fellowship from the National Institute of Child Health and Human Development (1T32HD091059), and the University of California, Los Angeles Graduate Summer Research Mentorship program fellowship.

I have been fortunate to be guided by brilliant mentors and advisors throughout my academic training without whom I would not be where I am now. Thank you to my graduate school mentor, Dr. Andrew Fuligni, for fostering my scientific passions, being a constant source of support and wisdom, and giving me every opportunity to advance my academic training. I know that I will never be able to pay back what you have given me but I promise to pay it forward for the rest of my life. Thank you to Dr. Naomi Eisenberger who graciously welcomed me into her lab and patiently taught me how to conduct fMRI analyses. I am immensely grateful to have learned from you and I aspire to demonstrate the same kindness and compassion you have shown me throughout my training to my students one day. Thank you to Dr. Adriana Galván who gave me my first home in neuroimaging research and always encouraged me to ride the learning curve of fMRI work. I would also like to thank my very first mentor from my undergraduate institution, Dr. Heejung Park – I am where I am today because you listened to me, believed in me, and encouraged me when it mattered most.

Thank you to my wonderful colleagues turned friends who nurtured me into the researcher that I am today. To my lab mates, past and present, in the Adolescent Development

Lab – Joanna Kim, Danny Rahal, Sarah Tashjian, Sunhye Bai, Leanna Hernandez, Sarah Rocha, Xochitl Arlene Smola, Jasmine Hernandez, Ava Trimble – I feel incredibly grateful and privileged to have learned with you and from you, and I look forward to seeing the remarkable ways in which each of you will advance psychological science. A special thank you everyone from the UCLA Brain Power Study team – this dissertation is a direct product of your admirable teamwork. I would especially like to thank Lee Lazar whose inspiring work-ethic and boundless support were instrumental in furthering my research. I will miss our zoom data analysis sessions, running scans (during COVID!), and navigating grad school with you – thank you for the beautiful memories. I would also like to express my immense gratitude for Carrianne Leschak whose meticulousness, extensive knowledge of fMRI analyses, and gifted teaching-abilities directly contributed to many of my accomplishments in graduate school including this dissertation. Thank you for serving as an incredible role-model, selflessly sharing your wisdom, and being so very kind every step of the way.

None of this would have been possible without the unwavering love and support of my family and friends. Mom, Dad, Abraar, and Tila – you are my whole world and I am the luckiest person of all to have lived near home during graduate school where we could spend time together and strengthen our bonds. Thank you for supporting my dreams and believing in me. To my partner in life – Saeb Ali Khan – thank you for loving me and standing by me through every season of life, especially when I couldn't clean Rambo's litter box on schedule. To my extraordinary friends and cohort – Sarah Tashjian, Amanda Baker, Julia Schorn, Ritika Rastogi, Razia Sahi, Jordan Levinson, Adriana Méndez Leal, and so many more – thank you for your friendship and for reminding me that there can be so much joy in the journey of graduate school.

Biographical Sketch

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Publications (*equal author contribution)

1. Rahal, D., Tashjian, S. **M., Karan**, N., Eisenberger, N., Galván, A., Fuligni, A. J., ... & Cole, S. W. (2023). Positive and Negative Emotion are Associated with Generalized Transcriptional Activation in Immune Cells. *Psychoneuroendocrinology*, 106103.
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8. **Karan, M.**, Park, H. (2020). The role of culture in sleep: Sleep quality and cultural orientation in East Asian college students. *Journal of American College Health.* doi: 10.1080/07448481.2020.176336s

Professional Poster Presentations (*equal author contribution)

1. **Karan, M.,** Lazar, L., Leschak, C.J., Eisenberger, N.I., Galván, A., Fuligni, A.J. (2022, September). Empathy Development during Adolescence: State versus Trait Differences. Poster presented at Flux Congress 2022, Paris, France.
2. Lazar, L.*, **Karan, M.*,** Leschak, C.J., Dieffenbach, M.C., Eisenberger, N.I., Galván, A., Telzer, E.H., Uy, J.P., Fuligni, A.J. (2020, September). The Neurodevelopment of Prosocial Behavior in Adolescence. Poster presented at Social Affective Neuroscience Society 2021, online.
3. **Karan, M.*,** Rahal, D.,* Fuligni, A.J. (2020, September). School Commute Time, Chronotype, and HPA Axis Functioning during Adolescence. Poster presented at Society for Research on Child Development Biennial 2021 Meeting, online.
4. **Karan, M.*,** Lazar, L.*, Leschak, C.J., Dieffenbach, M.C., Eisenberger, N.I., Galván, A., Telzer, E.H., Uy, J.P., Fuligni, A.J. (2020, September). The Neurodevelopment of Prosocial Behavior in Adolescence. Poster presented at Flux Virtual Conference 2020, online.
5. **Karan, M.,** Bai, S., Fuligni, A.J. (2019, March). Chronotype during the transition from adolescence to young adulthood. Poster presented at the Society for Research on Child Development 2019 Biennial Meeting, Baltimore, MD.
6. **Karan, M.**, Park, H. (2019, March). Cultural orientation and sleep quality among East Asian college students in the United States. Poster presented at the Society for Research on Child Development 2019 Biennial Meeting, Baltimore, MD.
7. Bai, S., **Karan, M.**, Gonzales, N., Fuligni, A. J. (2018, April). Sleep chronotype and externalizing symptoms in Mexican high school youth. Poster presented at the Society for Research on Adolescence Biennial Meeting, Minneapolis, MN.

CHAPTER 1

General Introduction

In recent years, there has been a notable shift from framing adolescence as period of "storm and stress" to re-characterizing this developmental phase as a time of opportune malleability when positive behaviors mature in concert with characteristics that enable adolescents to adequately explore their rapidly changing social world (NASEM, 2019). Dominant narratives of adolescence suggest that youth engage in heightened levels of risk-taking and experience a social reorientation away from family and toward their peers. However, more recent scientific investigations suggest that characteristics of adolescence typically viewed as risk factors do not inherently lead to negative outcomes. For instance, although social reorientation during adolescence can result in adolescents conforming to their peers' maladaptive behaviors, it is also implicated in positive and prosocial behaviors such as helping and thinking about others (Crone & Fuligni, 2020; Duell & Steinberg, 2021). Research demonstrates that empathy is critical to the maturation of prosocial behavior in youth, yet there is need for clarifying the behavioral and neural development of empathy during adolescence thereby limiting our understanding of the circumstances in which prosocial behavior develops (Eisenberg, 2006; van der Graaff et al., 2018). Specifically, research is needed to clarify how particular processes constituting empathy, namely perspective-taking (understanding another's emotional state) and empathic concern (feeling another's emotional state), as well as empathic responses such as personal distress, develop with age and relate to neural functioning and neural network connectivity among youth. This dissertation aimed to elucidate age-related differences in the development of empathic processes and responses as well as examine associated neural functioning and connectivity that align with empathy during adolescence.

Empathy is broadly defined as an individual's ability to discern the mental and emotional states of another person. Affective (feeling another's emotional state), mentalizing (understanding another's emotional state of mind), and cognitive control/emotion regulation processes together have been shown to produce an empathic response to another's suffering (Decety, 2010; Cuff et al., 2016; Zaki & Ochsner, 2016). Yet, knowledge of how these processes develop to support empathy during adolescence—a period of critical socioemotional maturation and neurodevelopment—remains somewhat limited. Additionally, even less is known about how personal distress, an adverse affective response to empathy, emerges in adolescence (Decety & Lamm, 2011; Eisenberg & Eggum, 2009). Neural regions that have been linked with empathy are known to undergo important developmental change during adolescence such as those involved in pain processing, social cognition, and emotion regulation (Decety et al., 2010; Dumontheil, 2016). Research is needed to clarify age-related differences in the behavioral and neural components associated with the cognitive and affective processes of empathy during the adolescent years.

Defining Empathy

The act of engaging in empathy requires the ability to both feel and understand what another person is feeling or experiencing. As such, despite varying operationalizations of empathy in the scientific literature, there is a consensus on the involvement of both affective and cognitive processes in producing empathic behavior. The affective process underlying empathy is often termed empathic concern and is defined as feeling sorrow or concern for another person's emotional and mental state (Hastings et al., 2013). The cognitive component of empathy is often termed perspective-taking and is defined as being able to understand another person's emotional and mental state (Decety, 2010). Personal distress, an affectively aversive self-oriented response to another’s pain, is a potential outcome of engaging in empathy, and it is worth examining because research has linked the experience of personal distress with reductions in prosocial behavior, such as helping others in need. Personal distress is theorized to emerge when the observer adopts the mental and emotional state of the other person but fails to maintain a clear distinction between the self and other, an important component of perspective-taking, thereby causing discomfort to the observer (Decety & Lamm, 2011). This discomfort is highly self-oriented in nature and has been linked with wanting to reduce personal distress over the distress of someone else. While it may seem difficult to distinguish empathic concern from personal distress, empathic concern is thought to rely on higher-level cognitive processes such as perspective taking, whereas personal distress is thought to rely on lower-level processes such as emotional reactivity and contagion (Eisenberg, 2000; Lamm, Batson, & Decety, 2007). Empathic concern, perspective-taking, and personal distress will be discussed further in the context of adolescent behavioral and brain development.

Empathy Development in Adolescence

Given that empathy is a highly multidimensional construct, it is important to identify the specific developmental trajectories that underlie each individual component to best understand empathy development overall. Empathy is not a behavior that develops specifically in adolescence as experimental research shows that infants as young as 3 months have demonstrated empathic concern, the affective component of empathy, in response to seeing their mothers in distress (Paz et al., 2021). However, longitudinal assessments have shown that empathy meaningfully increases in the adolescent years, and it is well-known that affective and cognitive abilities increases in their sophistication during this developmental period in particular (Allemand et al., 2015; Crone & Dahl, 2012). Research examining the developmental trajectories of empathic components in adolescence is somewhat limited and largely based upon self-report measures of dispositional empathy, leaving many questions to be answered about the development of empathy in adolescence. Studies on the affective and cognitive components of empathy suggest that empathic concern is moderately stable in adolescence while perspective-taking increases during adolescence (Farrell & Vaillancourt, 2020; van der Graaff et al., 2014). Taken together, these studies point to the increase in empathic processes involving higher order cognitive functions, such as perspective-taking, coupled with relatively stable empathic processes involving affect, such as empathic concern.

Compared to empathic concern and perspective-taking, research examining empathic personal distress in adolescence is much more limited. As a reminder, personal distress is an affectively aversive self-oriented response to another's pain, and is a potential outcome of engaging in empathy (Eisenberg, 2006). It emerges when the observer fails to maintain a clear distinction between self and other, and is linked with reductions in prosocial behavior, necessitating further study during adolescence, a period during which prosocial behavior has been shown to increase (van der Graaff et al., 2018; Do et al., 2019). Researchers have posited empathy to be a "risky strength" in adolescence because it can lead to personal distress which has been linked with poor emotion regulation, and this in turn can perpetuate internalizing disorders during this developmental period that has been characterized by vulnerability to the onset of mental health disorders (see Tone & Tully, 2014). In terms of its developmental trajectory, personal distress is theorized to decrease with older age as individuals are better able to engage in emotion regulation abilities that help with maintaining a clear distinction between your pain or suffering versus someone else's pain or suffering (Decety & Lamm, 2011).

Virtually no research has simultaneously examined adolescent age differences in empathic concern, perspective-taking, and personal distress to characterize their developmental trajectories. Furthermore, variable operationalizations of empathic processes and responses among limited age ranges used in prior studies contribute to a vague picture of the development of empathy across the adolescent years. Research using validated experimental tasks that measure explicit empathic processes and responses are needed among adolescents. Additionally, such work would help to elucidate age differences in personal distress during adolescence to address developmental differences in negative responses to engaging in empathy.

There has been renewed scientific interest in understanding prosocial behavior development in adolescence due to links with positive physical and psychosocial outcomes (Armstrong-Carter et al., 2020; Armstrong-Carter & Telzer, 2021; Tashjian et al., 2021). In order to fully understand the development of prosocial behavior, there must also be a revived attention to clarify the behavioral and neural development of empathy—a behavior purported to support prosocial behavior—during adolescence. Given prior work establishing the role of both affective and cognitive processes underlying empathy, this dissertation aimed to 1) examine age related differences in empathic processes and responses (empathic concern, perspective-taking, personal distress) during adolescence, 2) investigate age differences in functioning of regions linked with pain processing, social cognition, and emotion regulation associated with empathy, and 3) assess the association between prosocial behavior and personal distress and examine the moderating role of brain regions associated with emotion regulation.

Adolescent Brain Development: A Case for Examining Empathy

Theories of adolescent brain development converge to suggest different maturational trajectories of the socioemotional system and the cognitive control system to characterize the heightened propensity toward risk-taking observed during this period in the life course (Shulman et al., 2016; van Duijvenvoorde et al., 2016). Various studies of adolescent behavioral and neural development align with these different models of adolescent brain development indicating potential validity in all of them. However, more importantly, a commonality among these models suggests an increase in both of these systems with a protracted developmental trajectory in the cognitive control system compared to the socioemotional system during adolescence. It is theorized that the developmental mismatch of these systems creates heightened reward sensitivity to engaging in risky behaviors which make them more appealing during adolescence compared to other phases in the life course.

However, emerging neuroscientific evidence demonstrates that this pattern of neurodevelopment not only links with increased risk-taking, but is also related to increases and refinements in socially other-oriented behaviors as youth become more aware of the people around them. Research on adolescent prosocial behavior and neural functioning has shown activation in regions that are involved in both the socioemotional system and the cognitive control system, indicating that these two systems increasingly work in concert to orchestrate adolescent other-oriented decision-making with age (Do et al., 2019; Karan et al., 2022). However, more research is needed to apply these models of adolescent neurodevelopment to empathy to contextualize how this behavior develops and matures in adolescence. A critique of these models of adolescent brain development is that they attempt to simplify what is known to be a dynamic and complex process; however, that is what a theory does – it takes complexity and refines it into something palatable and, in the case of scientific research, something measurable. While the proposed research will not be able to account for all of the dynamic neurodevelopment that is occurring during adolescence in the context of empathy development that can be best captured by longitudinal assessments, this work aims to examine empathy and neural functioning within this dual systems perspective framework to fill missing gaps in our understanding of adolescent empathy.

Social cognitive neuroscience has identified several key brain regions associated with empathy among adults, but little work has examined how these regions relate to empathic processes among adolescents. The Shared Network Hypothesis is the primary driver of current scientific thinking around empathy and neural functioning. Put simply, this hypothesis states that in order for individuals to understand the affective experiences of others, they simulate these affective experiences internally using their own affective processes (Gallese, 2003; Singer & Lamm, 2009; Preckel, Kanske, & Singer, 2018). As such, most social neuroscience studies demonstrate that brain regions that are active during self-pain are also active when seeing another in pain (Jackson, Meltzoff, & Decety, 2005; Decety & Jackson, 2006). Specifically, cortical regions linked with social cognition (i.e., mentalizing) and with cognitive control (i.e., emotion regulation) have been associated with empathic processes, in addition to subcortical regions implicated in pain processing. Functional magnetic resonance imaging (fMRI) data show that blood-oxygen-level-dependent (BOLD) functioning in neural regions linked with social cognition (i.e., dorsal medial prefrontal cortex (dmPFC); temporal parietal junction (TPJ)) and pain processing (i.e., dorsal anterior cingulate cortex (dACC); anterior insula (AI)) are associated with perspective-taking and empathic concern, respectively (Jackson, Meltzoff, & Decety, 2005; Decety & Jackson, 2006; Schnell et al., 2011; Eres et al., 2015; Rameson, Morrelli, & Lieberman, 2012; Singer & Lamm, 2009; Lockwood et al., 2015). Additionally, regions implicated in emotion regulation (i.e., dorsolateral prefrontal cortex (dlPFC); ventrolateral prefrontal cortex (vlPFC); orbitofrontal cortex (OFC)) have been linked with reduced empathic personal distress (Decety & Lamm, 2011). Importantly, several brain regions found to be associated with empathy undergo significant changes during adolescence, which may suggest a link between empathy and neurodevelopment occurring in adolescence.

Empathy has been linked with neural regions and networks involved in pain processing, social cognition, and emotion regulation. Youth experience important neural developments in these very same brain regions while they navigate an increasingly complex social world during adolescence (Crone & Dahl, 2012; Mill et al., 2014; Crone & Fuligni, 2020). Previously, the dACC has been implicated in pain processing among adults and in response to seeing others in pain as well, suggesting a form of vicarious emotion sharing when seeing others in pain (Jackson, Meltzoff, & Decety, 2005; Jackson, Rainville, & Decety, 2006. Fundamental to the affective component of empathy, vicarious emotion sharing is measured as empathic concern, which is theorized to be relatively more developed in adolescence compared to the cognitive component of empathy. Research has demonstrated greater activation in brain regions involved in pain processing and emotional awareness, such as the anterior insula and dACC, during empathy among youth (Pfeifer et al., 2008; Masten et al., 2010). However, activation in the dACC and AI has also been shown to decrease with age from childhood to adulthood (7-40 years old, N = 57) in response to seeing others in pain, possibly indicating a more regulated affective response as people age into adulthood (Decety & Michalska, 2010). Brain activation in regions implicated in social cognition, such as the dmPFC, have been shown to increase in activation (12-13 years old, N = 16) as youth report greater perspective-taking (i.e., understanding another's emotions), but this has not been examined yet with respect to age (Masten et al., 2010). Other investigations of empathy in adolescence have identified the TPJ as being another relevant brain region associated with social cognition and mentalizing processes (Overgaauw et al., 2014;

Regions linked with emotion regulation, such as the dlPFC, vlPFC, and OFC, have also been implicated in empathy during adolescence and shown to increase in activation with respect to age (7-40 years, N = 57) (Decety & Michalska, 2010). While findings suggest the involvement of regions implicated in pain processing, social cognition, and emotion regulation in response to seeing others in pain, more research on relevant developmental age ranges are needed to address how neural systems underlying empathy develop during adolescence. Such research will help inform current theories of adolescent positive behavioral and associated brain development more broadly, which is greatly needed in the field of developmental cognitive and social neuroscience.

While previous research thus far has identified certain neural correlates of empathy, such as those involved in pain processing, social cognition, and emotion regulation, the majority of this fMRI work has been done in adult samples or largely ignored the context of adolescent development. The limited work that has examined the neural correlates of empathy in adolescence has focused heavily on social paradigms of empathy as opposed to examining visceral responses (i.e., pain) to empathy as done in adults warranting research to examine the latter. Visceral pain may be a more objective measure of empathy in adolescence compared to empathic stimuli that are social in nature, which are known to be highly more salient for adolescents in general (Balconi & Angioletti, 2022). Focusing on adolescents' neural responses to others experiencing pain could unveil possible age differences in functional brain activation among regions linked with pain processing, social cognition, and emotion regulation, and this could have implications for how and when empathic processes and responses develop behaviorally in adolescence. The overarching goal of this dissertation was to bring together social cognitive neuroscience and developmental approaches in order to examine adolescent empathy through a developmental social neuroscience framework. Elucidating the processes, responses, and neural components of empathy linked with increasing age in adolescence could fruitfully inform efforts aimed at nurturing prosocial adolescent behaviors.

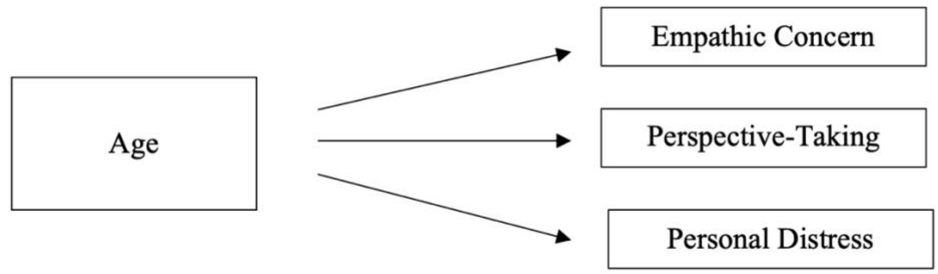
This dissertation

This dissertation aimed to fill gaps in the research on empathy during adolescence by examining the processes and responses involved in empathy to uncover age-related differences and associations with brain activation. In this dissertation research, adolescents aged 11 to 17 years old underwent fMRI brain scans while completing an empathy task in which they viewed human arms and legs in physically painful situations. Empathy was measured as empathic concern (affective component), perspective-taking (cognitive component), and personal distress (aversive affective response) while participants witnessed another in physical pain. Empathic responses were examined in relation to age and correlated with neural activation in regions implicated in pain processing, social cognition, and emotion regulation. The overall goal of this dissertation was to marry developmental and social neuroscience theories and methods to contribute to the scientific literature on the behavioral and neural development of empathy during adolescence, a period of notable maturation in terms of both social behaviors and associated neural functioning. This work characterized developmental trends in the cognitive and affective processes involved in empathy and sought to examine neural mechanisms underlying this behavioral development.

Dissertation Aims and Hypotheses

Aim 1: Examine age differences in empathic processes and responses—measured as empathic concern, perspective-taking, and personal distress—during adolescence (Figure 1).

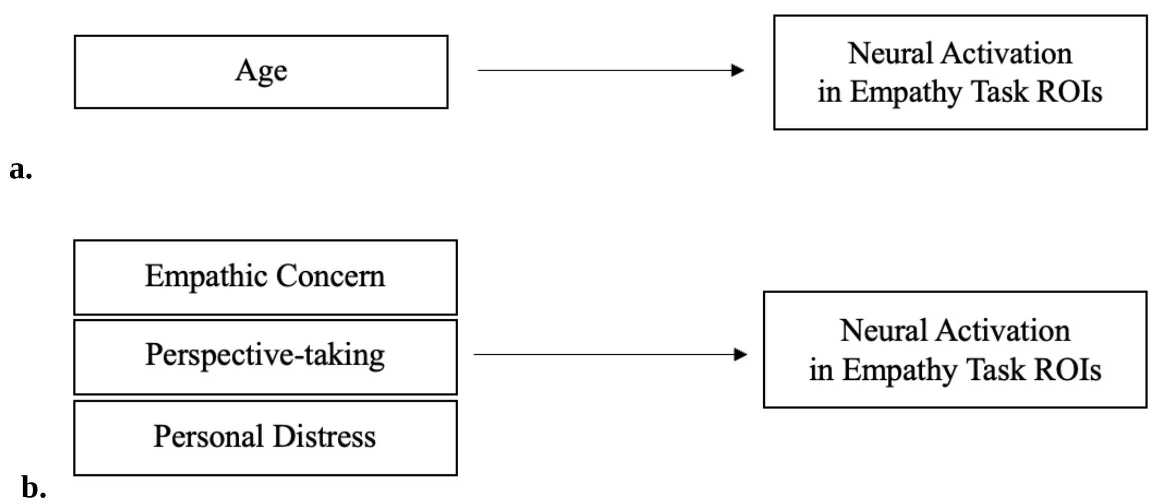
Figure 1.1. Statistical model of Aim 1.



Aim 1 Hypothesis: In line with prior research demonstrating protracted development of cognitive processes compared to affective processes in adolescence, it was hypothesized that empathic concern will be high at age 11 and remain high, perspective-taking will be low at age 11 and increase thereafter, and personal distress will be high at age 11 and decrease thereafter.

Aim 2: Investigate age differences in brain activation in regions implicated in pain processing, mentalizing, and emotion regulation among adolescents (Figure 2a). Assess associations between empathic concern, perspective-taking, and personal distress with brain activation in the aforementioned regions among adolescents (Figure 2b).

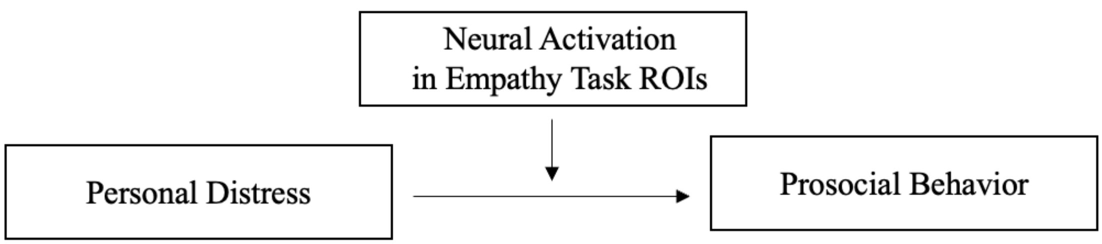
Figure 1.2. Statistical model of Aim 2.



Hypothesis 2: Considering previous fMRI research on the neural correlates of empathy, it was hypothesized that activation in pain processing-related regions of interest (dACC and AI) will not be associated with age, but activation in social cognition-related regions (mPFC TPJ, vmPFC) and emotion regulation-related regions (dlPFC, vlPFC, OFC) will be positively associated with age. Furthermore, it is hypothesized that higher empathic concern will be associated with higher activation in the dACC and AI, higher perspective-taking will be associated with higher activation in the dmPFC and TPJ, and higher personal distress will be associated with lower activation in the dlPFC, vlPFC, and OFC.

Aim 3: Assess the link between personal distress and prosocial behavior, and examine the moderating role of emotion regulation-related ROIs (dlPFC, vlPFC, OFC).

Figure 1.3. Statistical model of Aim 3.



Hypothesis 3: Informed by prior work, it was hypothesized the higher personal distress will be associated with lower prosocial behavior; however, activation in the dlPFC, vlPFC, and OFC will moderate this link such that higher personal distress will be associated with higher prosocial behavior.

Significance of this Dissertation

There has been a renewed scientific interest in characterizing prosocial behavior development in adolescence due to links with positive physical and psychosocial outcomes, but in order to advance science on the development of prosocial behavior, there must also be a revived attention to clarify the behavioral and neural development of empathy—a behavior shown to promote prosocial behavior—during adolescence. Given prior work establishing the role of both affective and cognitive processes underlying empathy, the proposed research aims to 1) examine age-related differences in empathic processes and responses (i.e., empathic concern, perspective-taking, personal distress) during adolescence, 2) investigate age differences in brain activation among neural regions linked with pain processing, social cognition, and emotion regulation associated with empathy, and 3) assess the link between personal distress and prosocial behavior as well as the moderating role of brain regions linked with emotion regulation. This work will lay a foundation for future research to examine the role of empathy in prosocial behavior development which will meaningfully inform intervention efforts aimed at enhancing positive adolescent behaviors to promote physical and psychosocial health among youth.

CHAPTER 2

Age Differences in Empathy during Adolescence

Introduction

Empathy, the process of caring for and understanding another person's emotional state, has remained underexamined during the period of adolescence, a time of significant socioemotional development and reorientation away from the self and toward others (Crone & Fuligni, 2020). Prosocial behavior (e.g., helping someone else) has been shown to increase in adolescence and helping behaviors have been linked with positive physical and psychosocial benefits (Do et al., 2019; Armstrong-Carter et al., 2020; Armstrong-Carter & Telzer, 2021). Empathy is known to precede prosocial behavior, thus characterizing the development of empathy in adolescence may help in promoting the development of prosocial behavior and its associated benefits in youth (van der Graaff, 2018). Few studies have examined age differences in empathy during adolescence, and those that have done so often measure either state or trait empathy but not both. The current study sought to characterize the development of empathy in adolescence using measures of state and trait empathy. Furthermore, previous research points to gender differences in empathy, therefore the current study assessed gender differences in the development of empathy during adolescence (van der Graaff, 2014).

Defining Empathy

Empathy is broadly defined as an individual's ability to discern the mental and emotional states of another person. Affective (feeling another's emotional state), mentalizing (understanding another's emotional state of mind), and cognitive control processes together have been shown to produce an empathic response to another's suffering (Decety, 2010; Cuff et al., 2016; Zaki & Ochsner, 2016). Yet, knowledge of how these processes develop to support empathy during adolescence—a period of critical socioemotional maturation and neurodevelopment—remains limited. Additionally, even less is known about how personal distress, an adverse affective response to empathy, emerges in adolescence (Decety & Lamm, 2011; Eisenber & Eggum, 2009). More research is needed to clarify age-related differences in the affective and cognitive components of empathy during the adolescent years.

Despite varying operationalizations of empathy in the scientific literature, there is a general consensus on the involvement of both cognitive and affective processes in producing empathic behavior. Existing developmental research based largely upon self-report measures of dispositional empathy, such as the Interpersonal Reactivity Index (IRI), suggests that the affective component of empathy (i.e., empathic concern, defined as feeling sorrow for another's emotional state) follows an accelerated developmental trajectory compared to the cognitive component of empathy (i.e., perspective-taking, defined as understanding another's emotional state) (van der Graaff et al., 2014). Research shows that empathic concern is moderately stable during adolescence, while perspective-taking increases during adolescence (Allemand et al., 2015). This aligns with the social reorientation shown to happen in adolescence wherein youth become more aware of the needs and mental states of others in their lives (Crone & Fuligni, 2020; Karan et al., 2022).

Personal distress, an affectively aversive self-oriented response to another's pain, is a potential outcome of engaging in empathy (Decety & Lamm, 2011). Importantly, personal distress to empathy emerges when the observer fails to maintain a clear distinction between self and other. Personal distress has been associated with reductions in prosocial behavior necessitating further study during adolescence, a period during which prosocial behavior has been shown to increase (Carrera et al., 2012; Do et al., 2019). In terms of its developmental trajectory, personal distress is theorized to decrease with older age as individuals are better able to engage in emotion regulation abilities that help with maintaining a clear distinction between your pain or suffering versus someone else's pain or suffering (Decety & Lamm, 2011).

Little to no research has simultaneously examined adolescent age differences in empathic concern, perspective-taking, and personal distress to characterize their developmental trajectories. Furthermore, variable operationalizations of empathic processes and responses among limited age ranges used in prior studies contribute to a vague picture of the development of empathy across the adolescent years. Research employing both self-report measures and proven experimental tasks that assess explicit empathic processes and responses are needed among adolescents. Such work would also help to elucidate age differences in personal distress during adolescence to address developmental differences in negative responses to engaging in empathy.

Prior research on empathy suggests that gender differences emerge such that females show greater empathy compared to males (Tretini et al., 2022; Christov-Moore et al., 2014). This gender difference has primarily been found in cross-sectional studies assessing self-reported trait measures of empathy. Although limited work has examined the development of empathy in adolescence, one longitudinal study found gender differences in empathy development such that females demonstrated stable empathic concern in adolescence but increasing perspective-taking with age (van der Graaff et al., 2014). Males demonstrated decreased empathic from early to middle adolescence with a rebound to the initial level thereafter. In light of these gender differences that have been detected in empathy during adolescence, research has also found associations between empathy and pubertal development. Specifically, the aforementioned longitudinal study found that males who were more physically mature reported less empathic concern compared to their less physically developed peers. Another study examining pubertal development and the neural correlates of empathy found that greater pubertal maturation was associated with more activation among brain regions linked with perspective-taking irrespective of gender (Masten et al., 2013). Taken together, these findings point to the role of pubertal development in empathy development.

The current study aimed to characterize the developmental trajectory of empathy during adolescence using both trait and state measures. To address this aim, age-related differences in empathic processes (i.e. empathic concern, perspective-taking, personal distress) were examined among a sample of adolescents. It was hypothesized that empathic concern will be high at age 11 and remain high, perspective-taking will be low at age 11 and increase thereafter, and personal distress will be high at age 11 and decrease thereafter. Given previous findings that have detected gender differences in empathy during adolescence, the current study also examined variations in empathy development by gender. Females were hypothesized to demonstrate a positive association between empathic concern, perspective-taking and age compared to males, while males were hypothesized to show decreased personal distress with age compared to females. Exploratory analyses examined the association between pubertal development and empathy. It was hypothesized that adolescents at more advanced pubertal stages would demonstrate greater empathic concern and perspective-taking as well as lower personal distress.

Method

Data were used from the second wave of the UCLA Brain Power Study, a three-wave longitudinal study aimed at examining the behavioral and neural development of prosocial behavior in adolescents. Youth returned for their second follow-up sessions during 2020-2021, and in addition to undergoing the main study protocol, they also completed an empathy task during an fMRI brain scan followed by a post-scan task measuring their empathic responses to the empathy task they completed in the scanner. The current study focuses on youths' self-reported responses to an empathy trait measure as well as their state empathy as measured during the empathy task.

Participants

Sample Characteristics. The current study consisted of 141 participants (49.28% female) ages 11-17 years ($\bar{x}$ = 13.97, SD = 1.83) who returned for the second wave of a three-wave longitudinal study. Youth were from the across the Los Angeles area and come from ethnically diverse backgrounds (35.51% European American, 26.09% Multi-ethnic, 13.04% Hispanic/Latinx, 8.70% Asian American, 10.14% African American, 3.62% Other, and 2.9% Native American). Average parent education (averaged across both parents if youth had 2 parents) was slightly above "graduated from college" ($\bar{x}$ = 9.24, SD = 1.37). Youth were recruited via flyers, advertisements, and through class presentations to schools within Los Angeles school districts, and from the Clinical and Translational Science Institute database of families in the UCLA and affiliated medical systems. Participants were fully compensated with funding from the longitudinal parent grant (up to $84).

Procedure

Participants and one of their parents reported on demographic information, and participants completed a set of questionnaires before attending an in-person study visit at a university-run magnetic resonance imaging (MRI) facility to complete behavioral tasks and a functional MRI (fMRI) scan.

Measures

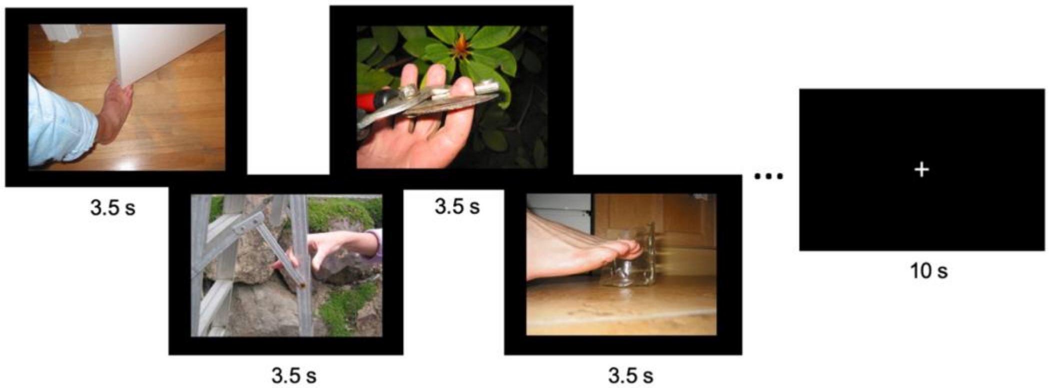
Interpersonal Reactivity Index. The Interpersonal Reactivity Index (IRI) (Davis, 1983) is a well-validated and popular measure of trait empathy that the current sample of adolescents completed. This self-report questionnaire of empathy consists of 4 components, but the current study measured 2 components of interest from this measure: empathic concern (7 items) and perspective-taking (7 items). Items measuring empathic concern focused on how participants generally feel about others that need care (e.g., "*I often have tender, concerned feelings for people less fortunate than me.*"; "*When I see someone being taken advantage of, I feel kind of protective towards them.*"), while items measuring perspective-taking focused on how participants generally view the perspectives of others (e.g., "*I sometimes try to understand my friends better by imagining how things look from their point of view*."; "*I believe that there are two sides to every question and try to look at them both*."). Participants responded to the items on a scale of 1 ("does not describe me at all") to 5 ("describes me very well"). Empathic concern items ($\bar{x}$ = 2.74, SD = 0.55; α = 0.75) and perspective-taking items ($\bar{x}$ = 2.46, SD = 0.60; α = 0.76) were averaged to generate mean values of empathic concern and perspective-taking for each participant. Empathic concern and perspective-taking on the IRI were correlated at r = 0.572, $p < .001$.

Empathy Task. The empathy task utilized in the current study has been used in children, adolescents, and other vulnerable populations (Jackson et al., 2005; 2006; Cheng, et al., 2012; Decety et al., 2013). Broadly, participants passively viewed photos of limbs in physically painful situations, and outside of the scanner they rate their empathic concern, perspective-taking, and personal distress for each photo.

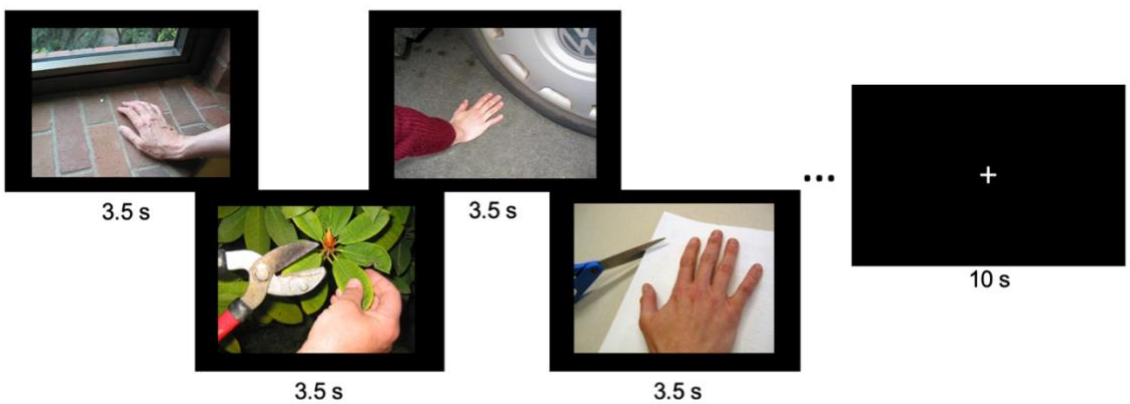
A series of 96 digital colored pictures (randomly chosen from a validated bank of 128 photos) showing right hands and right feet in painful and non-painful situations (48 each) were shot from angles that promoted first-person perspective, and these pictures are presented during this task. As shown in the adjacent schematic, we created a block design task as has been done in prior studies using the same set of stimuli. There were 12 blocks in the task (each 32s long) and it was presented in one run (Figure 4c). Each block varied based on photo condition (pain versus no-pain photos) with 6 pain photo blocks (Figure 4a) and 6 no-pain photo blocks (Figure 4b) comprising the task. Each block consisted of eight 4 second (s) photos of the same condition (photo = 3.5s, fixation cross = 0.5s), and each block had 4 photos of hands and 4 photos of feet randomly presented. A fixation cross screen of 10s was inserted between each block of trials. The order of conditions was randomized, but the first 2 blocks were always different conditions. No photo was presented more than once throughout the whole experiment. To control for ordering effects, there were 4 versions of the task which varied based on order of presentation and participants were randomly assigned a version. Participants were instructed to view the images carefully while in the MRI scanner, and to press a button every time they saw a photo to indicate that they are paying attention. In total, the task took 8 minutes and 13s to complete in the MRI scanner.

Figure 2.1. Schematic of the Empathy Task used in this dissertation: a) Example of a pain image block. b) Example of a no-pain image block. c) Diagram of task structure.

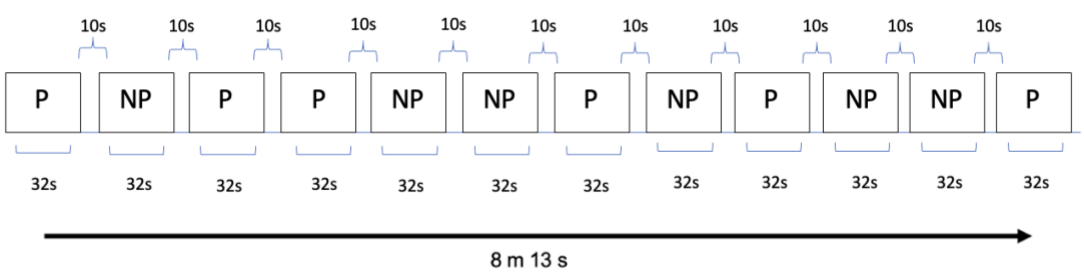
a.



b.



c.



After the fMRI scan, participants completed a post-scan empathy rating task where they were presented the same painful photos again in the same order, as well as a subset of nonpainful images, and asked to think about what they were feeling when they saw the images for the first time in the scanner. Specifically, participants were asked 1) “How sorry did you feel for this person?”, 2) “How much pain do you think this person was in?”, and 3) “How distressing did you find this photo?”. Participants were given options to rate from 1 (not at all sorry/no pain at all/no distress at all) to 7 (extremely sorry/extremely in pain/extremely distressing). Higher ratings on each of the three self-report questions about the photos indicate greater empathic concern, perspective-taking, and personal distress, respectively. Empathic concern was measured using the first self-report question, perspective-taking was measured using the second self-report question, and personal distress was measured using the third self-report question.

Ratings on the questions across all the photos were averaged to create mean scores of empathic concern ($\bar{x}$ = 4.89, SD = 1.19), perspective-taking ($\bar{x}$ = 5.05, SD = 1.06), and personal distress ($\bar{x}$ = 4.75, SD = 1.37) for each participant. The scanner and post-scan tasks were both programmed in PsychoPy3. The current study focuses on the self-report responses to the post-scan empathy task as a measure of state empathy. Empathic concern and perspective-taking on the task were strongly correlated ($r = 0.876$, $p < .001$), as was empathic concern and personal distress, ($r = 0.725$, $p < .001$) and perspective-taking and personal distress ($r = 0.660$, $p < .001$). Two-level multilevel models with averaged empathic concern, perspective-taking, and personal distress responses nested within participants were run to examine within-person differences in the empathy responses. Significant within-person differences emerged between empathic concern and perspective-taking (b = -0.18, SE = 0.09, $p = .037$), empathic concern and personal distress (b = 0.18, SE = 0.09, $p = .040$), and perspective-taking and personal distress (b = 0.34, SE = 0.09, $p < .001$). Results demonstrated that perspective-taking was higher than empathic concern and empathic concern was higher than personal distress. Follow-up models examined within-person differences by age, by gender, and an interaction between age and gender but results were not statistically significant (*p*'s > .05).

Pubertal Development Scale. Exploratory analyses examined the association between empathy and pubertal development as measured by the Pubertal Development Scale (PDS) (Petersen, 1988). The PDS is a self-report measure of physical maturation that has 5 items some of which are worded differently for males and females. Participants rated their physical development (i.e., breast growth, pubic hair, skin changes) on a scale from 1 (not yet begun) to 4 (already complete). PDS values were utilized to calculate the following: average PDS score, adrenal- versus gonadal-related average PDS scores, and pubertal category score. These summary scores were computed separately for male and female participants. Gonadal PDS scores were created for females by averaging growth spurt, breast development, and menarche PDS items; for males, by averaging growth spurt, deepening of voice, and facial hair growth PDS items. Adrenal scores were created by averaging pubic/body hair and skin changes from PDS items for both males and females. The puberty category score was derived for males by summing the body hair growth, voice change, and facial hair items and categorizing them as follows: prepubertal = 3 (all one-point responses); early pubertal = 4 or 5 (no 3-point responses); mid-pubertal = 6–8 (no 4-point responses); late pubertal = 9–11; and, post-pubertal = 12 (e.g. all 4-point responses). The puberty category score was derived for females by summing the body hair growth and breast development and using the menarche variable for categorizing them as follows: prepubertal = 2 and no menarche; early pubertal = 3 and no menarche; mid-pubertal ≥ 3 and no menarche; late pubertal ≤ 7 and menarche; post-pubertal = 8 and menarche (Herting et al., 2021). In the current sample, 5% (n = 6) were prepubertal, 11% (n = 13) were in early puberty, 27% (n = 32) were in midpuberty, 26% (n = 31) were in late puberty, and 29% (n = 34) were post-puberty.

Analytic Approach

Multiple regressions were employed to examine associations between age (linear and quadratic) and empathy, as measured by the IRI components and the empathy task. Models controlled for gender, ethnicity, and average parental education. Follow-up models examined interactions between age (linear and nonlinear) and gender. Age was mean-centered, and gender (male = 0) and ethnicity (European American = 0) were dummy-coded. Exploratory analyses focused on puberty also utilized regressions with the same control variables and coding scheme as the age models.

Results

Analytic Sample Descriptives. The final analytic sample varied depending upon the measure of empathy. When completing the IRI, an attention check was included to measure whether participants were paying attention to the items they were responding to and 16 participants out for 141 (11.3%) failed the attention check. As such, the final sample that completed the IRI measure was 125 participants (see Table 1 for sample Descriptives). Since the empathy task was completed at a separate study visit, not all participants who completed the IRI had completed the empathy task. Therefore, the final sample of participants that completed the empathy task was 122 participants (this sample did not differ statistically from the final sample of participants who completed the IRI). See **Table 2.1** for a list of descriptive statistics broken down by age.

Table 2.1. *Participant Descriptive Statistics by Age.*

Age	11	12	13	14	15	16	17
Observations (Range)*	*n* = 15-21	*n* = 21-25	*n* = 21-23	*n* = 14-15	*n* = 21-22	*n* = 16-17	*n* = 6-7
IRI Empathic Concern	2.78 (0.53)	2.76 (0.48)	2.71 (0.43)	2.73 (0.58)	2.67 (0.81)	2.76 (0.47)	3.09 (0.41)
IRI Perspective-taking	2.44 (0.46)	2.52 (0.48)	2.09 (0.58)	2.63 (0.66)	2.54 (0.80)	2.51 (0.52)	2.97 (0.42)
Task Empathic Concern	4.85 (1.19)	5.05 (1.17)	4.97 (1.003)	4.17 (1.45)	5.26 (1.09)	4.83 (0.93)	4.93 (1.66)
Task Perspective-taking	4.96 (0.93)	5.26 (1.02)	5.19 (0.97)	4.29 (1.33)	5.31 (1.04)	5.10 (0.99)	4.92 (1.05)
Task Personal Distress	4.53 (1.68)	4.77 (1.43)	4.75 (1.26)	4.30 (1.44)	5.20 (1.14)	4.73 (1.24)	5.13 (1.33)
Gender (% female)	35%	52%	44%	46%	67%	41%	80%
Asian American	24%	5%	5%	7%	0%	13%	40%
African American	0%	15%	9%	7%	10%	19%	20%
European American	33%	25%	41%	67%	33%	31%	20%
Latinx / Hispanic	10%	10%	0%	7%	24%	0%	20%
Multi-Ethnic	29%	35%	32%	13%	24%	31%	0%
Other	0%	5%	9%	0%	5%	6%	0%
Native American	0%	5%	5%	0%	5%	0%	0%
Avg. Parent Education	9.21 (1.09)	9.38 (1.26)	9.61 (0.98)	9.30 (1.83)	8.86 (1.41)	9.25 (1.54)	9.30 (0.98)

Note. Observations are indicative of the number of data points per variable by age. Since demographics and questionnaire data were collected online and the empathy task was completed in-person, not all participants provided data for all measures. Since this number varied depending on the variable of interest, a range of observations is listed above.

IRI and Age Associations. Empathic concern, as measured by the IRI, was not significantly associated with linear (**Table 2.2**) or quadratic age (**Table 2.3**). Similarly, perspective-taking, as measured by the IRI, was not was not significantly associated with linear (**Table 2.2**) or quadratic age (**Table 2.3**). Taken together, these findings indicate that trait empathic concern and trait perspective-taking did not significantly differ by age in the current sample.

Table 2.2. *Trait Empathy (IRI) and Linear Age.*

	Empathic Concern		Perspective-taking	
	b	SE	b	SE
Intercept	2.91***	0.43	2.30***	0.49
Age	0.02	0.03	0.06	0.03
Gender	0.06	0.10	0.07	0.11
Asian American	-0.03	0.18	0.14	0.19
African American	-0.11	0.19	-0.28	0.21
Hispanic/Latinx	-0.55*	0.20	-0.40	0.23
Multi-Ethnic	-0.13	0.13	-0.25	0.14
Native American	0.49	0.29	0.27	0.32
Other	0.12	0.25	-0.31	0.28
Parent Education	-0.01	0.04	0.03	0.05

Note. Age was mean-centered at 14.02 years. Male = 0; European American = 0. **p* < .05, ***p* < .01, ****p* < .001.

Table 2.3. *Trait Empathy (IRI) and Quadratic Age.*

	Empathic Concern		Perspective-taking	
	b	SE	b	SE
Intercept	2.89***	0.44	2.24***	0.48
Age	0.01	0.03	0.05	0.03
Age^2	0.02	0.02	0.02	0.02
Gender	0.05	0.10	0.07	0.11
Asian American	-0.08	0.19	0.06	0.21
African American	-0.13	0.19	-0.31	0.21
Hispanic/Latinx	-0.57**	0.20	-0.43	0.23

Multi-Ethnic	-0.14	0.13	-0.26	0.14
Native American	0.49	0.29	0.26	0.32
Other	0.11	0.26	-0.32	0.28
Parent Education	-0.01	0.04	0.03	0.48

Note. Age was mean-centered at 14.02 years. Male = 0; European American = 0. **p* < .05, ***p* < .01, ****p* < .001.

Empathy Task and Age Associations. Empathic concern, as measured by the empathy task post-scan responses, was not significantly associated with linear (**Table 2.4**) or quadratic age (**Table 2.5**). Similarly, neither perspective-taking nor personal distress, as measured by the empathy task, were not significantly associated with linear (**Table 2.4**) or quadratic age (**Table 2.5**). Taken together, these findings indicate that state empathic concern, perspective-taking, and personal distress did not significantly differ by age in the current sample.

Table 2.4. *State Empathy (task) and Linear Age.*

	Empathic Concern		Perspective-taking		Personal Distress	
	b	SE	b	SE	b	SE
Intercept	5.12***	0.96	5.33***	0.85	5.68***	1.09
Age	-0.01	0.06	-0.02	0.05	0.05	0.07
Gender	0.35	0.23	0.24	0.20	0.23	0.26
Asian American	0.10	0.45	0.37	0.40	0.42	0.51
African American	-0.60	0.48	-0.44	0.42	-1.06	0.54
Hispanic/Latinx	0.39	0.39	0.59	0.34	0.69	0.44
Multi-Ethnic	0.08	0.28	0.38	0.24	0.23	0.31
Native American	0.08	0.63	0.62	0.56	0.52	0.72
Other	-0.64	0.62	-0.18	0.54	0.02	0.70

Parent Education	-0.05	0.10	-0.06	0.08	-0.13	0.11

Note. Age was mean-centered at 14.02 years. Male = 0; European American = 0. **p* < .05, ***p* < .01, ****p* < .001.

Table 2.5. *State Empathy (task) and Quadratic Age.*

	Empathic Concern		Perspective-taking		Personal Distress	
	b	SE	b	SE	b	SE
Intercept	5.21***	0.97	5.40***	0.85	5.83***	1.09
Age	-0.01	0.06	-0.01	0.05	0.06	0.07
Age^2	-0.03	0.04	-0.02	0.03	-0.06	0.04
Gender	0.34	0.23	0.23	0.20	0.21	0.25
Asian American	0.24	0.49	0.48	0.43	0.69	0.55
African American	-0.58	0.48	-0.42	0.42	-1.02	0.54
Hispanic/Latinx	0.42	0.39	0.61	0.35	0.74	0.44
Multi-Ethnic	0.12	0.28	0.40	0.25	0.30	0.32
Native American	0.11	0.64	0.63	0.56	0.56	0.72
Other	-0.60	0.62	-0.15	0.55	0.11	0.70
Parent Education	-0.05	0.10	-0.06	0.08	-0.13	0.11

Note. Age was mean-centered at 14.02 years. Male = 0; European American = 0. **p* < .05, ***p* < .01, ****p* < .001.

IRI: Age × Gender Interactions. Follow-up models examining an age by gender interaction revealed that there was no significant interaction between linear age and gender in predicting empathic concern or perspective-taking on the IRI (**Table 2.6**). Furthermore, there was no significant interaction between quadratic age and gender in predicting empathic concern or perspective-taking on the IRI (**Table 2.7**).

Table 2.6. *Trait Empathy (IRI): Linear Age by Gender Interactions*

	Empathic Concern		Perspective-taking	
	b	SE	b	SE
Intercept	2.87***	0.44	2.26***	0.49
Age	-0.01	0.04	0.04	0.04
Gender	0.05	0.10	0.07	0.11
Age × Gender	0.06	0.06	0.04	0.06
Asian American	-0.01	0.18	0.15	0.20
African American	-0.11	0.19	-0.28	0.21
Hispanic/Latinx	-0.52	0.20	-0.39	0.23
Multi-Ethnic	-0.12	0.13	-0.25	0.14
Native American	0.48	0.29	0.26	0.32
Other	0.09	0.26	-0.33	0.28
Parent Education	-0.01	0.04	0.03	0.05

Note. Age was mean-centered at 13.05 years. **p* < .05, ***p* < .01, ****p* < .001.

Table 2.7. *Trait Empathy (IRI): Quadratic Age by Gender Interactions*

	Empathic Concern		Perspective-taking	
	b	SE	b	SE
Intercept	2.85***	0.44	2.22***	0.49
Age	-0.01	0.04	0.04	0.05
Age^2	0.01	0.03	0.03	0.03
Gender	0.02	0.15	0.09	0.17
Age × Gender	0.05	0.06	0.03	0.06
Age^2 × Gender	0.01	0.03	-0.01	0.04

Asian American	-0.06	0.20	0.08	0.21
African American	-0.13	0.20	-0.31	0.21
Hispanic/Latinx	-0.54	0.21	-0.42	0.23
Multi-Ethnic	-0.13	0.13	-0.25	0.14
Native American	0.48	0.30	0.25	0.32
Other	0.08	0.26	-0.33	0.29
Parent Education	-0.01	0.04	0.03	0.05

Note. Age was mean-centered at 13.05 years. **p* < .05, ***p* < .01, ****p* < .001.

Empathy Task: Age × Gender Interactions. Linear age × gender was significantly associated empathic concern on the empathy task (b = 0.34, SE = 0.12, *p* = .007); however, neither perspective-taking nor personal distress were associated with linear age × gender (**Table 2.8**). These analyses were followed-up by examining whether quadratic age × gender was associated with the three empathy task components. Results show that quadratic age × gender was significantly associated empathic concern (b = 0.14, SE = 0.07, *p* = .042) and perspective-taking (b = 0.13, SE = 0.06, *p* = .042), but not with personal distress (**Table 2.9**). Simple slopes analyses revealed that both empathic concern and perspective-taking follow similar age-related differences by gender. Specifically, females demonstrate increasing empathic concern and perspective-taking with age (U-shape), while males show decreasing empathic concern and perspective-taking with age (inverted U-shape) (**Figures 2.1 & 2.2**, respectively). Since the sample size for the older youth aged 17 years or over was relatively small compared to the other age groups (see Table 1), the aforementioned significant models were re-run to assess whether they remained statistically significant after removing youth aged 17 years and older. Results show that the coefficients for quadratic age × gender by empathic concern (b = 0.07, SE = 0.09,

p = .452) and perspective-taking (b = 0.10, SE = 0.08, p = .252) become smaller and lose statical significance when removing youth aged 17 years and older from the respective models.

Table 2.8. *State Empathy (task): Linear Age by Gender Interactions.*

	Empathic Concern		Perspective-taking		Personal Distress	
	b	SE	b	SE	b	SE
Intercept	4.90^{***}	0.93	5.19^{***}	0.84	5.59^{***}	1.09
Age	-0.18	0.08	-0.12	0.08	-0.02	0.10
Gender	0.34	0.22	0.23	0.20	0.23	0.26
Age × Gender	**0.34^{**}**	**0.12**	0.21	0.11	0.14	0.14
Asian American	0.10	0.44	0.36	0.40	0.42	0.51
African American	-0.56	0.46	-0.41	0.41	-1.04	0.54
Hispanic/Latinx	0.50	0.38	0.65	0.34	0.73	0.45
Multi-Ethnic	0.21	0.27	0.50	0.25	0.29	0.32
Native American	-0.02	0.62	0.55	0.55	0.47	0.72
Other	-0.82	0.60	-0.29	0.54	-0.05	0.70
Parent Education	-0.03	0.09	-0.05	0.08	-0.12	0.11

Note. Age was mean-centered at 13.05 years. $^*p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table 2.9. *State Empathy (task): Quadratic Age by Gender Interactions.*

	Empathic Concern		Perspective-taking		Personal Distress	
	b	SE	b	SE	b	SE
Intercept	5.30^{***}	0.94	5.53^{***}	0.84	6.05^{***}	1.09
Age	-0.16	0.08	-0.11	0.08	0.002	0.10
Age^2	-0.11^{*}	0.05	-0.09	0.04	-0.13	0.06

Gender	-0.14	0.32	-0.20	0.28	-0.27	0.37
Age × Gender	0.31*	0.12	0.19	0.11	0.11	0.14
Age^2 × Gender	**0.14***	**0.07**	**0.13***	**0.06**	0.15	0.08
Asian American	0.20	0.47	0.43	0.42	0.63	0.54
African American	-0.66	0.46	-0.50	0.41	-1.13	0.54
Hispanic/Latinx	0.52	0.38	0.67	0.34	0.78	0.44
Multi-Ethnic	0.24	0.27	0.48	0.25	0.35	0.32
Native American	-0.03	0.61	0.54	0.54	0.48	0.71
Other	-0.79	0.60	-0.27	0.53	0.01	0.69
Parent Education	-0.04	0.10	-0.06	0.08	-1.13	0.11

Note. Age was mean-centered at 13.05 years. *$p < .05$, **$p < .01$, ***$p < .001$.

Figure 2.2. Empathic concern associated with age^2 × gender.

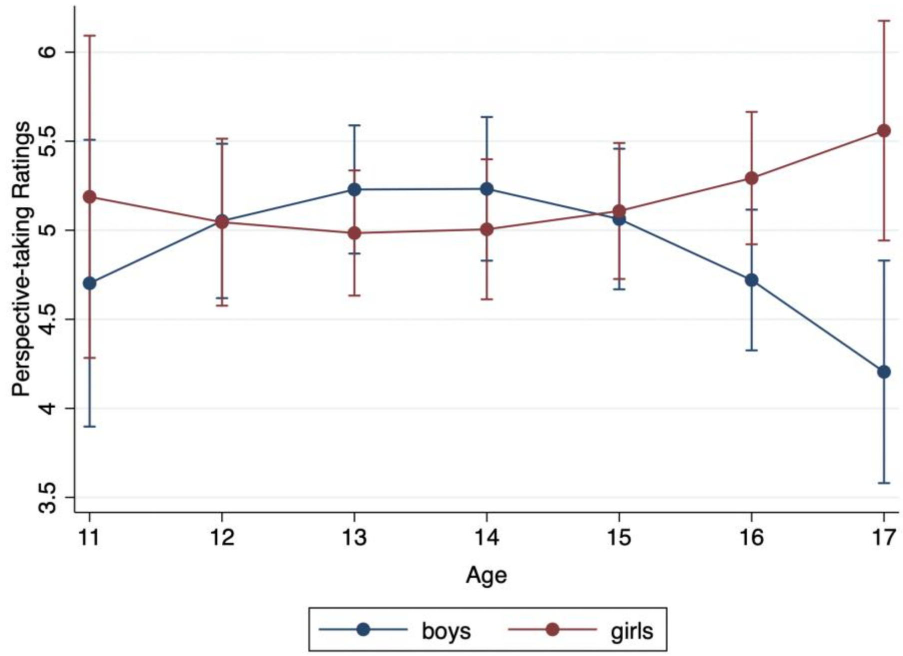
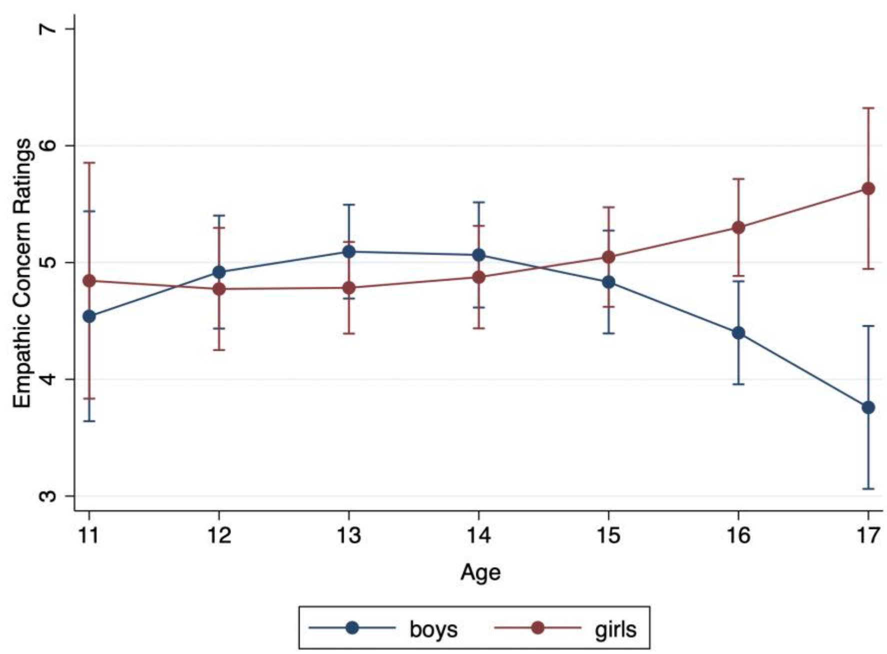


Figure 2.3. Perspective-taking associated with age^2 × gender.



Exploratory Analyses: Puberty and Empathy. The same set of main effect age models presented above were repeated for average PDS score, adrenal- versus gonadal-related average PDS scores, and pubertal category score. No significant main effects of the pubertal indices emerged as significantly associated with empathy measured by the IRI and the empathy task (all p's > .05) indicating that empathy was not associated with puberty in the current sample. Follow-up models of puberty × gender were examined given the significant age × gender interactions, but no significant interaction effects were found (p's > .05).

Discussion

Empathy development in adolescence remains an understudied facet of adolescents' socioemotional development and as such, the current study aimed to address this gap in the literature by examining a validated trait and state measure of empathy in a sample of adolescents aged 11 to 17 years old. In addition to examining age differences, age by gender and age by puberty differences were also examined. The current study found a significant interaction between quadratic age and gender associated with empathy, specifically empathic concern and perspective-taking, but not personal distress. These results only emerged in the empathy task, a state measure of empathy, but not the IRI, a trait measure of empathy. Implications of these results are discussed further.

Results from the current study found age differences by gender in empathic concern and perspective-taking among adolescents who completed the empathy task. The pattern for males and females by age looked similar for both empathic concern and perspective-taking, showing that empathic concern and perspective-taking were similar between males and females aged 12 to 15 years but demonstrated differences following 15 years with females showing more empathic concern and perspective-taking and males showing less. This general trend of females showing more empathic concern and perspective-taking was also found in a longitudinal study aimed at examining the development of empathic concern and perspective-taking among adolescents aged 13 to 18 years old (van der Graaff, 2014). Based on responses to the IRI subscales of empathic concern and perspective-taking, females generally showed more empathic concern and perspective-taking than males, and perspective-taking increased significantly with age for females but not for males.

It is important to note that when removing the oldest age group of adolescents from the analyses (≥ 17 years), who were also the least numerically powered, the age by gender findings for empathic concern and perspective-taking on the empathy task disappear. The coefficients in the respective models is slightly reduced for perspective-taking and is halved for empathic concern, thus it's unclear whether these results would have held-up if we had a larger sample of youth aged 17 years and older. Given that the trend seen in the full sample resembles previous empirical findings, it is possible that these data may replicate previous research but the current data are not able to assess this due to the small sample of older adolescents. As such, the behavioral findings for the empathy task and the associated figures (2.2 & 2.3) should be interpreted with caution.

In considering why the current investigation only found a significant age by gender interaction for the empathy task and not for the IRI, it may be worth considering what the empathy task and the IRI are respectively measuring. The empathy task is a state measure of empathy while the IRI is a trait measure of empathy. Thus, the empathy task is designed to elicit empathy to images of people experiencing visceral pain, whereas the IRI asks participants to think about their general behavior and respond to items about their typical approach to empathic concern and perspective-taking in their daily lives. Perhaps given the intensity of the images compared to the IRI items, it is possible that empathy in response to visceral pain may be tapping into gender differences by age better than the IRI in this cross-sectional assessment. The prior study that found gender differences by age in the IRI was leveraging longitudinal data across 6 consecutive years, whereas the current study was examining age differences in a cross-sectional sample of adolescents (van der Graaff, 2014). Longitudinal assessments assessing both state and trait empathy are needed among adolescents to clarify developmental trajectories of empathy.

Contrary to the hypothesis that perspective-taking, the cognitive component of empathy, would increase in adolescence, the current study did not find an association between age and perspective-taking as measured by both the IRI and the empathy task. Previous studies of empathy in adolescence has found a positive association between age and perspective-taking, therefore it was surprising that this association did not emerge in the current sample (Michalska & Decety, 2010; Farrell & Vallaincourt, 2020). Although the current study did not find an overall increase in perspective-taking during adolescence, gender differences in state perspective-taking indicates that the cognitive component of empathy demonstrates age-related changes in adolescence but this is dependent upon gender.

Personal distress, a negative response to engaging in empathy, was also examined to assess whether having a poor empathic response varies by age or gender during adolescent development. Analyses did not detect a significant association between personal distress, as measured by the empathy task, and age. Follow-up analyses examining age × gender interactions did not reveal developmental differences based on gender as was found in empathic concern and perspective-taking measured in the empathy task. Findings indicate that personal distress in response to engaging in empathy does not vary by age nor by gender development in adolescence. Previous research examining age differences in personal distress to empathy during adolescence are non-existent or possibly did not report on null findings with personal distress and age. More work is needed to characterize the developmental trajectory of personal distress to empathy in adolescence.

Exploratory analyses investigated whether pubertal development was associated with empathy. Empathy components as measured by the IRI and empathy task were not associated with any of the computed measures of puberty calculated from the PDS. Research investigating empathy and puberty are scarce, but studies have associations with puberty and empathy. For instance, one study found that more physically mature adolescent males reported less empathic concern compared to less physically mature adolescent males (van der Graaff et al., 2014). Pubertal differences in empathy have not been detected among females, which is consistent with the current study's findings; however, since pubertal maturation occurs later in males compared to females, it is possible that empathy differences exist in females but were not detected by the current sample as most females (85.9%) were in late or post-puberty.

The current results should be considered in conjunction with study limitations. First, the current sample was cross-sectional, thus the current results depict age differences as opposed to developmental changes in empathy. Personal distress was only measured by the empathy task in the current study, but future studies should include a self-report trait measure of personal distress as well such as the IRI subscale. Studies should examine state and trait measures of empathy to discern what components of empathy are malleable during adolescence that can be targeted in behavioral interventions for youth. Future work should address the current research aims by leveraging longitudinal data in large and diverse samples of adolescents who complete multiple state and trait measures of empathy over time.

Overall, this study sought to examine the development of empathy, measured as empathic concern, perspective-taking, and personal distress, during adolescence using a state and trait measure of empathy. Gender differences by age were examined and pubertal differences were explored. Findings point to developmental differences in only state empathic concern and perspective-taking by gender. Males demonstrated increased empathic concern and perspective-taking until mid-adolescence followed by a decrease in both of these empathy components with age. On the other hand, females showed increased empathic concern with age. Personal distress, a negative response to empathy, was not associated with age. Puberty was not associated with empathy in the current study. Taken together, findings point to age-related differences by gender in both affective and cognitive components of empathy during adolescence.

CHAPTER 3

Neural Correlates of Empathy in Adolescence

Introduction

Empathizing with others is critical for the formation of meaningful social connections and the development of this complex social skill has been shown to mature during adolescence – a period defined by increasingly sophisticated social development and associated neural processing (de Graaff et al., 2014). Empathy, the ability to feel and understand another's emotional state, is comprised of multiple processes both affective and cognitive in nature (Decety, 2010; Zaki & Ochsner, 2012). Relatedly, neuroimaging research has linked empathy with activation in brain regions associated affective and cognitive processes such as those involved in pain processing, social cognition, and self-regulation (Jackson et al., 2005; Decety, 2010). Importantly, these same brain regions undergo significant neurodevelopment during adolescence, yet limited research has examined the development of empathy and associated brain development during adolescence (Dumontheil, 2016; Mills et al., 2014; Tousignant, Eugène, & Jackson, 2017). As such, the goal of the current study was to assess age differences in functional brain activation among regions implicated in pain processing, social cognition, and self-regulation among adolescents, and examine associations with subjective ratings of affective and cognitive empathy as well as personal distress to empathy.

Social science research demonstrates that empathy is composed of both affective and cognitive processes that allow an individual to feel and also understand another's emotional state (Singer & Lamm, 2009). Neuroimaging evidence from functional magnetic resonance imaging (fMRI) studies shows that the dorsal anterior cingulate cortex (dACC) and anterior insula (AI) are two notable brain regions involved in the perception of pain in oneself, belonging to a larger network of brain regions involved in pain-perception known as the pain matrix (Wager et al., 2013). Studies on empathy have extended the neuroimaging work on pain to find significant brain activation in regions involved in the pain matrix in response to seeing someone else experience pain, both physical and social (Eisenberger & Lieberman, 2004; Jackson et al., 2005; Lamm, Decety, & Singer, 2011). Activation in the dACC and AI in response to seeing another person experience pain demonstrates that there are shared neural regions involved in experiencing pain oneself and seeing someone else experience pain. Importantly, much of this previous research has focused on adult samples, atypical samples, and has overlooked developmental changes during adolescence (Jackson et al., 2005; 2006; Cheng, et al., 2012; Decety et al., 2013). Nonetheless, some prior studies have found significant activation in the AI and dACC among adolescents engaging in empathy (Decety & Michalska, 2010; Kral et al. 2017). The present study sought to assess age-differences in brain activation within the dACC and AI in response to empathic stimuli.

Regions implicated in social cognition, such as the dorsal medial prefrontal cortex (dmPFC) and temporal parietal junction (TPJ) have been associated with the cognitive facet of empathy (Decety, 2010; Schnell et al., 2011; Eres et al., 2015). These social brain regions are thought to facilitate the understanding of another's emotional state through perspective-taking. Both the dmPFC and TPJ continue to show developmental changes into adolescence as social cognition becomes more refined with age (Mills et al., 2014). Though prior research has linked engaging in empathy with more activation in regions implicated in social cognition among adolescents, these studies focused on stimuli that were social in nature (i.e., social exclusion in the Cyberball task; negative emotional faces) and did report age differences (Masten et al., 2010; Overgaauw et al., 2014). The current study examined age-differences among adolescents in dmPFC and TPJ activation in response to less-socially oriented stimuli depicting physical pain. This is an important distinction because social-stimuli are especially salient to adolescents, thus examining empathic responses to other's in physical pain (i.e., less socially-charged stimuli compared to faces, for example) may provide a more objective assessment of empathy and associated neural correlates.

Regions associated with self-regulation, such as the dorsolateral and ventrolateral prefrontal cortices (dlPFC, vlPFC) and orbitofrontal cortex (OFC), also have shown activation during empathy and are proposed to play a role in emotional self-regulation (Decety, 2010; van der Heiden et al., 2013). One study found greater activation in the dlPFC and vlPFC associated with age, indicating that these prefrontal regions may increasingly be involved in emotion regulation processes during empathy across development (Decety & Michalska, 2010). One possible way in which these prefrontal regions may be contributing to emotion regulation during empathy is by reducing feelings of personal distress. Personal distress, an affectively aversive self-oriented response to another's suffering, is a potential outcome of engaging in empathy and it emerges when the empathizer fails to maintain a clear distinction between themselves and the other person (Decety & Lamm, 2011). Higher personal distress to empathy is associated with lower prosocial behavior necessitating further study during adolescence, a period during which prosocial behavior has been shown to increase (Carrera et al., 2013; Do et al., 2019). Furthermore, limited work has examined the neural correlates of personal distress in response to empathy more generally leaving a gap in knowledge. The current study thus examined age differences in self-regulation regions, such as the dlPFC, vlPFC, and OFC, in empathy and its association with personal distress.

The current study had two primary aims: 1) examine age differences in brain activation in response to implicit empathic stimuli in a priori regions of interest implicated in pain processing (AI, dACC), social cognition (dmPFC, TPJ), and self-regulation (dlPFC, vlPFC, TPJ), and 2) examine associations between brain activation in a priori ROIs and self-reported ratings of empathic concern, perspective-taking, and personal distress on implicit empathic stimuli. In line with the theory that regions involved in affective processes show heightened activation during adolescence compared to social cognition and regulatory regions that show increased activation with older adolescent age, it was hypothesized that there would be significant activation in all ROIs in response to viewing painful stimuli and that this activation would be positively associated with age. With respect to empathic ratings, higher empathic concern ratings were hypothesized to be associated with greater activation in the AI and dACC, higher perspective-taking ratings were hypothesized to be associated with greater activation in the dmPFC and TPJ, and higher personal distress was hypothesized to be associated with lower activation in the dlPFC, vlPFC, and OFC.

A supplemental aim in the current study was to explore potential gender differences in neural activation to empathy as previous work examining self-reports of empathy across adolescent development has detected differences by gender (van de Graaff et al., 2014). Patterns suggest that females show more empathy with age compared to males in adolescence. Although gender differences in neural activation to empathy among adolescents have not been observed previously (Michalska & Decety, 2010), the current study examined a slightly different set of ROIs and explored different task contrasts as well.

Method

A sample of 127 adolescents completed an empathy task where they viewed images of other people's arms and legs (only) in painful and non-painful situations while undergoing an fMRI brain scan. After the fMRI scan, youth viewed the same images that they saw in the scanner and provided ratings on empathic concern, perspective-taking, and personal distress.

Participants

Sample Characteristics. Although 127 participants completed the fMRI scan and empathy task, the final analytic sample included 92 participants ages 11-17 years ($\bar{x}$ = 14.10, SD = 1.82) (48.31% female). Participants were not included in the final analytic sample if their fMRI data had excessive head motion during the fMRI scan (n = 2), if they did not pass the task attention check (n = 31), and if their data revealed consistent outliers across multiple or all ROIs (n = 2).These participants were removed from the analyses in order to avoid unreliable estimates of neural signal. Youth were from the across the Los Angeles area and come from ethnically diverse backgrounds (37.5% European American, 30.68% Multi-ethnic, 12.5% Hispanic/Latinx, 7.95% Asian American, 3.41% African American, 3.41% Other, and 4.55% Native American). Average parent education (averaged across both parents if youth had 2 parents) was slightly above "graduated from college" ($\bar{x}$ = 9.34, SD = 1.36). Youth were recruited via flyers, advertisements, and through class presentations to schools within Los Angeles school districts, and from the Clinical and Translational Science Institute database of families in the UCLA and affiliated medical systems.

Procedure

Participants and one of their parents reported on demographic information, and participants completed a set of questionnaires before attending an in-person study visit at a university-run MRI facility to complete behavioral tasks and a fMRI scan. Participants were fully compensated with funding from a longitudinal parent grant (up to $84).

Measures

Empathy Task. In this task, participants viewed images of human hands and feet in one of two conditions: painful and non-painful. The task was 1 run with 12 blocks (each 32s long) and each block varied randomly based on photo condition (pain versus no-pain photos) with 6 pain photo blocks and 6 no-pain photo blocks. See Chapter 2 for full details about the task design. The current study focused on examining neural activation during this task, specifically contrasting the pain and no-pain photo block conditions (**Figure 3.1**). Participants were instructed to view the images while in the scanner and to press a button on a button box every time they saw a photo to acknowledge that they saw it and were paying attention (attention check). Participants with button presses missing for more than 10 photos (out of 96 total) during the task were removed from the final analyses (n = 31) as it was determined that these participants were not fully paying attention to the photos presented to them during the task. It is important to note that there was no task objective for the participants except to simply view the stimuli while lying in the scanner, therefore results cannot be attributed to accuracy of performance as this was not measurable.

Figure 3.1. Pain > No Pain Contrast: Neural activation was examined by contrasting activation from Pain blocks compared to No Pain blocks.

Empathy Ratings. After the fMRI scan, participants completed a post-scan empathy rating task where they were presented the same painful photos again in the same order, as well as a subset of nonpainful images, and asked to think about what they were feeling when they saw the images for the first time while in the scanner. Specifically, participants were asked 1) "How sorry did you feel for this person?", 2) "How much pain do you think this person was in?", and 3) "How distressing did you find this photo?". Participants were given options to rate from 1 (not at all sorry/no pain at all/no distress at all) to 7 (extremely sorry/extremely in pain/extremely distressing). Higher ratings on each of the three self-report questions about the photos indicate greater empathic concern, perspective-taking, and personal distress, respectively. Empathic concern was measured using the first self-report question, perspective-taking was measured using the second self-report question, and personal distress was measured using the third self-report question.

Ratings on the questions across all the photos were averaged to create mean scores of empathic concern ($\bar{x}$ = 4.94, SD = 1.23), perspective-taking ($\bar{x}$ = 5.12, SD = 1.04), and personal distress ($\bar{x}$ = 4.93, SD = 1.34) for each participant. The scanner and post-scan tasks were both programmed in PsychoPy3. The current study focuses on the self-report responses to the post-scan empathy task as a measure of state empathy. Empathic concern and perspective-taking on the task were strongly correlated (r = 0.862, p < .001), as was empathic concern and personal distress (r = 0.745, p < .001) as well as perspective-taking and personal distress (r = 0.7002, p < .001).

fMRI Data Acquisition. Imaging data were acquired on a Siemens Prisma 3-Tesla MRI scanner housed at UCLA's Staglin International Mental Health Research Organization Center for Cognitive Neuroscience. Foam padding was placed around each participant's head for comfort and to constrain head movement. The task was presented via a projector that participants viewed through a mirror attached to the head coil.

For each participant, an initial set of three (one in each plane: coronal, sagittal, axial) 2D structural scout (localizer) gradient-echo images (TR=3.15 ms, TE=1.37 ms, matrix size=160 × 160, FoV=260 mm, 128 slices, flip angle=8°, 1.6-mm thick, 1.6-mm inplane resolution, 0.32-mm gap) was acquired in order to enable prescription of slices obtained in structural and functional scans. A T1-weighted magnetization prepared rapid gradient echo (MPRAGE) structural scan (parameters for participants: TR=2000 ms, TE=2.52 ms, matrix size=256 × 256, FoV=256 mm, 192 slices, flip angle=12°, 1-mm thick, 1-mm inplane resolution, 0.5-mm gap), coplanar with the functional scans, was collected for all participants.

The empathy task consisted of one functional (echo planar T2 * -weighted gradient-echo) MRI scan. The functional run (TR=2000 ms, TE=30 ms, matrix size=64 × 64, FoV=192 mm, 34 slices, flip angle=90°, 4-mm thick, 3-mm inplane resolution, no gap) lasted 8 minutes and 20 seconds.

fMRI Data Preprocessing and Analysis

fMRI data preprocessing. fMRI data was preprocessed using Statistical Parametric Mapping 12 (SPM12; Welcome Department of Cognitive Neurology, Institute of Neurology, London, England). For each subject, functional images were realigned to the mean functional image and resliced to correct for head motion. Afterward, the subject's MPRAGE was segmented and bias-corrected. Deformation fields were computed for normalizing the MPRAGE to Montreal Neurological Institute (MNI) space. Functional images were co-registered to the bias-corrected structural grey matter. All images were then affine registered into Montreal Neurological Institute space. The previously generated deformation fields were used to normalize all images into MNI space, with functional images undergoing integrated spatial smoothing (5 mm, Gaussian kernel, full width at half maximum).

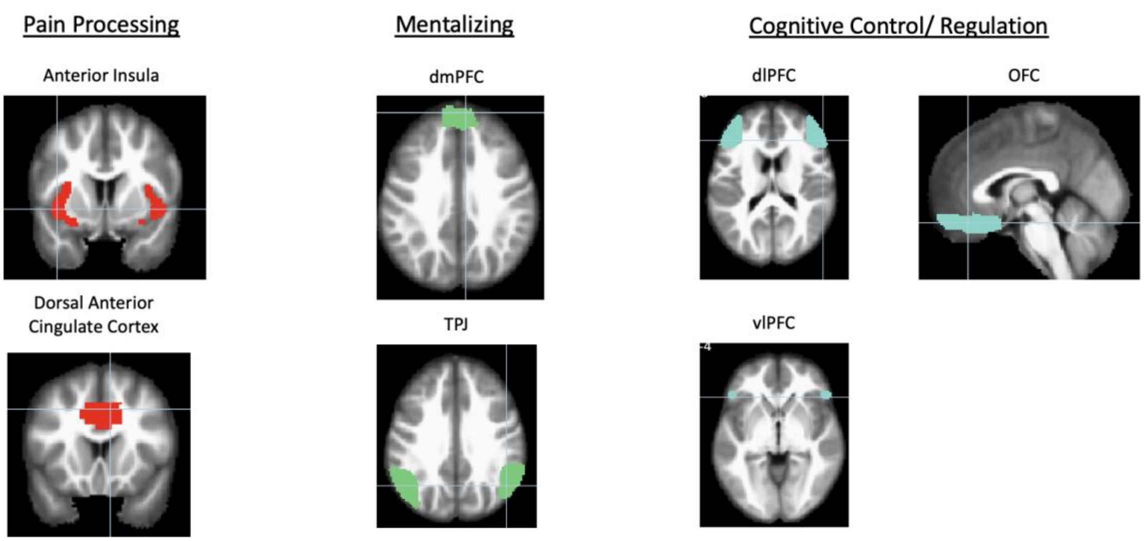
fMRI Data Analysis. Following pre-processing, a general linear model (GLM) was constructed for each participant in which the task was modeled as a block design. The time series was high-pass filtered using a 128 Hz function, and serial autocorrelation was modeled as an AR(1) process. In cases where motion of more than 1 mm frame-wise displacement was detected, individual nuisance regressors were added to remove such images from analyses.. Each active condition (Pain, No Pain) within the run was modeled in separate regressors. A linear contrast comparing Painful image blocks to Non-Painful image blocks was computed for each participant in order to examine empathy and associated neural processing.

Definitions of Bilateral Regions of Interest. A set of a priori brain regions of interest (ROIs) associated with pain processing, social cognition, and emotion regulation were selected for analysis. ROIs associated with pain processing included the bilateral anterior insula and the bilateral dACC. The anterior insula ROI was defined by taking the anatomical AAL Insula ROI, and cutting it at its midpoint of y=0, approximately separating dysgranular and granular insula (Slavich et al., 2010). The dACC ROI this ROI combines Brodman areas 32 and 24, and uses a rostral boundary of y = +36, and a caudal boundary of y = 0 (Slavich et al., 2010; Dedovic et al., 2016).

The ROIs associated with social cognition included the bilateral dmPFC, TPJ, and pSTS. The dmPFC ROI was defined using Neurosynth by searching and downloading the dmPFC region in the automated meta-analysis tool and then masking this with the medial frontal gyrus from the WFU PickAtlas, based on prior work (Maldjian et al., 2003, Yarkoni et al., 2011). The TPJ ROI was created by combining the right TPJ, comprised of 2812 voxels all z > 6 mm, centered at [54 − 52 23] and the left TPJ, comprised of 2444 voxels all z > 6 mm centered at [− 52 − 58 25], following past work (Dufour et al., 2013).

ROIs associated with emotion regulation included the bilateral dlPFC and vlPFC. The dlPFC ROI was anatomically defined by the Wake Forest University (WFU) PickAtlas (Maldjian et al., 2003), and the bilateral vlPFC was anatomically defined by the Harvard-Oxford Cortical Structural Atlas probability map implemented in the fMRIB Software Library (FSL) that was then thresholded at 25% probability. The bilateral OFC ROI was structurally defined using the Automated Anatomical Labeling atlas (Tzourio-Mazoyer et al., 2002). All ROIs used in this study can be viewed and downloaded in Neurovault (https://identifiers.org/neurovault.collection:12218). The dlPFC, TPJ, dmPFC and TPJ ROIs were based on work from Telzer and colleagues that can be found on Neurovault as well (https://neurovault.org/collections/SISNGRAB/).

Figure 3.2. Brain Regions of Interest.



Mean parameter estimates were extracted from the ROIs for each participant and entered into standard statistical software (see below) for further analysis. Whole-brain analyses were conducted using a voxel-wise height threshold of $p < .01$ (uncorrected) combined with a cluster-level extent threshold of $p < 0.05$, corrected for multiple comparisons using the family-wise error (FWE) rate.

Analysis Plan

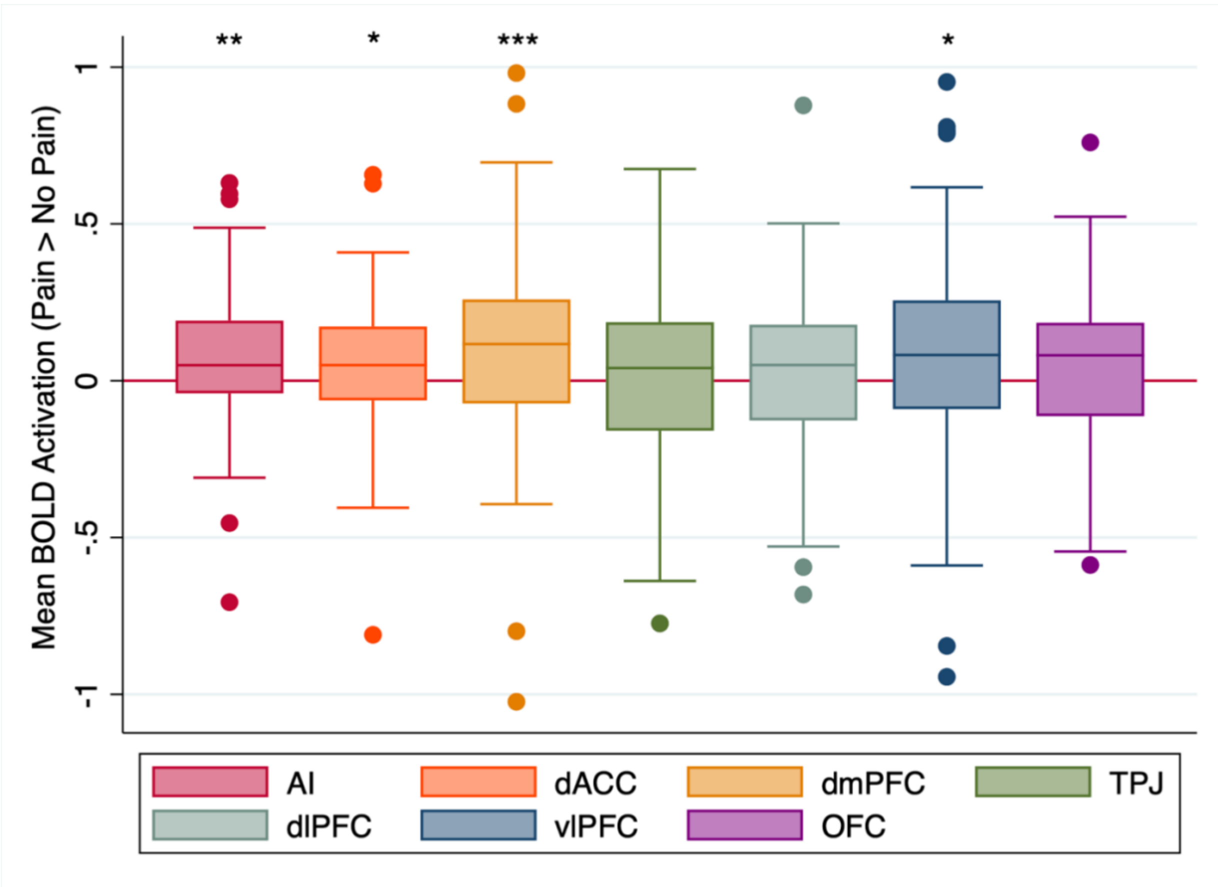
ROI parameters of mean activation were extracted and analyzed. Overall activation in ROIs during Pain > No Pain was examined using one sample t-tests that compared activation to 0 (no activation). Multiple regression models were used to test for age (linear and nonlinear), and empathy task rating (empathic concern, perspective-taking, personal distress) associations with activation during Pain > No Pain. Gender and age by gender interactions were examined given the results from Chapter 2. A Bonferroni correction approach was used to account for the analysis of multiple ROIs involved in 3 separate neural networks: 2 in from pain-processing, 2 from social cognition, and 3 from self-regulation. With a family-wise error rate of $p < .05$, effects from models examining pain-processing ROIs and social cognition ROIs had to be $p < .025$ and effects from models examining emotion regulation ROIs had to be $p < .013$. All models controlled for sex, ethnicity, and parent education. Analyses with ROI parameter estimates were run in STATA 15.1 (College Station, TX). Whole-brain parameter estimates were examined by entering linear age as a regressor in a GLM in SPM12.

Results

Activation in ROIs during Pain > No Pain

First, analyses were conducted to examine whether the a priori ROIs were active during the contrast of interest: Pain > No Pain photo blocks. Results revealed that the bilateral anterior insula ($t(89) = 2.86$, $p = .005$), bilateral dACC ($t(90) = 2.43$, $p = .017$), bilateral dmPFC ($t(91) = 3.49$, $p < .001$), and bilateral vlPFC ($t(91) = 2.52$, $p = .014$) showed significant positive activation during Pain > No Pain blocks. The bilateral TPJ ($t(89) = 0.58$, $p = .565$), bilateral dlPFC ($t(90) = 0.344$, $p = .732$), and bilateral OFC ($t(87) = 1.277$, $p = .205$) did not show mean activation that was statistically different from 0 (**Figure 3.3**).

Figure 3.3. Mean BOLD activation during Pain > No Pain blocks in the a priori ROIs. Activation was examined compared to 0.



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

No Significant Age Associations with Neural Processing during Pain > No Pain

Next, models examined linear and nonlinear age associations with mean BOLD activation in a priori ROIs linked with pain processing (dACC, AI), social cognition (dmPFC, TPJ), and self-regulation (dlPFC, vlPFC, OFC). Results did not demonstrate statistically significant associations between ROI activation and age (linear and nonlinear), p's > .05. Models were then run to examined age × gender interactions with ROI activation but results were not statistically significant (*p*'s > .05).

Associations with Empathy Ratings

Follow-up analyses assessed associations between empathy task ratings (empathic concern, perspective-taking, personal distress) and activation in the ROIs during Pain > No Pain blocks. Empathic concern was not significantly associated with activation in the ROIs (*p*'s > .05). Results demonstrated a positive association between perspective-taking and bilateral anterior insula activation (b = 0.10, SE = 0.05, *p* = .035), but this result did not pass multiple comparisons correction (*p* < .025) (**Table 3.1; Figure 3.4**). Personal distress was negatively associated with bilateral dlPFC activation (b = -0.11, SE = 0.03, *p* = .001), bilateral vlPFC activation (b = -0.11, SE = 0.04, *p* = .007), and bilateral OFC activation (b = -0.08, SE = 0.03, *p* = .013), though the bilateral OFC activation finding does not pass multiple comparisons correction (*p* < .013) (**Table 3.1; Figure 3.5 a-c)**.

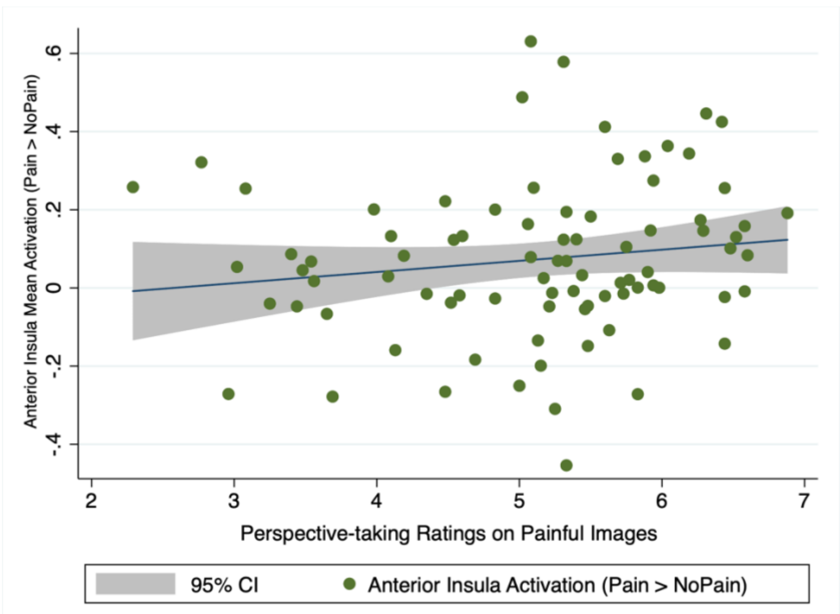
Table 3.1. *Significant Associations between Empathy Ratings and ROI Activation*

	Anterior Insula		dlPFC		vlPFC		OFC	
	b	SE	b	SE	b	SE	b	SE
Intercept	0.26	0.23	0.72**	0.26	1.08**	0.33	0.74**	0.25
Empathic Concern	-0.07	0.04	0.01	0.05	0.02	0.06	0.03	0.05
Perspective-taking	**0.10*†**	**0.05**	0.11	0.05	0.12	0.07	0.06	0.05
Personal Distress	-0.005	0.03	**-0.11****	**0.03**	**-0.11****	**0.04**	**-0.08*†**	**0.03**
Age	-0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01
Gender	0.004	0.05	-0.05	0.06	-0.05	0.07	-0.03	0.06
Asian American	-0.09	0.09	-0.17	0.10	-0.12	0.13	0.04	0.10

African American	-0.25	0.17	-0.67**	0.19	-0.61*	0.24	-0.54**	0.19
Hispanic/Latinx	-0.06	0.08	-0.08	0.09	-0.08	0.12	0.01	0.09
Multi-Ethnic	-0.09	0.06	-0.19*	0.07	-0.14	0.09	-0.14*	0.07
Native American	-0.08	0.12	-0.02	0.13	-0.06	0.17	-0.19	0.13
Other	0.06	0.13	-0.11	0.15	0.06	0.19	-0.15	0.14
Parent Education	-0.04	0.02	-0.07**	0.02	-0.11***	0.03	-0.07**	0.02

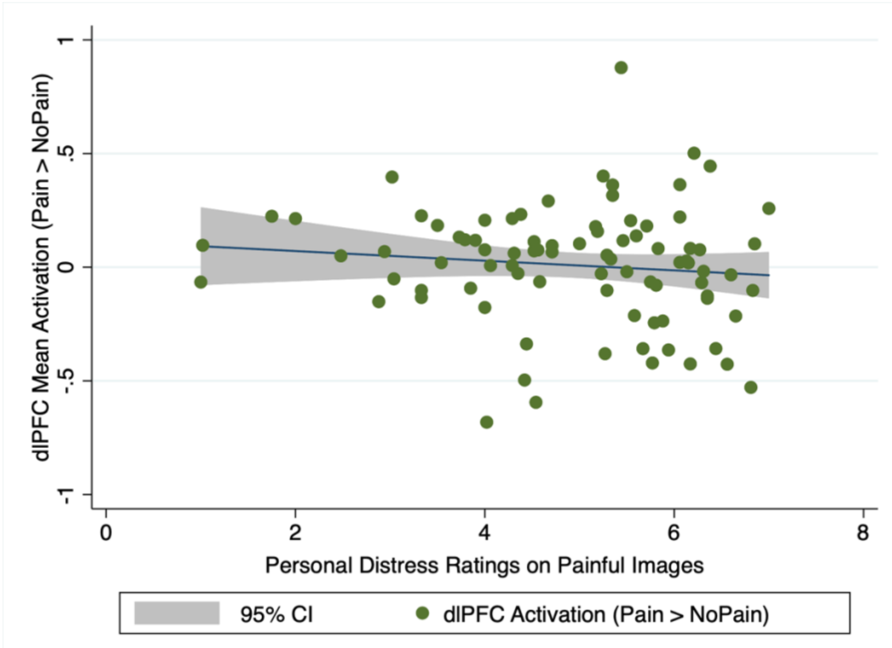
Note. Age was mean-centered at 13.05 years. *$p < .05$, **$p < .01$, ***$p < .001$. † = Does not pass multiple comparisons correction.

Figure 3.4. Bilateral Anterior Insula Activation by Perspective-taking during Pain > No Pain.

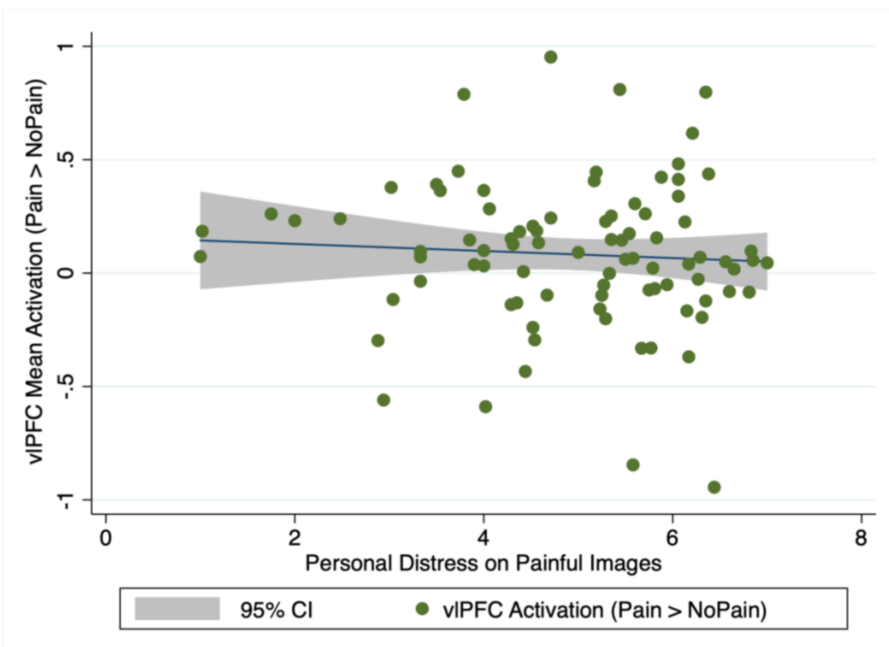


Perspective-taking on the empathy task was somewhat positively associated anterior insula activation, controlling for age, gender, ethnicity, and parent education. This finding did not pass the family-wise error (FWE) rate (FWEr) correction.

Figure 3.5. Bilateral dlPFC, vlPFC, and OFC Activation by Personal Distress during Pain > No Pain.

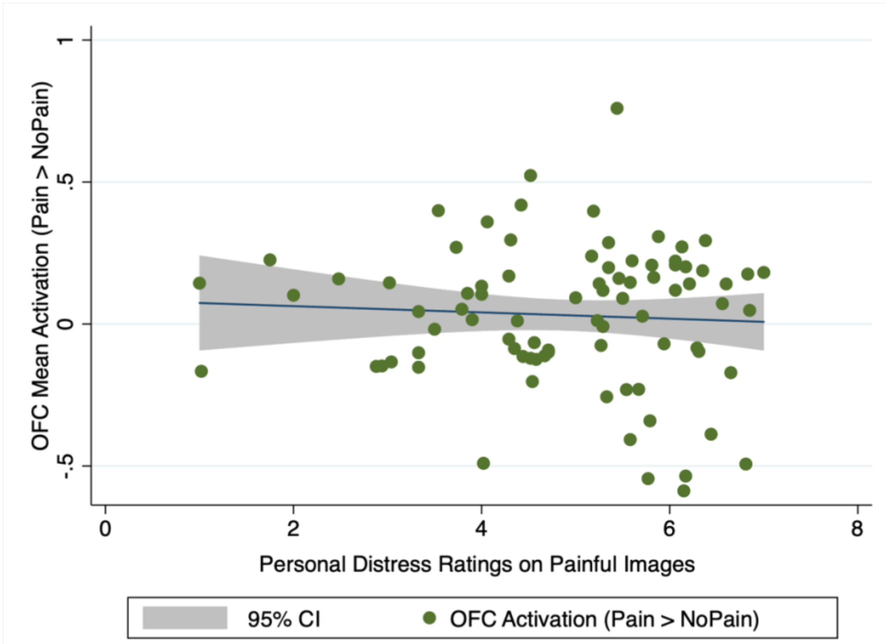


a.



b.

c.



Personal distress on the empathy task was negatively associated with bilateral a) dlPFC, b) vlPFC, and, to some extent, c) OFC activation, controlling for age, gender, ethnicity, and parent education. The OFC activation did not pass FWEr correction.

Whole Brain Results

Group-level results demonstrated significant activation in several brain regions (see **Table 3.2**). In line with ROI results, significant activation was found in the right ACC and right anterior insula. Results also showed positive associations between age and activation during Pain > No Pain in brain regions such as the inferior temporal gyrus, left posterior-medial frontal gyrus, left supramarginal gyrus, left inferior frontal gyrus, and left rolandic operculum (**Table 3.3**).

Table 3.2. *Whole Brain Activation during Pain > No Pain*

Area of Activation	**MNI Coordinates**			**Test Statistic**	**Cluster Size**
Pain > No Pain Blocks	**x**	**y**	**z**	***t***	
L Supramarginal Gyrus	-60	-28	35	4.84	94

L Inferior Temporal Gyrus	-48	-70	-4	4.25	99
R Inferior Temporal Gyrus	54	-67	-4	3.87	59
L Middle Occipital Gyrus	-30	-97	2	3.87	31
L Precentral Gyrus	-48	2	26	3.60	35
R Inferior Occipital Gyrus	33	-91	-4	3.29	33
R Middle Occipital Gyrus	39	-79	11	2.86	33
R Inferior Frontal Gyrus (Opercularis)	54	11	29	3.06	10
R Hippocampus	33	-16	-7	3.05	8
R ACC	3	8	32	3.02	10
R Inferior Frontal Gyrus (p. Opercularis)	39	14	20	2.94	10
R Anterior Insula Lobe	33	23	14	2.81	5
R Inferior Frontal Gyrus (p. Orbitalis)	45	26	2	2.78	6
R Postcentral Gyrus	54	-16	38	2.74	8
R ACC	6	26	20	2.63	8
L Middle Occipital Gyrus	-36	-79	5	2.61	6

*Note: Names are from the AAL toolbox in SPM. See https://identifiers.org/neurovault.collection:12218 to examine the unthresholded activation maps.

Table 3.3. *Whole Brain Activation during Pain > No Pain Positively Associated with Linear Age*

Area of Activation	**MNI Coordinates**			**Test Statistic**	**Cluster Size**
Pain > No Pain Blocks	**x**	**y**	**z**	***t***	
R Lingual Gyrus	12	-82	-7	3.72	32
R Superior Temporal Gyrus	66	-34	20	3.71	22
L Posterior-Medial Frontal Gyrus	-3	20	53	3.38	17
L Precentral Gyrus	-42	5	47	3.27	39
L Supramarginal Gyrus	-63	-37	29	3.21	9
R Cerebellum (VI)	33	-58	-28	3.19	24

R Calcarine Gyrus	15	-100	2	3.16	18
L Superior Temporal Gyrus	-57	-49	20	3.03	12
L Superior Temporal Gyrus	-60	-31	23	2.98	6
L Inferior Frontal Gyrus (p. Triangularis)	-51	17	32	2.92	14
L Middle Temporal Gyrus	-54	-55	8	2.71	10
L Rolandic Operculum	-57	-4	8	2.70	6
R Cerebellum (Crus 2)	27	-73	-37	2.61	8

*Note: Names are from the AAL toolbox in SPM. See https://identifiers.org/neurovault.collection:12218 to examine the unthresholded activation maps.

MNI coordinates of local maxima that were active for the t-test of Pain > No Pain blocks. Results are calculated using a voxel-wise height threshold of $p < .01$ (uncorrected) combined with a cluster-level extent threshold of $p < .05$, corrected for multiple comparisons using the FWEr.

Discussion

In order to investigate the neural correlates of empathy development during adolescence, the present study sought to examine age-differences in brain activation among adolescents in response to viewing implicit empathic stimuli. Adolescent participants viewed images of human arms and limbs in physically painful situations while undergoing an fMRI brain scan, and following the scan they provided subjective empathy ratings on the stimuli they saw in the scanner. An ROI-approach was used to examine age-differences in activation among brain regions implicated in pain processing (AI, dACC), social cognition (dmPFC, TPJ), and self-regulation (dlPFC, vlPFC, OFC). Associations between brain activation in the aforementioned ROIs and subjective measures of empathic concern, perspective-taking, and personal distress were also assessed.

Although the current study found no evidence of age differences in neural activation among the a priori ROIs, results show that irrespective of age, youth demonstrated heightened activation in the bilateral AI, dACC, dmPFC, and vlPFC when viewing images of human arms and limbs in physically painful situations. Heightened activation in the AI and dACC while viewing others in pain has been shown in previous research using the same set of stimuli, and these results highlight that youth were possibly recruiting regions implicated in pain perception while seeing others in pain (Jackson et al., 2005; 2006; Decety, 2010). Though it was hypothesized that subjective ratings of empathic concern would be associated with activation in the AI and dACC, no such association was found in the current study. Interestingly, results point to a positive association between bilateral anterior insula activation and subjective ratings of perspective-taking. Previous research examining an adult sample found anterior insula activation associated with perspective-taking during an empathy task focused on perspective-taking different points of view (Lamm, Batson, & Decety, 2007). The authors suggested that this activation may have pointed to participants potentially empathizing with the sensory-motor aspects of pain based on evidence from a meta-analysis of imaging studies (Wager & Feldman-Barrett, 2004). It is important to note that this particular association did not pass multiple comparisons correction in the current study.

The dmPFC, a region implicated in social cognition, also demonstrated heightened activation when youth saw others experiencing physical pain. Activation in the dmPFC has similarly been found among highly empathic adolescents in response to seeing someone experience social exclusion (Masten, et al., 2010). Contrary to the hypotheses, the TPJ did not show significant activation in response to viewing others in pain. Subjective ratings of perspective-taking were not associated activation in either the dmPFC or the TPJ.

Findings among self-regulation regions were mixed as the vlPFC, but not the dlPFC or OFC, demonstrated significant activation in response to seeing others in pain. Prior research has shown a significant activation in the vlPFC in response to viewing others experience pain purposefully inflicted by another individual (Decety & Michalska, 2010). Though prior investigations have found dlPFC and OFC activation in response to empathic stimuli, perhaps it is worth considering the results of one prior study that found greater dlPFC activation to socially-empathic stimuli (i.e., faces) compared to non-social empathic stimuli (i.e., hands) (Balconi & Angioletti, 2022). It is possible that socially-laden empathic stimuli would be better suited to examine in adolescence given the heightened salience of social factors. As hypothesized, subjective ratings of personal distress were negatively associated with activation in the dlPFC, vlPFC, and to a lesser extent, the OFC meaning that youth who showed more activation in brain regions implicated in self-regulation reported lower levels of subjective personal distress to the painful stimuli. This finding indicates that regions implicated in self-regulation may contribute to reducing responses of personal distress to empathy, but future studies examining longitudinal or causal patterns would have to examine this further. Few studies have examined the neural correlates of personal distress but one study using resting-state methods found a negative association between personal distress and dmPFC-dlPFC connectivity, indicating that regulatory regions may play a role in promoting emotion regulation of personal distress to someone else's suffering (Luo et al., 2018).

Findings from the current investigation should be considered with respect to study limitations. The primary aim of the current investigation was to examine neural correlates supporting empathy development in adolescence. The current study was limited by the use of cross-sectional data to address a developmental question that would be best addressed with longitudinal data. Results from this study only assess between-person age effects as a proxy for development, thus it is possible that developmental age trends in neural activation to empathy may be better captured by within-person measures. There was no measure of subjective pain ratings from the participants, and this would have been useful to compare to the empathy ratings are individuals with less pain sensitivity may not see the painful stimuli as painful. Subjective ratings of empathic concern, perspective-taking, and personal distress were asked after the fMRI scan and participants were asked to retrospectively report on their ratings from the first time they saw the images in the scanner. This decision was made intentionally to reduce scanner fatigue and limit the length of an already long task (8 minutes). Future investigations using the task from this dissertation should consider splitting the task into two 4-minute BOLD runs to avoid participant fatigue to the passive nature of the task.

It is also worth highlighting that even though the stimuli used in this study are well-validated in studies of empathy, it is possible that this set of stimuli is not as relatable to adolescents. For example, when viewing the painful stimuli, there is significant context about how the painful situation occurred and this lost information may limit youth from empathizing with the stimuli. In comparison, previous studies using similar stimuli have used the stimuli in a dynamic stimuli format (multiple pictures to convey a scene) where participants saw the painful act happening and also saw whether the act was intentionally inflicted by someone else or an accident (Decety & Michalska, 2010; Michalska, Kinzler, & Decety, 2013). This additional contextual information is important as it signals to an observer what the victim may be feeling and experiencing in terms of their mental and emotional states.

The results from the current study indicate that brain regions implicated in pain processing, social cognition, and emotion regulation are involved in empathy during adolescence. Although we did not detect age differences in the a priori ROIs, these findings indicate that these brain regions play a role in empathic processes during adolescence. Specifically, the current study found evidence of an association between the anterior insula and perspective-taking as well as personal distress and emotion regulation regions (dlPFC, vlPFC, OFC). Future investigations should assess the role of emotion regulation in personal distress during adolescence, as this is an understudied area that may point to helpful points of intervention that can promote empathy development during this period.

CHAPTER 4

Empathic Personal Distress and Prosocial Behavior in Adolescence: The Moderating Role of Emotion Regulation-related Brain Regions

Introduction

There has been a renewed scientific interest in understanding prosocial behavior as it relates to adolescent development, given that previous research has linked prosociality with positive outcomes such as better mental health and psychological well-being (Eisenberg et al., 2015; Schacter & Margolin, 2019; Tashjian et al., 2021). Prosocial behavior, defined as acts that are done in benefit of someone else, has been shown to increase in adolescence, when youth begin engaging more with the social world (van der Graaff et al., 2018). Previous research shows that empathy, defined as the ability to feel and understand another person's mental and emotion states, is an important precursor to engaging in prosocial behavior (Feldman-Hall et al., 2016). A possible aversive outcome of engaging in empathy is experiencing personal distress to seeing someone else suffering or feeling pain, and personal distress has been linked with reductions in prosocial behavior (Decety & Lamm, 2011). The current study sought to examine the association between empathic personal distress, or personal distress to engaging in empathy, and prosocial behavior among adolescents. Given the increasingly important role of the developing prefrontal cortex during adolescence in supporting emotion regulation abilities, the current study examined the moderating role of the dlPFC, vlPFC, and OFC in the association between empathic personal distress and prosocial behavior (Shulman et al., 2016; Dumontheil, 2016).

Prosocial behaviors notably increase during the period of adolescence, and research has focused on assessing the positive outcomes that are linked with engaging in prosocial behavior. Evidence points to the need to support the development of prosocial behavior in adolescence because it is associated with positive mental health, reduced markers of poor health, and more social connections (cites). Less research has focused on factors that could lead to the reduction of prosocial behaviors among youth, which is an important direction of research for potential intervention efforts aimed at increasing prosocial behavior. One deterrent to engaging in prosocial behavior that has been found is empathic personal distress (Carrera et al., 2012). Personal distress to engaging in empathy is theorized to be a result of the observer failing to make a clear distinction between themselves and the person that they are observing who may be suffering or feeling pain (Eisenberg, 2006). As such, personal distress is not a part of empathy but rather a potential outcome of engaging in it (Kim & Han, 2018). This is important because empathy is an important precursor to engaging in prosocial behavior – in order for someone to help another person, they will need to empathize with what they are experiencing to help them appropriately (Feldman-Hall et al., 2016). Researchers have posited that the aversive feeling of personal distress interferes with one's ability to help someone in the face of adversity likely because personal distress is a self-oriented reaction associated with wanting to reduce one's own distress over someone else's while prosocial behavior is an other-oriented action intended to benefit someone else (Eisenberg, 2006).

Despite accumulating evidence for a negative association between personal distress and prosocial behavior, some studies have found a positive association between personal distress and prosocial behavior. As personal distress is often strongly correlated with feelings of empathy, studies have found that higher personal distress has led to more prosocial behavior; however, these studies were focused on individuals who would need to maintain prosocial behavior under conditions of high personal distress, such as health care providers (Sze et al., 2011; Coll et al., 2017). The work on empathy and personal distress is relatively underexplored, thus more studies are needed to clarify these associations in the general population. Furthermore, studies examining the link between personal distress and prosocial behavior in adolescence are missing from the literature, thus the current study sought to fill this gap.

It is well-known that adolescents undergo critical neurodevelopment particularly in the frontal lobe, a region of the brain implicated in regulating emotions, among many other important functions (Shulman et al., 2016; Dumontheil, 2016). Social neuroscience literature on empathy suggests that empathic personal distress may be associated with reduced recruitment of neural regions implicated in emotion regulation that may be critical for maintaining a distinction between the self and other during empathy (Decety, 2010; Decety & Lamm, 2011). Brain regions such as the dorsolateral prefrontal cortex (dlPFC), ventrolateral prefrontal cortex (vlPFC), and orbitofrontal cortex (OFC) have been implicated in emotion regulation and have been shown to be involved in regulating emotions during empathy (Decety, 2010; Luo et al., 2018).

Regions implicated in emotion regulation may play an important role in modulating the association between prosocial behavior and personal distress by reducing the emotional impact of personal distress and allowing for a temporal association between empathy and prosocial behavior. Studies in adult samples has linked low effortful control and self-regulation with higher personal distress (Eisenber & Eggum, 2009). Furthermore, emotion regulation has been shown to moderate the association between empathy and prosocial behavior (Lockwood et al., 2014). Previous studies suggest a link between brain regions such as the dlPFC, vlPFC and OFC and emotion regulation abilities, and in the study of empathy, higher activation in these brain regions has been linked with more self-regulation (Hooker & Knight, 2002; Decety & Lamm, 2011). Furthermore, neural regions such as the dlPFC and inferior parietal lobe were identified as neural substrates of empathic personal distress in a resting-state MRI study (Fluornoy et al., 2016; Luo et al., 2018). Furthermore, These regions have been linked with emotion regulation abilities (Ochsner et al., 2012), thus current investigation sought to examine the modulating role of the bilateral dlPFC, vlPFC, and OFC in the association between empathic personal distress and prosocial behavior.

The current study sought examine the association between empathic personal distress and prosocial behavior, and assess the moderating role of brain regions involved in emotion regulation among adolescents. Specifically, the primary aims of this study were two-fold: 1) examine the association between personal distress and prosocial behavior, and 2) assess whether neural activation in the bilateral dlPFC, vlPFC, and OFC moderates the association between personal distress and prosocial behavior. It was hypothesized that higher personal distress would be associated with lower prosocial behavior, and that neural activation among brain regions implicated in self-regulation would be associated with higher prosocial behavior even when youth report high empathic personal distress.

Method

A sample of 127 adolescents completed an empathy task where they viewed images of other people's arms and legs in painful and non-painful situations while undergoing an fMRI brain scan. After the fMRI scan, youth viewed the same images that they saw in the scanner and provided ratings on empathic concern, perspective-taking, and personal distress. The current study is focused on the personal distress ratings on painful images in particular. Participants also completed a self-report questionnaire of prosocial behavior.

Participants

Sample Characteristics. Although 127 participants completed the fMRI scan and empathy task, the final analytic sample included 92 participants ages 11-17 years ($\bar{x}$ = 14.10, SD = 1.82)

(48.31% female). Participants were not included in the final analytic sample if their fMRI data had excessive head motion during the fMRI scan (n = 2), if they did not pass the task attention check (n = 31), and if their data revealed consistent outliers across multiple or all ROIs (n = 2). These participants were removed from the analyses in order to avoid unreliable estimates of neural signal. Youth were from the across the Los Angeles area and come from ethnically diverse backgrounds (37.5% European American, 30.68% Multi-ethnic, 12.5% Hispanic/Latinx, 7.95% Asian American, 3.41% African American, 3.41% Other, and 4.55% Native American). Average parent education (averaged across both parents if youth had 2 parents) was slightly above "graduated from college" ($\bar{x}$ = 9.34, SD = 1.36). Youth were recruited via flyers, advertisements, and through class presentations to schools within Los Angeles school districts, and from the Clinical and Translational Science Institute database of families in the UCLA and affiliated medical systems.

Procedure

Participants and one of their parents reported on demographic information, and participants completed a set of questionnaires before attending an in-person study visit at a university-run MRI facility to complete behavioral tasks and a fMRI scan. Participants were fully compensated with funding from a longitudinal parent grant (up to $84).

Measures

Prosocial Behavior. Prosocial behavior was measured using the prosocial behavior sub-scale from the Strengths and Difficulties Questionnaire (SDQ) (Goodman, 2001). Youth self-reported on the 5-item sub-scale how much each statement described them on a scale from 1 (not true) to 5 (certainly true). Items included statements such as "*I try to be nice to people. I care* *about their feelings.*" and "*I am helpful if someone is hurt, upset, or feeling ill.*" Items were averaged to create mean scores of prosocial behavior ($\bar{x}$ = 4.08, SD = 0.76; α = 0.84).

Interpersonal Reactivity Index. The Interpersonal Reactivity Index (IRI) (Davis, 1983) is a well-validated and popular measure of trait empathy that the current sample of adolescents completed. This self-report questionnaire of empathy consists of 4 components, but the current study measured 2 components of interest from this measure: empathic concern (7 items) and perspective-taking (7 items). Items measuring empathic concern focused on how participants generally feel about others that need care (e.g., "*I often have tender, concerned feelings for people less fortunate than me.*"; "*When I see someone being taken advantage of, I feel kind of protective towards them.*"), while items measuring perspective-taking focused on how participants generally view the perspectives of others (e.g., "*I sometimes try to understand my friends better by imagining how things look from their point of view*."; "*I believe that there are two sides to every question and try to look at them both*."). Participants responded to the items on a scale of 1 ("does not describe me at all") to 5 ("describes me very well"). Empathic concern items ($\bar{x}$ = 2.74, SD = 0.55; α = 0.75) and perspective-taking items ($\bar{x}$ = 2.46, SD = 0.60; α = 0.76) were averaged to generate mean values of empathic concern and perspective-taking for each participant. Empathic concern and perspective-taking on the IRI were correlated at r = 0.572, $p < .001$.

Empathy Task. Participants viewed images of human hands and feet in one of two conditions: painful and non-painful. The task was 1 run with 12 blocks (each 32s long) and each block varied randomly based on photo condition (pain versus no-pain photos) with 6 pain photo blocks and 6 no-pain photo blocks. See Chapter 2 for full details about the task design. The current study focused on examining neural activation during this task, specifically contrasting the pain and no-pain photo block conditions (Figure #, See Chapter 3). Participants were instructed to view the images while in the scanner and to press a button on a button box every time they saw a photo to acknowledge that they saw it and were paying attention (attention check). Participants with button presses missing for more than 10 photos (out of 96 total) during the task were removed from the final analyses (n = 31) as it was determined that these participants were not fully paying attention to the photos presented to them during the task. It is important to note that there was no task objective for the participants except to simply view the stimuli while lying in the scanner, therefore results cannot be attributed to accuracy of performance as this was not measurable.

Empathy Ratings. After the fMRI scan, participants completed a post-scan empathy rating task where they were presented the same painful photos again in the same order, as well as a subset of nonpainful images, and asked to think about what they were feeling when they saw the images for the first time while in the scanner. Specifically, participants were asked 1) “How sorry did you feel for this person?”, 2) “How much pain do you think this person was in?”, and 3) “How distressing did you find this photo?”. Participants were given options to rate from 1 (not at all sorry/no pain at all/no distress at all) to 7 (extremely sorry/extremely in pain/extremely distressing). Higher ratings on each of the three self-report questions about the photos indicate greater empathic concern, perspective-taking, and personal distress, respectively. The current study focuses solely on the personal distress ratings.

fMRI Data Acquisition. Imaging data were acquired on a Siemens Prisma 3-Tesla MRI scanner housed at UCLA’s Staglin International Mental Health Research Organization Center for Cognitive Neuroscience. Foam padding was placed around each participant’s head for comfort and to constrain head movement. The task was presented via a projector that participants viewed through a mirror attached to the head coil.

For each participant, an initial set of three (one in each plane: coronal, sagittal, axial) 2D structural scout (localizer) gradient-echo images (TR=3.15 ms, TE=1.37 ms, matrix size=160 × 160, FoV=260 mm, 128 slices, flip angle=8°, 1.6-mm thick, 1.6-mm inplane resolution, 0.32-mm gap) was acquired in order to enable prescription of slices obtained in structural and functional scans. A T1-weighted magnetization prepared rapid gradient echo (MPRAGE) structural scan (parameters for participants: TR=2000 ms, TE=2.52 ms, matrix size=256 × 256, FoV=256 mm, 192 slices, flip angle=12°, 1-mm thick, 1-mm inplane resolution, 0.5-mm gap), coplanar with the functional scans, was collected for all participants.

The empathy task consisted of one functional (echo planar T2 * -weighted gradient-echo) MRI scan. The functional run (TR=2000 ms, TE=30 ms, matrix size=64 × 64, FoV=192 mm, 34 slices, flip angle=90°, 4-mm thick, 3-mm inplane resolution, no gap) lasted 8 minutes and 20 seconds.

fMRI Data Preprocessing and Analysis

fMRI data preprocessing. fMRI data was preprocessed using Statistical Parametric Mapping 12 (SPM12; Welcome Department of Cognitive Neurology, Institute of Neurology, London, England). For each subject, functional images were realigned to the mean functional image and resliced to correct for head motion. Afterward, the subject's MPRAGE was segmented and bias-corrected. Deformation fields were computed for normalizing the MPRAGE to Montreal Neurological Institute (MNI) space. Functional images were co-registered to the bias-corrected structural grey matter. All images were then affine registered into Montreal Neurological Institute space. The previously generated deformation fields were used to normalize all images into MNI space, with functional images undergoing integrated spatial smoothing (5 mm, Gaussian kernel, full width at half maximum).

fMRI Data Analysis. Following pre-processing, a general linear model (GLM) was constructed for each participant in which the task was modeled as a block design. The time series was high-pass filtered using a 128 Hz function, and serial autocorrelation was modeled as an AR(1) process. In cases where motion of more than 1 mm frame-wise displacement was detected, individual nuisance regressors were added to remove such images from analyses.. Each active condition (Pain, No Pain) within the run was modeled in separate regressors. A linear contrast comparing Painful image blocks to Non-Painful image blocks was computed for each participant in order to examine empathy and associated neural processing.

Definitions of Bilateral Regions of Interest. A set of a priori brain regions of interest (ROIs) associated with self-regulation were selected for analysis. This included the bilateral dlPFC, vlPFC, and OFC. The dlPFC ROI was anatomically defined by the Wake Forest University (WFU) PickAtlas (Maldjian et al., 2003), and the bilateral vlPFC was anatomically defined by the Harvard-Oxford Cortical Structural Atlas probability map implemented in the fMRIB Software Library (FSL) that was then thresholded at 25% probability. The bilateral OFC ROI was structurally defined using the Automated Anatomical Labeling atlas (Tzourio-Mazoyer et al., 2002). All ROIs used in this study can be viewed and downloaded in Neurovault (https://identifiers.org/neurovault.collection:12218). Mean parameter estimates were extracted from the ROIs for each participant and entered into standard statistical software (see below) for further analysis.

Analysis Plan

ROI parameters of mean activation in the bilateral dlPFC, vlPFC, and OFC were extracted and analyzed for Pain > No Pain blocks. Multiple regression models were used to examine the association between prosocial behavior and personal distress ratings on the empathy task as well as the moderating effect of neural activation in the dlPFC, vlPFC, and OFC. A Bonferroni correction approach was used to account for the analysis of multiple ROIs; with a family-wise error rate of $p < .05$, effects from models had to be $p < .013$ to be statistically significant. All models controlled for sex, ethnicity, and parent education. Analyses with ROI parameter estimates were run in STATA 15.1 (College Station, TX). Whole-brain parameter estimates were examined by entering linear age as a regressor in a GLM in SPM12. Exploratory analyses examined the association between prosocial behavior and the IRI subscales of empathic concern and perspective-taking.

Results

Prosocial Behavior and Empathic Personal Distress

First, a multiple regression was run to examine the association between prosocial behavior and empathic personal distress. The association between prosocial behavior and personal distress was not significant (b = 0.04, SE = 0.06, $p = .493$) (**Table 4.1**). Next, exploratory models examined the association of empathic concern and personal distress with prosocial behavior to assess whether empathy was associated with prosocial behavior. Findings revealed that both state empathic concern (b = 0.80, SE = 0.013 $p < .001$) and state perspective-taking (b = 0.69, SE = 0.12, $p < .001$), measured by the IRI (see Chapter 2, Method), were positively associated with prosocial behavior, but trait empathic concern and trait perspective-taking measured by the empathy task were not associated with prosocial behavior (p's > .05) (**Table 4.2**).

Table 4.1. *Prosocial Behavior and Empathic Personal Distress.*

	Prosocial Behavior	
	b	SE
Intercept	4.05***	0.86
Personal Distress	0.04	0.06
Age	0.09*	0.04
Gender	0.15	0.18
Asian American	-0.0003	0.31
African American	-0.46	0.55
Hispanic/Latinx	-0.53	0.30
Multi-Ethnic	-0.40*	0.19
Native American	0.45	0.39
Other	-1.26**	0.42
Parent Education	-0.003	0.08

Note. Age was mean-centered at 14.02 years. Male = 0; European American = 0. *p < .05, **p < .01, ***p < .001.

Table 4.2. *Prosocial Behavior and Empathy: Empathic Concern and Personal Distress (IRI)*

	Prosocial Behavior			
	b	SE	b	SE
Intercept	1.93*	0.95	1.67	0.99
Empathic Concern	0.80***	0.05	--	--
Perspective-taking	--	--	0.69***	0.12
Age	0.02	0.04	0.04	0.04
Gender	0.02	0.15	0.11	0.16
Asian American	0.13	0.25	0.08	0.26

African American	-0.32	0.63	0.09	0.66
Hispanic/Latinx	0.01	0.30	-0.13	0.31
Multi-Ethnic	-0.06	0.17	0.03	0.18
Native American	0.0001	0.36	0.46	0.35
Other	-0.99**	0.36	-0.81*	0.37
Parent Education	-0.03	0.07	0.01	0.07

Note. Age was mean-centered at 14.02 years. Male = 0; European American = 0. *$p < .05$, **$p < .01$, ***$p < .001$.

Associations between Personal Distress and Activation in ROIs Implicated in Self-Regulation

As a reminder from Chapter 3, personal distress ratings on the painful images were negatively associated with bilateral dlPFC activation (b = -0.11, SE = 0.03, $p = .001$), bilateral vlPFC activation (b = -0.11, SE = 0.04, $p = .007$), and bilateral OFC activation (b = -0.08, SE = 0.03, $p = .013$), though the bilateral OFC activation finding did not pass multiple comparisons correction ($p < .013$) (see Chapter 3, Results).

Moderating Role of Brain Regions Implicated in Self-Regulation

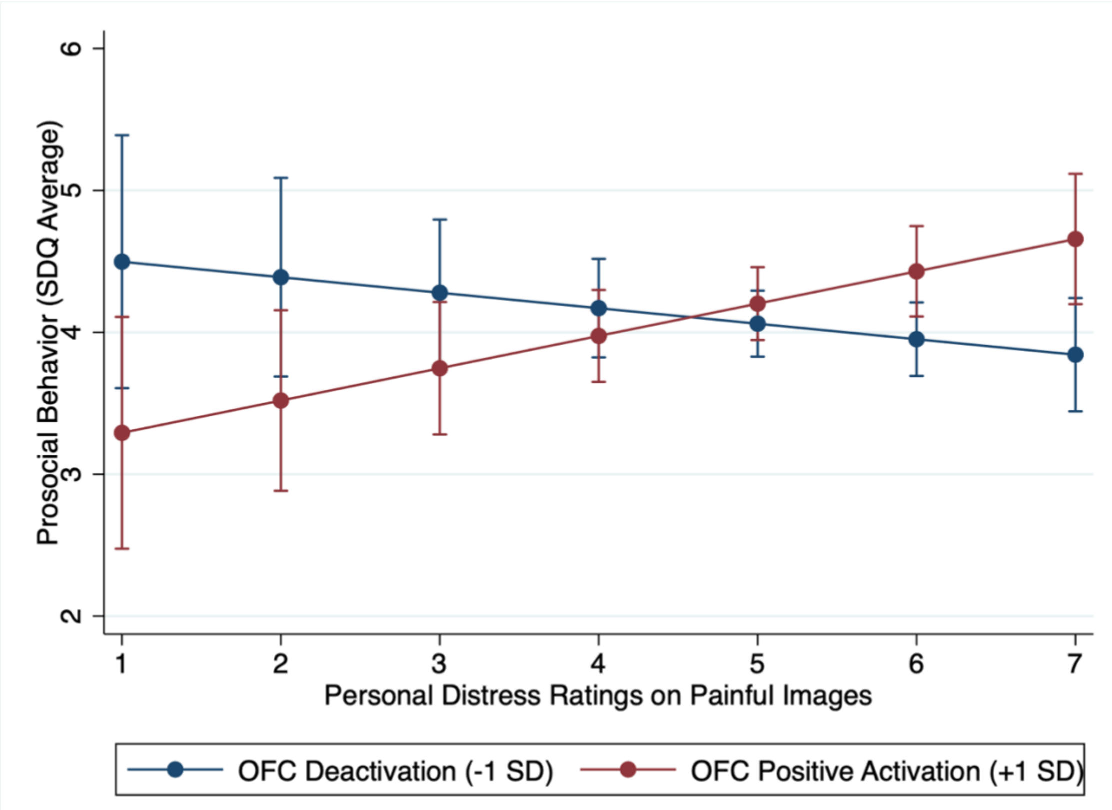
The following models examined the moderating role of brain activation in the dlPFC, vlPFC and OFC in the association between prosocial behavior and empathic personal distress. Activation in the dlPFC and vlPFC did not moderate the association (*p*'s > .05) between empathic personal distress and prosocial behavior; however, activation in the OFC did moderate the association between prosocial behavior and empathic personal distress (b = 0.70, SE = 0.31, $p = .028$) (**Table 4.3**). Specifically, youth who demonstrated deactivation in the OFC during painful images showed less prosocial behavior with higher personal distress, whereas youth who demonstrated activation in the OFC during painful images showed more prosocial behavior despite high personal distress (**Figure 4.1**). It is important to note that this finding does not pass multiple comparisons correction ($p < .013$).

Table 4.3. *Prosocial Behavior and Empathic Personal Distress: Moderating Role of Bilateral OFC*

	Prosocial Behavior	
	b	SE
Intercept	2.23*	1.08
Personal Distress (PD)	0.04	0.06
OFC Mean Activation	-3.21	1.72
PD × OFC Activation	0.70*	0.31
Age	0.09*	0.04
Gender	0.25	0.18
Asian American	0.03	0.30
African American	-0.54	0.60
Hispanic/Latinx	-0.49	0.31
Multi-Ethnic	-0.37	0.20
Native American	0.55	0.39
Other	-1.05*	0.41
Parent Education	0.04	0.08

Note. Age was mean-centered at 14.02 years. Male = 0; European American = 0. *$p < .05$, **$p < .01$, ***$p < .001$.

Figure 4.1. Bilateral OFC Activation by Prosocial Behavior and Personal Distress during Pain > No Pain.



Graph of OFC activation moderating the association between personal distress and prosocial behavior; finding does not pass FWEr correction.

Discussion

Empathy is a known precursor to engaging in prosocial behavior; however, experiencing personal distress from empathy is one way by which prosocial behavior may be reduced (Carrera et al., 2012; Feldman-Hall et al., 2016; Sze et al., 2011; Coll et al., 2017). The current investigation sought to assess the relationship between empathic personal distress and prosocial behavior among adolescents. Given the salient neurodevelopment of the prefrontal cortex during adolescence, this study also examined the moderating role of brain regions involved self-regulation in the association between empathic personal distress and prosocial behavior.

Results from the current investigation did not reveal a significant association between prosocial behavior and empathic personal distress. As such, results did not align with the hypothesis that higher empathic personal distress would be associated with lower prosocial behavior as has been found in prior studies (Eisenberg, 2006). Follow-up exploratory analyses revealed that higher empathic concern and personal distress, important components of empathy, were associated positively with prosocial behavior. These analyses were a helpful check to assess whether the current measure of prosocial behavior was related to empathy in the present sample. One possible reason for the lack of significant association between empathic personal distress and empathy may be that the current study used a state measure of empathic personal distress and a trait measure of prosocial behavior. A more ideal assessment to measure this association would be an experimental task specifically designed to test the causal link between empathic personal distress and subsequent prosocial behavior. This would help shed light on how personal distress to empathy may impact prosocial behavior in youth, an understudied association that may have important implications for behavioral interventions aimed at increasing prosocial behavior among adolescents.

Although there was no significant link between empathic personal distress and prosocial behavior, findings from the current study intimate the role of the bilateral OFC in moderating the association between empathic personal distress and prosocial behavior. Specifically, youth who demonstrated deactivation in the OFC when viewing painful images during the empathy task showed less trait prosocial behavior with higher state personal distress to the painful images. Youth who demonstrated positive activation in the OFC when viewing painful images during the empathy task showed more state prosocial behavior with higher trait personal distress to the painful images. It has been proposed that personal distress may interfere with prosocial behavior because of a failure on the part of the empathizer to maintain a distinction between the self and the other when seeing someone else suffer (Decety, 2010; Decety & Lamm, 2011). Thus it is possible that the bilateral OFC may be playing a regulatory role that results in more prosocial behavior even under conditions of high personal distress. Previous research has linked the OFC to regulatory functions in the practice of empathy, specifically in the context of having adult participants emotionally reappraise videos of others in pain (Lamm & Decety, 2011; Lamm, Decety, & Batson, 2007). As previously mentioned, the current measures were not ideal to test causal mechanisms, thus future research would need to examine the directionality of these associations. It is important to note that this finding did not pass multiple comparisons correction.

Evidence for the moderating role of the bilateral dlPFC and vlPFC was not found in the current investigation. Though there is a plethora of evidence linking the dlPFC and vlPFC to emotion regulation in youth, it is possible that the OFC may be more sensitive to this negative stimuli. One study found that while the dlPFC and OFC were associated with emotion regulation, the OFC was sensitive to emotion regulation of negative stimuli while the dlPFC did not distinguish between emotion regulation to negative versus neutral stimuli (Golkar et al., 2012). Furthermore, research has implicated the OFC in taking on a more regulatory function with increasing age during empathy. Specifically, individuals have demonstrated a medial to lateral transition in OFC activation across age in response to empathy, and this may signal the importance of the OFC in facilitating the experience of empathy with increasing emotion regulation abilities (Decety & Michalska et al., 2010; Decety, 2010). Future research will need to examine the unique roles of these various brain regions implicated in emotion regulation on empathy in adolescence.

In addition to the limitations listed in Chapter 3, the following study limitations should be considered with the study results. First, this study used a trait measure of prosocial behavior with a state measure of empathic personal distress, but ideally future investigations would measure both state and traits measures of empathic personal distress, empathy, emotion regulation, and prosocial behavior. Cross-sectional data was used, but longitudinal or experimental data should be collected in future investigations to assess temporal relationships between personal distress and prosocial behavior in the MRI scanner. Doing so would allow for a better examination of the moderating role of regions linked with emotion regulation.

The current study sought to explore the association between empathic personal distress and prosocial behavior during adolescence, and assess whether activation in prefrontal cortex brain regions would modulate the link between personal distress and prosocial behavior. This investigation did not find evidence for an association between empathic personal distress and prosocial behavior, but there was preliminary evidence of the OFC modulating the link between empathic personal distress and prosocial behavior. Future research should utilize experimental designs to examine the causal association between empathic personal distress and prosocial behavior as well as the moderating role of neural activation among brain regions involved in regulatory processes.

CHAPTER 5

General Discussion

Adolescence is a period marked by the development of complex and multidimensional characteristics that bridge affective and cognitive abilities to produce socioemotionally adept behaviors that allow youth to navigate their social shifting social landscapes. This dissertation was guided by the renewed scientific attention that has been paid to prosocial behavior during adolescence, with studies demonstrating increases in helping and other-oriented behaviors during this transitional period of development. In order for youth to be able to help another person, it is critical that they can feel and understand the feelings and experiences of the other person. Cross-sectional and longitudinal studies demonstrate the importance of empathy in subsequent prosocial behavior; thus it is important to clarify the behavioral and neural correlates associated with empathy in adolescence. The goal of the current dissertation was to examine age-related differences in empathy, associated neural activation, and moderators that can increase prosocial behavior in adolescence even in the face of a maladaptive empathic response such as personal distress.

Empathy is a multidimensional construct comprised of both affective and cognitive components that together allow an individual to feel and understand another person's emotional and mental state (Hastings et al., 2013). Empathic concern, or feeling sorrow or concern for another person's emotional state, is typically defined as the affective component of empathy; whereas perspective-taking, or understanding another's frame of mind, is typically defined as the cognitive component of empathy (Decety et al., 2010). The current investigation also examined personal distress in response to empathy, defined as self-oriented discomfort to seeing another person suffering or in pain. Given that personal distress is purported to be an aversive response to empathy that emerges when someone fails to make a clear distinction between self and other, it seemed as though personal distress may demonstrate age-related differences in adolescence, a time when behavioral and neural processes are refining themselves to distinguish between the self and other (Crone & Fuligni, 2020).

This dissertation found that state empathic concern and perspective-taking as measured by the empathy task demonstrated age-related changes as a function of gender. The pattern for males and females by age looked similar for both empathic concern and perspective-taking, showing that empathic concern and perspective-taking were similar between males and females aged 12 to 15 years but demonstrated differences following 15 years with females showing more empathic concern and perspective-taking compared to their males counterparts. This increase in empathic concern and perspective-taking among females in later adolescence may be indicative of more mature affective and cognitive processes compared to males at that same age. Although the role of puberty was examined, given the known difference in puberty development among males and females, there was no evidence of the role of puberty in the current investigation.

Although age by gender differences were found in empathic concern and perspective-taking ratings on the empathy task, these results were not replicated when examining the neural activation in ROIs associated with pain processing, social cognition, and personal distress during the empathy task. Another study examining age and associated neural activation to empathy during across a sample of 4 to 17 year old participants similarly found an age by gender interaction in IRI ratings of empathic concern and perspective-taking, but did not find age by gender differences in neural activation (Michalska, Kinzler, & Decety, 2013). Furthermore, EEG evidence has also not detected differences in empathy by despite significant gender differences in reporting with females self-reporting more empathy than males (Pang et al., 2023). Taken together, these findings indicate a dissociation between explicit ratings of empathy and a neurophysiological response to empathy in adolescence. Previous researchers have questioned whether this may be indicative of females heightened willingness to report on empathy compared to males as opposed to a true behavioral difference between males and females given that neuroimaging evidence has not detected clear gender differences in the neural substrates of empathy.

It is curious that we did not observe age-related differences in neural activation among the a priori ROIs, given that there are some studies showing age-related changes in neural activation associated with empathy (Decety & Michalska, 2010; Michalska, Kinzler, & Decety, 2013). An important difference between those investigations and the current investigation and that this study used a considerably narrower age range that hyper-focused on adolescence (ages 11 to 17 years) compared to other investigations looking at participants aged 4 to 17 years or 7 to 40 years old. As such, it could be that a larger age range or an adult comparison group is needed to detect developmental differences that are particular to adolescence, both of which were missing from the current investigation.

This dissertation also examined the neural correlates of empathic concern, perspective-taking and personal distress individually to assess whether overlapping or distinct neural correlates emerged for each of these empathic processes. Empathic concern was not associated with activation in the bilateral anterior insula or dACC as has been shown in previous research; however, some evidence was found for a positive link between perspective-taking and bilateral anterior insula activation, though this finding did not pass FWEr correction. Higher personal distress seemed more strongly linked to lower neural activation in brain regions associated with emotion regulation, such as the bilateral dlPFC, vlPFC, and to a lesser extent the OFC. This is an important finding in the context of research on adolescent empathy and its neural correlates as previous studies of adolescent empathy and brain activation have overlooked the relevance of personal distress to empathy. Findings indicate a potential regulatory role that has been associated with frontal cortex regions, that may be involved in reducing personal distress to empathy.

To further examine the regulatory function of the dlPFC, vlPFC, and OFC in empathy during adolescence, the final study in this dissertation assess the link between personal distress and prosocial behavior as well as the moderating role of the dlPFC, vlPFC and OFC in this link. Findings from this dissertation demonstrated that youth with higher activation in the OFC show a somewhat positive association between prosocial behavior and personal distress. Findings must be interpreted in the context of study limitations—this finding did not pass FWEr correction and there is a glaring mismatch of state and trait measures of personal distress and prosocial behavior (see Chapter 4, Discussion). Nonetheless, this finding provides some support for the possible regulatory role of the OFC in the link between personal distress and prosocial behavior.

Taken together, findings from the current dissertation indicate a mismatch between empathy and associated neural activation, potentially indicating a gender bias in empathy self-reporting that is not reflected in the neural processing associated with empathy among youth. Furthermore, findings demonstrate the involvement of brain regions associated with pain processing (i.e. bilateral anterior insula, dACC), social cognition (i.e. bilateral dmPFC), and emotion regulation (i.e., vlPFC) during empathy in adolescence, irrespective of age and gender. While the neural correlates of empathic concern and perspective-taking were less unequivocal, results pointed to an association between higher personal distress and lower activation in regions associated with emotion regulation. Lastly, there was preliminary evidence that the bilateral OFC moderates the association between personal distress and prosocial behavior.

Future research on empathy development in adolescence should incorporate both state and trait measures of empathy along with implicit (i.e., empathy task) and explicit measures (i.e., IRI). Empathy development should be examined using longitudinal assessments, and in order to assess adolescent-specific development, large age spans using cross-lagged designs or a comparison child/adult control group should be assessed to confirm that findings are indeed adolescent specific. Implicit measures of empathy, such as the empathy task, should contain enough contextual information for the participant to surmise what happened in the empathic scene (i.e., dynamic stimuli showing someone accidentally falling down the stairs or getting pushed versus an image of someone falling down the stairs with no context). Furthermore, empathic personal distress demonstrates interesting results in the current dissertation, indicating that this aversive reaction to empathy may be important to examine in adolescence. This dissertation provided some preliminary evidence that less personal distress is linked with more activation in brain regions linked with emotion regulation and that this may be relevant for the association between personal distress and prosocial behavior in youth. Should future investigations find stronger evidence for this link, behavioral intervention efforts aimed at increasing empathy or prosocial behavior may be able to look to emotion regulation strategies to increase and strengthen these positive behaviors among adolescents.

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