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Brain and Behavioral Correlates of Internalizing Symptoms in Adolescence

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Brain and Behavioral Correlates of Internalizing Symptoms in Adolescence

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Neuroscience

by

Namita Padgaonkar

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ABSTRACT OF THE DISSERTATION

Brain and Behavioral Correlates of Internalizing Symptoms in Adolescence

by

Namita Padgaonkar

Doctor of Philosophy in Neuroscience

University of California, Los Angeles, 2021

Professor Mirella Dapretto, Co-Chair

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Internalizing symptoms and disorders – such as anxiety and depression – increase in adolescence (Meyer and Lee, 2019) and can interact with youth brain and behavioral development. As youth develop, changing biological and environmental factors necessitate developing novel skills, such as emotion regulation and reward-based learning strategies, while balancing new drives toward risk-taking. Given how complex and in-flux this period of life is, investigating the role of internalizing symptoms in a variety of adolescent behaviors is crucial for better understanding how to support youth through this dynamic developmental stage. The studies in this dissertation examine how internalizing symptoms relate to brain development – specifically, functional connectivity and activity associated with emotion regulation and reward learning – as well as risk-taking in the real world. Chapter 1 provides a general introduction to the research outlined in the following chapters. Chapter 2 describes research relating internalizing symptomatology in subclinical youth to amygdala-whole brain functional

connectivity. Findings demonstrate that the relationship between internalizing symptoms and amygdala connectivity is stronger in girls than boys, and that youth generally demonstrate greater connectivity between the amygdala and regions associated with emotional processing as a function of greater internalizing symptoms. In Chapter 3, findings from the first study to investigate brain and behavioral differences in emotion regulation between youth with and without anxiety are presented. Youth with anxiety regulated their emotions to the same extent as non-anxious peers; however, regulation may have been especially effortful for youth with anxiety as they demonstrated stronger prefrontal cortex activation and connectivity with the amygdala during regulation. Research presented in Chapter 4 characterizes the relationship between anxiety severity and reward learning in a subclinical sample. While all youth were capable of learning stimulus-reward associations, youth with higher anxiety allocated value toward non-rewarding stimuli to a greater extent and showed a stronger relationship between brain activity and behavior; furthermore, within this group, those with the highest intolerance of uncertainty showed the least reward network activation when receiving rewards. Finally, Chapter 5 examines racial disparities in the juvenile justice system, as well as tracks the longitudinal change in internalizing symptoms alongside criminal offending. Black youth, and to a slightly lesser extent Latino youth, faced the greatest disparities through system processing. All youth demonstrated greater improvements in internalizing symptoms alongside decreased offending, showing the tight relationship between mental health and criminal offending. Taken together, results from this dissertation demonstrate the varied effects of internalizing symptoms on adolescent brain and behavioral development. As such, these studies present a multi-disciplinary look at the role of mental health in the lives of adolescents.

The dissertation of Namita Padgaonkar is approved.

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University of California, Los Angeles 2021

DEDICATION

This dissertation is dedicated to my family.

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Chapter 3 is based on the work: Padgaonkar, N.T., Uy, J.P, DePasque, S., Galván, A., & Peris, T.S. (2021, in press). Neural correlates of emotional reactivity and regulation in youth with and without anxiety. Depression & anxiety.

Chapter 4 is based on work in preparation for submission: Padgaonkar, N.T., Baker, A.E., Peris, T.S., Galván, A. *Probabilistic reward learning in adolescents across an anxiety continuum.*

Chapter 5, Study 1 is based on work: *Padgaonkar, N. T., *Baker, A. E., Dapretto, M., Galván, A., Frick, P. J., Steinberg, L., & Cauffman, E. (2020). *Exploring Disproportionate Minority Contact in the Juvenile Justice System Over the Year Following First Arrest*. Journal of Research on Adolescence.

Chapter 5, Study 2 is based on work in preparation for submission: *Baker, A. E., *Padgaonkar, N. T., Dapretto, M., Galván, A., Frick, P. J., Steinberg, L., & Cauffman, E. *Characterizing trajectories of anxiety, depression, and criminal offending in male adolescents over the 5 years following their first arrest*.

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1. **Padgaonkar N.T.**, Uy J., DePasque S., Galván A., Peris T. (In Press). Neural correlates of emotional reactivity and regulation in youth with and without anxiety. *Depression & Anxiety.*
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3. Lawrence K.E., Hernandez L.M., Bowman H.C., **Padgaonkar N.T.**, Fuster E., Jack A., Aylward E., Gaab N., Van Horn J.D., Bernier R.A., McPartland J.C., Nelson C.A., Webb S.J., Pelphrey K.A., Green S.A., Bookheimer S.Y., Dapretto M. (2020). Sex differences among youth with ASD in functional connectivity of the salience, default mode, and central executive networks. *Cerebral Cortex*.
4. Hernandez L.M., Lawrence K.E., **Padgaonkar N.T.**, Inada M., Hoekstra J.N., Lowe J.K., Eilbott J., Jack A., Aylward E., Gaab N., Van Horn J.D., Bernier R.A., McPartland J.C., Webb S.J., Pelphrey K.A., Green S.A., Geschwind D.H., Bookheimer S.Y., Dapretto M. (2020). Imaging-genetics of sex differences in ASD: distinct effects of OXTR variants on brain connectivity. *Transl Psychiatry 10*(82): 1-12.
5. **Padgaonkar N.T.**, Lawrence K.E., Hernandez L.M., Green S., Galván A., Dapretto M. Sex differences in internalizing symptoms and amygdala functional connectivity in neurotypical youth. (2020). *Dev Cog Neuro 44*: 100797.
6. Zanto T.P, **Padgaonkar N.T.**, Gazzaley A. (2019). A tablet-based assessment of sensorimotor synchronization. *Front. Psychol. 10*(2471).
7. **Padgaonkar N.A.**, Zanto T.P., Bollinger J., Gazzaley A. (2017). Predictive cues and age-related declines in working memory performance. *Neurobiology of Aging* 49: 31-39.

8. Russo K.A., La J.L., Stephens S.B.Z., Poling M.C., **Padgaonkar N.A.**, Jennings K.J., Piekarski D.J., Kauffman A.S., Kriegsfeld L.J. (2015). Circadian control of the female reproductive axis through gated responsiveness of the RFRP-3 system to VIP signaling. *Endocrinology 156*(7): 2608-2618.

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CONFERENCE PRESENTATIONS

1. **Padgaonkar N.T**., Uy J., DePasque S., Peris T., Galván A. (May 2020). *Alterations in Activation and Connectivity of Prefrontal Regions during Emotion Regulation in Youth with and without Anxiety Disorders*. Social & Affective Neuroscience Society Meeting; cancelled due to COVID-19.
2. Lawrence K.E., Hernandez LM., **Padgaonkar N.T.**, Green S.A., Bowman H., Bookheimer S., Dapretto M. (June 2019). *Effects of gender on within- and between-network functional connectivity in youth with ASD.* Program No. M021. Organization for Human Brain Mapping, Rome, Italy.
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6. **Padgaonkar N.T**., Sherman L., Hernandez L.M., Dapretto M. (Nov 2017). *Age a'int nothing but a number: salience and central executive network connectivity in high school and college students.* Program No. 371.04. Neuroscience Meeting Planner, Washington D.C.: Society for Neuroscience.
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8. **Padgaonkar N.T.**, Sherman L., Hernandez L.M., Dapretto M. (Aug 2017). *Salience network connectivity and risk-taking behavior in high school and college students.* Program No. 3-C-118. Flux Conference, Portland, OR.
9. Zanto T.P., **Padgaonkar N.T.**, Gazzaley A. (May 2016). *Assessment of rhythm abilities on a tablet-based mobile platform.* Co-author on invited talk: Rhythm, Meter & Timing 1: International Conference for Music Perception and Cognition, San Francisco, CA.
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CHAPTER 1

General Introduction to the Dissertation

Adolescence constitutes a period of life with tremendous change – including but not limited to brain, socioemotional, and physical development – amongst a backdrop of changing expectations and priorities. These fluctuating biological and environmental events can contribute to the high prevalence of internalizing symptoms (such as anxiety and depression) observed in youth as they transition into adolescence. Internalizing symptoms can interact with adolescent development, contributing to brain development differences, emotion dysregulation, atypical reward learning, and altered risk taking. However, the mechanisms relating internalizing symptoms – both at the level of the brain and behavior – to variations within these aspects of adolescent development remain elusive. The studies presented in the first section of this dissertation aim to bridge this gap in the knowledge by investigating how internalizing symptoms and disorders relate to brain activity and functional connectivity, emotion regulation, and reward learning. The second part of this dissertation examines risk-taking in the real world, and the relationships between internalizing, racism, and offending in a sample of adolescents involved in the juvenile justice system.

Overview of Studies

Internalizing symptoms and amygdala functional connectivity

Internalizing disorders refer to anxiety, depressive, and somatic disorders, which show increased prevalence during adolescence (Meyer and Lee, 2019). While treatment focuses on reducing distress arising from these disorders, the subclinical manifestation of disorder

symptoms can themselves be distressing and impairing. Youth experiencing symptoms of one category of internalizing disorders often also experience co-morbid symptoms of another (Cummings et al., 2014); greater symptom severity and comorbidity is more common in girls (Eaton et al., 2012; Garber and Weersing, 2010). Rapid brain development also occurs during this time, especially in functional connections between regions relevant for emotional processing such as the amygdala and the prefrontal cortex (Casey et al., 2019). Functional connectivity can be assessed in the resting brain by correlating low frequency, spontaneous fluctuations in neural activity across brain regions to identify functionally-related brain networks (Raichle, 2010). While prior work has investigated how functional connectivity is different between youth with and without internalizing disorders (Blackford and Pine, 2012), it is unclear how classes of internalizing symptoms themselves relate to functional connectivity of the amygdala and its subnuclei, and how this may differentially affect girls relative to boys. Assessing the relationship between functional connectivity and subclinical symptoms can help elucidate whether circuit-level alterations are apparent even before disorder onset. Further, examining gender differences in these relationships can help explain why girls might be at higher risk for internalizing conditions.

Chapter 2 presents functional connectivity research from a study of typically-developing youth who vary across a continuum of internalizing symptomatology. Findings in this chapter suggest stronger relationships between amygdala functional connectivity and subclinical internalizing symptoms in girls relative to boys, specifically in regions implicated in emotional and salience processing. Fine-grained analyses investigating amygdala subnuclei revealed domain-specific alterations in connectivity with respect to symptom classes. For instance, heightened somatic symptomatology in females related to greater connectivity between the

centromedial amygdala and somatosensory cortices. While future longitudinal assessments are crucial to unpack the directionality of these effects, these findings indicate that there is a relationship between symptom severity and amygdala functional connectivity, even in a sample of youth who are not clinically diagnosed with any internalizing disorders. Results could suggest that atypicalities in connections between brain regions involved in emotional processing precede full disorder development. Further, these results demonstrate that investigating internalizing dimensionally, as opposed to categorically, can help identify the relationship between symptomatology and functional connectivity.

Emotion regulation in youth with anxiety

Youth with anxiety can experience difficulties in perceiving ambiguous situations and managing their resulting emotions (Taghavi et al., 2000). For instance, youth with anxiety often exhibit information processing biases such as heightened allocation of attention to threat (Dudeney et al., 2015) and a reduced ability to discriminate between threat and safety cues (Britton et al., 2013). The increased salience afforded to threatening and fearful stimuli often generalizes to situations and stimuli that could signal future distress (Lau and Waters, 2017), such as social interactions with peers or new experiences. Often, both enhanced distress as well as difficulty in downregulating this distress are observed in youth with anxiety disorders (Suveg and Zeman, 2004). Neurobiologically, behavioral distress is often accompanied by heightened activation of brain regions that encode salience, such as the amygdala, whereas reappraisal of distress is accompanied by reduced amygdala activation (Buhle et al., 2014). When explicitly instructed to reappraise their emotions, youth with anxiety are capable of doing so at the level of their non-anxious peers (Carthy et al., 2010a, 2010b). How youth with anxiety recruit brain

regions to support successful reappraisal, and how these regions may differ from youth without anxiety, has not been previously examined. This research question is crucial to investigate in adolescence, as the prevalence of mental health symptoms increases steadily in this age range, and youth are faced with changing social situations which require emotion regulation skill development.

Using measures of behavior, brain activation, and brain connectivity, the study presented in Chapter 3 examined emotion regulation in youth with and without clinical anxiety. While undergoing MRI, youth performed an emotion regulation task where they were alternatively cued to either regulate their emotions or to experience their emotions freely while viewing either aversive or neutral stimuli. In this study, youth with and without anxiety displayed similar levels of both emotional reactivity and emotion regulation. Whole-brain analyses similarly revealed no differences in activation during reactivity or regulation between groups. However, youth with anxiety did self-report greater negative affect when viewing aversive images, and region of interest analyses demonstrated heightened amygdala and ventrolateral prefrontal cortex activation while viewing aversive images both with and without explicit regulation instruction. Further, stronger connectivity between amygdala and ventromedial prefrontal cortex during regulation correlated with fewer symptoms of anxiety in youth with anxiety, but more symptoms of anxiety in youth without anxiety. These results suggest two key differences in emotion regulation between youth with and without anxiety. First, youth with anxiety demonstrated heightened arousal as indexed by both greater negative affect and greater amygdala activation while viewing aversive imagery. Second, while regulating, youth with anxiety showed greater prefrontal activation and greater connectivity within frontolimbic circuitry which may index that regulation was particularly effortful. Taken together, these results suggest that focusing

intervention strategies both on reducing initial emotional reactivity, as well as practicing successful reappraisal may be especially important for youth with anxiety.

Probabilistic reward learning across anxiety continuum

Intolerance toward ambiguity is a behavioral hallmark of anxiety (Osmanağaoğlu et al., 2018). Unfamiliar or unpredictable situations habitually become associated with distress, leading to behavioral avoidance (Grenier et al., 2005). Behavioral avoidance can be particularly impairing in adolescence, as avoiding ambiguous situations can prevent youth from engaging in reward learning, which is an experience-dependent form of associative learning. As youth develop, they begin ascribing salience to cues in their environment that predict rewards, thereby refining their reward learning. Neurobiologically, this manifests as heightened reward network activation during anticipation of rewards as well as during receipt of reward (Hoogendam et al., 2013). In contrast, youth at risk for, or who are diagnosed with, anxiety demonstrate above-typical levels of reward network activation during anticipation (Lahat et al., 2016) and high activation during loss of (or absence of) reward (Helfinstein et al., 2011). Mechanistically, this process may be explained by differences in decision value and prediction error processing. However, the relationship between these reward learning constructs and anxiety has not been examined.

Chapter 4 examines a population of children and early adolescents who vary across a continuum of anxiety symptomatology, from normative development through clinical anxiety. Youth performed a probabilistic reward learning task while undergoing MRI in which they sought to learn associations between categories and abstract stimuli to earn points. The task probed probabilistic learning as 2/3 of the stimuli were associated with a given category 83% of

the time (predictive stimuli) and the other 1/3 were associated with a given category 50% of the time (non-predictive stimuli). Further, half of the stimuli from each category were associated with high rewards (5 points) and half with low rewards (1 point). A Rescorla-Wagner reinforcement learning model was employed to investigate trial-by-trial decision values (the value youth ascribe to a given stimuli) and prediction errors (the difference between the expected and received reward). Youth were faster for predictive relative to non-predictive and high relative to low rewarding stimuli. Results were the same for accuracy and decision values, with particularly high accuracy and decision values for predictable high rewarding stimuli. Prediction errors were similar across all trials in which youth responded incorrectly; for correct responses, prediction errors were higher for both predictive and non-predictive high rewards relative to low rewards. Decision values more strongly modulated task-related brain activation when youth viewed non-predictive stimuli, particularly in the hubs of the default mode network – the posterior cingulate and precuneus. Greater modulation during non-predictive relative to predictive trials could reflect on-going efforts to learn stimulus-reward associations in this context where associations are constantly changing. Further, youth with the most severe anxiety and who showed greater activity in bilateral nucleus accumbens (NAcc) for predictive than non-predictive stimuli performed most accurately; conversely, these same youth performed least accurately if they recruited bilateral NAcc more for non-predictive than predictive stimuli. Prediction errors more strongly modulated task-related brain activation when youth received feedback for incorrect than correct responses; as with decision values, this may reflect learning following deviations from expected stimulus-reward associations. When receiving feedback for correct vs. incorrect responses for predictive stimuli, youth who engaged right NAcc and putamen more display greater tolerance toward uncertainty in their daily lives, as reported by

their parents. Overall, results indicate that traits which characterize youth with anxiety – namely, heightened anxiety symptomatology and intolerance of uncertainty – relate to reward anticipation and processing. Higher anxiety can moderate the extent to which brain activation in reward circuitry contributes to task performance; whereas youth with lower anxiety may perform similarly regardless of the extent to which the brain tracks predictive information, youth with anxiety may pay particular attention to the predictive validity of stimuli which can affect task performance. Similarly, youth who are less tolerant of ambiguity may show reduced engagement of reward circuitry when receiving rewarding feedback. Results suggest that contexts which lack certainty may make reward learning difficult for youth with anxiety. Understanding that earning rewards may be contingent upon changing behaviors for a given situation is particularly important during adolescence – a period of life that is especially dynamic and unpredictable.

Adolescents in the juvenile justice system – race and mental health

A particularly stressful context experienced by roughly 2% of American youth between 10-17 years of age (*How Is The Juvenile Justice Population Defined?*, 2015) is involvement with the juvenile justice system in which stressors such as racism and lack of mental health services are experienced at high levels (Johnson, 2007; Zajac et al., 2015). Interactions with the juvenile justice system through law enforcement, court proceedings, probation, and/or incarceration can lead to increased risk of suicide (Perry and Morris, 2014) and increased risk of mental health problems (Wasserman et al., 2010), as well as increased recidivism (Gatti et al., 2009; Lambie and Randell, 2013; Loughran et al., 2009) and poorer academic and global functioning outcomes (Lewinsohn et al., 1995). Minority youth, especially Black and Latino youth, experience greater contact with the system, and are thus exposed to these stressors more than their white peers.

Tracking the persistent effects of racism through first system contact, as well as the lasting consequences to mental health and recidivism are crucial for improving juvenile rehabilitation as well as reducing the harmful effects of racism and lack of mental health care in the juvenile justice setting.

Chapter 5 first examines racial disparities in system processing and then examines the trajectories of internalizing symptoms and self-reported offending in a sample of male youth enrolled in the study at the time of their first arrest. In this sample, Black youth were arrested after committing the fewest offenses (relative to Latino and white youth), both Black and Latino youth were more likely to receive formal court processing (thereby increasing their exposure to the system and, as a result, increasing their risk for poorer outcomes), and Black youth were most likely to be re-arrested 1 year after first arrest (after committing the fewest offenses in the interim period). These youth also demonstrated variable levels of anxiety and depression at baseline which, together with self-reported offending, demonstrated initial linear declines followed by significant increases over the 5-year follow-up window. Rates of internalizing symptoms and offending changed together over time. Interestingly, youth within this sample who were re-arrested at least once following initial arrest demonstrated the least improvement in both depressive symptoms and recidivism. Results from this chapter demonstrate the pervasive and harmful role of racism in the juvenile justice system, and several strategies for addressing disparities are discussed. Results also show that mental health needs co-occur alongside criminogenic needs, such that mental health care concerns need to be appropriately screened (at intake, as well as throughout justice system involvement) and addressed through increased funding for services.

CHAPTER 2

Sex Differences in Internalizing Symptoms and Amygdala Functional Connectivity in Neurotypical Youth

Amygdala resting-state functional connectivity (rsFC) is altered in adolescents with internalizing disorders, though the relationship between rsFC and subclinical symptomatology in neurotypical youth remains unclear. Here we examined whether amygdala rsFC varied across a continuum of internalizing symptoms in 110 typically-developing (TD) youths 8 to 17 years old using functional magnetic resonance imaging (fMRI). We assessed overall internalizing symptoms, as well as anxious-depressed, withdrawn-depressed, and somatic complaints. Given known sex differences in the prevalence of internalizing disorders, we compared connectivity between males and females. As compared to males, females with greater internalizing, anxious-depressed, and somatic symptoms displayed greater connectivity with the cingulate gyrus, insula, and somatosensory cortices. In contrast, males with greater anxious-depressed symptoms demonstrated weaker connectivity with the subcallosal prefrontal cortex. Sex differences in rsFC in relation to symptom severity were evident for the whole amygdala and for two of its subnuclei (centromedial and superficial amygdala). Overall, results suggest that, for females, higher internalizing symptoms are associated with greater rsFC between the amygdala and regions implicated in emotional and somatosensory processing, salience detection, and action selection. Future longitudinal investigations are needed to determine whether this hyperconnectivity may confer resilience to, or pose risk for, the development of internalizing disorders.

INTRODUCTION

Internalizing disorders constitute a group of related psychiatric conditions including anxiety disorders, somatic disorders, and depression; these disorders display significant overlap of symptom expression and are twice as common in females than in males (Eaton et al., 2012). Such conditions are highly prevalent during adolescence, a time when considerable brain development occurs, specifically in networks relevant for socio-emotional processing (Blakemore and Mills, 2014; Casey, 2015; Casey et al., 2019; Crone and Dahl, 2012; Guyer et al., 2016). Female adolescents in particular exhibit greater subclinical internalizing symptoms than males and are more likely to be diagnosed with an internalizing disorder (Angold et al., 2002; Costello and Angold, 2000; Crick and Zahn-Waxler, 2003; Hankin et al., 1998; Lewinsohn et al., 1995). Nearly 1 in every 3 adolescents will receive a diagnosis of an anxiety disorder before adulthood (Merikangas et al., 2010), and college students are increasingly seeking mental health services due to anxiety (Center for Collegiate Mental Health, 2015). While the DSM-5 (American Psychiatric Association, 2013) conceptualizes these internalizing disorders separately for diagnosis and treatment, anxiety and depression are often sequentially or concurrently comorbid amongst adolescents (Cummings et al., 2014; Garber and Weersing, 2010). Other types of symptoms such as rumination (McLaughlin and Nolen-Hoeksema, 2011) and emotion dysregulation (McLaughlin et al., 2011) are also transdiagnostic features of both anxiety and depression. In the absence of comorbidity, adolescents who meet criteria for one internalizing disorder often endorse subclinical symptoms for another. Such symptom overlap is especially true for adolescents with anxiety who often display high, albeit subthreshold, levels of depression (Garber and Weersing, 2010).

In addition to considerable behavioral evidence suggesting comorbidity and similarities between internalizing disorders, a growing body of neuroimaging research demonstrates shared neural alterations across internalizing disorders. Adolescents with depression and anxiety both demonstrate amygdala hyperactivation to fearful faces relative to neutral faces as compared to neurotypical youth (Beesdo et al., 2009). Relatedly, re-grouping adults with generalized anxiety disorder (GAD) and major depressive disorder (MDD) based on whether they exhibit high vs. low intra-limbic functional connectivity better predicts the extent of their attentional threat bias than when grouping by clinical diagnosis (Bijsterbosch et al., 2018). Notably, another study indicates that clustering MDD patients using limbic and fronto-striatal network connectivity reveals patient subtypes that are predictive of responsivity to repetitive transcranial magnetic stimulation (rTMS) therapy (Drysdale et al., 2017).

Neural network alterations observed in children and adolescents with internalizing disorders are broadly evident in brain circuits relevant for emotional processing and salience detection, particularly involving the amygdala (for review, see Blackford and Pine, 2012). Alterations in these networks can manifest as atypical resting-state functional connectivity (rsFC), a metric indexing co-activation history between regions supporting similar functions which allows for the identification of functionally related-brain networks (Raichle, 2010). The basolateral amygdala (BLA), centromedial amygdala (CMA), and superficial amygdala (SFA) demonstrate separable rsFC networks that relate to distinct roles in both the processing of sensory stimuli and the expression of different behaviors (Amunts et al., 2005; Bzdok et al., 2013; Roy et al., 2009). The BLA receives sensory and threat-related information and is thought to process emotions via communication between regions such as visual association cortices, medial prefrontal cortex, and the cingulate gyrus (Dolan and Vuilleumier, 2006; LeDoux, 2000;

Pessoa and Adolphs, 2010). The CMA contributes to the expression of emotions via its communication with sensorimotor regions, brainstem, and cerebellum (LeDoux, 2007, 2000; Roy et al., 2009). The SFA plays a role in emotion processing, displaying connectivity with the ventral striatum, orbitofrontal cortex, cingulate, insula, and hippocampus (Koelsch et al., 2013). Given their distinct connectivity patterns and their relation to different processes, assessing connectivity for each amygdala subnuclei could better inform our understanding of neural circuit alterations in relation to internalizing symptoms.

Research in neurotypical youth has also characterized normative developmental trajectories of functional connectivity with the amygdala and its subnuclei (Alarcón et al., 2015; Gabard-Durnam et al., 2014; Jalbrzikowski et al., 2017; Qin et al., 2014); however, less is known about how subclinical symptomatology amongst typically-developing (TD) youth may relate to amygdala rsFC. Within this existing literature, reports are mixed with regard to the directionality of the relationship between amygdalar connectivity and internalizing symptoms, as well as with regard to the brain regions showing such relationships. These disparities may reflect the specificity or severity of the symptoms examined, the developmental period under investigation (i.e., childhood versus late adolescence), whether whole amygdala rsFC or amygdala subnuclei rsFC is considered, and other sample characteristics. A longitudinal study of TD youth (average age ~13) with no psychopathology at baseline compared amygdala rsFC, on average 2.5 years later, between youth who remained free of symptoms and those who showed greater depressive symptomatology (referred to as “escalators”). Relative to this group, neurotypical youth showed greater baseline connectivity between the right amygdala and left IFG, supramarginal gyrus, and right mid-cingulate cortex, as well as less connectivity between left amygdala and cerebellum (Scheuer et al., 2017). In contrast, a cross-sectional study investigating amygdala subnuclei rsFC

in a younger sample of TD children (average age ~8) showed that greater symptoms of anxiety related to greater connectivity between the left amygdala, particularly the BLA, and several regions implicated in sensory processing, higher-order frontal regions, and subcortical regions (Qin et al., 2014). In a sample of youth exposed to early-life stress, greater adolescent amygdala-vmPFC connectivity related to less symptoms of anxiety, but more symptoms of depression, particularly for females (Burghy et al., 2012). Assessments of TD adolescents who exhibit subclinical internalizing symptoms can help inform whether known circuit-level alterations in functional connectivity seen in adolescents with a clinical diagnosis arise prior to disorder onset and could thus be used as biomarkers, or instead are merely symptomatic of a clinical diagnosis. Further, investigating the association between amygdala functional connectivity and distinct internalizing symptoms affords the ability to detect similarities and differences across disorders with shared symptom expression.

Here, we used a dimensional approach to understand how subclinical internalizing symptomatology might modulate rsFC of the amygdala and its subnuclei in a sample of 110 TD children and adolescents. Given differential rates of internalizing symptoms and disorders in males and females, we particularly focused on sex differences in rsFC. To our knowledge, this is the first study to specifically examine the role of sex when relating subclinical internalizing symptoms to amygdala rsFC in a large sample of otherwise typically-developing youth. The entire bilateral amygdala, as well as the BLA, CMA, and SFA subnuclei in exploratory analyses, were used as seed regions of interest in independent analyses. The internalizing scale of the Child Behavior Checklist (CBCL), a parent-report of child and adolescent symptoms, was used to assess symptom severity; furthermore, its three constituent subscales – anxious-depressed, somatic complaints, and withdrawn-depressed – were used to examine how specific types of

symptoms might relate to distinct patterns of amygdala functional connectivity. Supplemental analyses were also conducted to explore how age might affect any observed relationships between amygdala connectivity and internalizing symptomatology. Given the limited relevant literature and lack of consistent results, we refrained from formulating specific hypotheses as per the relationship between internalizing symptoms and functional connectivity of the amygdala or its subnuclei. However, prior work does suggest the presence of sex differences in whole amygdala and amygdala subnuclei functional connectivity (Engman et al., 2016), and that atypicalities in amygdala task-based functional connectivity may vary as a function of mood in females but not in males (Mareckova et al., 2016). Thus, we predicted that internalizing symptomatology would modulate amygdala connectivity, and that this relationship would differ between females and males.

MATERIALS AND METHODS

Study Participants

Participants included 124 typically developing children and adolescents who were recruited as part of the Gender Exploration of Neurogenetics and Development to Advance Autism Research (GENDAAR) multisite consortium. Participants were recruited for this study through traditional recruitment strategies (e.g., flyers distributed at community events, youth organizations, school events, etc.); the fact that these youth were enrolled as neurotypical controls in a study focused on Autism Spectrum Disorder (ASD) had no influence on the choice of strategy. Data collection occurred at 4 institutions: Harvard Medical School, Seattle Children's Research Institute, University of California Los Angeles (UCLA), and Yale University (scanner and site were both included as covariates in all analyses). Fourteen subjects

were excluded from the analyses due to excessive motion during the MRI scan (see Methods 2.5), yielding a total sample of 110 participants (57 females: M_{age} = 13.1, SD = 2.9, range = 8.28 – 17.9 years; 53 males: M_{age} = 13.7, SD = 2.5, range = 8.26-17.8 years; see Table 2.1). All participants were right-handed, had no contraindications for MRI, had no previous or current history of neurological, psychiatric, or neurodevelopmental disorders, and no history of ASD in any first-degree relatives. Further, the Social Responsiveness Scale (Constantino and Gruber, 2012) was used to exclude participants with elevated ASD symptomatology. 75% of participants identified as White, 12% as more than one race, 8% as Asian, and 5% as Black or African American (Table 2.1). Family income was collected as a proxy for socioeconomic status; however, this information was missing for 36 participants. Additionally, all participants self-reported about their pubertal status using the Pubertal Development Scale (Table 2.1; PDS, Petersen et al., 1988). Written informed consent and assent were obtained from all legal guardians and study participants in accordance with all sites' Institutional Review Boards. All participants were compensated for their participation in this study.

Behavioral Measures

Internalizing symptoms were assessed via parental reports on the Child Behavior Checklist (CBCL) internalizing scale (Achenbach, 1991) which provides a global categorization of all internalizing problems. We also examined the scores on its 3 subscales (anxious-depressed, somatic complaints, and withdrawn-depressed) to explore how specific symptomatology might differentially modulate amygdala connectivity. Appendix 2.1 lists the specific items parents were asked, grouped by each subscale. Each CBCL subscale score is generated by summing values indicating how often a parent perceives their child experiencing a symptom on a scale from 0-2, where 0 indicates that this symptom is not endorsed by their child ("Not True (as far as you

know)"), 1 indicates that parents believe this symptom is sometimes expressed by their child ("Somewhat or Sometimes True"), and 2 indicates that parents believe this symptom is often expressed by their child ("Very True or Often True"). There are 32 total items on the Internalizing scale (scores range from 0-64), which is composed of 13 items on the anxious-depressed subscale (scores range from 0-26), 11 items on the somatic complaints subscale (scores range from 0-22), and 8 items on the withdrawn-depressed subscale (scores range from 0-16).

The anxious-depressed subscale primarily measures various types of fears (e.g., fear of being perfect, fear of social situations) as well as some symptoms of depression (e.g., cries a lot). The somatic complaints subscale addresses physical manifestations of internalizing problems, including nausea, tiredness, and digestive problems. The withdrawn-depressed subscale primarily assesses symptoms of depression, particularly related to social situations (e.g., would rather be alone than with others). These subscales were chosen for their ability to capture dimensional symptom severity in youth with and without a clinical diagnosis. Internalizing symptom severity was compared between males and females using two-tailed t-tests. All analyses were conducted using CBCL raw scores. As CBCL T-scores are normed separately for males and females, using T-scores would have precluded meaningful sex comparisons.

MRI Data Acquisition

Resting-state functional magnetic resonance imaging (rs-fMRI) data were obtained for all participants using either a Siemens 3T Trio (12-channel head coil) or a Prisma 3T whole-body scanner (20-channel head coil). For registration, each participant also received a matched-bandwidth echo-planar image (TR=5000ms, TE=34ms for Trio or 35ms for Prisma, FOV=192mm, 34 slices, slice thickness 4mm, in-plane voxel size 1.5x1.5mm). The T2*-

weighted rs-fMRI sequence (TR=2000ms, TE=30ms, FOV=192mm, 34 slices, slice thickness 4mm, in-plane voxel size 3x3mm on both platforms) was acquired while participants were instructed to view a white crosshair on a black background, and at least 5.5 minutes of resting state data were acquired for each participant.

MRI Preprocessing

MRI data were analyzed using FSL and AFNI (Analysis of Functional NeuroImages; Cox, 1996). The following pre-processing steps were implemented prior to analyzing amygdala functional connectivity. Images were skull-stripped using AFNI, then realigned using the mean functional volume via FSL's Motion Correction Linear Registration Tool (MCFLIRT; Jenkinson et al., 2002). Registration of rs-fMRI data to structural images was conducted via a 2-step process whereby functional data were linearly registered to the matched-bandwidth EPI volume (6 degrees of freedom), and then registered to the MNI 152 2mm standard brain (12 degrees of freedom). Images were smoothed using a 6 mm FWHM Gaussian kernel. To remove potential confounds resulting from head motion, smoothed data were denoised using Independent Component Analysis (ICA)-based Automatic Removal of Motion Artifacts (ICA-AROMA; Pruim et al., 2015) to regress out single-subject components labeled as motion or noise. ICA-AROMA has been shown to be one of the very best approaches for addressing head motion when compared to 18 other commonly employed denoising pipelines (Parkes et al., 2018). We chose to use ICA-AROMA, as opposed to motion scrubbing, as scrubbing results in both data loss and alterations in subjects' time series (Parkes et al., 2018). As compared with other pipelines, ICA-AROMA also does not alter estimates of long-range connectivity, which is a concern especially for pediatric samples (Van Dijk et al., 2012). Eight subjects were removed for having fewer than 10 resting-state components remaining after implementing ICA-AROMA; an additional six

subjects were removed due to high maximum absolute motion (greater than 8 mm). Data from the remaining 110 participants were bandpass filtered (0.1 Hz > t > 0.01 Hz). FSL's Automatic Segmentation Tool (FAST) was then used to create white matter, cerebrospinal fluid, and global signal masks from high-resolution anatomical scans, and signal from these masks and their derivatives were regressed out from functional data using FSL's FEAT. Resulting subject-level residuals were normalized and registered to standard space. As global signal regression (GSR) may introduce spurious anti-correlations (Murphy & Fox, 2017), only positive connectivity findings are reported and discussed here. We opted to apply GSR as it is effective at removing motion and respiratory related global artifacts, as well as increasing the relationship between functional connectivity and neuroanatomical structures; when used in conjunction with ICA-AROMA, GSR can be especially effective at denoising data (Parkes et al., 2018).

MRI Data Analysis

All statistical analyses were performed using the general linear model in FSL's FEAT. Time series were extracted from the whole bilateral amygdala at a probabilistic threshold of 25% in the Harvard-Oxford atlas, consistent with previous amygdala rsFC studies (e.g., Bickart et al., 2012). Separate exploratory analyses were also conducted for the bilateral centromedial (CMA), basolateral (BLA), and superficial (SFA) nuclei. These bilateral amygdala subnuclei ROIs were generated using the Jülich histological atlas available in FSL (FMRIB's Software Library, https://fsl.fmrib.ox.ac.uk/fsl/fslwiki; Smith et al., 2004). Voxels were assigned to the subnuclei with the highest probability of containing them only if they had at least a 40% probability of belonging to that subnuclei and not to any other nearby structures. Then, each thresholded subnuclei was subtracted from the other two and binarized to generate final non-overlapping ROIs of each subnuclei. These time series were then independently correlated with every other

voxel in the brain to generate distinct functional connectivity maps for each participant. Finally, all subject-level correlation maps were transformed to z-statistic maps using Fisher's *r* to *z* transform to allow for between-subject comparisons. Group analyses were conducted in FSL's FEAT using FLAME 1+2, a mixed effects model. All regression analyses described below were focused on (i.e., masked by) brain regions where either males or females showed significant whole amygdala functional connectivity (thresholded at $z > 2.3$, $p < 0.05$), in keeping with our main aim of characterizing how amygdala connectivity might be modulated by internalizing symptoms in males and females. Restricting our search space to the networks of regions showing significant connectivity with the amygdala (in either group) does not allow for identification of regions which may show amygdala connectivity only as a function of symptoms; however, given that our sample involved neurotypical youth experiencing a limited range of symptoms, we opted to assess the modulatory role of internalizing symptomatology only in brain regions that showed significant amygdala connectivity in either group.

Raw, demeaned scores for the CBCL internalizing scale, as well as for the anxious-depressed, somatic complaints, and withdrawn-depressed subscales, were entered as covariates of interest in separate higher-level FEAT regression analyses to assess whole-group (males + females), within-group (males and females separately), and between-group (males vs. females) effects. Scanner and data collection site were also entered as regressors of no interest. Analyses were first conducted for the internalizing scale to identify general patterns of altered connectivity; these were followed by separate analyses for each subscale to assess the specific relationship between amygdala functional connectivity and distinct symptom profiles. All bottom-up analyses were thresholded at $z > 3.1$ ($p < 0.001$) and corrected for multiple comparisons at $p < 0.05$ in accordance with current recommendations in the field for more

stringent statistical thresholding (Kessler et al., 2017). Correction for multiple tests (i.e., across multiple seeds) is not feasible using FEAT; however, false discovery rate (FDR) correction was applied whereby the p-values averaged across each significant cluster resulting from 16 independent tests (i.e., 4 amygdala ROIs x 4 internalizing symptoms scales) were entered into the p.adjust function of the R stats package (R Core Team, 2019) to correct for multiple tests. All analyses were additionally conducted including age as a covariate, given that amygdala functional connectivity might change over the course of development. Results that differed when including age in the models are described in the relevant sections below; all results from these additional analyses with age as a covariate are included in Tables 2.3, 2.5, 2.7, and 2.9. Finally, to examine the extent to which any observed relationship between internalizing symptoms and amygdala connectivity might have been moderated by age, we extracted parameter estimates of connectivity from the regions where internalizing symptoms significantly modulated amygdala connectivity and conducted moderation analyses in R; only one significant moderating effect of age was observed as detailed below (section: Amygdala Connectivity as a Function of Anxious-Depressed Symptoms).

RESULTS

Demographics and Head Motion

Males and females did not significantly differ in age ($p = 0.22$, Table 2.1) or in pubertal status as measured by the PDS ($p = 0.08$, Table 2.1). Males and females also did not differ in mean relative motion, the percentage of ICA components retained following ICA-AROMA, or framewise displacement (Table 2.1).

Internalizing Symptoms

There were no significant differences between males and females on any of CBCL measures of internalizing (internalizing scale: $t(108) = 1.78$, $p = 0.08$; anxious-depressed subscale: $t(108) = 1.63$, $p = 0.10$; somatic complaints subscale: $t(108) = 1.68$, $p = 0.10$; withdrawn-depressed subscale: $t(108 = 0.73$, $p = 0.46$; see Table 2.1)). None of the CBCL measures correlated with age or with the PDS. 84 participants (76% of the sample) were reported by parents as exhibiting some internalizing symptoms.

We also evaluated whether any participant was an outlier on the CBCL measures, as defined as at least two standard deviations above the group average. Six participants were considered outliers across one or more scale (i.e., outliers on the anxious-depressed and somatic complaints subscales), 1 on only the somatic subscale, 1 on only the anxious-depressed subscale, and 4 on only the withdrawn-depressed subscale. All of these participants were included in our sample as our main study question of interest was to understand how a continuous range of symptoms would impact connectivity patterns. However, we ensured that all reported connectivity findings remained significant when behavioral outliers were removed.

Lastly, to ensure that observed sex differences in connectivity did not merely reflect sex differences in internalizing symptoms, we more closely matched the groups (all ps > 0.3) by removing females with the highest reported symptoms and males with the lowest reported symptoms (2 males and 2 females for the anxious-depressed and somatic complaints subscales, 3 males and 3 females for the internalizing scale). All reported between-group effects remained significant after excluding these participants.

Amygdala Functional Connectivity

While our primary analyses focused on examining amygdala rsFC in relation to internalizing symptoms, the patterns of whole amygdala rsFC (not accounting for internalizing

symptoms) for both males and females are presented in Figure 2.1 (displayed at $z > 3.1$, $p < 0.05$).

Amygdala Connectivity as a Function of Overall Internalizing Symptoms

As a function of increasing internalizing symptoms, females displayed increased whole amygdala connectivity with the posterior mid-cingulate cortex (pMCC); this pMCC cluster extended into the supplementary motor area (SMA) and precentral gyri (Table 2.2). A similar pattern of connectivity was also evident for the SFA and CMA (Table 2.2). In separate analyses conducted with age as a covariate of no interest, females also displayed greater connectivity between the pMCC and the BLA as a function of increased internalizing symptoms (Table 2.3). The CMA also uniquely displayed stronger connectivity with the left somatosensory cortex as a function of increased internalizing symptoms (Table 2.2). Overall internalizing symptoms did not significantly modulate whole amygdala connectivity in males. Direct between-group comparisons showed that, as a function of increased internalizing symptoms, females displayed significantly greater whole amygdala connectivity than males with pMCC, SMA, precentral gyri, and right superior frontal gyrus (SFG). Again, these results held for the SFA and CMA subnuclei (Figure 2.2, Table 2.2, Figure 2.3A, 2.3B), except for the SFG for which significant sex differences were only observed for the whole amygdala. At the whole-group level (across male and female youth), greater internalizing symptoms were associated with stronger connectivity between the whole amygdala and the pMCC (Table 2.2).

Amygdala Connectivity as a Function of Anxious-Depressed Symptoms

With increasing anxious-depressed symptoms, females displayed stronger connectivity of the whole amygdala, CMA, and SFA with midline precentral gyri and SMA (Table 2.4). In contrast, males demonstrated weaker connectivity between the SFA and subcallosal cortex as a

function of anxious-depressed symptoms (Table 2.4). This last effect was not significant when age was included as a covariate in separate bottom-up analyses (Table 2.5); a moderation analysis further revealed a significant interaction ($p < .01$) between age and anxious-depressed symptoms in males whereby weaker connectivity between the SFA and subcallosal cortex as a function of greater anxious-depressed symptoms was more pronounced for younger than older males.

When directly comparing male and female youth, females displayed greater connectivity between the whole amygdala and the pMCC, a pattern also seen for the SFA and CMA (Figure 2.4, Table 2.4, Figure 2.5A, 2.5B). At the whole-group level (across male and female youth combined), greater anxious-depressed symptomatology was associated with stronger connectivity between the BLA and the left thalamus (Table 2.4). Whole-group connectivity between the BLA and left thalamus was no longer significant when including age as a covariate (Table 2.5).

Amygdala Connectivity as a Function of Somatic complaints

Females displayed greater connectivity between the whole amygdala and the pMCC as a function of increased somatic complaints (Table 2.6). This pattern was mirrored for the SFA (Table 2.6); stronger SFA connectivity with increasing somatic complaints was also observed in the right anterior superior temporal gyrus (STG), left central operculum, and left insula (Table 2.6). CMA connectivity with the bilateral postcentral gyri was stronger in females with more somatic complaints (Table 2.6). In males, amygdala connectivity did not vary as a function of somatic symptoms. In direct between-group comparison with males, females showed greater connectivity between the SFA and the precentral gyrus, SMA, and pMCC (Figure 2.6, Table 2.6) as a function of increased somatic symptoms. Additionally, females showed greater connectivity

than males between the SFA and the left anterior STG with increasing somatic complaints (Figure 2.6, Table 2.6), as well as increased connectivity between the CMA and bilateral pre and postcentral gyri (Figure 2.6, Table 2.6).

Amygdala Connectivity as a Function of Withdrawn-Depressed Symptoms

Females showed greater connectivity between both the whole amygdala and the SFA with the pMCC and SMA cluster (Table 2.8) with increasing withdrawn-depressed symptoms. This was the only observed modulation of amygdala connectivity with regards to withdrawn-depressed symptomatology.

DISCUSSION

The goals of the present study were to examine how subclinical internalizing symptoms in typically-developing youth might relate to functional connectivity of the amygdala, and whether distinct patterns might be observed between males and females in light of known sex differences in the rate of internalizing problems (Eaton et al., 2012). While not a significant difference, females in our sample were rated by their parents as showing slightly more internalizing symptomatology overall than males, specifically more anxious-depressed and somatic symptoms. Significant sex differences in amygdala functional connectivity, as related to internalizing symptoms, were also observed. As a function of increasing overall internalizing symptoms and as compared to males, females displayed hyperconnectivity between the whole amygdala and several regions associated with emotional and sensory processing, salience detection, and action selection, including the posterior mid-cingulate cortex (pMCC), insula, and somatosensory cortices. As detailed below, although internalizing symptoms modulated amygdala connectivity similarly across its three subnuclei, some specific relationships were also

observed between different types of internalizing symptoms and functional connectivity of distinct amygdala subnuclei in males and females.

At the whole-group level (i.e., in both males and females), increased anxious-depressed symptomatology was associated with stronger connectivity between the basolateral amygdala (BLA) and the left thalamus. Some afferent thalamic relays of sensory information converge in the BLA (Amaral et al., 1992), and this sensory input, in conjunction with descending cortical information to the amygdala, allows for significant associative learning to occur within the BLA, especially fear-related associations (Benarroch, 2015). The BLA is often implicated in emotional learning through consolidation of fear memories and threat estimation in both rodents (Fanselow and Ledoux, 1999) and humans (Klumpers et al., 2015), with the BLA playing a key role in integrating and computing the valence of stimuli via emotional cues (Hortensius et al., 2016). The hyperconnectivity between the BLA and the thalamus observed in both male and female youths suggests that greater anxious-depressed symptoms may be related to an increased or biased orientation toward sensory and emotional information, perhaps leading to overestimation of threat – a key component of anxiety (Grupe and Nitschke, 2013). Interestingly, when age was included as a covariate in the model, the relationship between BLA-thalamic connectivity and anxious-depressed symptomatology was no longer significant. Prior longitudinal work demonstrated that connectivity between the BLA and thalamus increases with age (Gabard-Durnam et al., 2014), and future longitudinal investigations might help uncover the interaction between age and internalizing symptoms on this circuit. No other symptom-related modulation specific to the BLA was observed, which is surprising given that rsFC of the BLA has been shown to be altered in adults with generalized anxiety disorder (Etkin et al., 2009), related to state anxiety in healthy adults (Baur et al., 2013), and even predictive of trait anxiety severity in

healthy children (Qin et al., 2014). Nevertheless, our findings are consistent with the notion that hyperarousal to threat in response to sensory and emotional stimuli seen in anxiety disorders may be linked to altered thalamic-amygdala circuitry.

With increasing anxious-depressed symptoms, females, compared to males, also showed greater connectivity between the whole amygdala – as well as the centromedial amygdala (CMA) and superficial amygdala (SFA) – with the pMCC, the SMA, and the precentral gyri, similar to prior work examining adolescents with subclinical depression (Scheuer et al., 2017). Interestingly, the CMA, SFA, and BLA in adults all tend to show connectivity with the pMCC and surrounding motor regions (Kerestes et al., 2017). Our results similarly demonstrate connectivity between the pMCC and all examined amygdala subnuclei, suggesting that this amygdala-cingulate network develops prior to adulthood. The mid-cingulate cortex is associated with salience processing and allocation of attentional and motor resources toward behaviorally relevant stimuli (Vogt, 2005). Specifically, the pMCC monitors the environment for salient stimuli and, through connections with the cingulate motor area and regions such as the precentral gyri and SMA, can coordinate bodily responses in the early anticipation of pain (Vogt, 2005). Tract tracing studies in rhesus monkeys (Morecraft et al., 2007) and diffusion tensor imaging studies in humans (Grèzes et al., 2014) have demonstrated direct anatomical connections between the amygdala and motor circuitry within the cingulate. This circuit might underlie motor behaviors in socio-emotional contexts to promote either approach or avoidance behaviors. Indeed, these motor regions are also shown to be consistently activated during successful emotion regulation (Kohn et al., 2014). Thus, the observation of hyperconnectivity between the amygdala and the pMCC, as well as other early motor regions, with increasing anxious-depressed symptoms may reflect greater engagement of this limbic-motor circuit in youth

expressing higher symptomatology. Given that these regions are involved in emotion regulation, perhaps this network is especially primed and over-active in these children and adolescents who may regularly attempt to regulate their emotions and suppress feelings of anxiety, albeit perhaps unsuccessfully given their heightened symptomatology.

While internalizing symptoms modulated amygdala connectivity to a lesser degree in males than in females, males did show reduced functional connectivity between the SFA and subcallosal cortex as a function of increasing anxious-depressed symptomatology. This result was unexpected given that the subcallosal cortex tends to be hyperconnected to the amygdala in both male and female adolescents with clinical depression relative to controls (Connolly et al., 2013), and that positive coupling between the whole amygdala and the subcallosal cortex in neurotypical youth 8-29 years old tends to remain steady over time (Duijvenvoorde et al., 2019). Here the opposite pattern of connectivity was observed in that males endorsing fewer anxious-depressed symptoms showed stronger connectivity between the SFA and subcallosal cortex, whereas males with higher symptoms showed weaker connectivity. There are some potential explanations for these divergent findings. First, prior research demonstrating hyperconnectivity between the amygdala and the subcallosal cortex examined the whole amygdala, whereas our analyses identified hypoconnectivity only with the SFA (Connolly et al., 2013). The seemingly contradictory findings may thus reflect a finer level of analysis and/or degree of specificity within amygdalar subnuclei. Second, our sample consisted of typically-developing males expressing subclinical symptomatology; accordingly, this pattern of weaker SFA-subcallosal connectivity could reflect a compensatory or protective mechanism. Indeed, hyperactivity in the subcallosal cortex in depression is thought to index ruminative and self-referential processing (Nejad et al., 2013) and this hyperactivity has been shown to diminish after treatment in adults

with depression (Hamani et al., 2011). Thus, despite the endorsement of some anxious-depressed symptoms, the hypoconnectivity between SFA and subcallosal cortex observed in our sample of neurotypical youth could actually help down-regulate activity in this region and guard against the onset of more severe symptoms. Of note, we also found that, when controlling for age, the relationship between SFA-subcallosal connectivity and anxious-depressed symptomatology was no longer significant, suggesting that age may account for a portion of the variance relating anxious-depressed symptoms to amygdala connectivity. Indeed, a moderation analysis revealed that weaker SFA-subcallosal connectivity as a function of anxious-depressed symptomology was more pronounced in younger, relative to older, males. A longitudinal follow-up would be required to determine whether connectivity within this SFA-subcallosal cortex circuit may confer resilience versus risk for the emergence of clinically meaningful symptomatology.

Finally, females also displayed hyperconnectivity of the whole amygdala – as well as the CMA and SFA – in relation to somatic complaints, compared to males. More specifically, females showed stronger CMA connectivity with somatosensory cortices with greater somatic complaints. The CMA is involved in salience detection and is well connected with sensorimotor regions (LeDoux, 2007, 2000; Roy et al., 2009). The observed hyperconnectivity between the CMA and somatosensory cortices might reflect greater allocation of attentional resources to the processing of somatosensory information/interoceptive stimuli in female youth with heightened somatic complaints. Similarly, females also showed stronger connectivity between the SFA and the right STG, left central operculum, posterior insula, and pMCC as a function of increased somatic complaints; as compared to males, females also displayed connectivity between the SFA and the left anterior STG and SMA. Of note, the increased SFA-insula connectivity was strongest with the posterior insula whose resting-state network is prominently associated with

sensorimotor integration (Cauda et al., 2011). In this network, the posterior insula demonstrates connectivity with the amygdala as well as SMA and right STG (Cauda et al., 2011), which is considered a part of the "social brain" (Blakemore, 2008). This heightened SFA connectivity observed in females who express more somatic complaints is likely related to atypical sensorimotor and socio-emotional processing; however, future studies using a longitudinal design are needed to determine whether this hyperconnectivity reflects a compensatory mechanism or increased risk for worsening symptoms over time.

To our knowledge, this study offers the first look into sex differences in amygdala functional connectivity profiles in relation to subclinical internalizing symptoms in typically-developing children and adolescents. However, there are important limitations and future directions to consider. Though we were able to investigate the impact of subclinical symptomatology on functional connectivity of the amygdala, the cross-sectional nature of this study prevents a full characterization of the likely bi-directional nature of the relationship between the emergence of internalizing symptoms and developmental changes in functional connectivity. While we found that the majority of our findings did not change when age was included as a covariate in our models, age effects were most prominent in analyses using the anxious-depressed subscale; this suggests that the relationship between amygdala connectivity and this class of symptoms might be the most impacted by age. Longitudinal studies investigating the relationship between amygdala connectivity, age, and anxious-depressed symptomatology are crucial to further understanding this circuitry in developmental samples. Future research might also utilize a larger sample size with different age-cohorts to more fully address developmental issues, such as examining developmental changes in amygdala connectivity in relation to amygdala volume. Furthermore, since our sample consisted of

typically-developing youth, the observed range of internalizing symptoms was limited. While this is expected in a sample of children and adolescents without a clinical diagnosis of any internalizing disorder, it does limit our ability to examine how functional connectivity might vary as a function of a broader range of internalizing symptoms. Future investigations incorporating more clinically enriched samples with a wider range of symptom severity are needed to better understand the relationship between subclinical internalizing symptoms and amygdala connectivity. Nevertheless, our findings highlight the importance of considering individual variability within samples of putatively neurotypical youth, especially in the context of comparisons with a clinical sample. Future studies involving developmental samples may also want to consider the moderating effect of factors such as socioeconomic status and presence of other comorbidities.

In conclusion, this work highlights the shared and distinct functions of the amygdala and its subnuclei as hubs of neural integration of salience, action, emotion, and sensory processing. Compared to males, females displayed greater internalizing symptoms and greater modulation of amygdala circuits in relation to these symptoms. In accordance with taking a dimensional approach toward psychiatric disorders, this work demonstrates that the effects of subclinical symptomatology on neural circuitry can be readily detected in neurotypical populations. This lays the groundwork for future research investigating whether these network atypicalities could be predictive of worsening symptoms and/or of a future clinical diagnosis. These early alterations in amygdala functional connectivity may reflect risk for the onset of an internalizing disorder in the future but they could also reflect neuroplasticity that could promote resilience. Longitudinal investigations with large samples, such as the Adolescent Brain Cognitive Development Study (ABCD Study; http://abcdstudy.org), will help further elucidate the complex

nature of these brain-behavior relationships and ultimately inform early screening, diagnosis, and interventions for psychiatric disorders that emerge during adolescence.

Table 2.1 Subject demographics

	Females (n = 57)	Males (n = 53)	*p*-value
Age	13.1 (2.9)	13.7 (2.5)	0.22
Mean Relative Motion (mm)	0.14 (0.12)	0.11 (0.08)	0.21
Framewise Displacement (mm)	0.23 (0.20)	0.19 (0.13)	0.20
Percentage ICA Components	49.3% (11.5)	51.2% (10.9)	0.38
Pubertal Development Status	12.6 (4.2)	11.2 (3.8)	0.08
Self-Reported Race/Ethnicity			
Asian	4	5	-
Black/African American	4	1	-
More than one race	7	6	-
White	42	41	-
Internalizing Scale	4.10 (4.22)	2.73 (3.80)	0.07
Anxious-Depressed Subscale	2.03 (2.38)	1.35 (1.94)	0.10
Somatic Complaints Subscale	1.10 (1.65)	0.60 (1.47)	0.10
Withdrawn-Depressed Subscale	0.96 (1.25)	0.77 (1.46)	0.46

Table 2.2 Peak coordinates of brain regions where amygdala connectivity varied as a function of internalizing symptoms (Int)

Internalizing Modulation – Whole Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Male and Female Int +	Posterior Mid-Cingulate Cortex	-2	-4	40	4.65
Female Int +	Posterior Mid-Cingulate Cortex	2	-10	48	4.99
Female > Male Int +	Supplementary Motor Area	8	-12	70	5.06

Internalizing Modulation – Centromedial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female Int +	Posterior Mid-Cingulate Cortex	2	-10	54	4.38
	Left Somatosensory Cortex	-38	-22	34	4.42
Female > Male Int +	Supplementary Motor Area	10	-6	50	4.77

Internalizing Modulation – Superficial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female Int +	Precentral Gyrus	0	-16	64	4.78
Female > Male Int +	Posterior Mid-Cingulate Cortex	8	-6	44	4.81

Table 2.3 Peak coordinates of brain regions where amygdala connectivity varied as a function of internalizing symptoms (Int) when controlling for age

Internalizing Modulation – Whole Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Male and Female Int +	Posterior Mid-Cingulate Cortex	-2	-4	40	4.65
Female Int +	Posterior Mid-Cingulate Cortex	2	-10	48	4.99
Female > Male Int +	Supplementary Motor Area	8	-12	70	5.06

Internalizing Modulation – Centromedial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female Int +	Posterior Mid-Cingulate Cortex	2	-10	54	4.38
	Left Somatosensory Cortex	-38	-22	34	4.42
Female > Male Int +	Supplementary Motor Area	10	-6	50	4.77

Internalizing Modulation – Superficial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female Int +	Precentral Gyrus	0	-16	64	4.78
Female > Male Int +	Posterior Mid-Cingulate Cortex	8	-6	44	4.81

Table 2.4 Peak coordinates of brain regions where amygdala connectivity varied as a function of anxious-depressed symptoms (AD)

Anxious-Depressed Modulation – Whole Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female AD +	Precentral Gyrus	2	-16	48	4.37
Female > Male AD +	Posterior Mid-Cingulate Cortex	6	-8	44	4.56

Anxious-Depressed Modulation – Basolateral Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Male and Female AD +	Left Thalamus	-2	-26	2	3.97

Anxious-Depressed Modulation – Centromedial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female AD +	Precentral Gyrus	-2	-16	56	4.1
Female > Male AD +	Posterior Mid-Cingulate Cortex	8	-8	44	4.33

Anxious-Depressed Modulation – Superficial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female AD +	Supplementary Motor Area	2	-16	64	4.42
Male AD -	Subcallosal Cortex	2	24	-18	3.67
Female > Male AD +	Posterior Mid-Cingulate Cortex	8	-6	44	4.28

Table 2.5 Peak coordinates of brain regions where amygdala connectivity varied as a function of anxious-depressed symptoms (AD) when controlling for age

Anxious-Depressed Modulation – Whole Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female AD +	Precentral Gyrus	2	-16	48	4.45
Female > Male AD +	Posterior Mid-Cingulate Cortex	6	-8	44	4.79

Anxious-Depressed Modulation – Centromedial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female AD +	Precentral Gyrus	-2	-16	64	4.35
Female > Male AD +	Posterior Mid-Cingulate Cortex	8	-6	44	4.25

Table 2.6 Peak coordinates of brain regions where amygdala connectivity varied as a function of somatic complaints (Somatic)

Somatic Modulation – Whole Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female Somatic +	Posterior Mid-Cingulate Cortex	-8	-6	42	4.09

Somatic Modulation – Centromedial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female Somatic +	Left Somatosensory Cortex	-40	-24	34	4.36
	Right Somatosensory Cortex	58	0	26	3.93
Female > Male Somatic +	Left Precentral Gyrus	-50	-6	26	4.57
	Right Precentral Gyrus	58	0	28	4.50

Somatic Modulation – Superficial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female Somatic +	Posterior Mid-Cingulate Cortex	-6	-2	42	4.71
	Right Anterior Superior Temporal Gyrus	60	0	-4	4.17
	Left Central Operculum	-46	-2	14	4.18
Female > Male Somatic +	Precentral Gyrus	-10	-14	66	4.68
	Left Anterior Superior Temporal Gyrus	-42	-2	-18	4.05

Table 2.7 Peak coordinates of brain regions where amygdala connectivity varied as a function of somatic symptoms (Somatic) when controlling for age

Somatic Modulation – Whole Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female Somatic +	Posterior Mid-Cingulate Cortex	-8	-6	42	4.12

Somatic Modulation – Centromedial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female Somatic +	Left Somatosensory Cortex	-40	-22	32	4.34
	Right Somatosensory Cortex	58	0	28	3.98
Female > Male Somatic +	Right Somatosensory Cortex	58	0	28	4.85
	Left Somatosensory Cortex	-50	-6	-4	3.88

Somatic Modulation – Superficial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female Somatic +	Posterior Mid-Cingulate Cortex	-6	-4	42	4.85
	Right Superior Temporal Gyrus	58	-2	-2	4.19
	Left Central Operculum Cortex	-44	-4	14	4.06
Female > Male Somatic +	Posterior Mid-Cingulate Cortex	-10	-14	66	4.53
	Left Superior Temporal Gyrus	-54	-6	-4	3.88

Table 2.8 Peak coordinates of brain regions where amygdala connectivity varied as a function of withdrawn-depressed symptoms (WD)

Withdrawn-Depressed Modulation – Whole Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female WD +	Posterior Mid-Cingulate Cortex	2	-10	48	4.48

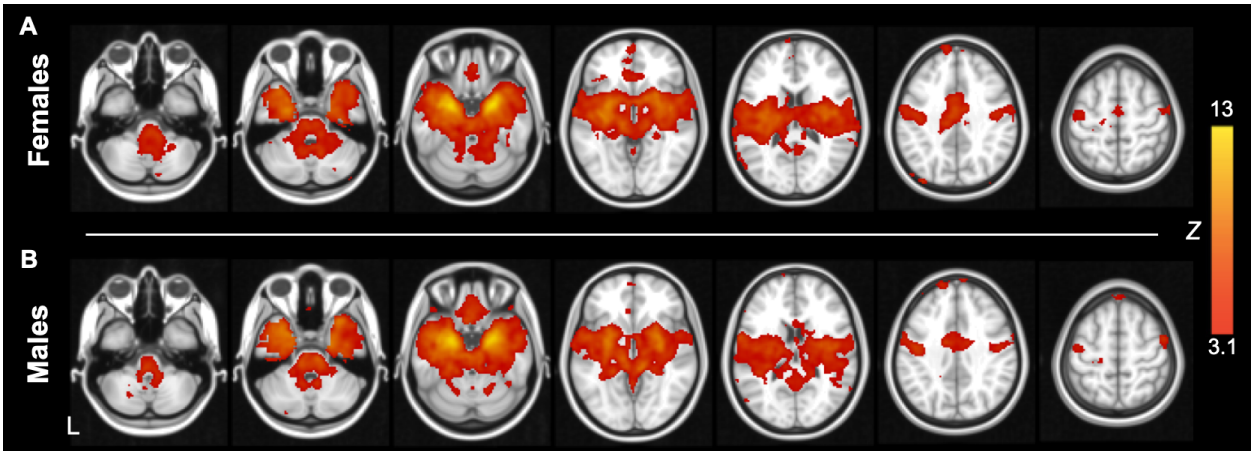
Withdrawn-Depressed Modulation – Superficial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female WD +	Precentral Gyrus	-6	-16	66	4.5

Table 2.9 Peak coordinates of brain regions where amygdala connectivity varied as a function of withdrawn-depressed symptoms (WD) when controlling for age

Withdrawn-Depressed Modulation – Whole Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female WD +	Posterior Mid-Cingulate Cortex	2	-10	46	4.43

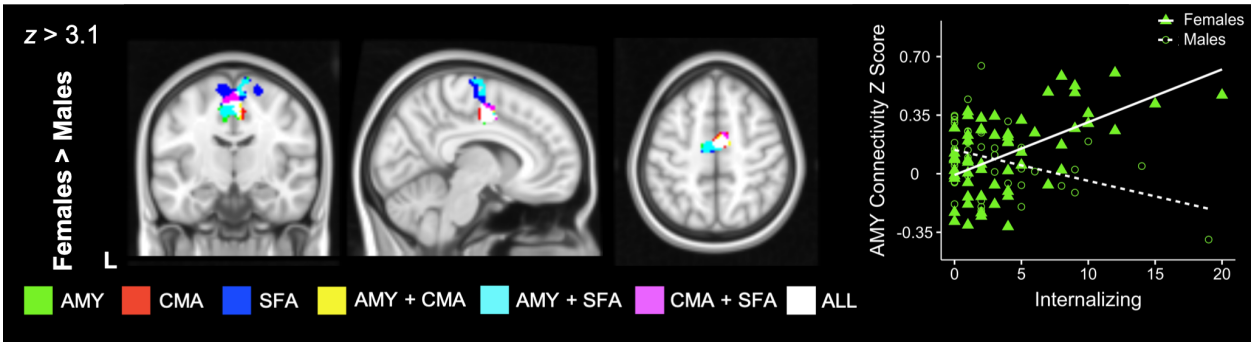
Withdrawn-Depressed Modulation – Superficial Amygdala		MNI Peak (mm)			Z-Max
		x	y	z	
Female WD +	Right Precentral Gyrus	-6	-16	66	4.42

Figure 2.1 Whole-brain positive rsFC with the Amygdala in Females and Males



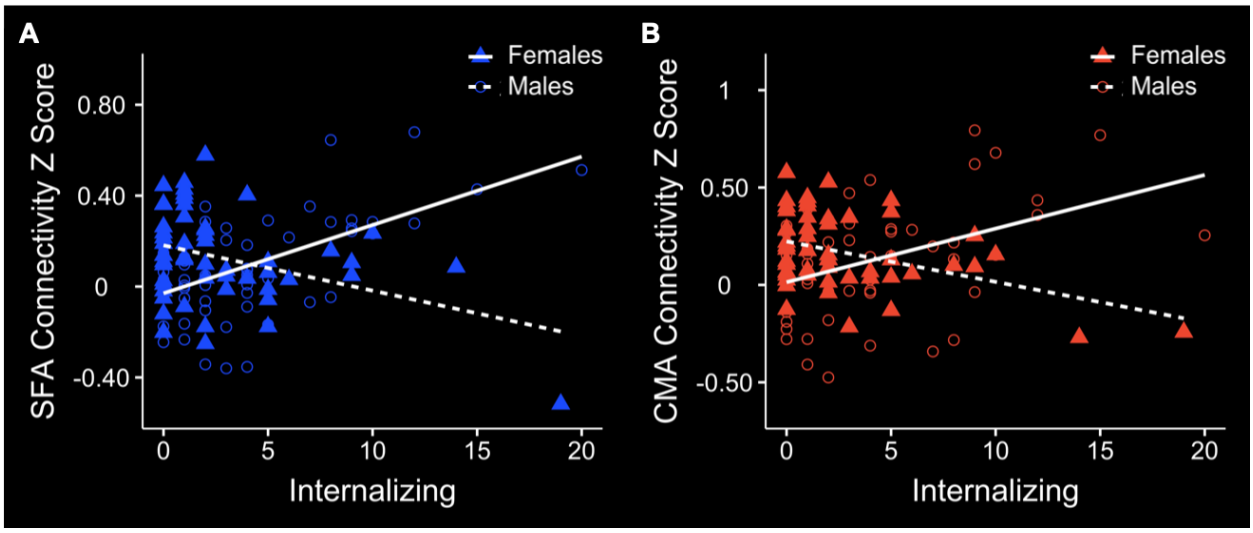
Brain regions demonstrating connectivity with the whole, bilateral amygdala in females (A) and males (B).

Figure 2.2 Amygdala rsFC and overall internalizing symptoms



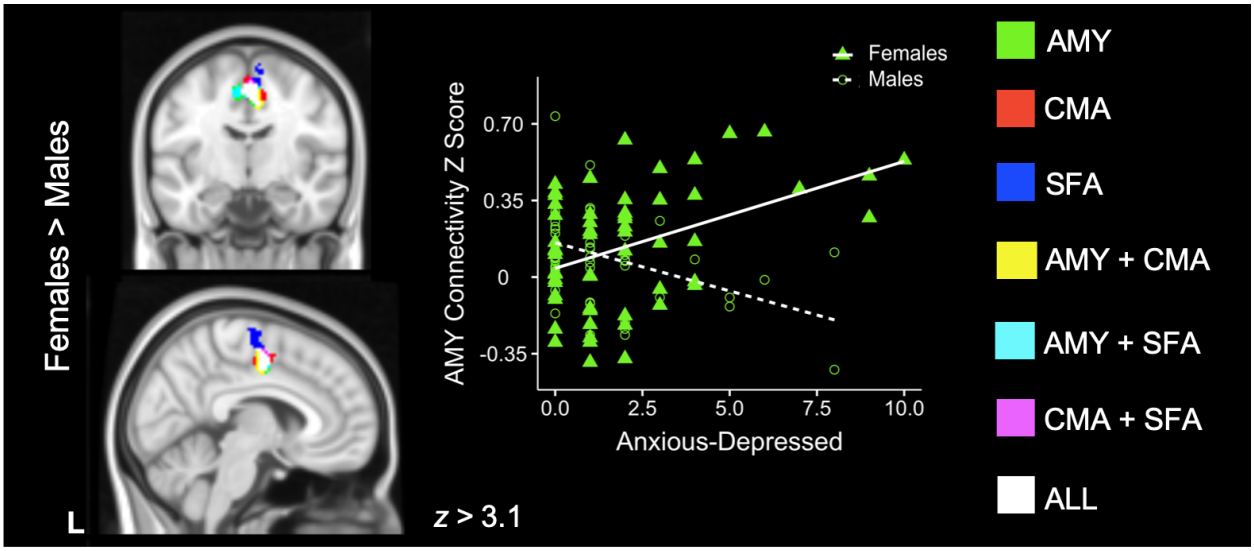
Brain regions displaying connectivity modulated by internalizing symptoms with the whole amygdala (green); the centromedial amygdala (CMA, red); the superficial amygdala (SFA, blue); both the whole amygdala and CMA (yellow); both the whole amygdala and SFA (cyan); both the CMA and SFA (pink); or the whole amygdala, CMA, and SFA (white). Scatterplots are included for illustrative purposes. Females displayed greater connectivity than males as a function of higher internalizing symptoms; scatterplot shows whole amygdala connectivity as related to internalizing symptoms in females (green triangles) and males (open green circles).

Figure 2.3 rsFC in relation to internalizing symptoms in SFA and CMA



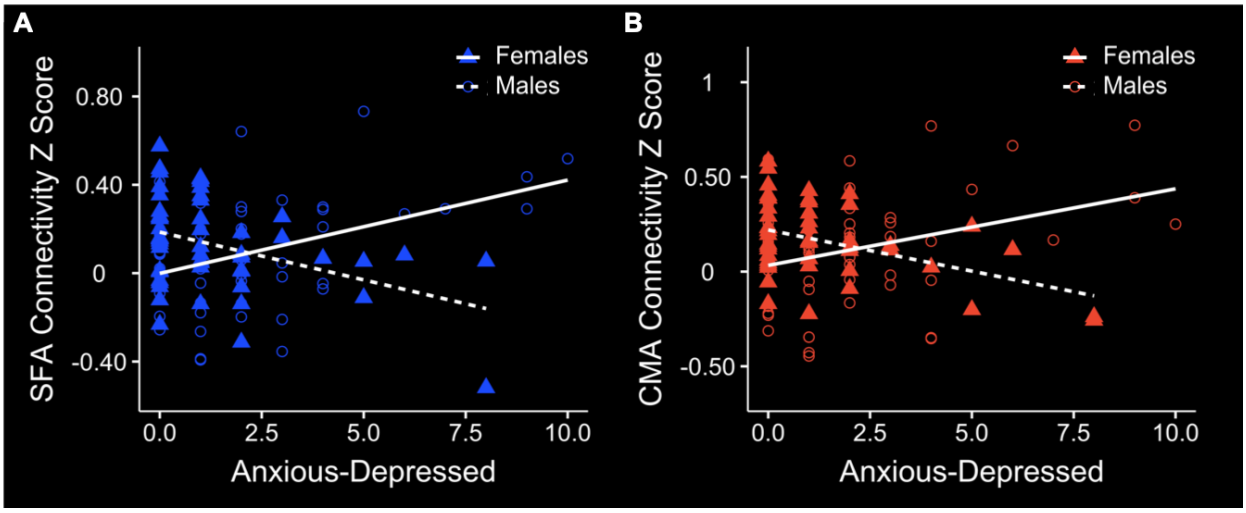
Scatterplots are included to illustrate the relationship between internalizing symptoms and positive SFA as well as CMA connectivity. As compared with males, females show greater SFA connectivity (A) and CMA connectivity (B) with increasing internalizing symptoms.

Figure 2.4 Amygdala rsFC and anxious-depressed symptoms



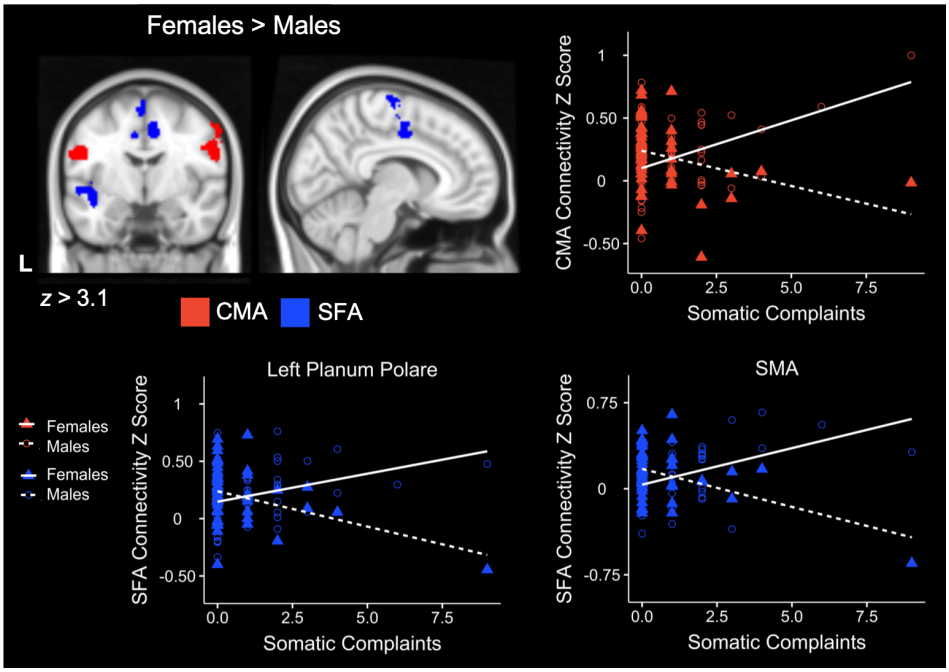
Brain regions displaying connectivity modulated by anxious-depressed symptoms with the whole amygdala (green); centromedial amygdala (CMA, red); superficial amygdala (SFA, blue); both the whole amygdala and CMA (yellow); both the whole amygdala and SFA (cyan); both the CMA and SFA (pink); and the whole amygdala, CMA, and SFA (white). Scatterplots are included for illustrative purposes. Females displayed greater connectivity than males as a function of higher anxious-depressed symptoms; scatterplot shows that higher anxious-depressed symptoms were associated with greater whole amygdala connectivity in females (green triangles) as compared to males (open green circles).

Figure 2.5 rsFC in relation to anxious-depressed symptoms in SFA and CMA



Scatterplots are included to illustrate the relationship between anxious-depressed symptoms and positive SFA as well as CMA connectivity. As compared to males, females showed greater SFA connectivity (A) and CMA connectivity (B) with increasing anxious-depressed symptoms.

Figure 2.6 Amygdala rsFC and somatic complaints



Brain regions displaying connectivity modulated by somatic complaints with the centromedial amygdala (CMA, red) and the superficial amygdala (SFA, blue). Scatterplots are included for illustrative purposes. Females displayed greater connectivity than males as a function of higher somatic complaints; scatterplots show that CMA connectivity (red) and SFA connectivity (blue) was stronger as a function of greater somatic complaints in females (triangles) as compared to males (open circles).

Appendix 2.1. CBCL Instructions and Questions

CBCL Instructions:

Below is a list of items that describe children and youths. For each item that describes your child ***now or within the past 6 months***, please circles the ***2*** if the item is ***very true or often true*** of your child. Circle the ***1*** if the item is ***somewhat or sometimes true*** of your child. If the item is ***not true*** of your child, circle the ***0***. Please answer all the items as well as you can, even if some do not seem to apply to your child.

0 = Not True (as far as you know)
1 = Somewhat or Sometimes True
2 = Very True or Often True

CBCL Questions – separated by subscale:

Anxiety-Depression:
14. Cries a lot
29. Fears certain animals, situations, or places, other than school (describe): ___
30. Fears going to school
31. Fears he/she might think or do something bad
32. Feels he/she has to be perfect
33. Feels or complains that no one loves him/her
35. Feels worthless or inferior
45. Nervous, high strung, or tense
50. Too fearful or anxious
52. Feels too guilty
71. Self-conscious or easily embarrassed
91. Talks about killing self
112. Worries

Somatic Complaints:
47. Nightmares
49. Constipated, doesn't move bowels
51. Feels dizzy or lightheaded
54. Overtired without good reason
56. Physical problems ***without known medical causes:***
    a. Aches or pains (***not*** stomach or headaches)
    b. Headaches
    c. Nausea, feels sick
    d. Problems with eyes (***not*** if corrected by glasses): describe __
    e. Rashes or other skin problems
    f. Stomachaches
    g. Vomiting, throwing up
    h. Other (describe): __

Withdrawn-Depressed
5. There is very little he/she enjoys
42. Would rather be alone than with others
65. Refuses to talk
69. Secretive, keeps things to self
75. Too shy or timid
102. Underactive, slow moving, or lacks energy
103. Unhappy, sad, or depressed
111. Withdrawn, doesn't get involved with others

REFERENCES

Achenbach, TM., 1991. Manual for the Child Behavior Checklist 4–18 and 1991 Profile, University of Vermont Department of Psychiatry, Burlington.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders. (5th ed.). Arlington, VA: American Psychiatric Publishing.

Amaral, D.G., Price, J.L., Pitkanen, A., Carmichael S.T., 1992. Anatomical organization of the primate amygdaloid complex. The Amygdala: Neurobiological Aspects of Emotion, 1-66.

Alarcón, G., Cservenka, A., Rudolph, M.D., Fair, D.A., Nagel, B.J., 2015. Developmental sex differences in resting state functional connectivity of amygdala sub-regions. Neuroimage 115, 235–244. https://doi.org/10.1016/j.neuroimage.2015.04.013

Amunts, K., Kedo, O., Kindler, M., Pieperhoff, P., Mohlberg, H., Shah, N.J., Habel, U., Schneider, F., Zilles, K., 2005. Cytoarchitectonic mapping of the human amygdala, hippocampal region and entorhinal cortex: intersubject variability and probability maps. Anat. Embryol. (Berl). 210, 343–352. https://doi.org/10.1007/s00429-005-0025-5

Angold, A., Erkanli, A., Silberg, J., Eaves, L., Costello, E.J., 2002. Depression scale scores in 8-17-year-olds: effects of age and gender. J. Child Psychol. Psychiatry 43, 1052–1063. https://doi.org/10.1111/1469-7610.00232

Baur, V., Hänggi, J., Langer, N., Jäncke, L., 2013. Resting-State Functional and Structural Connectivity Within an Insula-Amygdala Route Specifically Index State and Trait Anxiety. BPS 73, 85–92. https://doi.org/10.1016/j.biopsych.2012.06.003

Beesdo, K., Lau, J.Y.F., Guyer, A.E., McClure-Tone, E.B., Monk, C.S., Nelson, E.E., Fromm, S.J., Goldwin, M.A., Wittchen, H.-U., Leibenluft, E., Ernst, M., Pine, D.S., 2009. Common and Distinct Amygdala-Function Perturbations in Depressed vs Anxious Adolescents. Arch.

Gen. Psychiatry 66, 275. https://doi.org/10.1001/archgenpsychiatry.2008.545

Benarroch, E.E., 2015. The amygdala: Functional organization and involvement in neurologic disorders. Neurology 84, 313–324. https://doi.org/10.1212/WNL.0000000000001171

Bickart, K.C., Hollenbeck, M.C., Barrett, L.F., Dickerson, B.C., 2012. Intrinsic amygdala-cortical functional connectivity predicts social network size in humans. J. Neurosci. 32, 14729–41. https://doi.org/10.1523/JNEUROSCI.1599-12.2012

Bijsterbosch, J.D., Ansari, T.L., Smith, S., Gauld, O., Zika, O., Boessenkool, S., Browning, M., Reinecke, A., Bishop, S.J., 2018. Stratification of MDD and GAD patients by resting state brain connectivity predicts cognitive bias. https://doi.org/10.1016/j.nicl.2018.04.033

Blackford, J.U., Pine, D.S., 2012. Neural substrates of childhood anxiety disorders: a review of neuroimaging findings. Child Adolesc. Psychiatr. Clin. N. Am. 21, 501–25. https://doi.org/10.1016/j.chc.2012.05.002

Blakemore, S.-J., 2008. The social brain in adolescence. Nat. Rev. Neurosci. 9, 267–277. https://doi.org/10.1038/nrn2353

Blakemore, S.-J., Mills, K.L., 2014. Is Adolescence a Sensitive Period for Sociocultural Processing? Annu. Rev. Psychol. 65, 187–207. https://doi.org/10.1146/annurev-psych-010213-115202

Burghy, C.A., Stodola, D.E., Ruttle, P.L., Molloy, E.K., Armstrong, J.M., Oler, J.A., Fox, M.E., Hayes, A.S., Kalin, N.H., Essex, M.J., Davidson, R.J., Birn, R.M., 2012. Developmental pathways to amygdala-prefrontal function and internalizing symptoms in adolescence. Nat. Neurosci. 15, 1736–1741. https://doi.org/10.1038/nn.3257

Bzdok, D., Laird, A.R., Zilles, K., Fox, P.T., Eickhoff, S.B., 2013. An investigation of the structural, connectional, and functional subspecialization in the human amygdala. Hum.

Brain Mapp. 34, 3247–3266. https://doi.org/10.1002/hbm.22138

Casey, B.J., 2015. Beyond Simple Models of Self-Control to Circuit-Based Accounts of Adolescent Behavior. Annu. Rev. Psychol 66, 295–319. https://doi.org/10.1146/annurev-psych-010814-015156

Casey, B.J., Heller, A.S., Gee, D.G., Cohen, A.O., 2019. Development of the emotional brain. Neurosci. Lett. 693, 29–34. https://doi.org/10.1016/J.NEULET.2017.11.055

Cauda, F., D'Agata, F., Sacco, K., Duca, S., Geminiani, G., Vercelli, A., 2011. Functional connectivity of the insula in the resting brain. Neuroimage 55, 8–23. https://doi.org/10.1016/J.NEUROIMAGE.2010.11.049

Center for Collegiate Mental Health, 2015. Annual Report.

Connolly, C.G., Wu, J., Ho, T.C., Hoeft, F., Wolkowitz, O., Eisendrath, S., Frank, G., Hendren, R., Max, J.E., Paulus, M.P., Tapert, S.F., Banerjee, D., Simmons, A.N., Yang, T.T., 2013. Resting-State Functional Connectivity of Subgenual Anterior Cingulate Cortex in Depressed Adolescents. Biol. Psychiatry 74, 898–907. https://doi.org/10.1016/J.BIOPSYCH.2013.05.036

Constantino, J.N., Gruber, C., 2012. Social Responsiveness Scale-Second Edition (SRS-2). Western Psychological Services, Torrance, CA.

Costello, E.J., Angold, A.C., 2000. Developmental Epidemiology, in: Sameroff, A.J., Lewis, M., Miller, S.M. (Eds.), Handbook of Developmental Psychopathology. Springer, Boston, MA.

Cox, R.W., 1996. AFNI: Software for Analysis and Visualization of Functional Magnetic Resonance Neuroimages. Comput. Biomed. Res. 29, 162–173.

Crick, N.R., Zahn-Waxler, C., 2003. The development of psychopathology in females and males: Current progress and future challenges. Dev. Psychopathol. 15, 719–742.

https://doi.org/10.1017.S095457940300035X

Crone, E.A., Dahl, R.E., 2012. Understanding adolescence as a period of social–affective engagement and goal flexibility. Nat. Publ. Gr. 13. https://doi.org/10.1038/nrn3313

Cummings, C.M., Caporino, N.E., Kendall, P.C., 2014. Comorbidity of Anxiety and Depression in Children and Adolescents: 20 Years After NIH Public Access. Psychol Bull 140, 816–845. https://doi.org/10.1037/a0034733

Dolan, R.K., Vuilleumier, P., 2006. Amygdala Automaticity in Emotional Processing. Ann. N. Y. Acad. Sci. 985, 348–355. https://doi.org/10.1111/j.1749-6632.2003.tb07093.x

Drysdale, A.T., Grosenick, L., Downar, J., Dunlop, K., Mansouri, F., Meng, Y., Fetcho, R.N., Zebley, B., Oathes, D.J., Etkin, A., Schatzberg, A.F., Sudheimer, K., Keller, J., Mayberg, H.S., Gunning, F.M., Alexopoulos, G.S., Fox, M.D., Pascual-Leone, A., Voss, H.U., Casey, B., Dubin, M.J., Liston, C., 2017. Resting-state connectivity biomarkers define neurophysiological subtypes of depression. Nat. Med. 23, 28–38. https://doi.org/10.1038/nm.4246

Duijvenvoorde, A.C.K., Westhoff, B., Vos, F., Wierenga, L.M., Crone, E.A., 2019. A three-wave longitudinal study of subcortical–cortical resting-state connectivity in adolescence: Testing age- and puberty-related changes. Hum. Brain Mapp. 40, hbm.24630. https://doi.org/10.1002/hbm.24630

Eaton, N.R., Keyes, K.M., Krueger, R.F., Balsis, S., Skodol, A.E., Markon, K.E., Grant, B.F., Hasin, D.S., 2012. An invariant dimensional liability model of gender differences in mental disorder prevalence: evidence from a national sample. J. Abnorm. Psychol. 121, 282–8. https://doi.org/10.1037/a0024780

Engman, J., Linnman, C., Dijk, K.R.A. Van, Milad, M.R., 2016. Amygdala subnuclei resting-

state functional connectivity sex and estrogen differences. Psychoneuroendocrinology 63, 34–42. https://doi.org/10.1016/j.psyneuen.2015.09.012

Etkin, A., Prater, K.E., Schatzberg, A.F., Menon, V., Greicius, M.D., 2009. Disrupted Amygdalar Subregion Functional Connectivity and Evidence of a Compensatory Network in Generalized Anxiety Disorder. Arch. Gen. Psychiatry 66, 1361. https://doi.org/10.1001/archgenpsychiatry.2009.104

Fanselow, M.S., Ledoux, J.E., 1999. Why We Think Plasticity Underlying Viewpoint Pavlovian Fear Conditioning Occurs in the Basolateral Amygdala in the ABL is temporarily disrupted only during learning. Each of these conditions has been satisfied. Destruction of the ABL before Training Prevents Learning Lesions of the amygdala produce a pronounced and, Neuron. Fanselow.

Gabard-Durnam, L.J., Flannery, J., Goff, B., Gee, D.G., Humphreys, K.L., Telzer, E., Hare, T., Tottenham, N., 2014. The development of human amygdala functional connectivity at rest from 4 to 23 years: A cross-sectional study. Neuroimage 95, 193–207. https://doi.org/10.1016/J.NEUROIMAGE.2014.03.038

Garber, J., Weersing, V.R., 2010. Comorbidity of Anxiety and Depression in Youth: Implications for Treatment and Prevention. Clin. Psychol. Sci. Pract. 17, 293–306. https://doi.org/10.1111/j.1468-2850.2010.01221.x

Grèzes, J., Valabrègue, R., Gholipour, B., Chevallier, C., 2014. A direct amygdala-motor pathway for emotional displays to influence action: A diffusion tensor imaging study. Hum. Brain Mapp. 35, 5974–5983. https://doi.org/10.1002/hbm.22598

Grupe, D.W., Nitschke, J.B., 2013. Uncertainty and anticipation in anxiety: an integrated neurobiological and psychological perspective. Nat. Rev. Neurosci. 14, 488–501.

https://doi.org/10.1038/nrn3524

Guyer, A.E., Silk, J.S., Nelson, E.E., 2016. The neurobiology of the emotional adolescent: From the inside out. Neurosci. Biobehav. Rev. 70, 74–85. https://doi.org/10.1016/j.neubiorev.2016.07.037

Hamani, C., Mayberg, H., Stone, S., Laxton, A., Haber, S., Lozano, A.M., 2011. The Subcallosal Cingulate Gyrus in the Context of Major Depression. Biol. Psychiatry 69, 301–308. https://doi.org/10.1016/J.BIOPSYCH.2010.09.034

Hankin, B.L., Abramson, L.Y., Moffitt, T.E., Silva, P.A., Mcgee, R., Angell, K.E., 1998. Development of Depression From Preadolescence to \bung Adulthood: Emerging Gender Differences in a 10-Year Longitudinal Study, Journal of Abnormal Psycholoe.

Hortensius, R., Terburg, D., Morgan, B., Stein, D.J., van Honk, J., de Gelder, B., 2016. The role of the basolateral amygdala in the perception of faces in natural contexts. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 371. https://doi.org/10.1098/rstb.2015.0376

Jalbrzikowski, M., Larsen, B., Hallquist, M.N., Foran, W., Calabro, F., Luna, B., 2017. Development of White Matter Microstructure and Intrinsic Functional Connectivity Between the Amygdala and Ventromedial Prefrontal Cortex: Associations With Anxiety and Depression. Biol. Psychiatry 82, 511–521. https://doi.org/10.1016/J.BIOPSYCH.2017.01.008

Jenkinson, M., Bannister, P., Brady, M., Smith, S., 2002. Improved Optimization for the Robust and Accurate Linear Registration and Motion Correction of Brain Images. Neuroimage 17, 825–841. https://doi.org/10.1006/NIMG.2002.1132

Kerestes, R., Chase, H.W., Phillips, M.L., Ladouceur, C.D., Eickhoff, S.B., 2017. Multimodal evaluation of the amygdala's functional connectivity. Neuroimage 148, 219–229.

https://doi.org/10.1016/j.neuroimage.2016.12.023

Kessler, D., Angstadt, M., Sripada, C.S., 2017. Reevaluating "cluster failure" in fMRI using nonparametric control of the false discovery rate. Proc. Natl. Acad. Sci. U. S. A. 114, E3372–E3373. https://doi.org/10.1073/pnas.1614502114

Klumpers, F., Morgan, B., Terburg, D., Stein, D.J., van Honk, J., 2015. Impaired acquisition of classically conditioned fear-potentiated startle reflexes in humans with focal bilateral basolateral amygdala damage. Soc. Cogn. Affect. Neurosci. 10, 1161–1168. https://doi.org/10.1093/scan/nsu164

Koelsch, S., Skouras, S., Fritz, T., Herrera, P., Bonhage, C., Küssner, M.B., Jacobs, A.M., 2013. The roles of superficial amygdala and auditory cortex in music-evoked fear and joy. https://doi.org/10.1016/j.neuroimage.2013.05.008

Kohn, N., Eickhoff, S.B., Scheller, M., Laird, A.R., Fox, P.T., Habel, U., 2014. Neural network of cognitive emotion regulation — An ALE meta-analysis and MACM analysis. Neuroimage 87, 345–355. https://doi.org/10.1016/J.NEUROIMAGE.2013.11.001

LeDoux, J.E., 2007. The amygdala. Curr. Biol. 17.

LeDoux, J.E., 2000. Emotion Circuits in the Brain. Annu. Rev. Neurosci. 23, 155–184. https://doi.org/10.1146/annurev.neuro.23.1.155

Lewinsohn, P.M., Rohde, P., Seely, J.R., 1995. Adolescent psychopathology: III. The clinical consequences of comorbidity. J. Am. Acad. Child Adolesc. Psychiatry 34, 510–519.

Mareckova, K., Holsen, L.M., Admon, R., Makris, N., Seidman, L., Buka, S., Whitfield-Gabrieli, S., Goldstein, J.M., 2016. Brain activity and connectivity in response to negative affective stimuli: Impact of dysphoric mood and sex across diagnoses. Hum. Brain Mapp. 37, 3733–3744. https://doi.org/10.1002/hbm.23271

McLaughlin, K.A., Hatzenbuehler, M.L., Mennin, D.S., Nolen-Hoeksema, S., 2011. Emotion dysregulation and adolescent psychopathology: a prospective study. Behav. Res. Ther. 49, 544–54. https://doi.org/10.1016/j.brat.2011.06.003

McLaughlin, K.A., Nolen-Hoeksema, S., 2011. Rumination as a transdiagnostic factor in depression and anxiety. Behav. Res. Ther. 49, 186–93. https://doi.org/10.1016/j.brat.2010.12.006

Merikangas, K.R., He, J., Burstein, M., Swanson, S.A., Avenevoli, S., Cui, L., Benjet, C., Georgiades, K., Swendsen, J., 2010. Lifetime Prevalence of Mental Disorders in U.S. Adolescents: Results from the National Comorbidity Survey Replication–Adolescent Supplement (NCS-A). J. Am. Acad. Child Adolesc. Psychiatry 49, 980–989. https://doi.org/10.1016/J.JAAC.2010.05.017

Morecraft, R.J., McNeal, D.W., Stilwell-Morecraft, K.S., Gedney, M., Ge, J., Schroeder, C.M., van Hoesen, G.W., 2007. Amygdala interconnections with the cingulate motor cortex in the rhesus monkey. J. Comp. Neurol. 500, 134–165. https://doi.org/10.1002/cne.21165

Murphy, K., Fox, M.D., 2017. Towards a consensus regarding global signal regression for resting state functional connectivity MRI. Neuroimage 154, 169–173. https://doi.org/10.1016/j.neuroimage.2016.11.052

Nejad, A.B., Fossati, P., Lemogne, C., 2013. Self-Referential Processing, Rumination, and Cortical Midline Structures in Major Depression. Front. Hum. Neurosci. 7, 666. https://doi.org/10.3389/fnhum.2013.00666

Parkes, L., Fulcher, B., Yücel, M., Fornito, A., 2018. An evaluation of the efficacy, reliability, and sensitivity of motion correction strategies for resting-state functional MRI. Neuroimage 171, 415–436. https://doi.org/10.1016/J.NEUROIMAGE.2017.12.073

Pessoa, L., Adolphs, R., 2010. Emotion processing and the amygdala: from a “low road” to “many roads” of evaluating biological significance. Nat. Rev. Neurosci. 11, 773–782. https://doi.org/10.1038/nrn2920

Petersen, A.C., Crockett, L., Richards, M., Boxer, A., 1988. A Self-Report Measure of Pubertal Status: Reliability, Validity, and Initial Norms, Journal of Youth and Adolescence.

Pruim, R.H.R., Mennes, M., van Rooij, D., Llera, A., Buitelaar, J.K., Beckmann, C.F., 2015. ICA-AROMA: A robust ICA-based strategy for removing motion artifacts from fMRI data. Neuroimage 112, 267–277. https://doi.org/10.1016/J.NEUROIMAGE.2015.02.064

Qin, S., Young, C.B., Duan, X., Chen, T., Supekar, K., Menon, V., 2014. Amygdala subregional structure and intrinsic functional connectivity predicts individual differences in anxiety during early childhood. Biol. Psychiatry 75, 892–900. https://doi.org/10.1016/j.biopsych.2013.10.006

R Core Team, 2019. R: A language and environment for statistical computing.

Raichle, M.E., 2010. Two views of brain function. Trends Cogn. Sci. 14, 180–190. https://doi.org/10.1016/J.TICS.2010.01.008

Roy, A.K., Shehzad, Z., Margulies, D.S., Kelly, A.M.C., Uddin, L.Q., Gotimer, K., Biswal, B.B., Castellanos, F.X., Milham, M.P., 2009. Functional connectivity of the human amygdala using resting state fMRI. Neuroimage 45, 614–626. https://doi.org/10.1016/j.neuroimage.2008.11.030

Scheuer, H., Alarcón, G., Demeter, D. V, Earl, E., Fair, D.A., Nagel, B.J., 2017. Reduced fronto-amygdalar connectivity in adolescence is associated with increased depression symptoms over time. Psychiatry Res. Neuroimaging 266, 35–41. https://doi.org/10.1016/j.pscychresns.2017.05.012

Smith, S.M., Jenkinson, M., Woolrich, M.W., Beckmann, C.F., Behrens, T.E.J., Johansen-Berg, H., Bannister, P.R., De Luca, M., Drobnjak, I., Flitney, D.E., Niazy, R.K., Saunders, J., Vickers, J., Zhang, Y., De Stefano, N., Brady, J.M., Matthews, P.M., 2004. Advances in functional and structural MR image analysis and implementation as FSL. Neuroimage 23, S208–S219. https://doi.org/10.1016/J.NEUROIMAGE.2004.07.051

Van Dijk, K.R.A., Sabuncu, M.R., Buckner, R.L., 2012. The influence of head motion on intrinsic functional connectivity MRI. Neuroimage 59, 431–438. https://doi.org/10.1016/J.NEUROIMAGE.2011.07.044

Vogt, B.A., 2005. Posterior cingulate, precuneal and retrosplenial cortices: cytology and components of the neural network correlates of consciousness. Prog. Brain Res. 150, 205–217. https://doi.org/10.1016/S0079-6123(05)50015-3

CHAPTER 3

Neural Correlates of Emotional Reactivity and Regulation in Youth with and without Anxiety

Youth with anxiety disorders struggle with managing emotions relative to peers, but the neural basis of this difference has not been examined. Youth (M_{age}=13.6; range=8-17) with (n=37) and without (n=24) anxiety disorders completed a cognitive reappraisal task while undergoing fMRI. Emotional reactivity and regulation, functional activation, and beta-series connectivity were compared across groups. Groups did not differ on emotional reactivity or regulation. However, fronto-limbic activation after viewing aversive imagery with and without regulation, as well as affect ratings without regulation, were higher for anxious youth. Neither group demonstrated age-related changes in regulation, though anxious youth became less reactive with age. Stronger amygdala-vmPFC connectivity related to greater anxiety in control youth, but less anxiety in anxious youth. Anxious youth regulated when instructed, but regulation ability did not relate to age. Viewing aversive imagery related to heightened fronto-limbic activation even after reappraisal. Emotion dysregulation in youth anxiety disorders may stem from heightened emotionality and potent bottom-up neurobiological responses to aversive stimuli. Findings suggest the importance of treatments focused on both reducing initial emotional reactivity and bolstering regulatory capacity.

INTRODUCTION

Youth anxiety disorders are pervasive and impairing (Merikangas et al., 2010) and can persist through adulthood (Beesdo-Baum & Knappe, 2012). Affected youth exhibit impairments in managing emotional experiences adaptively (Suveg & Zeman, 2004) and may face particular difficulty when distress intensifies (Legerstee, Garnefski, Jellesma, Verhulst, & Utens, 2010). Evidence-based treatments such as cognitive behavioral therapy (CBT) teach youth to regulate distress via cognitive reappraisal of anxiogenic thoughts. Although this technique is effective (Peris et al., 2015), and CBT more generally is efficacious for treating childhood and adolescent anxiety disorders (Higa-McMillan, Francis, Rith-Najarian, & Chorpita, 2016), anxiety symptoms often persist following treatment (Ginsburg et al., 2018); further, traditional anxiety-focused CBT does not improve emotion-related impairments other than worry (Suveg, Sood, Comer, & Kendall, 2009). Treatments may be improved by better understanding the neurobiological mechanisms driving the effects of cognitive reappraisal in anxious youth.

Neural correlates of cognitive reappraisal are commonly studied using emotion regulation paradigms in which participants view negative emotional stimuli and are instructed to either reduce their evoked negative affect or simply experience it. These paradigms isolate emotional reactivity, or the intensity of an emotional response, from emotion regulation, or the capacity to modify the intensity of an emotional response. Distinguishing between these constructs can elucidate whether emotion dysregulation in anxious youth stems from heightened reactivity, insufficient regulation of reactivity, or both (Lewis, Zinbarg, & Durbin, 2010). Emotional reactivity decreases with age across both anxious and non-anxious youth (Carthy, Horesh, Apter, Edge, & Gross, 2010), though others have found no age-related changes in control youth (McRae, Gross, et al., 2012; Silvers et al., 2012). In contrast, emotion regulation capacity

develops across age in control youth, demonstrating both linear and quadratic trajectories (McRae, Gross, et al., 2012; Silvers et al., 2016, 2012). While anxious youth regulate as successfully as non-anxious peers when cued to regulate (Carthy, Horesh, Apter, Edge, et al., 2010; Carthy, Horesh, Apter, & Gross, 2010), they do not increase their tendency to use adaptive emotion regulation with age (Schäfer et al., 2017). As such, low regulation use may become a stable characteristic by adulthood (Aldao, Nolen-Hoeksema, & Schweizer, 2010); however, the developmental trajectory of regulation ability has not been examined in anxious youth.

Development of affective control brain regions relates to improved emotion regulation abilities in typically developing youth (Ahmed, Bittencourt-Hewitt, & Sebastian, 2015). Cognitive reappraisal studies find age-related decreases in amygdala activation during down-regulation of affect (see Buhle et al., 2014 for meta-analysis) though not always (McRae, Gross, et al., 2012). Higher adolescent trait anxiety attenuates age-related trajectories of decreased amygdala activation (Hare et al., 2008). Healthy adults demonstrate greater left vlPFC activation during reappraisal (Kohn et al., 2014); similarly, better emotion regulation in youth relates to age-related increases in vlPFC activation (Silvers et al., 2012). vmPFC activation relates to down-regulation of negative affect during reappraisal (Diekhof, Geier, Falkai, & Gruber, 2011) and valuation of stimulus valence (Ochsner, Silvers, & Buhle, 2012). Youth at risk for anxiety (e.g., have experienced early life trauma) demonstrate heightened prefrontal activation during reappraisal (McLaughlin, Peverill, Gold, Alves, & Sheridan, 2015), possibly reflecting enhanced effort to employ reappraisal, as these youth also exhibit greater emotional reactivity and greater activation in brain regions encoding emotional salience when viewing negative stimuli (Hein & Monk, 2017).

Refinement of subcortical-cortical connectivity (Casey, Heller, Gee, & Cohen, 2019) also contributes to improvements in emotion regulation abilities in youth. Age predicts more negative amygdala-vmPFC connectivity during passive viewing of fearful faces and relates to less anxiety (Gee et al., 2013), as well as more negative amygdala-vlPFC connectivity during reappraisal (Silvers, Shu, Hubbard, Weber, & Ochsner, 2015). Youth with stronger negative amygdala-vmPFC connectivity also evince left vlPFC activation that mediates the relationship between age and decreased amygdala activation (Silvers et al., 2016). In contrast, healthy adults with less negative affect demonstrate positive fronto-limbic coupling during reappraisal (Banks, Eddy, Angstadt, Nathan, & Luan Phan, 2007).

Here, we used an fMRI paradigm to investigate behavioral and neurobiological differences in emotional reactivity and regulation between youth with and without anxiety disorders. Although emotion regulation requires coordination across several brain regions, the amygdala, vlPFC, and vmPFC can serve as targets for which prior literature consistently finds effects related to cognitive reappraisal in both healthy adults and children. As such, and given this is the first study examining neurobiological differences between youth with and without anxiety in emotion regulation (Young, Sandman, & Craske, 2019), we focused on this circumscribed portion of the emotion regulation circuit as *a priori* seed regions in activation and connectivity analyses, while also exploring whole-brain activation. We hypothesized that anxious youth would display heightened emotional reactivity but comparable emotion regulation relative to control youth. Age-specific hypotheses for emotional reactivity were not formulated given limited and mixed prior findings; however, emotion regulation was expected to develop linearly and quadratically in control youth, but not expected to demonstrate age-related changes in anxious youth. Amygdala activation during reappraisal was expected to decline across age in

control but not in anxious youth, and to correlate with greater anxiety severity across both groups. We did not formulate directional hypotheses relating amygdala-frontal connectivity to reappraisal, given mixed prior findings. However, age was hypothesized to relate to amygdala-vmPFC and amygdala-vlPFC connectivity; anxiety severity was hypothesized to moderate this association. Exploratory whole-brain analyses were also conducted for activation. Results can offer insights into mechanisms at play during CBT and suggest techniques to bolster treatment efficacy.

MATERIALS AND METHODS

Study Participants

The sample consists of 61 children and adolescents 8-17 years old: 37 participants with anxiety (28 females, M_{age}=13.8, SD_{age}=3.0) and 24 control youth (17 female, M_{age}=13.3, SD_{age}=3.3). Nine participants (n=5 anxious, n=4 controls) were included in behavioral analyses but excluded from imaging analyses for excessive motion. The greater proportion of females in this sample is consistent with disorder prevalence (Hantsoo & Epperson, 2017). All participants were evaluated by a trained clinical psychologist using the Anxiety Disorder Interview Schedule IV to assess for an anxiety disorder (Albano & Silverman, 1996). Youth were excluded if they had any contraindications to MRI, present or current history of neurodevelopmental or neurological disorder, or any psychiatric medication use. Additionally, control youth were excluded if they had any previous or current history of psychiatric disorder. Full scale IQ was estimated using the Vocabulary and Matrix Reasoning subtests from the Weschler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999); youth with IQ below 70 were excluded. Maternal education was used as a proxy for socioeconomic status.

Behavioral Measures

All participants completed the 39-item Multidimensional Anxiety Scale for Children (MASC) (March, Parker, Sullivan, Stallings, & Conners, 1997) to assess anxiety symptom severity. Participants reported on a scale from 0 to 3 to describe how often they experience symptoms, where 0 indicates never, 1 rarely, 2 sometimes, and 3 often. Scores were averaged to examine composite anxiety severity.

MRI Data Acquisition

Task fMRI data were obtained using a Siemens 3T Prisma (20-channel head coil) or Siemens Trio at UCLA. Each participant received a matched-bandwidth echo-planar image for registration (TR=5000ms, TE=35ms, FOV=192mm, 34 slices, slice thickness 4mm, in-plane voxel size 1.5x1.5mm). The T2*-weighted task fMRI sequence (TR=2000ms, TE=30ms, FOV=192mm, 34 slices, slice thickness 4mm, in-plane voxel size 3x3mm) was acquired while participants completed the emotion regulation task (Figure 3.1).

Each trial started with a 2 second instructional cue ("Look," the instruction to react naturally or "Decrease," the instruction to regulate emotions). Either an aversive or a neutral picture followed for 8 seconds, after which participants were presented with a rating scale for 4 seconds to report the strength of their negative affect. The scale ranged from 1 to 4 where 1 indicates feeling "not at all badly" and 4 indicates feeling "very badly". Trials were presented in an event-related design, with "Look" and "Decrease" trials interspersed. A total of 24 Look and 24 Decrease trials were presented across 2 runs, separated into 12 negative and 12 neutral trials. Conditions of interest include Look Aversive (emotional reactivity), Look Neutral (non-emotional responding), and Decrease Aversive (emotion regulation).

Emotion regulation was calculated as the difference in aversiveness ratings between Look Aversive and Decrease Aversive trials. Emotional reactivity was calculated as the difference in aversiveness ratings between Look Aversive and Look Neutral trials. One anxious youth was an outlier in emotional reactivity (+3 standard deviations above group average). Results are only reported if they remained significant with and without this participant.

Behavioral Data Analysis

Affect ratings were compared in a series of 6 independent t-tests to examine whether youth with and without anxiety differed on the following: overall affect ratings (e.g., the average affect rating from Look Aversive, Look Neutral, and Decrease Aversive), ratings within condition (e.g., affect ratings from Look Aversive, Look Neutral, and Decrease Aversive separately), and ratings within contrast (e.g., affect ratings during emotional reactivity and emotion regulation separately). To assess for developmental trends, emotional reactivity and regulation were compared (in two separate regressions) across groups while controlling for age as well as the interaction between age and group. Similarly, to assess for the effect of anxiety severity, emotional reactivity and regulation were compared (in two separate regressions) across groups while controlling for anxiety severity as well as the interaction between anxiety severity and group. As such, 4 separate regression analyses were conducted.

MRI Data Analysis

Analyses were performed using FMRIB's Software Library (FSL) 5.0.9 (www.fmrib.ox.ac.uk/fsl). Task data underwent motion correction using MCFLIRT, removal of non-brain matter using FSL brain extraction tool (BET), spatial smoothing (5 mm FWHM Gaussian kernel), non-linear high-pass filtering (100-s cutoff). EPI images were registered to the

corresponding matched-bandwidth scan using boundary-based registration (Greve & Fischl, 2009) and then to standard Montreal Neurological Institute (MNI) space (MNI 152, T1 2mm) using linear registration with 12 degrees of freedom using FSL FMRIB's Linear Image Registration Tool (FLIRT). Participants were excluded from all imaging analyses if motion exceeded 1 mm meal relative motion in both runs and/or if greater than 30% of volumes contained motion ≥ 1 mm framewise displacement. Data were pre-whitened to correct for autocorrelation using FILM in FSL (Woolrich, Ripley, Brady, & Smith, 2001). 24 motion regressors were included as nuisance regressors, including 3 translation and 3 rotation regressors, as well as their 1st and 2nd derivatives, and the difference between their 1st and 2nd derivatives, as recommended for robustly reducing motion related noise in task fMRI data as well as spin history related artifacts (Caballero, Granberg, & Tseng, 2016). Additionally, individual spike regressors were created using FSL Motion Outliers which regressed trials with ≥ 1 mm framewise displacement.

Following pre-processing, participants' individual run-level data were analyzed using a fixed-effects general linear model (GLM). Regressors for each trial type were created by convolving a delta function representing the onset time with a canonical double-gamma hemodynamic response function. Six total regressors were created: 4 for stimuli (Decrease Aversive, Decrease Neutral, Look Aversive, Look Neutral), 1 representing all cues, and 1 representing all rating events.

Group level analyses were conducted using a mixed effects model in FSL (FLAME1), thresholded at $z>3.1$ ($p<0.001$) and corrected for multiple comparisons at $p<0.05$. As 5 participants were scanned prior to institutional scanner upgrade, scanner type was included as a covariate of no interest in all group level analyses. Conditions of interest included Decrease

Aversive, Look Aversive, and Look Neutral. Contrasts of interest investigated emotion regulation (Decrease Aversive>Look Aversive) and emotional reactivity (Look Aversive>Look Neutral). Given *a priori* interest in activation of the amygdala, vmPFC, and vlPFC, parameter estimates were extracted for these regions of interest (ROIs). A 10 mm spherical mask of the vmPFC was created via peak coordinates (x = 0, y = 58, z = -10) reported in the association test for a meta-analysis of the vmPFC from Neurosynth (https://www.neurosynth.org) (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011). Masks for bilateral amygdala and bilateral vlPFC (inferior frontal gyrus, pars triangularis) were defined using FSL's Harvard-Oxford atlas and thresholded at a probabilistic threshold of 40%. For ROI analyses, time series were extracted from each subject at the group level from bilateral amygdala, bilateral vmPFC, and vlPFC. Laterality effects were not examined. Region of interest analyses focused on activation from bilateral amygdala, bilateral ventrolateral prefrontal cortex, and ventromedial prefrontal cortex during each condition of interest (e.g., Look Aversive, Look Neutral, and Decrease Aversive) and during each contrast of interest (e.g., emotional reactivity and emotion regulation). Benjamini-Hochberg correction was used to control for the number of tests (3 for conditions; 2 for contrasts) within ROI; reported p-values are adjusted for multiple comparisons. Exploratory whole-brain analyses were conducted as well given the novelty of the sample.

Trial-by-trial functional connectivity was generated for each subject using a least-squares separate beta-series regression analysis (Mumford, Turner, Ashby, & Poldrack, 2012; Rissman, Gazzaley, & D'Esposito, 2004) in FSL. A least-squares separate beta-series regression analysis was employed to investigate functional connectivity in an event-related design across trial types (i.e., functional connectivity associated with Decrease Aversive). In this approach, a separate generalized linear model (GLM) is created for each of the trials of interest where the stimulus of

interest from one trial is modeled as the regressor of interest, and all other trials and nuisance signals are combined into a single nuisance regressor. Each trial is modeled with a delta function representing trial onset time and duration, and then convolved with a canonical double-gamma hemodynamic response function.

Separate regressors modeling Decrease Aversive and Look Aversive trials were defined in separate GLMs to generate condition-wise beta values for every voxel in the brain, where beta values reflect the magnitude of the hemodynamic response evoked by each event. Beta series were generated by sorting beta images by condition and concatenating across runs. Analyses focused on stimulus events. Bilateral amygdala, bilateral ventrolateral prefrontal cortex, and ventromedial prefrontal cortex were used as seed regions; ROIs were defined as described above; laterality effects were not examined. All ROIs were binarized and then warped into subject space for extraction of beta series to compare across groups within condition (e.g., during Decrease Aversive and Look Aversive separately). Extracted beta-series values were z-transformed to perform correlations. Participants were included in analyses if they provided 2 usable runs of imaging data.

Functional connectivity analyses assessed group differences in 2 connections: 1) bilateral amygdala-bilateral ventrolateral prefrontal cortex and 2) bilateral amygdala-ventromedial prefrontal cortex. These tests examined connectivity during each condition (e.g., Look Aversive, Look Neutral, and Decrease Aversive). Benjamini-Hochberg correction was used to correct for the number of tests (3 for each condition) within connection; reported p-values are adjusted for multiple comparisons. The association between age and connectivity was also assessed for each condition (3) and corrected for multiple comparisons using the Benjamini-Hochberg correction.

Lastly, connectivity during Decrease Aversive (e.g., during explicit emotion regulation) was specifically interrogated for relationship to anxiety severity.

RESULTS

Participant Characteristics

Anxious youth displayed greater anxiety severity than control youth ($t(55.3)=5.41$, $p<0.001$; Table 3.1). There was a trending difference in maternal education between groups ($\chi^2(4)=8.44$, $p=0.08$). IQ was included as a covariate of no interest in all analyses given a significant group difference ($t(46.7)=-2.48$, $p=0.02$). There were no significant differences between groups in age ($t(45.6)=0.66$, $p=0.51$), sex ($\chi^2(1)=0.18$, $p=0.67$), race/ethnicity ($\chi^2(16)=6.07$, $p=0.19$), or mean relative motion ($t(34.1)=-0.34$, $p=0.73$). Youth who did and did not (n=9) provide usable imaging data did not differ in anxiety severity ($t(14.6)=0.89$, $p=0.39$), race/ethnicity ($\chi^2(16)=2.09$, $p=0.72$), maternal education ($t(12.2)=0.98$, $p=0.35$), or IQ ($t(12.2)=-1.21$, $p=0.25$); however, youth with usable data were older ($t(35.1)=9.91$, $p<0.001$) and female ($\chi^2(1)=4.69$, $p=0.03$), consistent with prior findings (Dosenbach et al., 2017).

Aversiveness Ratings

Aversiveness ratings averaged across all trials demonstrated that anxious youth displayed greater negative affect compared to control youth for all image types ($\beta=-0.22$, $p=0.05$; Table 3.1). Specifically, anxious youth reported significantly greater negative affect during Look Aversive trials ($\beta=-0.35$, $p=0.04$). Ratings were not significantly different during Decrease Aversive ($\beta=-0.26$, $p=0.14$) or Look Neutral trials ($\beta=-0.07$, $p=0.37$).

Emotion Reactivity and Regulation

Across both groups, youth reported significantly greater negative affect during Look Aversive relative to Look Neutral trials ($t(60)=-15.3$, $p<0.001$), demonstrating that aversive images elicited a negative affective response. Groups did not differ in the extent of emotional reactivity ($\beta=-0.28$, $p=0.11$; Table 3.1, Figure 3.2a).

Youth reported significantly lower negative affect during Decrease Aversive relative to Look Aversive trials ($t(60)=-2.51$, $p=0.01$), demonstrating that negative affect was being regulated. Groups did not differ in the extent of emotion regulation ($\beta=-0.09$, $p=0.49$; Table 3.1, Figure 3.2b).

Effects of Anxiety Severity and Age on Emotional Reactivity and Regulation

There was no significant main effect of anxiety severity ($\beta=-0.07$, $p=0.76$), group ($\beta=0.56$, $p=0.53$), or anxiety severity by group interaction ($\beta=-0.47$, $p=0.27$) on emotional reactivity. Age ($\beta=-0.08$, $p=0.02$) and group ($\beta=-2.10$, $p=0.003$) both predicted emotional reactivity. However, there was a significant group by age interaction ($\beta=0.13$, $p=0.008$); post-hoc simple slopes analyses revealed that emotional reactivity decreased with age in anxious youth, but age and emotional reactivity were unrelated in control youth (Figure 3.2c).

There was no significant main effect of anxiety severity ($\beta=-0.01$, $p=0.95$), group ($\beta=0.30$, $p=0.68$), or anxiety severity by group interaction ($\beta=-0.21$, $p=0.54$) on emotion regulation. There was also no significant main effect of age ($\beta=0.04$, $p=0.19$), group ($\beta=-0.74$, $p=0.18$), or age by group interaction ($\beta=0.05$, p=0.23) on emotion regulation (Figure 3.2d).

Functional Activation Differences within Look Aversive, Decrease Aversive, and Look Neutral

Whole-brain analyses revealed activation in anxious youth in the thalamus, lateral occipital cortex (LOC), and fronto-parietal regions across all 3 conditions (Figures 3.3-3.5 and Tables 3.2-3.4). In controls, activation during all 3 conditions occurred mainly in temporal and

occipital regions. Between-group analyses revealed greater activation in anxious youth in the middle frontal and precentral gyri during Look Aversive and Decrease Aversive trials; anxious youth also showed greater activation in right LOC, supramarginal gyrus, and caudate during Decrease Aversive trials. In Look Neutral trials, anxious youth showed greater activation in left occipital pole and right LOC.

Anxious youth displayed significantly higher activation of the bilateral amygdala relative to control youth during Look Aversive (β=4.89, p=0.003; Figure 3.6a), Decrease Aversive (β=3.99, p=0.009; Figure 3.6b), and Look Neutral trials (β=6.74, p=0.0003; Figure 3.6c). vlPFC activation was higher in anxious youth during Look Aversive (β=4.31, p=0.04), Decrease Aversive (β=4.11, p=0.05), and Look Neutral trials (β=5.94, p=0.01). vmPFC activation did not differ between groups during Look Aversive (β=1.23, p=0.71), Decrease Aversive (β=2.17, p=0.71), or Look Neutral trials (β=3.91, p=0.48).

Functional Activation During Emotional Reactivity

Whole-brain analyses revealed activation in both groups during emotional reactivity (Look Aversive>Look Neutral; Figure 3.7, Table 3.5) in temporo-occipital regions, superior and inferior frontal gyri, and several subcortical regions including the bilateral thalamus, striatum, and amygdala. No significant activation was observed for control youth, nor any observed between-group differences.

ROI analyses revealed no between-group differences during emotional reactivity in activation of the amygdala (β=1.66, p=0.31), vlPFC (β=2.65, p=0.73), or vmPFC (β=2.78, p=0.49*)*; Figure 3.6d). Extracted parameter estimates from bilateral amygdala, bilateral vlPFC, and vmPFC did not correlate with age, anxiety severity, or extent of emotional reactivity.

Functional Activation During Emotion Regulation

In whole-brain emotion regulation analyses (Decrease Aversive>Look Aversive; Figure 3.8, Table 3.6), anxious youth demonstrated significant activation of LOC and left angular gyrus. No significant activation was observed for control youth, nor any significant between-group differences.

ROI analyses revealed no between-group differences during emotion regulation in activation of the amygdala (β=0.91, p=0.49), vlPFC (β=-2.14, p=0.73), or vmPFC (β=-1.16, p=0.57); Figure 3.6e). Extracted parameter estimates from bilateral amygdala, bilateral vlPFC, and vmPFC did not correlate with age, anxiety severity, or extent of emotion regulation.

Functional Connectivity Results

Amygdala-vlPFC connectivity did not differ between groups during Look Aversive (β=-0.01, p=0.91), Decrease Aversive (β=0.12, p=0.65), or Look Neutral trials (β=-0.04, p=0.91). Similarly, Amygdala-vmPFC connectivity did not differ between groups during Look Aversive (β=-0.02, p=0.79), Decrease Aversive (β=0.09, p=0.79), or Look Neutral trials (β=0.03, p=0.79). Connectivity did not relate to age in either group in any condition.

Amygdala-vmPFC connectivity during Decrease Aversive trials showed a significant group by anxiety severity interaction (β=0.43, p=0.05; Figure 3.9). Whereas greater anxiety severity was associated with greater amygdala-vmPFC connectivity in control youth, greater anxiety was associated with less amygdala-vmPFC connectivity in anxious youth. Amygdala-vlPFC connectivity did not relate to anxiety severity.

DISCUSSION

To our knowledge, this is the first study to examine neurobiological differences during emotional reactivity and regulation among youth with and without clinical anxiety, with an eye toward understanding processes engaged during a key component of current CBT treatments: cognitive reappraisal. We found similar emotion regulation in both groups which did not correlate with anxiety severity. There was no observed developmental relationship with emotion regulation capacity in either group. Targeted ROI analyses revealed heightened amygdala and vlPFC activation in anxious relative to control youth during all conditions. Amygdala connectivity with vmPFC during emotion regulation differentially related to anxiety severity in youth with and without anxiety.

Contrary to expectations, anxious youth were not significantly more emotionally reactive than control youth. Anxious youth did however self-report more distress following Look Aversive trials which index youth's dispositional reactions to negatively valanced images. Higher reactivity suggests that anxious youth may generally experience greater negative emotions in response to aversive imagery. Anxious youth also displayed significantly greater amygdala and vlPFC activation during Look Aversive trials, consistent with work in anxious adults suggesting an overall heightened behavioral and neurobiological response to negative images (Fitzgerald et al., 2017). Altogether, findings suggest that the Look Aversive condition was more distressing for anxious compared to control youth. Coupled with prior findings that anxious youth rely on maladaptive coping strategies (Schäfer et al., 2017), negative situations may present a source of heightened and difficult-to-control emotions.

In line with our hypothesis, instructing anxious youth to regulate resulted in regulation capacity at the level of their non-anxious peers. Examining Decrease Aversive trials specifically revealed similar ratings across all youth, further demonstrating efficacious reappraisal following

instruction. Despite similar behavioral performance, anxious youth displayed greater amygdala and vlPFC activation during Decrease Aversive trials. Heightened amygdala activation during reappraisal could reflect attentional bias toward threatening (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007) and emotionally salient (McRae, Misra, Prasad, Pereira, & Gross, 2012) stimuli, which persists in parallel with reduced negative affect. The general tendency of anxious youth to not use reappraisal could result in heightened amygdala responsivity that is difficult to down-regulate. Indeed, anxious youth also exhibited greater vlPFC activation which could reflect greater effort (Etkin, Büchel, & Gross, 2015) required to employ effective reappraisal, especially if they are less experienced with this emotion regulation strategy (Silvers et al., 2016). The lack of subjective perception of negative affect despite heightened neurobiological response suggests that therapies should specifically address strategies for incentivizing adolescents to employ reappraisal when faced with heightened emotions, in addition to skill development. Emotion regulation tendency and capacity may co-develop in adolescence (Silvers & Moreira, 2017), further suggesting the need to encourage reappraisal as this may boost its efficacy. Examining both the tendency to use and efficacy of reappraisal in anxious youth can elucidate whether youth who reappraise more often also exhibit less amygdala activation during reappraisal.

Neither emotional reactivity nor emotion regulation related to age in control youth in contrast with prior work demonstrating linear increases in emotion regulation across age (McRae, Gross, et al., 2012; Silvers et al., 2012). Stable emotional reactivity combined with lack of emotion regulation development may contribute to vulnerability for developing affective disorders during the period in which regulatory capabilities may not yet be developed enough to manage reactivity (Meyer & Lee, 2019). In contrast, emotional reactivity decreased over age in

anxious youth, but emotion regulation did not relate to age. This lack of development may contribute to the continuation or exacerbation of anxious symptomatology. Continued dysregulation across development may serve as a risk factor for comorbid psychopathology (Sloan et al., 2017); emotion regulation deficits predict risk for both future anxiety and depressive disorder diagnoses (Schäfer et al., 2017). Reduced emotion regulation development, coupled with infrequent use of adaptive emotion regulation strategies, may contribute to deficits in emotion regulation use in adulthood (Hofmann, Sawyer, Fang, & Asnaani, 2012). Longitudinal studies are necessary for investigating developmental trajectories of emotion regulation in anxious youth as they transition into adulthood.

We did not observe developmental relationships involving amygdala activation or connectivity unlike prior work (Gee et al., 2013; Silvers et al., 2016, 2015). Stronger amygdala-vmPFC connectivity related to significantly fewer anxiety symptoms in anxious youth, but more anxiety symptoms in control youth, in line with work in adults (Young et al., 2017). While beta series connectivity analyses cannot address directionality within circuits, anxious youth may have recruited prefrontal regions to down-regulate the heightened emotionality and amygdala activation observed during Decrease Aversive trials relative to control youth. Perhaps positive coupling between the amygdala and regulatory regions is necessary for attenuating heightened amygdala responsivity but is not necessary in the absence.

These findings should be interpreted with limitations in mind. The modest sample size may have limited our power to detect significant differences. Future studies should aim for larger sample sizes, which may also allow for investigating sex differences. As such, this study should be interpreted as pilot work in need of replication in larger studies of pediatric anxiety. Further, as emotion regulation develops with age, longitudinal studies are crucial for identifying

differential trajectories of development across psychiatric conditions. Capitalizing on dimensional anxiety rather than dichotomizing participants may also help isolate the relationship between anxiety symptoms and emotional development.

Despite these limitations, this study provides novel context for emotion dysregulation in anxiety disorders. Anxious youth exhibit intact regulatory abilities relative to non-anxious peers, though still demonstrate greater fronto-limbic activation following aversive imagery. Regulation may require additional effort in anxious youth, as potentially indexed both by greater recruitment of lateral prefrontal cortex and greater amygdala-frontal connectivity. Therapeutics may confer greater clinical benefit by addressing strategies for attenuating heightened emotional response following negative experiences in addition to encouraging reappraisal use in daily life to support healthy emotional development into adulthood.

Table 3.1 Subject demographics

	Anxious n = 37	Controls n = 24	*p*-value
Age	13.8 (3.0)	13.3 (3.3)	0.51
Sex	28 F, 9 M	17 F, 7 M	0.67
Mean Relative Motion (mm)	0.11 (0.09)	0.12 (0.12)	0.73
MASC	2.47 (0.44)	1.91 (0.37)	< 0.001
Aversiveness Ratings			0.05
Emotional Reactivity	1.33 (0.64)	1.05 (0.58)	0.11
Emotion Regulation	0.20 (0.44)	0.09 (0.55)	0.49
Look Aversive	2.58 (0.58)	2.18 (0.65)	0.04
Look Neutral	1.25 (0.32)	1.14 (0.21)	0.37
Decrease Aversive	2.38 (0.58)	2.10 (0.65)	0.14
Self-Reported Race/Ethnicity			0.19
Asian	4	3	-
Black	5	1	-
Hispanic	2	5	-
More than one race	8	7	-
White	18	7	-
Missing	-	1	-
Maternal Education			0.08
Has not Completed High School	1	4	-
Completed High School	1	1	-
Completed Associate's Degree	6	0	-
Completed Bachelor's Degree	11	10	-
Completed Master's Degree or above	11	5	-
Full Scale IQ	105.7 (14.6)	115.6 (15.7)	0.02

Table 3.2 Peak coordinates of brain activity during Look Aversive > Baseline

Group	Region Label	Peak MNI Coordinates			*z*-max	Voxels (mm^3)
		x	y	z		
Anxious	Right thalamus	20	-30	4	7.84	6,389
	Right lateral occipital cortex, superior division	30	-88	10	7.8	4,270
	Left lateral occipital cortex, inferior division	-30	-90	6	7.43	2,938
	Left thalamus	-22	-30	-2	7.75	2,396
	Left precentral gyrus	-34	-6	46	5.48	2,282
	Medial superior frontal gyrus	4	12	60	5.88	1,772
	Left superior parietal lobe	-26	-56	56	5.12	395
	Right frontal pole	10	60	40	4.6	239
Controls	Right occipital pole	18	-94	8	4.62	326
	Left occipital pole	-20	-90	4	5.44	298
	Right temporal occipital fusiform cortex	38	-54	-10	5.38	286
	Left temporal occipital fusiform cortex	-38	-48	-10	5	224
	Right thalamus	20	-32	0	5.71	155
	Left thalamus	-20	-30	-4	4.91	135
Anxious > Controls	Right middle frontal gyrus	38	0	46	5.1	245
	Left precentral gyrus	-34	-10	48	3.88	132

Table 3.3 Peak coordinates of brain activity during Decrease Aversive > Baseline

Group	Region Label	Peak MNI Coordinates			*z*-max	Voxels (mm^3)
		x	y	z		
Anxious	Right thalamus	20	-30	4	7.5	5,433
	Left superior frontal gyrus	-6	14	62	6.37	3,168
	Right lateral occipital cortex, superior division	30	-88	10	7.67	3,161
	Left lateral occipital cortex, inferior division	-30	-90	6	7.19	2,378
	Left frontal operculum cortex	-44	24	4	5.2	2,163
	Left thalamus	-18	-30	-4	6.96	1,932
	Right lateral occipital cortex, superior division	26	-62	62	5.76	505
	Left superior parietal lobe	-26	-56	56	4.82	209
Controls	Right lateral occipital cortex, superior division	32	-82	14	4.3	278
	Left occipital pole	-20	-92	4	5.68	236
	Right temporal occipital fusiform cortex	38	-54	-10	5.03	193
	Left temporal occipital fusiform cortex	-38	-48	-10	5.59	177
Anxious > Controls	Right middle frontal gyrus	42	20	26	4.49	647
	Right lateral occipital cortex, superior division	26	-62	60	4.77	487
	Left precentral gyrus	-32	-2	40	4.2	146
	Right supramarginal gyrus, posterior division	48	-36	50	3.94	118
	Right caudate	20	18	4	4.34	112

Table 3.4 Peak coordinates of brain activity during Look Neutral > Baseline

Group	Region Label	Peak MNI Coordinates			*z*-max	Voxels (mm^3)
		x	y	z		
Anxious	Right lateral occipital cortex, superior division	30	-88	10	7.63	1,633
	Left lateral occipital cortex, inferior division	-30	-90	6	6.91	1,280
	Right thalamus	22	-30	4	6.46	1,086
	Left thalamus	-20	-30	-4	7.03	413
	Left temporal occipital fusiform cortex	-34	-58	-10	5.97	346
	Left superior frontal gyrus	-6	14	64	4.88	315
	Left putamen	-18	-2	12	3.86	118
	Left frontal orbital cortex	-38	24	-6	3.88	106
Controls	Left occipital pole	-20	-92	4	4.91	167
	Right lateral occipital cortex, inferior division	34	-82	10	3.86	119

Table 3.5 Peak coordinates of brain activity during emotional reactivity (Look Aversive>Look Neutral)

	Hemisphere	Region Label	Peak MNI Coordinates			*z*-max	Voxels (mm^3)
			x	y	z		
Anxious	Right	Precentral Gyrus	42	0	46	6.31	4,692
			42	4	32	5.69	
			38	4	30	5.67	
			48	4	28	5.35	
			52	10	30	5.02	
	Medial	Superior frontal gyrus	4	10	56	5.03	
	Left	Lateral occipital cortex, inferior division	-48	-78	6	7.33	4,445
			-48	-66	4	7	
			-48	-70	10	6.84	
			-44	-84	10	6.83	
			-42	-60	0	6.51	
		Temporal occipital fusiform cortex	-40	-46	-16	6.57	
	Right	Lateral occipital cortex, inferior division	44	-64	-2	6.74	3,503
			46	-68	2	6.67	
			46	-64	4	6.58	
			48	-62	12	6.21	
		Middle temporal gyrus, temporooccipital part	40	-54	4	6.59	
		Lateral occipital cortex, superior division	42	-60	16	6.23	
	Right	Thalamus	18	-30	0	5.46	1,988
			4	-12	10	5.04	
			14	-28	-4	4.99	
			10	-26	-2	4.93	
	Left	Thalamus	-6	-28	-2	5.1	
		Amygdala	-18	-6	-12	4.88	
	Left	Precentral gyrus	-32	-6	46	5.53	1,169
			-34	-6	50	5.52	
			-46	2	34	5.33	
			-42	0	30	4.99	
		Superior frontal gyrus	-24	-2	58	4.42	

		Middle frontal gyrus	-42	10	30	4.01	
	Left	Frontal operculum cortex	-32	26	6	4.45	221
		Insular cortex	-34	16	6	4.27	
			-28	16	10	4.1	
			-34	14	-4	3.51	
			-34	14	-8	3.47	
		Putamen	-24	10	10	3.29	
	Right	Supramarginal gyrus, anterior division	48	-28	40	4.01	179
			60	-24	38	3.76	
			62	-20	40	3.75	
			64	-28	30	3.58	
Controls	Right	Middle temporal gyrus, temporooccipital part	50	-60	2	5.82	873
		Lateral occipital cortex, inferior division	48	-62	8	5.75	
			46	-68	2	5.52	
			44	-72	12	4.8	
		Inferior temporal gyrus, temporooccipital part	44	-58	-6	5.25	
		Angular gyrus	42	-56	16	4.79	
	Left	Lateral occipital cortex, inferior division	-46	-74	4	5.98	670
			-52	-70	8	5.7	
			-40	-62	0	4.29	
		Temporal occipital fusiform cortex	-38	-52	-14	4.8	
			-38	-46	-16	4.25	
			-38	-58	-4	3.99	
	Right	Inferior frontal gyrus, pars triangularis	50	26	8	4.44	487
			44	32	14	4.24	
			58	28	14	4.06	
			52	28	12	3.86	
		Middle frontal gyrus	44	26	24	4.44	
		Frontal pole	54	40	12	4.43	
	Right	Precentral gyrus	42	6	28	4.53	410
			46	6	28	4.44	
			50	10	32	4.42	
		Middle frontal gyrus	54	16	40	3.39	

	Left	Thalamus	-6	-6	6	5.03	347
		Caudate	-8	10	10	4.58	
			-10	8	2	3.69	
		Pallidum	-16	-6	6	3.87	
	Right	Thalamus	4	-8	8	3.65	
			4	-14	8	3.51	
	Left	Frontal pole	-10	64	26	4.65	225
			-8	62	34	4	
	Right		4	62	36	4.06	
			8	64	28	3.79	
			8	58	40	3.67	
		Superior frontal gyrus	0	54	28	3.53	
	Left	Thalamus	-16	-32	2	4.61	186
		Hippocampus	-16	-24	-8	4.07	
			-20	-24	-8	4.04	
			-22	-28	-6	4.01	
		Putamen	-28	-22	-6	3.71	
	Right	Amygdala	18	-6	-14	5.51	161
			30	-6	-14	3.66	
	Right	Thalamus	18	-32	0	4.79	147
			22	-26	-4	4.28	
	Left	Precentral gyrus	-46	4	32	4.39	127
		Middle frontal gyrus	-56	10	40	3.39	

Table 3.6 Peak coordinates of brain activity during emotion regulation (Decrease Aversive>Look Aversive)

	Hemisphere	Region Label	Peak MNI Coordinates			*z*-max	Voxels (mm^3)
			x	y	z		
Anxious	Right	Lateral occipital cortex, superior division	56	-60	32	4.58	199
			54	-64	36	4.39	
			52	-60	44	4.25	
			54	-62	40	4.23	
		Angular gyrus	56	-54	32	4.55	

Figure 3.1 Emotion regulation task

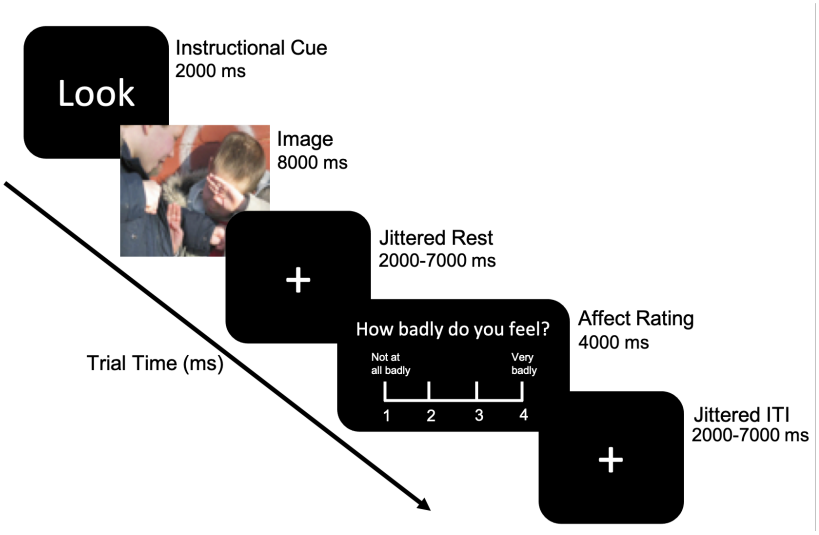
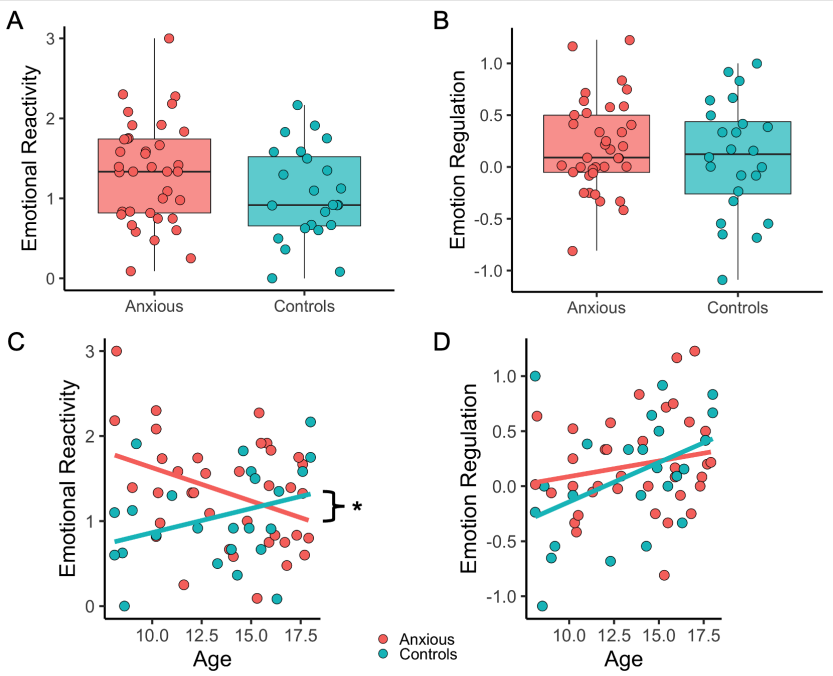
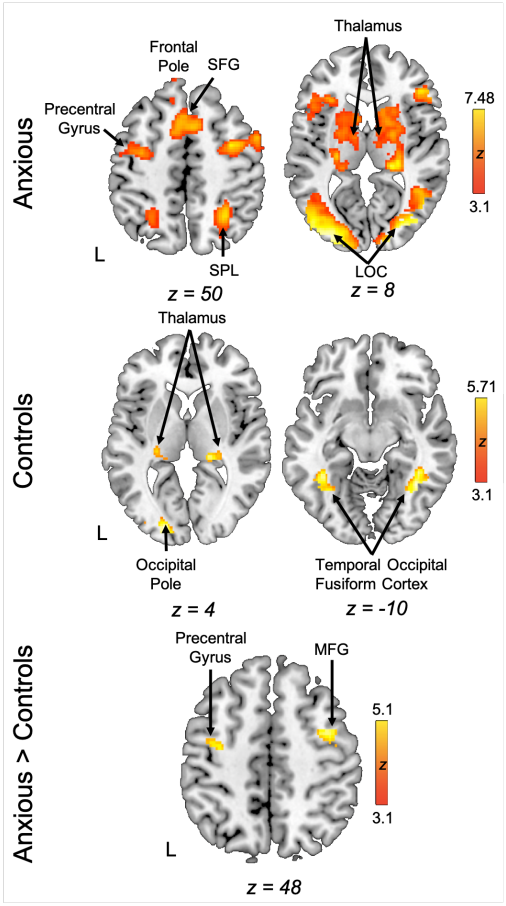


Figure 3.2 Emotional reactivity and regulation



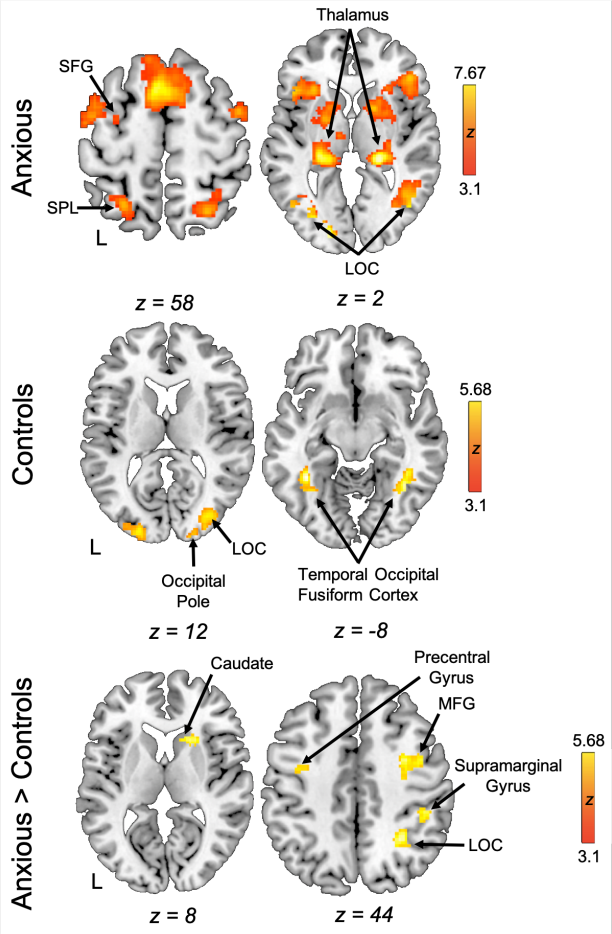
A. Emotional reactivity (Look Aversive-Look Neutral affect ratings). B. Emotion regulation (Decrease Aversive-Look Aversive affect ratings). C. Emotional reactivity across age. D. Emotion regulation across age. * $p < 0.05$

Figure 3.3 Neural activation during Look Aversive > Baseline



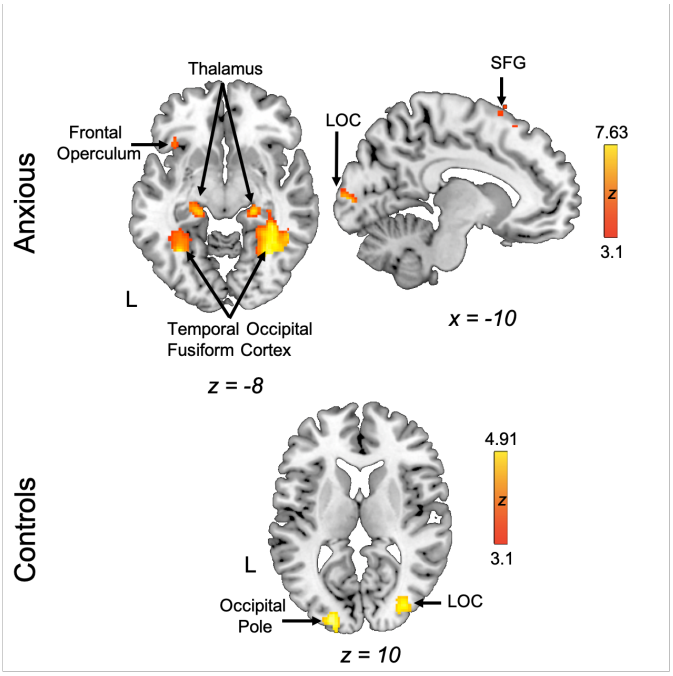
Whole-brain activation for Look Aversive > Baseline. SFG: Superior Frontal Gyrus. SPL: Superior Parietal Lobule. LOC: Lateral Occipital Cortex. MFG: Middle Frontal Gyrus.

Figure 3.4 Neural activation during Decrease Aversive > Baseline



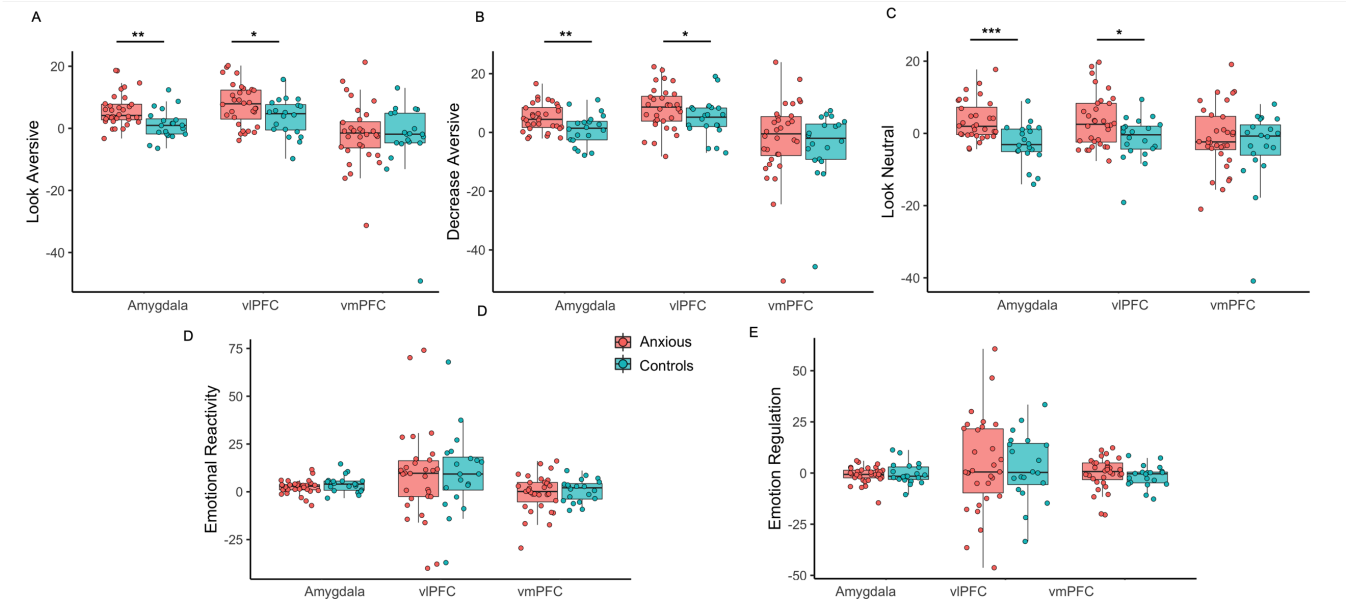
Whole-brain activation for Decrease Aversive > Baseline. SFG: Superior Frontal Gyrus. SPL: Superior Parietal Lobule. LOC: Lateral Occipital Cortex. MFG: Middle Frontal Gyrus.

Figure 3.5 Neural activation during Look Neutral > Baseline



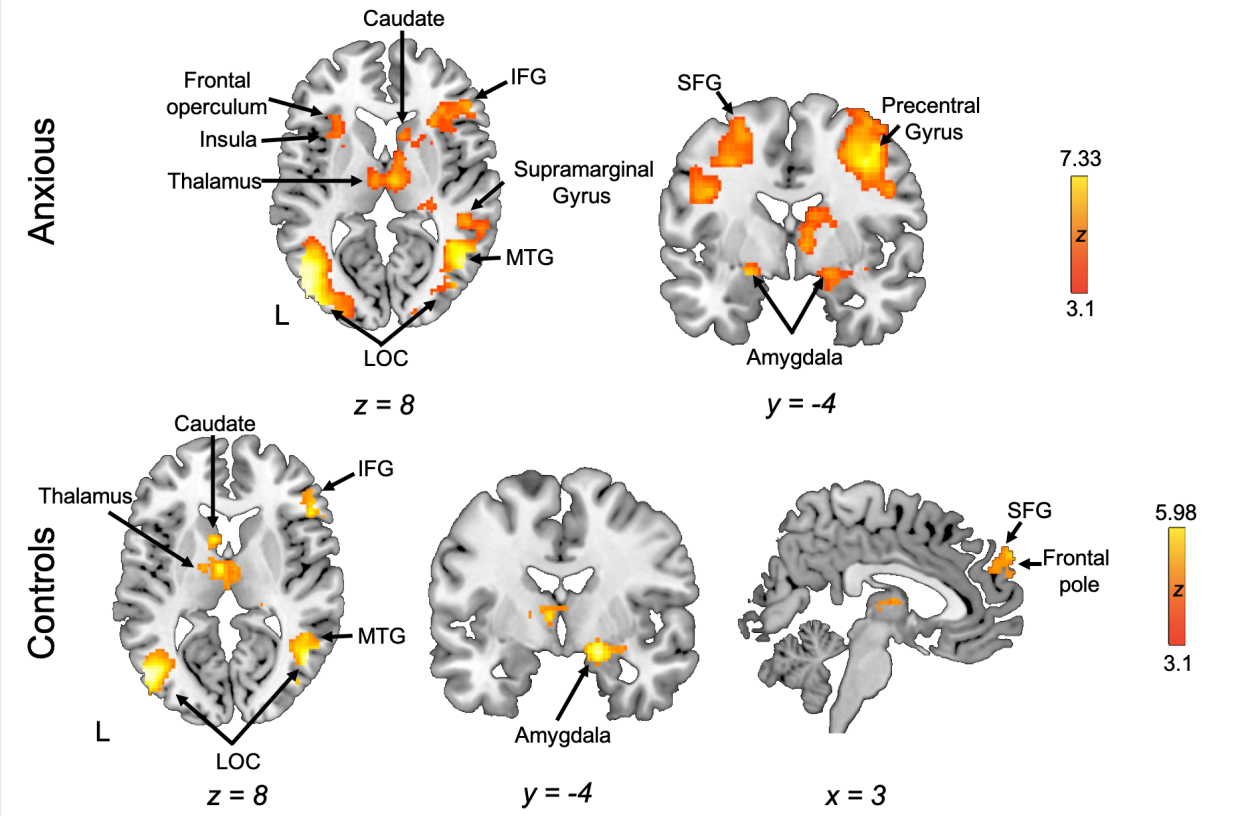
Whole-brain activation for Look Neutral > Baseline. SFG: Superior Frontal Gyrus. LOC: Lateral Occipital Cortex.

Figure 3.6 Amygdala, vlPFC, and vmPFC parameter estimates



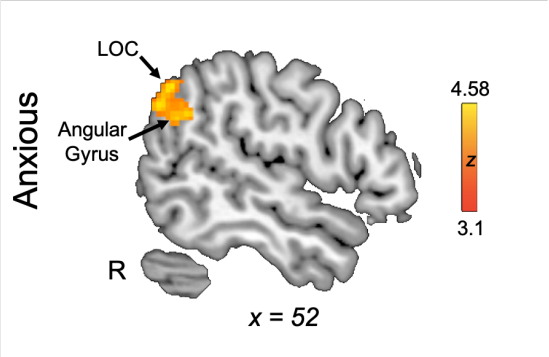
Parameter estimates extracted from *a priori* regions of interest during A. Look Aversive trials, B. Decrease Aversive trials, C. Look Neutral trials, D. Emotional reactivity, and E. Emotion regulation.

Figure 3.7 Neural activation during emotional reactivity



Whole-brain activation for the emotional reactivity contrast (Look Aversive>Look Neutral). IFG: Inferior Frontal Gyrus. MTG: Middle Temporal Gyrus. SFG: Superior Frontal Gyrus. LOC: Lateral Occipital Cortex.

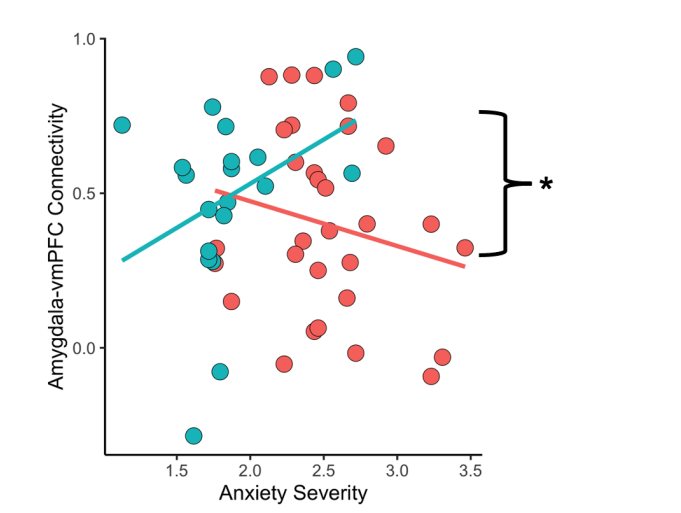
Figure 3.8 Neural activation during emotion regulation



Whole-brain activation for the emotion regulation contrast (Decrease Aversive>Look Aversive).

LOC: Lateral Occipital Cortex.

Figure 3.9 Beta-series amygdala-frontal connectivity



Amygdala-vmPFC functional connectivity as a function of anxiety severity. * $p < 0.05$

REFERENCES

Ahmed, S. P., Bittencourt-Hewitt, A., & Sebastian, C. L. (2015). Neurocognitive bases of emotion regulation development in adolescence. *Developmental Cognitive Neuroscience*, *15*, 11–25. https://doi.org/10.1016/J.DCN.2015.07.006

Albano, A. M., & Silverman, W. K. (1996). *The Anxiety Disorders Interview Schedule for DSM-IV: Clinician manual (child and parent versions)*. San Antonio, TX: Psychological Corporation.

Aldao, A., Nolen-Hoeksema, S., & Schweizer, S. (2010). Emotion-regulation strategies across psychopathology: A meta-analytic review. *Clinical Psychology Review*, *30*(2), 217–237. https://doi.org/10.1016/j.cpr.2009.11.004

Banks, S. J., Eddy, K. T., Angstadt, M., Nathan, P. J., & Luan Phan, K. (2007). Amygdala-frontal connectivity during emotion regulation. *Social Cognitive and Affective Neuroscience*, *2*, 303–312. https://doi.org/10.1093/scan/nsm029

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin*, *133*(1), 1–24. https://doi.org/10.1037/0033-2909.133.1.1

Beesdo-Baum, K., & Knappe, S. (2012). Developmental Epidemiology of Anxiety Disorders. *Child and Adolescent Psychiatric Clinics of North America*, *21*(3), 457–478. https://doi.org/10.1016/j.chc.2012.05.001

Buhle, J. T., Silvers, J. A., Wager, T. D., Lopez, R., Onyemekwu, C., Kober, H., … Ochsner, K. N. (2014). Cognitive Reappraisal of Emotion: A Meta-Analysis of Human Neuroimaging Studies. *Cerebral Cortex*, *24*(11), 2981–2990. https://doi.org/10.1093/cercor/bht154

Caballero, A., Granberg, R., & Tseng, K. Y. (2016). Mechanisms contributing to prefrontal cortex maturation during adolescence. *Neuroscience and Biobehavioral Reviews*, *70*. https://doi.org/10.1016/j.neubiorev.2016.05.013

Carthy, T., Horesh, N., Apter, A., Edge, M. D., & Gross, J. J. (2010). Emotional reactivity and cognitive regulation in anxious children. *Behaviour Research and Therapy*, *48*, 384–393. https://doi.org/10.1016/j.brat.2009.12.013

Carthy, T., Horesh, N., Apter, A., & Gross, J. J. (2010). Patterns of Emotional Reactivity and Regulation in Children with Anxiety Disorders. *J Psychopathol Behav Assess*, *32*, 23–36. https://doi.org/10.1007/s10862-009-9167-8

Diekhof, E. K., Geier, K., Falkai, P., & Gruber, O. (2011). Fear is only as deep as the mind allows. A coordinate-based meta-analysis of neuroimaging studies on the regulation of negative affect. *NeuroImage*, *58*(1), 275–285. https://doi.org/10.1016/j.neuroimage.2011.05.073

Dosenbach, N. U. F., Koller, J. M., Earl, E. A., Miranda-Dominguez, O., Klein, R. L., Van, A. N., … Fair, D. A. (2017). Real-time motion analytics during brain MRI improve data quality and reduce costs. *NeuroImage*, *161*, 80–93. https://doi.org/10.1016/j.neuroimage.2017.08.025

Etkin, A., Büchel, C., & Gross, J. J. (2015). The neural bases of emotion regulation. *Nature Reviews Neuroscience*, *16*(11), 693–700. https://doi.org/10.1038/nrn4044

Fitzgerald, J. M., Phan, K. L., Kennedy, A. E., Shankman, S. A., Langenecker, S. A., & Klumpp, H. (2017). Prefrontal and amygdala engagement during emotional reactivity and regulation in generalized anxiety disorder. *Journal of Affective Disorders*, *218*, 398–406. https://doi.org/10.1016/j.jad.2017.05.013

Gee, D. G., Humphreys, K. L., Flannery, J., Goff, B., Telzer, E. H., Shapiro, M., … Tottenham, N. (2013). A developmental shift from positive to negative connectivity in human amygdala-prefrontal circuitry. *Journal of Neuroscience*, *33*(10), 4584–4593. https://doi.org/10.1523/JNEUROSCI.3446-12.2013

Ginsburg, G. S., Becker-Haimes, E. M., Keeton, C., Kendall, P. C., Iyengar, S., Sakolsky, D., … Piacentini, J. (2018). Results From the Child/Adolescent Anxiety Multimodal Extended Long-Term Study (CAMELS): Primary Anxiety Outcomes. *J Am Acad Child Adolesc Psychiatry*, *57*(7), 471–480. https://doi.org/10.1016/j.jaac.2018.03.017

Greve, D. N., & Fischl, B. (2009). Accurate and robust brain image alignment using boundary-based registration. *NeuroImage*, *48*(1), 63–72. https://doi.org/10.1016/J.NEUROIMAGE.2009.06.060

Hantsoo, L., & Epperson, C. N. (2017). Anxiety Disorders Among Women: A Female Lifespan Approach. *FOCUS*, *15*(2), 162–172. https://doi.org/10.1176/appi.focus.20160042

Hare, T. A., Tottenham, N., Galvan, A., Voss, H. U., Glover, G. H., & Casey, B. J. (2008). Biological substrates of emotional reactivity and regulation in adolescence during an emotional go-nogo task. *Biological Psychiatry*, *63*(10), 927–934. https://doi.org/10.1016/J.BIOPSYCH.2008.03.015015

Hein, T. C., & Monk, C. S. (2017). Research Review: Neural response to threat in children, adolescents, and adults after child maltreatment - a quantitative meta-analysis. *Journal of Child Psychology and Psychiatry*, *58*(3), 222–230. https://doi.org/10.1111/jcpp.12651

Higa-McMillan, C. K., Francis, S. E., Rith-Najarian, L., & Chorpita, B. F. (2016). Evidence Base Update: 50 Years of Research on Treatment for Child and Adolescent Anxiety. *Journal of Clinical Child & Adolescent Psychology*, *45*(2), 91–113.

https://doi.org/10.1080/15374416.2015.1046177

Hofmann, S. G., Sawyer, A. T., Fang, A., & Asnaani, A. (2012). EMOTION DYSREGULATION MODEL OF MOOD AND ANXIETY DISORDERS. *Depression and Anxiety*, *29*(5), 409–416. https://doi.org/10.1002/da.21888

Kohn, N., Eickhoff, S. B., Scheller, M., Laird, A. R., Fox, P. T., & Habel, U. (2014). Neural network of cognitive emotion regulation — An ALE meta-analysis and MACM analysis. *NeuroImage*, *87*, 345–355. https://doi.org/10.1016/J.NEUROIMAGE.2013.11.001

Legerstee, J. S., Garnefski, N., Jellesma, F. C., Verhulst, F. C., & Utens, E. M. W. J. (2010). Cognitive coping and childhood anxiety disorders. *European Child and Adolescent Psychiatry*, *19*(2), 143–150. https://doi.org/10.1007/s00787-009-0051-6

Lewis, A. R., Zinbarg, R. E., & Durbin, C. E. (2010). Advances, Problems, and Challenges in the Study of Emotion Regulation: A Commentary. *Journal of Psychopathology and Behavioral Assessment*, *32*(1), 83–91. https://doi.org/10.1007/s10862-009-9170-0

March, J. S., Parker, J. D. A., Sullivan, K., Stallings, P., & Conners, C. K. (1997). The Multidimensional Anxiety Scale for Children (MASC): Factor Structure, Reliability, and Validity. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*(4), 554–565. https://doi.org/10.1097/00004583-199704000-00019

McLaughlin, K. A., Peverill, M., Gold, A. L., Alves, S., & Sheridan, M. A. (2015). Child Maltreatment and Neural Systems Underlying Emotion Regulation. *Journal of the American Academy of Child & Adolescent Psychiatry*, *54*(9), 753–762. https://doi.org/10.1016/j.jaac.2015.06.010

McRae, K., Gross, J. J., Weber, J., Robertson, E. R., Sokol-Hessner, P., Ray, R. D., … Ochsner, K. N. (2012). The development of emotion regulation: an fMRI study of cognitive

reappraisal in children, adolescents and young adults. *Social Cognitive and Affective Neuroscience*, *7*, 11–22. https://doi.org/10.1093/scan/nsr093

McRae, K., Misra, S., Prasad, A. K., Pereira, S. C., & Gross, J. J. (2012). Bottom-up and top-down emotion generation: implications for emotion regulation. *Social Cognitive and Affective Neuroscience*, *7*(3), 253–262. https://doi.org/10.1093/scan/nsq103

Merikangas, K. R., He, J., Burstein, M., Swanson, S. A., Avenevoli, S., Cui, L., … Swendsen, J. (2010). Lifetime Prevalence of Mental Disorders in U.S. Adolescents: Results from the National Comorbidity Survey Replication–Adolescent Supplement (NCS-A). *Journal of the American Academy of Child & Adolescent Psychiatry*, *49*(10), 980–989. https://doi.org/10.1016/J.JAAC.2010.05.017

Meyer, H. C., & Lee, F. S. (2019). Translating Developmental Neuroscience to Understand Risk for Psychiatric Disorders. *American Journal of Psychiatry*, *176*(3), 179–185. https://doi.org/10.1176/appi.ajp.2019.19010091

Mumford, J. A., Turner, B. O., Ashby, F. G., & Poldrack, R. A. (2012). Deconvolving BOLD activation in event-related designs for multivoxel pattern classification analyses. *NeuroImage*, *59*(3), 2636–2643. https://doi.org/10.1016/J.NEUROIMAGE.2011.08.076

Ochsner, K. N., Silvers, J. A., & Buhle, J. T. (2012). Functional imaging studies of emotion regulation: a synthetic review and evolving model of the cognitive control of emotion. *Annals of the New York Academy of Sciences*, *1251*, E1–E24. https://doi.org/10.1111/j.1749-6632.2012.06751.x

Peris, T. S., Compton, S. N., Kendall, P. C., Birmaher, B., Sherrill, J., March, J., … Piacentini, J. (2015). Trajectories of change in youth anxiety during cognitive-behavior therapy. *Journal of Consulting and Clinical Psychology*, *83*(2), 239–252. https://doi.org/10.1037/a0038402

Rissman, J., Gazzaley, A., & D'Esposito, M. (2004). Measuring functional connectivity during distinct stages of a cognitive task. *NeuroImage*, *23*(2), 752–763. https://doi.org/10.1016/J.NEUROIMAGE.2004.06.035

Schäfer, J. Ö., Naumann, • Eva, Emily, •, Holmes, A., Tuschen-Caffier, B., & Samson, A. C. (2017). Emotion Regulation Strategies in Depressive and Anxiety Symptoms in Youth: A Meta-Analytic Review. *Journal of Youth and Adolescence*, *46*, 261–276. https://doi.org/10.1007/s10964-016-0585-0

Silvers, J. A., Insel, C., Powers, A., Franz, P., Helion, C., Martin, R. E., … Ochsner, K. N. (2016). vlPFC–vmPFC–Amygdala Interactions Underlie Age-Related Differences in Cognitive Regulation of Emotion. *Cerebral Cortex*, *27*(7), bhw073. https://doi.org/10.1093/cercor/bhw073

Silvers, J. A., McRae, K., Gabrieli, J. D. E., Gross, J. J., Remy, K. A., & Ochsner, K. N. (2012). Age-related differences in emotional reactivity, regulation, and rejection sensitivity in adolescence. *Emotion*, *12*(6), 1235–1247. https://doi.org/10.1037/a0028297

Silvers, J. A., & Moreira, J. F. G. (2017). Capacity and tendency: A neuroscientific framework for the study of emotion regulation. *Neuroscience Letters*, *693*, 35–39. https://doi.org/10.1016/j.neulet.2017.09.017

Silvers, J. A., Shu, J., Hubbard, A. D., Weber, J., & Ochsner, K. N. (2015). Concurrent and lasting effects of emotion regulation on amygdala response in adolescence and young adulthood. *Developmental Science*, *18*(5), 771–784. https://doi.org/10.1111/desc.12260

Sloan, E., Hall, K., Moulding, R., Bryce, S., Mildred, H., & Staiger, P. K. (2017). Emotion regulation as a transdiagnostic treatment construct across anxiety, depression, substance, eating and borderline personality disorders: A systematic review. *Clinical Psychology*

Review, *57*, 141–163. https://doi.org/10.1016/j.cpr.2017.09.002

Suveg, C., Sood, E., Comer, J. S., & Kendall, P. C. (2009). Changes in Emotion Regulation Following Cognitive-Behavioral Therapy for Anxious Youth. *Journal of Clinical Child & Adolescent Psychology*, *38*(3), 390–401. https://doi.org/10.1080/15374410902851721

Suveg, C., & Zeman, J. (2004). Emotion Regulation in Children With Anxiety Disorders. *Journal of Clinical Child and Adolescent Psychology*, *33*(4), 750–759. https://doi.org/10.1207/s15374424jccp3304_10

Wechsler, D. (1999). Wechsler Abbreviated Scale of Intelligence (WASI). San Antonio, TX: Psychological Corporation.

Woolrich, M. W., Ripley, B. D., Brady, M., & Smith, S. M. (2001). Temporal Autocorrelation in Univariate Linear Modeling of FMRI Data. *NeuroImage*, *14*(6), 1370–1386. https://doi.org/10.1006/NIMG.2001.0931

Yarkoni, T., Poldrack, R. A., Nichols, T. E., Van Essen, D. C., & Wager, T. D. (2011). Large-scale automated synthesis of human functional neuroimaging data. *Nature Methods*, *8*(8), 665–670. https://doi.org/10.1038/nmeth.1635

Young, K. S., Burklund, L. J., Torre, J. B., Saxbe, D., Lieberman, M. D., & Craske, M. G. (2017). Treatment for social anxiety disorder alters functional connectivity in emotion regulation neural circuitry. https://doi.org/10.1016/j.pscychresns.2017.01.005

Young, K. S., Sandman, C. F., & Craske, M. G. (2019, April 1). Positive and negative emotion regulation in adolescence: links to anxiety and depression. *Brain Sciences*. MDPI AG. https://doi.org/10.3390/brainsci9040076

CHAPTER 4

Probabilistic Reward Learning in Adolescents across an Anxiety Continuum

Reward learning is refined across adolescence and, neurobiologically, is marked by reward network activation during anticipation of and receipt of reward. Relative to non-anxious peers, youth with anxiety demonstrate higher striatal engagement during reward anticipation as well as dampened reward network activation during receipt of reward. In a sample of 137 children and early adolescents (65 girls; M_{age} = 11.3; SD_{age} = 1.39) who varied in anxiety symptomatology, we investigated the role of decision value and prediction error in a probabilistic reward learning task to elucidate the mechanisms that may contribute to these altered neurobiological phenotypes. Behaviorally, all youth learned which stimuli were reliably associated with rewards and which were associated with high relative to low rewards. Neurobiologically, decision value exerted greater modulation on task-related activity during non-predictive relative to predictive cues regardless of anxiety, perhaps reflecting on-going efforts to characterize the predictive validity of stimuli which do not reliably predict rewards. The direct contrast of non-predictive relative to predictive stimuli revealed activation in precuneus and posterior cingulate cortex – the hubs of the default mode network – which could reflect efforts to learn stimulus-reward associations. ROI analyses showed that greater nucleus accumbens activation during predictive relative to non-predictive stimuli was associated with higher accuracy for youth with the most anxiety. Prediction error modulated incorrect responses, particularly in fronto-striatal regions. In the contrast of predictive correct relative to incorrect responses, greater prediction error related to greater activation of bilateral nucleus accumbens and right putamen; greater activation in these regions corresponded with greater tolerance of

uncertainty. Youth across a spectrum of anxiety showed similar learning, though youth with the highest anxiety and intolerance of uncertainty demonstrated the strongest brain-behavior relationships reflecting altered decision value and prediction error signaling.

INTRODUCTION

Reward-seeking is a cross-cultural hallmark of adolescence across typically developing youth (Duell et al., 2018). Receipt of reward results in strong engagement of brain regions, such as the striatum, involved in processing motivationally salient stimuli (Galván, 2010). Cues that reliably predict later rewards activate similar regions of the brain while anticipating future reward (Silverman, Jedd, & Luciana, 2015). As youth develop, reward anticipation elicits even greater striatal activation than receipt of reward (Hoogendam, Kahn, Hillegers, van Buuren, & Vink, 2013). This shift of increased activation to anticipation relative to reward outcome suggests a developmental refinement of reward-based learning. Cues that precede higher rewards compared to lower rewards result in even greater anticipatory activation of reward processing regions, indicating that the expected value of rewards plays an important role in reward learning (Cohen et al., 2010; Lahat, Benson, Pine, Fox, & Ernst, 2016).

In contrast, youth at-risk for, or diagnosed with, anxiety often exhibit risk-aversion (Charpentier, Aylward, Roiser, & Robinson, 2017) potentially given high levels of intolerance toward uncertain or risky situations (Osmanağaoğlu, Creswell, & Dodd, 2018), and error monitoring (Buzzell et al., 2017). These features of youth anxiety may make the anticipatory period particularly distressing and arousing. Indeed, relative to typically developing youth, youth with anxiety and at-risk youth display greater striatal engagement during reward anticipation (Guyer et al., 2014, 2012, 2006) which scales as a function of anxiety severity (Lahat et al., 2016), especially when rewards are earned based on task performance (Bar-Haim et al., 2009;

Benson, Guyer, Nelson, Pine, & Ernst, 2015). In stark contrast to their typically developing counterparts, youth with anxiety and at-risk youth demonstrate heightened reward network activation during *loss* of reward relative to gain of reward (Helfinstein et al., 2011). This seemingly paradoxical finding may represent enhanced negative prediction error signaling in response to aversive outcomes (Helfinstein, Fox, & Pine, 2012), which is in line with the predisposition of anxious youth to exhibit heightened awareness of their task performance.

Both decision value, defined as the value associated with a given stimulus, and prediction error, or the difference between expected and received reward, can be estimated from behavior using simple reinforcement learning models (e.g., Rescorla-Wagner). Such models estimate the signals that shape learning including α (alpha; learning rate), which approximates how behavior changes following feedback, and β (beta; inverse temperate parameter) which approximates the tendency to pursue high value rewards. The resulting trial-by-trial estimates of decision value and prediction error can be related to fluctuations in brain activation to assess how these learning signals modulate brain activation during anticipation and receipt of rewards. Parsing these components of reward learning can provide a mechanistic approach to understanding how anxiety relates to reward anticipation and receipt of reward separately.

In this pre-registered study, we used a probabilistic reward learning task to examine reward anticipation and receipt of reward in a sample of children and early adolescents across a continuum of anxiety severity. We hypothesized that youth would respond more quickly and more accurately in response to predictive than non-predictive stimuli, and that higher anxiety would relate to slower response times but would not affect accuracy. Similarly, we predicted that decision value would be greater for predictive than non-predictive stimuli, and that anxiety severity would relate to greater decision value for predictive, but not non-predictive, stimuli.

Higher anxiety was hypothesized to relate to larger negative prediction errors (during incorrect responses) but be unrelated to positive prediction error (during correct responses). We hypothesized greater activation in reward processing regions (e.g., ventral and dorsal striatum, hippocampus, dorsal anterior cingulate cortex, orbitofrontal cortex, and ventromedial prefrontal cortex) during anticipation of reward during predictive relative to non-predictive stimuli, as a function of decision value. While we expected greater reward network activation for all youth, we predicted that this relationship would be strongest for youth with the highest anxiety. We hypothesized greater ventral striatum activation when contrasting correct relative to incorrect feedback during receipt of reward, as a function of positive prediction error; however, we predicted that youth with higher anxiety would have lower positive prediction errors, and thus lower striatal signal during rewarding feedback. In contrast, comparing incorrect relative to correct feedback, we anticipated greater striatal activation as a function of higher negative prediction errors, which would be highest for youth with the highest anxiety. Concomitant brain development and changes in youth's socio-emotional environment render the life stage of adolescence especially prime for reward-driven approach behaviors, risk-averse avoidance behaviors, and complex interactions across approach-avoidance systems (Baker & Galván, 2020). Applying reinforcement learning models to reward learning can thus further our understanding of the nuanced relationship between anxiety and risk-taking in adolescence.

MATERIALS AND METHODS

Study Participants

174 youth were recruited from the greater Los Angeles area to complete a probabilistic reward learning task at UCLA, as part of a larger 3-wave longitudinal study. Of these, 23 were

not scanned: 13 visits were canceled due to the COVID-19 pandemic and 10 youth were unable to proceed with the scan due to discomfort with the MR environment. Data were unable to be analyzed due to technical errors for 15 participants. Youth were eligible to participate in the study if they were between the ages of 9-13, free of metal or any contraindications to imaging, had no medical or psychiatric conditions contraindicating study participation (e.g., suicidality), were not taking any psychotropic medication, and were not receiving any treatment or medication for anxiety. Recruitment efforts were targeted to over-sample from highly anxious individuals (as assessed by a dimensional anxiety measure), as these youth are at greatest risk for crossing over diagnostically into anxiety disorder during follow-up assessments within the study period. Written informed consent and assent were obtained from all legal guardians and study participants in accordance with the UCLA Institutional Review Board. Youth were compensated for study participation with $100 and were eligible to win up to an additional $10 based on their task performance during the fMRI tasks (up to $5 per task). Data were excluded from analysis if fMRI data for any runs exceeded 1 mm mean relative motion (n=4 runs; no youth were excluded). Data are presented for 137 children and adolescents 9-13 years old (65 girls; M_{age} = 11.3; SD_{age} = 1.39; Table 4.1).

Behavioral Measures

All participants were administered the 41-item self-report Screen for Child Anxiety and Related Emotional Disorders (SCARED) as a measure of dimensional anxiety severity (Birmaher et al., 1997). Data were missing for 2 youth who were excluded for any analyses including the SCARED. Youth were asked to decide how often several statements describing symptoms of anxiety are true for them on a scale from 0 indicating “Not True or Hardly Ever True” to 1 indicating “Somewhat True or Sometimes True” to 2 indicating “Very True or Often

True." A higher average score on the SCARED indicates higher levels of anxiety severity. Solely for recruitment purposes (to capture a full continuum of anxiety severity), youth were binned using the SCARED into those who show little-to-no symptoms (n=56; score: 0-17), those in the moderate range (n=41; score: 17-25), and those in the highly symptomatic range (n=38; score: 25 and above). All participants were also evaluated by a trained clinical psychologist using the Anxiety Disorder Interview Schedule IV to assess for an anxiety disorder (Albano & Silverman, 1996).

Parents of participants completed the 17-item Responses to Uncertainty and Low Environmental Structure (RULES) as a measure of dimensional intolerance of uncertainty (Sanchez et al., 2017). Data were missing for 5 youth who were excluded for any analyses including the RULES. Parents report on how accurately descriptions characterize their child on a 5-point scale from 1 indicating "not at all" to 5 indicating "very much." A higher average score on the RULES indicates higher intolerance of uncertainty.

MRI Data Acquisition

Task fMRI data were obtained using a Siemens 3T Prisma (20-channel head coil) at UCLA. For registration, each participant also received a MPRAGE scan (TR=1900ms, TE=2.26ms, FOV=250mm, 176 slices, slice thickness 1mm, in-plane voxel size 1.0x1.0mm). The T2*-weighted task fMRI sequence (TR=800ms, TE=37ms, FOV=208mm, 72 slices, slice thickness 2mm, in-plane voxel size 2x2mm) was acquired while participants played the T-Shirt Game (Cohen et al., 2010), a probabilistic reward learning task. Participants performed 2 runs (~14 minutes; 72 trials per run) of the T-Shirt Game (Figure 4.1) presented via Psychtoolbox Version 2 through Matlab R2012B. Prior to data collection, participants were given task instructions and practiced the task. Trials were presented in an event-related design. Participants

were shown abstract stimuli (3,000 ms averaged, 2,500-5,000 ms range, jittered; 6 distinct fractal patterns) referred to as "t-shirts" and asked to classify them as belonging to one of two schools (Northern University or Eastern University) using a 2-button response box. Response time was measured as the duration in milliseconds from stimulus onset to participant response. Stimuli were followed by feedback (1,250 ms) displaying the correct response; if their response matched the outcome, the feedback also included a monetary reward of gold coin(s) which were converted to cash and included in participant compensation. Stimuli were either predictable (associated 83% of the time with one of the two categories; 2/3 of stimuli) or non-predictable (associated 50% of the time with each category; 1/3 of stimuli); stimuli were also associated with either large rewards (5 gold coins; 1/2 of stimuli) or small rewards (1 gold coin; 1/2 of stimuli). Accuracy was measured as the proportion of optimal responses; for example, "Northern" would be the correct response for a predictable stimuli associated with Northern, even if feedback on any given trial was "Eastern." For non-predictable stimuli which do not have an optimal response, a response of Northern was used as optimal for calculations (Cohen et al., 2010). Feedback was followed by an inter-trial interval (750 ms, 150-1,500 ms range, jittered). Stimulus order was the same within-run across all participants but differed between runs.

Behavioral Data Analysis

We used a simple reinforcement learning algorithm (Rescorla-Wagner) to model the trial-by-trial variance in participants' choices (Rescorla & Wagner, 1972). All analyses were implemented in Matlab R2019b with the use of the mfit package (https://github.com/sjgershm/mfit). Rescorla-Wagner modeling captures the relationships between choices and both prediction error (δ), or the difference between expected and received reward (r), as well as decision value (V). This model was estimated according to 2 free

parameters: alpha (α, indexing how quickly behavior is modified following feedback where higher values indicate rapid behavior changes) and beta (β, the inverse temperature parameter, indexing stochasticity in choice behavior where higher values indicate prioritizing higher value choices). Decision value is updated on each trial based on whether their received reward differed from expectations and is weighted by both learning rate and the inverse temperature parameter. Alpha [0: 0.01: 1] and beta [0: 0.01: 5] were estimated for each run of each participant separately using fminunc which finds the minimum of an unconstrained multivariate function to find the optimal pair of alpha and beta that best simulate participant choice data. On each trial (*t*), prediction error and decision value were updated as follows:

$$\delta = (r_t - V_t)$$
$$V_{t+1} = V_t + \alpha * \delta_t$$

Similarly, on each trial, the decision value associated with both choices was updated via a softmax choice function as follows:

$$V_{t+1} = \beta * V_t$$

To determine the recoverability of the better fitting model, data were simulated from a model with 1 learning rate (Model 1) and a model with 2 learning rates (Model 2, which separated alpha into positive alpha and negative alpha to index learning following rewards or absence of reward, respectively) 10,000 times. Then, the simulated data were fit by both Model 1 and Model 2 to compare model fit as assessed by the Bayesian information criterion (BIC). A confusion matrix was created to demonstrate model fitting results (Table 4.2).

To determine which model was better at fitting real participant data, we compared exceedance probability (XP) values; XP values measure the probability that a model is more likely compared to other tested models, where a higher value indicates a greater probability. The

number of participants better fit by Model 1 compared to Model 2 was also assessed using BIC for each run separately to examine if model fit differed between runs (Figure 4.2). XP values averaged across runs for both models were also correlated with SCARED values to ensure that the extent to which a model fit participant data was not influenced by anxiety severity (Figure 4.3).

Parameter recovery for the winning model (Model 1) was conducted on simulated data to ensure that alpha and beta values could be recovered within the range of values to be assessed on participant data. Choice and reward data were simulated using paired combinations of alpha [0: 0.01: 1] and beta [0: 0.01: 5]. Simulated data were then subjected to model fitting to estimate the best fitting alpha and beta parameters that could have given rise to the simulated choice and reward data. Parameter recovery was assessed via correlations between simulated and fit alpha and beta parameters, as well as scatterplots (Figure 4.4).

Main effects of stimulus type (predictable vs. non-predictable), reward size (high vs. low), and stimulus type x reward size interactions were investigated for both mean accuracy (proportion of optimal responses) and response time using 2 separate linear mixed-effects models with a random intercept for each participant to account for repeated measures within participant using lme4 in R; the lmerTest function was used to provide *p*-values. Anxiety was added as a covariate in separate analyses, followed by gender and age. Exploratory analyses examined how decision value interacted with anxiety severity to affect accuracy and response time.

MRI Data Analysis

Analyses were performed using FMRIB's Software Library (FSL) 5.0.9 (www.fmrib.ox.ac.uk/fsl). Task data underwent motion correction using MCFLIRT, removal of non-brain matter using FSL brain extraction tool (BET), spatial smoothing (5 mm FWHM

Gaussian kernel), non-linear high-pass filtering (100-s cutoff). EPI images were registered to the corresponding Magnetization-Prepared Rapid Gradient-Echo (MPRAGE) scan using boundary-based registration (Greve & Fischl, 2009) and then to standard Montreal Neurological Institute (MNI) space (MNI 152, T1 2mm) using linear registration with 12 degrees of freedom using FSL FMRIB's Linear Image Registration Tool (FLIRT). Data were pre-whitened to correct for autocorrelation using FILM in FSL (Woolrich, Ripley, Brady, & Smith, 2001). 24 motion regressors were included as nuisance regressors, including 3 translation and 3 rotation regressors, as well as their 1st and 2nd derivatives, and the difference between their 1st and 2nd derivatives, as recommended for robustly reducing motion related noise in task fMRI data as well as spin history related artifacts (Caballero, Granberg, & Tseng, 2016). Additionally, individual spike regressors were created using FSL Motion Outliers to regress trials with ≥ 1 mm framewise displacement. First level analyses were conducted using fixed-effects modeling with FLAME-1 with both unmodulated and parametrically modulated EVs. The following EVs were created for task stimuli: high reward predictive stimuli, low reward predictive stimuli, high reward non-predictive stimuli, low reward non-predictive stimuli. The following EVs were created for task feedback: high reward predictive correct feedback, high reward predictive incorrect feedback, low reward predictive correct stimuli, low reward predictive incorrect stimuli, high reward non-predictive correct stimuli, high reward non-predictive incorrect stimuli, low reward non-predictive correct stimuli, low reward non-predictive incorrect stimuli. Feedback was assigned probabilistically. Corresponding unmodulated and modulated EVs were orthogonalized due to high expected collinearity given shared onset times and durations (Mumford, Poline, & Poldrack, 2015). Second level analyses were conducted to collapse across task runs.

Group level analyses were conducted using mixed-effects modeling and thresholded at $z > 3.1$ ($p < 0.001$) and corrected for multiple comparisons at $p < 0.05$. Modulation of task-related activation by decision values during anticipation were examined for predictive stimuli and non-predictive stimuli separately. The contrasts of predictive > non-predictive and non-predictive > predictive were employed to investigate regions where decision value modulated task-related activation more for one condition over the other. In an exploratory analysis, bilateral nucleus accumbens (NAcc) activation during non-predictive stimuli was subtracted from activation during predictive stimuli to index the extent to which activation was greater when viewing predictive stimuli – referred to as a "NAcc predictive index." Higher values on the NAcc predictive index indicate greater NAcc activation during predictive relative to non-predictive stimuli; lower value indicate greater activation during non-predictive relative to predictive stimuli. We investigated the extent to which the NAcc predictive index would relate to task accuracy, as a function of anxiety severity.

Modulation of task-related activation by prediction errors during feedback processing were examined when participants were correct and incorrect separately. The contrasts of correct > incorrect and incorrect > correct were employed to investigate regions where prediction error modulated task-related activation more for one condition over the other. In an exploratory analysis, we examined the contrast of correct > incorrect for predictive and non-predictive stimuli separately.

RESULTS

Model recoverability from simulated data demonstrated that data generated by either Model 1 or Model 2 were best fit by Model 1. Similar results were evident from model

comparison results based on real participant data which demonstrated that for both tasks runs, Model 1 fit participant data better than Model 2. Further, XP values comparing model fit on task data averaged across runs demonstrated that the probability that Model 1 generated participant data was 73% whereas the probability that Model 2 generated participant data was 27%. There was no significant correlation observed between anxiety severity and XP for Model 1 (r = -0.01, p = 0.88) or for Model 2 (r = 0.01, p = 0.88), suggesting that model fit was not related to anxiety severity. Parameter recovery analyses based on α and β values from Model 1 revealed a strong relationship between simulated and fitted α (r = 0.97, $p < 0.0001$) and β (r = 0.83, $p < 0.0001$). Overall, results suggest the superior performance of Model 1 compared to Model 2.

All participants were more accurate for predictive stimuli relative to non-predictive stimuli (β=-0.09, SE=0.02, 95% CI=[-0.13, -0.06], p<0.0001; Figure 4.5a) and, at a trend level, more accurate for high reward relative to low reward stimuli (β=-0.03, SE=0.02, 95% CI=[-0.07, 0], p=0.09; Table 4.3; Figure 4.5a). A significant interaction between stimulus type and reward size revealed that accuracy differed between predictive and random stimuli that were associated with high rewards, but much less so for low rewards (β=0.06, SE=0.03, CI=(0.01, 0.11), p=0.01; Figure 4.5a). There was no significant effect of age or gender on accuracy.

All participants responded faster for predictive stimuli relative to non-predictive stimuli (β=40, SE=12.4, 95% CI=[15.8, 64.3], p=0.001; Figure 4.5b) and for high reward relative to low reward stimuli (β=43.7, SE=12.4, 95% CI=[19.5, 67.9], p=0.0004; Figure 4.5b). There was no significant interaction between stimulus type and reward size. There was no significant effect of age or gender on response time.

There was no relationship between learning rate and anxiety severity (r=0.001, p=0.90), and this relationship was unchanged when accounting for age or gender. Across all youth,

decision values were greater for stimuli that were predictive relative to non-predictive (β=-0.28, *SE*=0.08, 95% CI=[-0.44, -0.12], p=0.0007; Figure 4.5c) and stimuli associated with high relative to low rewards (β=-1.2, *SE*=0.08, 95% CI=[-1.37, -1.05], p<0.0001). A significant stimulus type by reward size interaction showed that predictive and non-predictive stimuli differed more for high rewards than for low rewards (β=0.23, *SE*=0.16, 95% CI=[0.002, 0.46], p=0.048). There was no effect age or gender on decision values.

Across all youth, prediction errors were higher for high rewards relative to low rewards (β=-4.01, *SE*=0.03, 95% CI=[-4.07, -3.95], p<0.0001) and correct responses relative to incorrect responses (β=-4.96, *SE*=0.03, 95% CI=[-5.01, -4.90], p<0.0001), but there was no main effect of stimulus type. There was a significant three-way interaction between stimulus type, reward size, and accuracy (β=0.22, *SE*=0.06, 95% CI=[0.10, 0.34], p=0.0003) such that prediction errors were similar for all incorrect responses (across both stimulus type and reward size; Figure 4.5e) but for correct responses (Figure 3d), prediction errors were higher for high rewards of both predictive and non-predictive stimuli relative to low rewards. There was no effect of anxiety, age, or gender on prediction errors.

An exploratory analysis revealed no significant relationship between anxiety and decision value. However, there was a significant interaction between decision value and stimulus type, such that greater decision value related to higher accuracy for predictive stimuli, but lower accuracy for non-predictive stimuli (Figure 4.6a). An exploratory analysis revealed a significant stimulus type x reward size x decision value x anxiety interaction (Figure 4.6b). For both predictive and non-predictive high reward stimuli, response time was not modulated by anxiety severity across all levels of decision value. For low values of decision value, youth responded faster for non-predictive stimuli but not for predictive stimuli. Conversely, for high values of

decision value, youth responded more slowly for non-predictive stimuli but not for predictive stimuli.

Whole-brain analyses revealed that the magnitude of decision values modulated activation during reward anticipation for both predictive and non-predictive stimuli, though more modulation was observed for non-predictive stimuli (Table 4.3). Decision values were positively associated with BOLD activity when viewing both predictive (Figure 4.7a) and non-predictive (Figure 4.7b) stimuli in visual processing regions, motor areas, and precuneus cortex. For non-predictive stimuli, decision values were additionally associated with greater activation in medial and lateral frontal cortex, as well as temporal regions. There were no regions that demonstrated greater activation during predictive relative to non-predictive stimuli. The contrast of non-predictive to predictive stimuli revealed greater activation in bilateral precuneus and left posterior cingulate (Figure 4.7c).

In a targeted exploratory analysis, bilateral nucleus accumbens (NAcc) activation did not differ between stimulus type or reward size, nor was there a significant stimulus type x reward size interaction (Figure 4.7d). Examining the interaction between the NAcc predictive index and anxiety severity showed that greater NAcc predictive index values in youth with the highest anxiety related to greater accuracy whereas smaller values related to worse accuracy (Figure 4.7e).

Whole brain analyses investigating regions that showed greater activation as a function of prediction errors (Table 4.4) demonstrated greater left lateral occipital cortex (LOC) activation during correct responses (Figure 4.8a). More regions demonstrated modulation as a function of prediction error for incorrect responses, including bilateral LOC, right parietal opercular cortex, left postcentral gyrus, right frontal pole, bilateral putamen, and left pallidum (Figure 4.8b). When

directly contrasting activation in regions that were modulated by prediction errors, the contrast of correct > incorrect responses yielded significant clusters in occipital regions such as bilateral occipital fusiform and lingual gyri (Figure 4.8c). The contrast of incorrect > correct responses revealed greater activation as a function of prediction error in precuneus, pre- and postcentral gyri and SMA, superior and middle frontal gyri, right supramarginal and parietal opercular cortices, left insular and central opercular cortices, as well as subcortical regions including the left thalamus, caudate, and putamen (Figure 4.8d).

An exploratory analysis examined the contrast of correct > incorrect responses for predictive and non-predictive stimuli separately. There was no significant activation observed in the contrast of non-predictive correct > incorrect responses. However, the contrast of predictive correct > incorrect responses revealed greater activation as a function of prediction error in bilateral nucleus accumbens and right putamen (Figure 4.8e). Activation from the left NAcc cluster did not correlate with either anxiety severity or intolerance of uncertainty. Activation from right NAcc and putamen cluster did not relate to anxiety severity but was negatively correlated with intolerance of uncertainty ($r = 0.24$, $p = 0.02$ after Benjamini-Hochberg correction for multiple comparisons), such that greater intolerance of uncertainty was related to less activation (Figure 4.8f).

DISCUSSION

In this study, we examined how decision value and prediction error relate to probabilistic learning in youth who displayed a range of anxiety symptomatology to better understand altered brain and behavioral reward-learning in youth with anxiety. Regardless of anxiety severity, youth performed better for stimuli that were associated with rewards. Task performance was influenced

by decision value, such that higher decision value for predictive stimuli yielded greater accuracy. Anxiety severity affected response times such that youth with the greatest anxiety responded faster for high value non-predictive stimuli and slower for low value non-predictive stimuli. Across reward size and anxiety severity, decision value modulated brain activation during processing of ambiguous, or non-predictive stimuli. Targeted bilateral nucleus accumbens (NAcc) analyses revealed that, for youth with the greatest anxiety, greater activation when viewing predictive relative to non-predictive stimuli afforded the greatest accuracy. Similar to decision value processing, prediction error modulated brain activation during processing of incorrect responses, or when expectations deviated from reality. Right NAcc and putamen activation during predictive correct responses relative to incorrect responses negatively correlated with intolerance of uncertainty; youth who were more tolerant toward ambiguity showed the greatest activation in these hubs of the reward network.

As expected based on prior work using this reinforcement learning paradigm (Cohen et al., 2010), youth were more accurate and faster for stimuli that were more predictable and relatively more rewarding. Youth also achieved greater task accuracy when allocating greater decision value for predictive stimuli, though worse accuracy when greater decision value was afforded to non-predictive stimuli. This interaction between decision value and stimulus type highlights that greater ability to discriminate between predictive and non-predictive stimuli is key to reward learning. Further, we observed a relationship between decision value and anxiety severity for low rewards whereby the most anxious youth were spending the least amount of time before making a choice for non-predictive stimuli of low decision value but the most amount of time before making a choice for non-predictive stimuli of high decision value. This finding demonstrates an interesting paradox in youth with anxiety – more anxious youth appropriately

spent little time on non-predictive low reward stimuli, which are unlikely to yield rewards, but spent more time on high value non-predictive stimuli, which are also unlikely to yield rewards. Youth with anxiety are often concerned with their performance (Bar-Haim et al., 2009; Guyer et al., 2006) which may result in greater deliberation on all stimuli regardless of actual predictive validity. Interestingly, youth with higher anxiety only demonstrated slowed responding for high value, but not low value, non-predictive stimuli. Youth with higher anxiety were able to discern which of the non-predictive stimuli were associated with higher rewards, but the high value afforded to these stimuli resulted in them responding more slowly even though greater deliberation would not yield to greater likelihood of rewards. Given that higher decision value for non-predictive stimuli related to worse accuracy, this misallocation of decision value may be detrimental to reward learning in youth with anxiety.

Results from whole-brain analyses ran contrary to our hypotheses. We did not observe greater activation in any brain regions during predictive relative to non-predictive stimuli as a function of decision value. However, when examining task-related activation within condition, there were overall more widespread effects of decision value variability on brain response during non-predictive stimuli processing. It might be the case that the unpredictable nature of the non-predictive stimuli engaged brain regions associated with value tracking as youth were attempting to make sense of and understand the predictive validity – or lack thereof – of the non-predictive stimuli. Given the regions modulated as a function of decision value, including inferior frontal and paracingulate gyri, it is plausible that regions involved with encoding and tracking stimulus value (DePasque & Galván, 2017) were engaged during non-predictive stimuli processing. Interestingly, the between-condition contrast of non-predictive > predictive stimuli revealed significant activation in the hubs of the default mode network (DMN): bilateral precuneus and

posterior cingulate cortex. While DMN activation is often thought to be suppressed during task engagement (Raichle et al., 2001), this suppression may be lifted during learning or when learned associations deviate from expectations (Pearson, Heilbronner, Barack, Hayden, & Platt, 2011). Relative to predictive stimuli, non-predictive stimuli may necessitate on-going monitoring and flexibility as represented by greater DMN activation.

Targeted bilateral NAcc analyses revealed that greater activation during predictive relative to non-predictive stimuli for youth with the greatest anxiety resulted in the higher accuracy. Conversely, these same youth evinced the lowest accuracy when activation was greater for non-predictive relative to predictive stimuli. These results are in line with neurobiological susceptibility to the environment model, which posits that susceptible individuals may thrive in certain environments but do poorly in others, whereas less susceptible individuals will be less influenced by their environment overall (Ellis, Boyce, Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2011). Brain function can be thought of as an "environment" or characteristic influencing susceptible individuals (Guyer, 2020). Youth who are the most susceptible – those experiencing the greatest anxiety – perform extremely well when NAcc predictive index is higher, but poorly when NAcc predictive index is lowest. Given the central role of reward processing in healthy adolescent development, tracking the development of NAcc predictive index longitudinally may be useful for understanding vulnerabilities faced by the most susceptible youth.

Results from whole-brain analyses during feedback processing did not relate to anxiety severity, nor did results align with our predictions when comparing correct relative to incorrect responses. When examining activation within correct and incorrect responses separately, more modulation was observed for incorrect responses than for correct responses. Between-condition

contrasts similarly demonstrated greater modulation when youth were processing feedback alerting them to an incorrect response in regions including the precuneus, insula, and basal ganglia regions. These results may suggest that processing incorrect feedback recruits brain regions involved with feedback monitoring and learning, as the incorrect feedback alerted youth that they may need to change their strategy or correct their stimulus associations. Greater striatal activation was observed for correct (vs. incorrect) responses, but only for predictive feedback. Further, youth who were described as less tolerant of uncertainty by their parents exhibited the least activation in reward regions for correct (vs. incorrect) responses. Higher tolerance toward ambiguity has been shown to drive risk-taking in youth (Tymula et al., 2012; van den Bos & Hertwig, 2017); struggling with this ambiguity may dampen the rewarding effects of responding correctly.

These findings should be interpreted with some limitations in mind. Due to the cross-sectional design of this study, it was not possible to assess the directionality of the observed effects; longitudinal studies are crucial for identifying how the development of anxiety over time relates to decision value and prediction error. Further, the probabilistic reward learning task employed in this study did not adequately allow for the separation of positive and negative learning rate, perhaps due to the lack of a monetary loss condition. Given that loss conditions may tap into threat-processing in anxiety more strongly than gain conditions (Helfinstein et al., 2011), future studies examining reward learning in anxiety should consider loss of reward in addition to gain of reward. While monetary rewards are motivationally salient to children and early adolescents (Schreuders et al., 2018), future studies may also consider the role of socially rewarding stimuli which are especially salient in this age range (Jones et al., 2014).

Despite these limitations, this study provides a mechanistic examination of brain and behavioral reward processing in youth across a range of anxiety symptomatology. Although reward learning was similar across all youth, those with the greatest anxiety had difficulties disengaging from high value stimuli that were not rewarding and their performance was associated with NAcc activation. Further, prediction error modulation of predictive correct (vs. incorrect) responses revealed that greater reward-related brain activation occurred for youth with the greatest ability to tolerate ambiguity. Altogether, results demonstrate that anxiety-related alterations in reward processing in youth may relate to complex relationships between reward-network function, decision value, and prediction error.

Table 4.1. Subject demographics

	Participants n=137
Age	11.3 (1.39)
Gender	65 girls, 72 boys
Mean relative motion (mm)	0.20 (0.07)
Anxiety severity (SCARED)	19.0 (11.6); Range: 0-52
Self-reported race/ethnicity	
Asian	24 (17.5%)
Black	18 (13.1%)
Hispanic	29 (21.2%)
More than one race	20 (14.6%)
White	46 (33.6%)

Table 4.2 Model Recovery

	Fit Model		
Simulated Model		1	2
	1	0.9848	0.0152
	2	0.9841	0.0159

The confusion matrix denotes the probability that the data generated by Model 1 or Model 2 are best fit by Model 1 or Model 2, representing *p* (fit model | simulated model).

Table 4.3. Brain regions demonstrating greater activation as a function of increasing decision value during reward anticipation for predictive and non-predictive stimuli

Contrast	Region Label	Peak MNI Coordinates			*z*-max	Voxels (mm^3)
		x	y	z		
Predictive > Baseline	L lingual gyrus	-6	-88	-4	6.86	743
	L intracalcarine cortex	-4	-82	2	6.57	
	L cuneal cortex	-8	-86	20	5.59	
	L occipital pole	-2	-90	-2	5.59	
		-8	-90	4	5.23	
	R intracalcarine cortex	6	-76	6	5.27	
	R cuneal cortex	2	-80	38	5.28	175
		12	-86	28	4.38	
		10	-86	34	4.06	
	R precuneus	14	-76	44	5.04	
		16	-64	38	4.6	
		6	-78	44	4.35	
	R precentral gyrus	24	-18	70	4.88	100
		26	-14	66	4.85	
		24	-14	60	4.67	
		26	-20	60	3.98	
		22	-22	66	3.65	
		18	-22	72	3.52	
	Precentral gyrus	0	-16	58	5.41	91
		0	-24	64	3.74	
		4	-14	74	3.63	
		2	-14	70	3.56	
	Supplementary motor area	6	-8	70	4.35	
		-2	-12	68	3.51	
Non-Predictive > Baseline	R lingual gyrus	8	-68	0	5.4	1,794
		10	-66	4	4.93	
	L occipital pole	-10	-94	16	4.88	
	L precuneus cortex	-10	-66	24	4.85	
	Supracalcarine cortex	0	-76	16	4.87	
	Cuneal cortex	0	-80	28	4.71	
	L posterior cingulate gyrus	-4	-46	38	5.47	1,124
	L precuneus cortex	-2	-44	44	5.14	
		-10	-48	50	4.99	
		-2	-50	66	4.73	

	R precuneus cortex	14	-42	42	4.94	
		12	-46	52	4.88	
	R middle temporal gyrus, temporooccipital part	60	-54	4	4.87	885
		56	-52	0	4.84	
		66	-38	8	4.67	
		44	-56	12	4.48	
	R angular gyrus	58	-48	24	4.54	
	R superior temporal gyrus, posterior division	56	-32	4	4.54	
	L supramarginal gyrus, posterior division	-60	-42	14	5.51	567
	L middle temporal gyrus, temporooccipital part	-58	-52	-6	5.43	
		-58	-56	6	5.26	
		-60	-56	-2	5.07	
	L lateral occipital cortex, superior division	-42	-74	24	4.41	
		-50	-66	18	4.29	
	R inferior frontal gyrus, pars opercularis	56	18	28	5.45	323
		56	18	16	4.39	
		58	16	10	3.83	
	R inferior frontal gyrus, pars triangularis	56	30	20	4.29	
		56	32	16	4.24	
	R middle frontal gyrus	52	14	40		
	Paracingulate gyrus	2	48	18	4.58	153
		4	-6	48	4	
		0	38	26	3.64	
		-8	44	14	3.5	
		0	46	30	3.45	
	Superior frontal gyrus	0	54	34	3.73	
	R precentral gyrus	22	-18	68	4.16	92
		20	-14	72	3.86	
		20	-22	74	3.59	
	Superior frontal gyrus	-2	28	48	4.84	90
		2	26	56	3.96	
		0	18	62	3.27	
	L precentral gyrus	-10	-26	72	5.35	78
		-4	-20	64	4.04	
		0	-20	68	3.93	

		-6	-18	68	3.79	
		-8	-28	78	3.61	
		2	-26	66	3.44	
	Anterior cingulate gyrus	-6	38	8	3.88	78
	L cuneal cortex	-8	-82	38	4.11	55
	L superior temporal gyrus, posterior division	-60	-30	4	4.18	54
	L planum temporale	-62	-24	6	3.74	
	L Heschl's gyrus	-42	-26	14	4.35	51
	L planum temporale	-40	-36	14	4.13	
Non-Predictive > Predictive	L precuneus cortex	-18	-50	4	5.09	109
		-18	-58	12	4.23	
		-4	-56	10	4.06	
	L posterior cingulate	-8	-48	4	4.12	
		-22	-46	2	3.73	
	R precuneus cortex	14	-44	46	4.77	92
		14	-42	42	4.51	
		14	-48	54	4.46	
		10	-50	46	3.4	

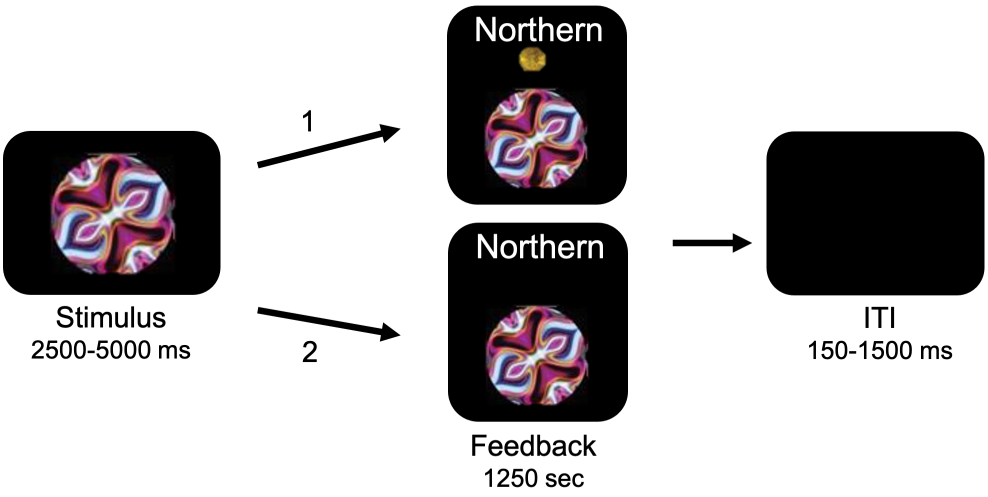
Table 4.4. Brain regions demonstrating greater activation as a function of increasing prediction error during receipt of reward for correct and incorrect responses

Contrast	Region Label	Peak MNI Coordinates			*z*-max	Voxels (mm^3)
		x	y	z		
Correct > Baseline	L lateral occipital cortex, superior division	-38	-76	38	4.4	90
		-34	-84	30	3.8	
		-26	-82	42	3.7	
		-30	-80	44	3.35	
Incorrect > Baseline	L Heschl's gyrus	-48	-16	8	8.16	24,128
	R parietal operculum cortex	62	-26	20	7.64	
		46	-26	18	7.37	
	L lateral occipital cortex, superior division	-38	-76	38	7.6	
		-38	-78	32	7.44	
	L postcentral gyrus	-56	-28	50	7.46	
	R middle frontal gyrus	24	30	36	5.15	347
		30	30	42	5.02	
	R frontal pole	38	40	38	4.63	
		34	42	42	4.12	
		28	38	48	3.97	
		30	46	34	3.88	
	L putamen	-24	8	-2	4.86	219
		-26	-4	-6	4.34	
		-30	4	-6	3.55	
	L pallidum	-16	4	-6	4.62	
		-16	6	2	4	
	R lateral occipital cortex, superior division	50	-68	16	5.02	122
		48	-72	26	5.01	
		48	-66	34	4.52	
		46	-68	16	4.38	
		42	-74	30	4.24	
		36	-72	24	4.04	
	R putamen	20	4	-6	4.33	98
		22	4	-2	4.19	
		24	8	0	3.81	
		30	-2	-6	3.77	
		16	10	-6	3.77	

		16	2	-4	3.71	
Correct > Incorrect	L occipital fusiform gyrus	-20	-84	-6	5.38	441
	R occipital fusiform gyrus	18	-88	-6	5.38	
	Lingual gyrus	-2	-78	-4	4.82	
		-2	-90	-6	4.49	
		2	-82	-6	4.32	
	L lingual gyrus	-8	-84	-6	4.42	
Incorrect > Correct	Precuneus cortex	0	-42	46	6.09	749
		2	-52	38	5.14	
		4	-50	54	5.03	
		2	-46	44	4.9	
		0	-36	52	4.88	
		-4	-52	54	4.53	
	L precentral gyrus	-24	-8	68	5.26	609
	R superior frontal gyrus	14	-4	72	5.16	
	L superior frontal gyrus	-14	-8	72	4.95	
		-22	18	62	4.95	
		-26	24	44	4.94	
	L precentral gyrus	-28	-28	52	4.82	431
		-30	-24	50	4.42	
	L postcentral gyrus	-32	-34	56	4.68	
		-46	-18	56	4.68	
		-48	-24	46	4.43	
		-46	-20	52	4.39	
	R supramarginal gyrus, anterior division	66	-26	20	5.53	427
	R supramarginal gyrus, posterior division	68	-28	14	5.4	
		60	-40	22	4.15	
	R parietal operculum cortex	44	-28	16	5.22	
		44	-20	20	4.4	
	R planum temporale	48	-34	18	4.28	
	L insular cortex	-36	-22	14	6.03	420

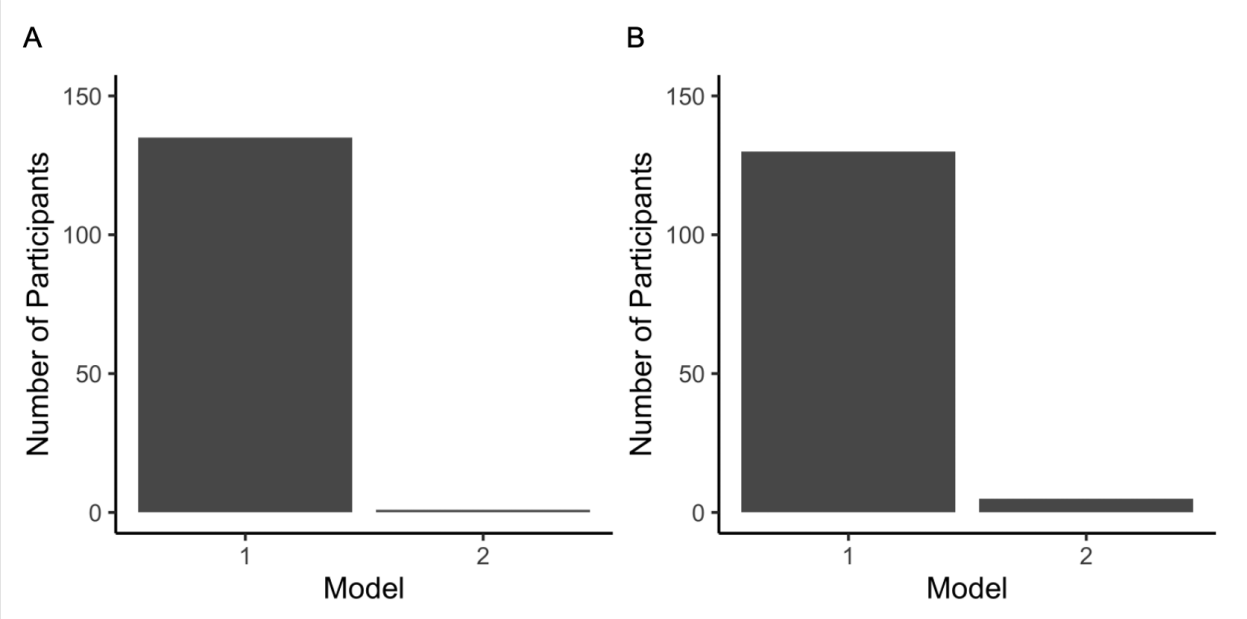
	L central opercular cortex	-54	-18	14	5.67	
		-56	-16	10	5.45	
		-60	-16	12	4.83	
	L postcentral gyrus	-62	-22	22	4.76	
	L Heschl's gyrus	-48	-16	8	4.66	
	R precentral gyrus	20	-24	74	4.65	215
	R postcentral gyrus	24	-30	74	4.56	
		34	-38	68	4.4	
		36	-34	68	4.29	
		30	-30	70	4.01	
		34	-38	60	3.72	
	L thalamus	-6	-2	10	5.1	167
	L caudate	-8	16	6	4	
		-12	14	10	3.22	
	R postcentral gyrus	44	-18	52	5.27	160
		54	-12	54	4.71	
		54	-20	56	3.85	
		54	-26	58	3.6	
		48	-24	48	3.51	
		48	-28	56	3.18	
	L putamen	-24	2	-2	4.1	77
		-24	10	-2	4.06	
		-18	8	-4	3.78	
	R middle frontal gyrus	30	30	44	4.85	76
	Supplementary motor area	0	-6	50	4.61	63
		4	6	56	3.65	
		2	4	62	3.39	
	Precentral gyrus	0	-14	50	3.94	
Predictive: Correct > Incorrect	L nucleus accumbens	-10	8	-6	5.39	91
		-6	4	-6	4.68	
	R putamen	16	10	-6	5.69	78
	R nucleus accumbens	10	6	-6	5.02	

Figure 4.1 Reinforcement learning task



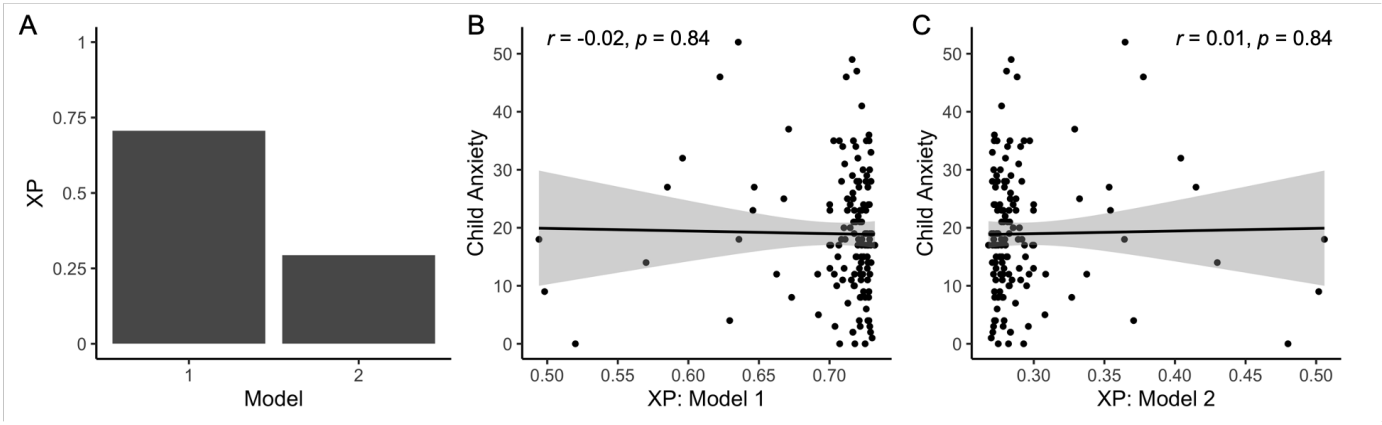
Abstract stimuli are displayed during which participants are instructed to categorize the stimulus as belonging to one of two categories (Northern or Eastern). If their response matched the outcome, they were rewarded with either 1 or 5 gold coins. Participants were paid bonus cash based on their total reward to ensure motivation. If their response did not match the outcome, the correct response was displayed to ensure participants learned the correct stimulus-reward association. Each trial was followed by a brief ITI. Abbreviations refer to milliseconds (ms) and inter-trial interval (ITI).

Figure 4.2 Model comparison between 1 and 2 learning rate models



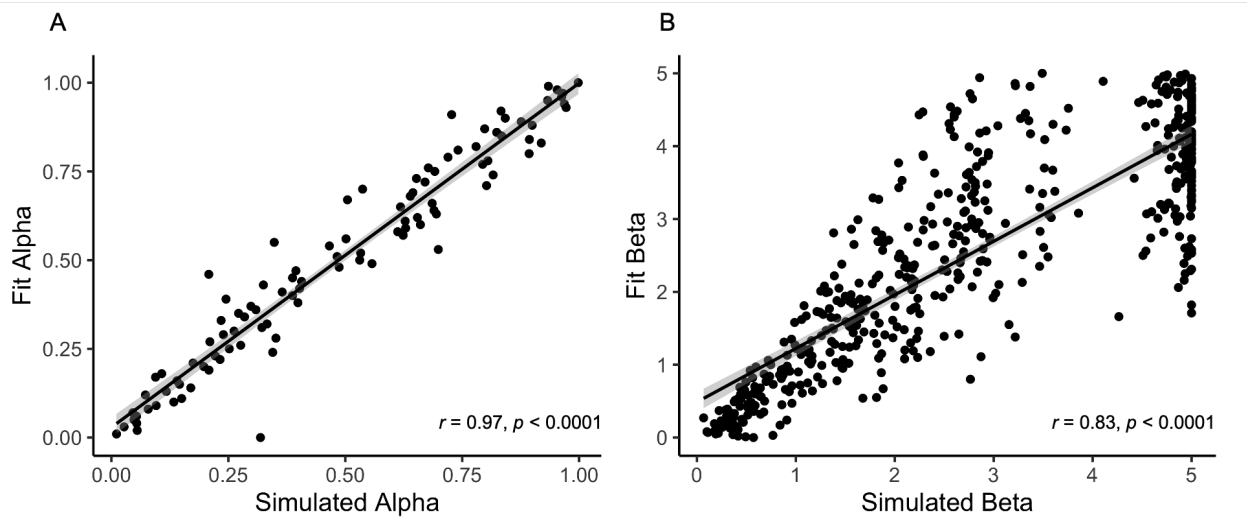
Bar graphs depict the number of participants better fit (according to BIC) by Model 1 (with 1 learning rate) compared to Model 2 (with 2 learning rates) for (A) Run 1 and (B) Run 2.

Figure 4.3 Model comparison and relation to child anxiety



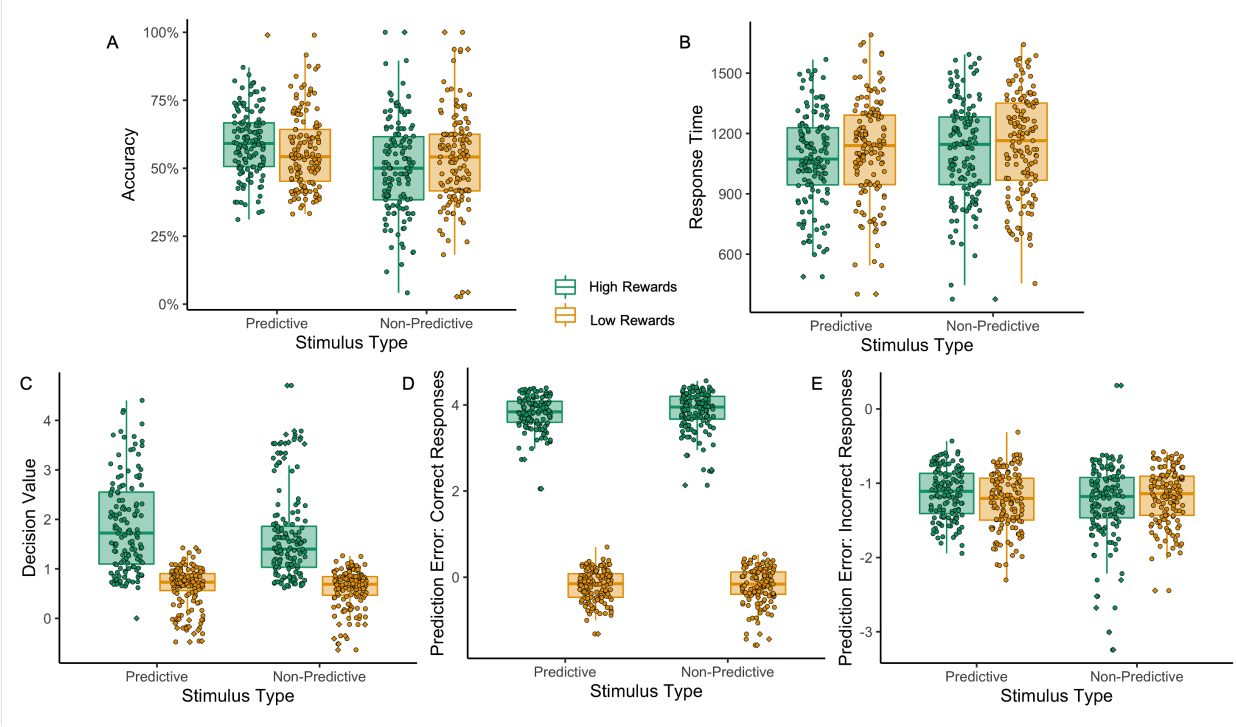
(A) Exceedance probabilities (XP) compared between Model 1 (1 learning rate) and Model 2 (2 learning rates). Scatterplots demonstrating the lack of relationship between child anxiety and model fit, as assessed by exceedance probability (XP), for (A) Model 1 and (B) Model 2.

Figure 4.4 Parameter recovery for the 1 learning rate model



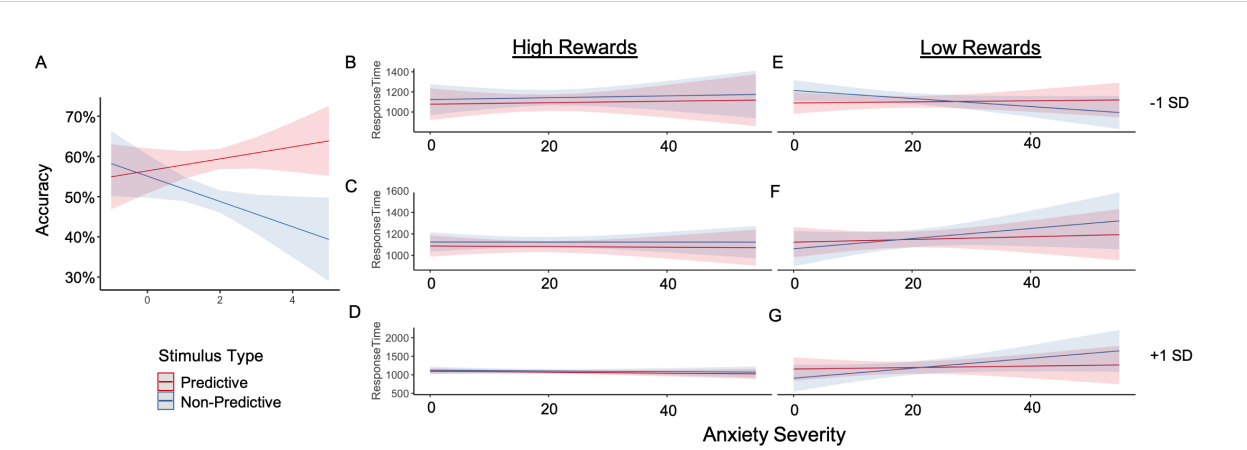
Scatterplots show the relationship between simulated parameters and fit parameters for (A) alpha and (B) beta with the line of best in black and the 95% confidence interval in dark gray.

Figure 4.5 Accuracy and response time and estimated decision value and prediction error



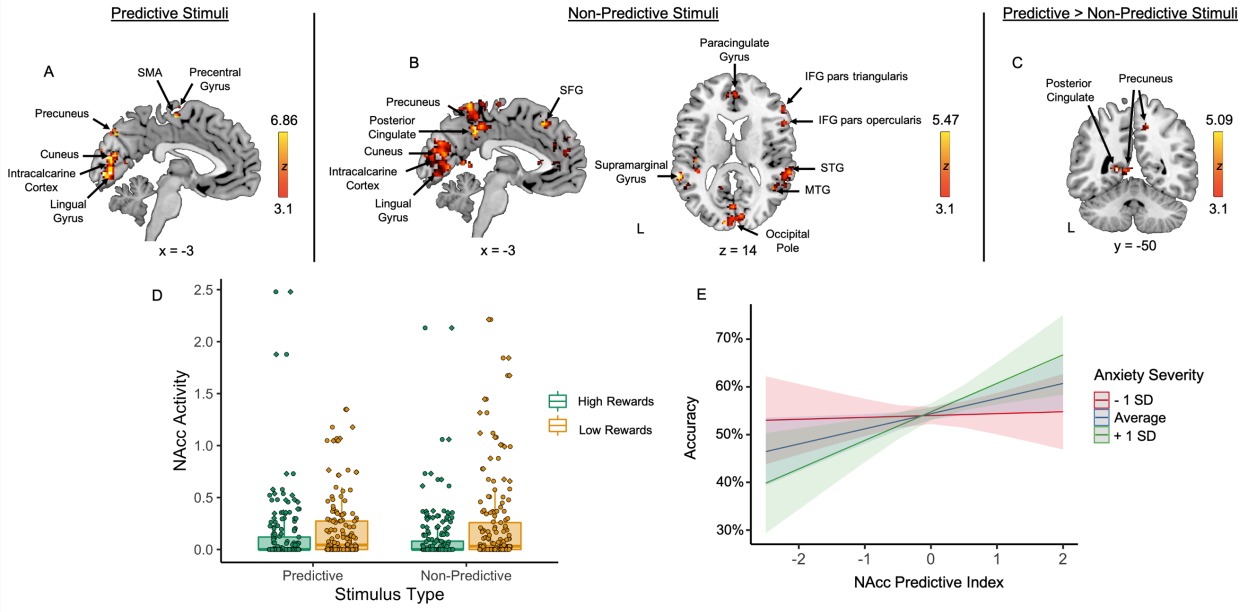
A) Youth were more accurate for predictive relative to non-predictive stimuli, as well as for high relative to low rewards. There was a significant stimulus type x reward size interaction, such that youth performed similarly for predictive and non-predictive low rewards but were more accurate for predictive high rewards relative to non-predictive high rewards. B) Youth were faster for predictive relative to non-predictive stimuli, as well as for high relative to low rewards. C) Decision value was higher for predictive relative to non-predictive stimuli, as well as for high relative to low rewards. There was a significant stimulus type x reward size interaction, such that youth ascribed similar value to predictive and non-predictive low rewards, but greater decision value for predictive high rewards relative to non-predictive high rewards. D) Prediction errors were higher for high rewards relative to low rewards when responses were correct. E) Prediction errors did not differ across stimulus type or reward size when responses were incorrect.

Figure 4.6 Influence of decision value on task accuracy and response time



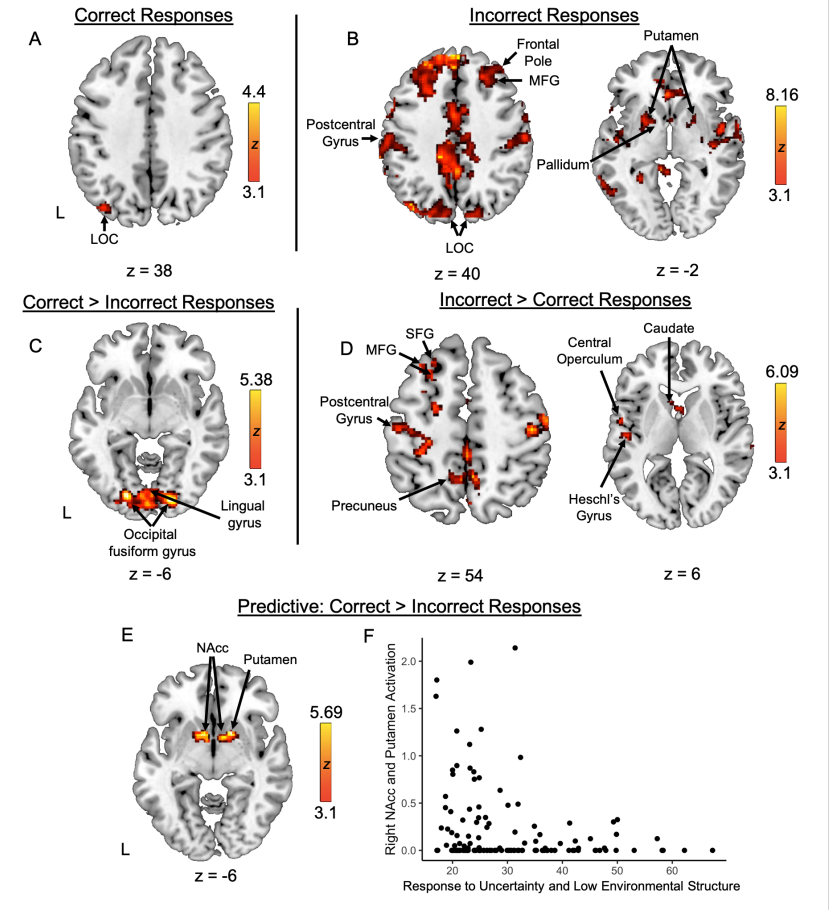
A) As decision value increased, youth were more accurate for predictive stimuli; however, for non-predictive stimuli, higher decision value related to worse accuracy. B-D) Across both predictive and non-predictive high rewards, anxiety severity and decision value were unrelated to response times. E-G) Across predictive low rewards, anxiety severity and decision value were unrelated to response times. However, for non-predictive low rewards, greater anxiety severity related to faster response times when decision value was low; greater anxiety severity related to slower response times when decision value was high. Values are plotted with 95% confidence intervals.

Figure 4.7 Brain response to decision value during anticipation for predictive and non-predictive stimuli



Whole brain activation during anticipation as a function of increasing decision value for A) predictive stimuli, B) non-predictive stimuli, and C) the contrast of non-predictive > predictive stimuli. Abbreviations refer to supplementary motor area (SMA), superior frontal gyrus (SFG), inferior frontal gyrus (IFG), superior temporal gyrus (STG), and middle temporal gyrus (MTG). D) Nucleus accumbens (NAcc) activation during predictive and non-predictive stimuli of high and low rewards. E) NAcc predictive index (NAcc activity during predictive minus non-predictive stimuli, collapsed across reward size) as a function of anxiety severity (plotted for average severity and +/- 1 standard deviation (SD) with 95% confidence intervals) as it relates to task accuracy. Higher NAcc predictive index values represent greater activation during predictive relative to non-predictive stimuli, whereas lower NAcc predictive index values represent greater activation during non-predictive relative to predictive stimuli.

Figure 4.8 Brain response to prediction error during correct and incorrect responses



Whole brain activation during feedback as a function of increasing prediction error for A) correct responses, B) incorrect responses, C) the contrast of correct > incorrect responses, D) the contrast of incorrect > correct responses, and E) the contrast of predictive correct > incorrect responses. Abbreviations refer to lateral occipital cortex (LOC), middle frontal gyrus (MFG), superior frontal gyrus (SFG), and nucleus accumbens (NAcc). F) Parameter estimates extracted from the right NAcc and putamen demonstrated negative correlation with parent-report on the response to uncertainty and low environmental structure questionnaire.

REFERENCES

Albano, A. M., & Silverman, W. K. (1996). *The Anxiety Disorders Interview Schedule for DSM-IV: Clinician manual (child and parent versions)*. San Antonio, TX: Psychological Corporation.

Baker, A. E., & Galván, A. (2020). Threat or thrill? the neural mechanisms underlying the development of anxiety and risk taking in adolescence. *Developmental Cognitive Neuroscience*, *45*, 100841. https://doi.org/10.1016/j.dcn.2020.100841

Bar-Haim, Y., Fox, N. A., Benson, B., Guyer, A. E., Williams, A., Nelson, E. E., … Ernst, M. (2009). Neural Correlates of Reward Processing in Adolescents With a History of Inhibited Temperament. *Psychological Science*, *20*(8), 1009–1018. https://doi.org/10.1111/j.1467-9280.2009.02401.x

Benson, B. E., Guyer, A. E., Nelson, E. E., Pine, D. S., & Ernst, M. (2015). Role of contingency in striatal response to incentive in adolescents with anxiety. *Cognitive, Affective, & Behavioral Neuroscience*, *15*(1), 155–168. https://doi.org/10.3758/s13415-014-0307-6

Birmaher, B., Khetapral, S., Brent, D., Cully, M., Balach, L., Kaufman, J., & Neer, S. M. (1997). The Screen for Child Anxiety Related Emotional Disorders (SCARED): Scale Construction and Psychometric Characteristics. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*(4), 545–553. https://doi.org/10.1097/00004583-199704000-00018

Buzzell, G. A., Troller-Renfree, S. V., Barker, T. V., Bowman, L. C., Chronis-Tuscano, A., Henderson, H. A., … Fox, N. A. (2017). A Neurobehavioral Mechanism Linking Behaviorally Inhibited Temperament and Later Adolescent Social Anxiety. *Journal of the American Academy of Child & Adolescent Psychiatry*, *56*(12), 1097–1105. https://doi.org/10.1016/j.jaac.2017.10.007

Caballero, A., Granberg, R., & Tseng, K. Y. (2016). Mechanisms contributing to prefrontal cortex maturation during adolescence. *Neuroscience and Biobehavioral Reviews*, *70*. https://doi.org/10.1016/j.neubiorev.2016.05.013

Charpentier, C. J., Aylward, J., Roiser, J. P., & Robinson, O. J. (2017). Enhanced Risk Aversion, But Not Loss Aversion, in Unmedicated Pathological Anxiety. *Biological Psychiatry*, *81*(12), 1014–1022. https://doi.org/10.1016/j.biopsych.2016.12.010

Cohen, J. R., Asarnow, R. F., Sabb, F. W., Bilder, R. M., Bookheimer, S. Y., Knowlton, B. J., & Poldrack, R. A. (2010). A unique adolescent response to reward prediction errors. *Nature Neuroscience*, *13*(6), 669–671. https://doi.org/10.1038/nn.2558

DePasque, S., & Galván, A. (2017, September 1). Frontostriatal development and probabilistic reinforcement learning during adolescence. *Neurobiology of Learning and Memory*. Academic Press Inc. https://doi.org/10.1016/j.nlm.2017.04.009

Duell, N., Steinberg, L., Icenogle, G., Chein, J., Chaudhary, N., Di Giunta, L., … Chang, L. (2018). Age Patterns in Risk Taking Across the World. *Journal of Youth and Adolescence*, *47*(5), 1052–1072. https://doi.org/10.1007/s10964-017-0752-y

Ellis, B. J., Boyce, W. T., Belsky, J., Bakermans-Kranenburg, M. J., & van Ijzendoorn, M. H. (2011). Differential susceptibility to the environment: An evolutionary–neurodevelopmental theory. *Development and Psychopathology*, *23*(1), 7–28. https://doi.org/10.1017/S0954579410000611

Galván, A. (2010). Adolescent development of the reward system. *Frontiers in Human Neuroscience*, *4*, 6. https://doi.org/10.3389/neuro.09.006.2010

Greve, D. N., & Fischl, B. (2009). Accurate and robust brain image alignment using boundary-based registration. *NeuroImage*, *48*(1), 63–72.

https://doi.org/10.1016/J.NEUROIMAGE.2009.06.060

Guyer, A. E. (2020). Adolescent Psychopathology: The Role of Brain-Based Diatheses, Sensitivities, and Susceptibilities. *Child Development Perspectives*, *14*(2), 104–109. https://doi.org/10.1111/cdep.12365

Guyer, A. E., Benson, B., Choate, V. R., Bar-Haim, Y., Perez-Edgar, K., Jarcho, J. M., … Nelson, E. E. (2014). Lasting associations between early-childhood temperament and late-adolescent reward-circuitry response to peer feedback. *Development and Psychopathology*, *26*(1), 229–243. https://doi.org/10.1017/S0954579413000941

Guyer, A. E., Choate, V. R., Detloff, A., Benson, B., Nelson, E. E., Perez-Edgar, K., … Ernst, M. (2012). Striatal Functional Alteration During Incentive Anticipation in Pediatric Anxiety Disorders. *American Journal of Psychiatry*, *169*(2), 205–212. https://doi.org/10.1176/appi.ajp.2011.11010006

Guyer, A. E., Kaufman, J., Hodgdon, H. B., Masten, C. L., Jazbec, S., Pine, D. S., & Ernst, M. (2006). Behavioral Alterations in Reward System Function: The Role of Childhood Maltreatment and Psychopathology. *J. Am. Acad. Child Adolesc. Psychiatry*, *45*(9), 1059–1067. https://doi.org/10.1097/01.chi.0000227882.50404.11

Helfinstein, S. M., Benson, B., Perez-Edgar, K., Bar-Haim, Y., Detloff, A., Pine, D. S., … Ernst, M. (2011). Striatal responses to negative monetary outcomes differ between temperamentally inhibited and non-inhibited adolescents. *Neuropsychologia*, *49*(3), 479–485. https://doi.org/10.1016/j.neuropsychologia.2010.12.015

Helfinstein, S. M., Fox, N. A., & Pine, D. S. (2012). Approach–withdrawal and the role of the striatum in the temperament of behavioral inhibition. *Developmental Psychology*, *48*(3), 815–826. https://doi.org/10.1037/a0026402

Hoogendam, J. M., Kahn, R. S., Hillegers, M. H. J., van Buuren, M., & Vink, M. (2013). Different developmental trajectories for anticipation and receipt of reward during adolescence. *Developmental Cognitive Neuroscience*, *6*, 113–124. https://doi.org/10.1016/j.dcn.2013.08.004

Jones, R. M., Somerville, L. H., Li, J., Ruberry, E. J., Powers, A., Mehta, N., … Casey, B. J. (2014). Adolescent-specific patterns of behavior and neural activity during social reinforcement learning. *Cognitive, Affective and Behavioral Neuroscience*, *14*(2), 683–697. https://doi.org/10.3758/s13415-014-0257-z

Lahat, A., Benson, B. E., Pine, D. S., Fox, N. A., & Ernst, M. (2016). Neural responses to reward in childhood: relations to early behavioral inhibition and social anxiety. *Social Cognitive and Affective Neuroscience*, *13*(3), 281–289. https://doi.org/10.1093/scan/nsw122

Mumford, J. A., Poline, J.-B., & Poldrack, R. A. (2015). Orthogonalization of Regressors in fMRI Models. *PLOS ONE*, *10*(4), e0126255. https://doi.org/10.1371/journal.pone.0126255

Osmanağaoğlu, N., Creswell, C., & Dodd, H. F. (2018). Intolerance of Uncertainty, anxiety, and worry in children and adolescents: A meta-analysis. *Journal of Affective Disorders*, *225*, 80–90. https://doi.org/10.1016/j.jad.2017.07.035

Pearson, J. M., Heilbronner, S. R., Barack, D. L., Hayden, B. Y., & Platt, M. L. (2011). Posterior cingulate cortex: adapting behavior to a changing world. *Trends in Cognitive Sciences*, *15*(4), 143–151. https://doi.org/10.1016/j.tics.2011.02.002

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences*, *98*(2), 676–682. https://doi.org/10.1073/pnas.98.2.676

Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the

effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning II: Current research and theory* (pp. 64–99). New York: Appleton Century Crofts.

Sanchez, A. L., Cornacchio, D., Chou, T., Leyfer, O., Coxe, S., Pincus, D., & Comer, J. S. (2017). Development of a scale to evaluate young children's responses to uncertainty and low environmental structure. *Journal of Anxiety Disorders*, *45*, 17–23. https://doi.org/10.1016/j.janxdis.2016.11.006

Schreuders, E., Braams, B. R., Blankenstein, N. E., Peper, J. S., Güroğlu, B., & Crone, E. A. (2018). Contributions of Reward Sensitivity to Ventral Striatum Activity Across Adolescence and Early Adulthood. *Child Development*, *89*(3), 797–810. https://doi.org/10.1111/cdev.13056

Silverman, M. H., Jedd, K., & Luciana, M. (2015). Neural networks involved in adolescent reward processing: An activation likelihood estimation meta-analysis of functional neuroimaging studies. *NeuroImage*, *122*, 427–439. https://doi.org/10.1016/j.neuroimage.2015.07.083

Tymula, A., Rosenberg Belmaker, L. A., Roy, A. K., Ruderman, L., Manson, K., Glimcher, P. W., & Levy, I. (2012). Adolescents' risk-taking behavior is driven by tolerance to ambiguity. *Proceedings of the National Academy of Sciences*, *109*(42), 17135–17140. https://doi.org/10.1073/pnas.1207144109

van den Bos, W., & Hertwig, R. (2017). Adolescents display distinctive tolerance to ambiguity and to uncertainty during risky decision making. *Scientific Reports*, *7*(1), 40962. https://doi.org/10.1038/srep40962

Woolrich, M. W., Ripley, B. D., Brady, M., & Smith, S. M. (2001). Temporal Autocorrelation in

Univariate Linear Modeling of FMRI Data. *NeuroImage*, *14*(6), 1370–1386. https://doi.org/10.1006/NIMG.2001.0931

CHAPTER 5

Adolescents in the Juvenile Justice System – Effects of Race and Mental Health

CHAPTER INTRODUCTION

This chapter extends the characterization of adolescent internalizing symptoms and risk-taking into a sample of youth involved in the juvenile justice system. By investigating these questions in justice-involved youth, we can examine how internalizing and risk-taking might differ after youth are subject to justice system involvement. The studies in this chapter utilize data from the Crossroads study, a longitudinal multisite project of male adolescents who were enrolled in it at the time of their first arrest. This unique dataset affords the ability to investigate potential biases into how youth enter the juvenile justice system, as well as how profiles of internalizing symptoms change after first contact with the system. The overall aim of this work is to better understand the challenges faced by system-involved youth to generate evidence-based recommendations for practitioners. This chapter will focus on two key topics. First, Study 1 will depict differential treatment of youth in the justice system based upon their race. Second, Study 2 will describe the longitudinal relationship between internalizing symptoms and self-reported offending to better understand how mental health – an oft overlooked concern for youth in the juvenile justice system – develops along with criminal activities.

Decades of research demonstrate that adolescents engage in higher levels of risk-taking relative to children and adults (Spear, 2000), albeit with individual differences in risk-taking propensity. In Study 1, we examine how the consequences of risk-taking during adolescence – in the context of real-world, self-reported offending – may relate to different levels of justice system involvement for youth of different races. A unique strength of this study is that youth

were enrolled following their first arrest, and as such, these youth have no prior history of involvement with the juvenile justice system. This is an important control, as a meta-analysis reveals that offense history is the strongest predictor of juvenile re-arrest (Cottle, Lee, & Heilbrun, 2001); by selecting youth with no criminal background, we can be assured that justice decisions were not driven by prior criminal history. Further, following these youth longitudinally allows us to track the persistence of racism through multiple stage of juvenile processing over time. The study first examined whether self-reported history of offending prior to first arrest differs across Black, Latino, and white youth. Then, differences across race in the stringency of processing (e.g., whether cases are formally versus informally processed) were assessed. Finally, differential risk by race for re-arrest one year following first arrest was examined. This work has important implications for law enforcement and those working within the justice system, as implicit or explicit racial biases can substantially alter how youth are treated.

In addition to peak levels of risk-taking and offending occurring during adolescence (Farrington, Piquero, & Jennings, 2013), the prevalence of mood and anxiety disorders also increases during the adolescent-early adulthood years (Merikangas et al., 2010a), with the majority of internalizing disorders emerging by age 24 (Meyer & Lee, 2019). For youth in the juvenile justice system, rates of internalizing are even higher than for non-system-involved youth (Wasserman, McReynolds, Schwalbe, Keating, & Jones, 2010a) and their mental health needs are seldom treated (Zajac, Sheidow, & Davis, 2015). Study 2 examined the co-development of internalizing symptom severity and self-reported offending across 5 years following first arrest. Those working with youth in the justice system often focus on predictors of recidivism, or re-offending. Several factors including but not limited to severity of offending and externalizing symptoms strongly predict recidivism (Mulder, Brand, Bullens, & van Marle, 2011), and thus

such factors have received the vast majority of empirical interest. More recently, studies have also begun examining the predictive validity of other mental health concerns, namely internalizing symptoms such as anxiety and depression (Hoeve, Mcreynolds, & Wasserman, 2013). A key consideration missing from this body of work is whether symptom trajectories relate to offending trajectories in these youth. This research question is key as on-going brain development (Galván, 2017; Romeo, 2017), changes in socio-emotional environments (Blakemore & Mills, 2014), and pubertal development (Hamilton, Hamlat, Stange, Abramson, & Alloy, 2014) can represent a time of risk for the development of internalizing symptoms and disorders during adolescence. Thus, examining the trajectory of these symptoms in a population already facing compounding vulnerabilities such as incarceration (Lambie & Randell, 2013) is crucial for better understanding their mental health needs. Further, while the question of whether mental health status predicts later recidivism is still under investigation, it has been established the mental health can moderate the efficacy of programs addressing recidivism (McCormick, Peterson-Badali, & Skilling, 2017), such that greater engagement follows improved mental health. Because both mental health and offending are dynamic processes, it is important to track the relationship between these processes over time to identify key periods where intervention – for both mental health and recidivism – may be most efficacious.

ABSTRACT: STUDY 1

Minority youth are disproportionately represented in the juvenile justice system. Examining how racial disparities relate to biased entry into and continued involvement with the system, while accounting for past and current offending, can provide context about the mechanisms behind overrepresentation. 1,216 male adolescents were examined after first arrest

to explore associations between race and history of self-reported offending, likelihood of formal processing, and likelihood of re-arrest. Black youth committed fewer offenses prior to arrest than White youth, Black and Latino youth were more likely to be formally processed, and Black youth were most likely to be re-arrested (even controlling for post-baseline offending), highlighting that minority youth are overrepresented in the juvenile justice system despite similar or lower levels of criminal behavior.

INTRODUCTION: STUDY 1

Disproportionate minority contact (DMC) is evident throughout the stages of juvenile justice system processing in the United States. More than 1.6 million U.S. youths are processed by the juvenile justice system annually, and youth of color – especially Black youth (Moore, 2007) – are more likely to have contact with this system than are their White counterparts (Dmitrieva, Monahan, Cauffman, & Steinberg, 2012). Indeed, while Black youth comprise 17% of the 10-17 year old population, they make up more than double that percentage of arrests especially in communities with low Black populations, formal court proceedings, and incarcerations in the juvenile justice system (Andersen, 2015). Once arrested, Black youth typically receive more restrictive sentences and are more often formally charged than White peers regardless of offense or prior record, with referrals to juvenile court being three times more likely for Black than for White youth (Mitchell, 2005; Onifade, Barnes, Campbell, & Mandalari, 2019). Likelihood of referral to secure confinement is also highest for Black youth (Lowery, Burrow, & Kaminski, 2018). Black youth are also more likely to be transferred to criminal court to be tried as an adult (regardless of offense or age) (Bishop, 2016), confined for a longer period of time, and referred to adult prison than are White youth (Moore, 2007).

Multiple studies attempt to explain the etiology of DMC. From this vast body of literature, the prevailing hypothesis - the *differential selection and processing hypothesis* - asserts that minority youth are overrepresented in the justice system due to differences in the patrolling, profiling, and processing of minorities by law enforcement officials, courts, and correctional systems (Piquero, 2008). Moreover, youths' race predicts the level of scrutiny and stringency that law enforcement officials impose on those engaging in criminal activity (Onifade et al., 2019). For example, in a study utilizing data from the Project on Human Development in Chicago Neighborhoods, researchers found that Black youth report more trouble with police, even after controlling for other possible contributing variables such as criminal offending, impulsivity, mental health symptoms, and gang membership (Unnever, Owusu-Bempah, & Deryol, 2019).

The sources and consequences of DMC are especially important to examine within the juvenile justice system, as youth are especially sensitive to their environments compared to adults. Isolating youth from their typical socio-emotional context following arrest and placing them in correctional institutions with greater deviant peer presence (Johnson, Simons, & Conger, 2004) increases emotional vulnerability and impedes psychosocial development (Dmitrieva et al., 2012); indeed this incarceration can itself be a criminogenic factor (Lambie & Randell, 2013). In particular, younger youths and those from minority groups are often at a higher risk of victimization within the prison system (Kiessl & Würger, 2002). These factors may help explain the strong correlation between juvenile and adult offending, highlighting the importance of juvenile rehabilitation and the risk that accrues during justice system contact (Piquero, 2008; Rodriguez, 2010). About 70-80% of juveniles in correctional programs are subsequently re-arrested within the next three years (Mendel, 2011), and research suggests that juvenile

incarceration is often ineffective at reducing both recidivism and antisocial behavior (Aizer & Doyle, 2015; Black, 2016). Given the increased risk of law enforcement contact among minority youth, along with the detrimental effects and repercussions shown to accompany juvenile justice system involvement, it is crucial to identify the sources of DMC in order to diminish racial disparities in the juvenile justice system.

Significant reform efforts have attempted to address disparities in the juvenile justice system (for review, see Leiber & Fix, 2019). The 1988 federal Juvenile Justice and Delinquency Protection Act mandated that states address minority overrepresentation in order to receive federal funding, but this has been met with limited success. For example, Black youth in Iowa, a Congress-mandated "reference" state for DMC mandate implementation (Federal Register, 1991),were referred to formal processing more than White youth following the implementation (Leiber, Bishop, & Chamlin, 2011). Attempts to decrease the use of pre-dispositional detention for youths such as the Juvenile Detention Alternatives Initiative (JDAI; Mendel, 2009) have yielded success for White youth, though in parallel increased the likelihood for detention for Black youth (Maggard, 2015) and resulted in overall greater system contact for minorities relative to White youth (Mendel, 2014). The state of race relations in the United States today as evidenced by numerous instances of violence against Black youth further underscores the rampant disparities in justice system involvement.

The present study utilizes official arrest, processing, and re-arrest data as well as retrospective and prospective self-report data to generate a comprehensive depiction of offending behaviors over time. Reform attempts, extent of DMC, and history of racial tensions differ across the country (Zane, Mears, & Welsh, 2020); as such, this study leverages multi-site data to investigate similarities and differences in justice system processing across the country. With

these data, we examined 3 primary aims which seek to identify evidence for the differential selection hypothesis and examine the persistent relationship between justice system contact and race for minority youth. In Aim 1, we investigated the association between race and history of self-reported offending prior to an adolescent's first contact with the juvenile justice system. Finding that Black youth commit fewer offenses prior to arrest compared to White youth would contribute to the existing evidence for the differential selection hypothesis, demonstrating that minority youth are not necessarily committing more crimes than other youth groups, but may be differentially targeted in policing.

Aim 2 examined whether the severity of justice system processing related to race. Uniquely, this study disposes with confounding effects of severity of crime by restricting study entry to only those involved in moderate-range crimes; furthermore, we controlled for the commission of violent offense. As all youth in the study were arrested for similarly moderate crimes, we were able to systematically address whether race related to justice system processing without the confounding effects of variability in crime severity on the association between race and processing decisions. Racial differences in likelihood of being formally processed would highlight the enduring effects of racism once youth enter the juvenile justice system.

In Aim 3, we investigated whether DMC persists after first contact with the justice system by examining how race relates to re-arrest while controlling for self-reported offending and extra-legal factors. After controlling for contextual factors, finding that Black youth are more likely to be re-arrested than White youth would demonstrate the continued role of racism in police targeting of Black youth. Based on prior literature, we hypothesized that Black youth would be arrested after committing the fewest offenses, most likely to receive formal justice system processing, and most likely to be re-arrested. This study adds to the previous literature

examining DMC by assessing the role of race in entry into the juvenile justice system and stringency of processing following arrest, as well as tracking the longitudinal relationship between race and re-arrest.

MATERIALS AND METHODS: STUDY 1

Data for the following analyses were collected as part of the Crossroads Study, an on-going multi-site longitudinal assessment of 1,216 male adolescents ages 13-17 who were arrested for moderate offenses (i.e., misdemeanors) in either Jefferson Parish, Louisiana, Orange County, California, or Philadelphia, Pennsylvania. These study sites were selected to represent culturally and demographically distinct regions of the country (South, West, and East). Youth were enrolled in the study at the time of their first arrest for midrange, non-felony crimes such as theft of goods, simple battery (e.g., offensive physical contact such as punching), and vandalism (e.g., graffiti); these are distinct from felony-level offenses (e.g., armed robbery, homicide). Detailed information regarding sampling procedures and data collection methodology can be found via the study website: https://sites.uci.edu/crossroadsinfo/about-the-study/study-design/ and in prior publication (Thornton et al., 2015). Briefly, youth with pending intake hearings were screened for eligibility (e.g., no prior arrests) by research associates and invited to participate in the study following informed consent and assent regarding study involvement. Youth were provided $50 for completion of the first interview; an additional $15 was provided at follow-up interviews as retention incentive.

The Institutional Review Board (IRB) at all three institutions approved the study procedures. Signed caregiver consent as well as youth assent were obtained from all participants prior to study interviews. Data were obtained via research interviews with youth, and official

data came from the probation department. Interviews were conducted for all participating youth a maximum of six weeks following their first arrest, with each interview lasting two to three hours. Interviews were conducted on laptop computers within the community (including participants' homes), areas in their local community which were private, or at the universities conducting the research. To ensure comprehension of study questions, interviewers read questions aloud to participants. For any interview sections that covered sensitive information, youth completed their own data entry using computer software designed to allow anonymous keystrokes. Importantly, participants were assured that their identity and all of their study responses would be held in strict confidence pursuant a Privacy Certificate from the Department of Justice. As such, no information from the study could be released via subpoenas, court orders, or any other involuntary disclosures. Participants were informed prior to the start of the interview, as well as throughout the interview before disclosing any sensitive or potentially incriminating information.

The current study focuses on data from the baseline interview and from follow-up interviews conducted six months and one year later, collected from 2011 to 2014. The sample for Aims 1 and 2 consists of 1,186 adolescents (M_{age} = 15.7, SD_{age} = 1.31; Table 5.1.1). Multiple imputation was used to estimate parental education data which were missing for 49 youth. Adolescents in this sample self-reported their ethnicity as White (15.7%), Black (38.1%), or Latino (46.1%). Information regarding ethnicity was missing for 30 participants (e.g., was coded as "Other"), who were therefore excluded from all analyses. Multiple imputation was also used to estimate missing self-reported offending data from follow-up waves (n=91) and for missing official arrest data from follow-up waves (n=4).

Behavioral Measures: Study 1

Demographic Information

Youth reported demographic information including age and race/ethnicity. Also, youth provided self-reports of their parents' highest level of education, which was used as a proxy for socioeconomic status, and used as a continuous variable (Galobardes, Lynch, & Smith, 2007). Prior research supports the validity of child report of this variable in adolescent samples (Lien, 2001), and socioeconomic status relates strongly to juvenile offending and arrests (Thompson & Morris, 2016). Results remained consistent when parental education was dichotomized by whether or not parents graduated from high school (yes/no). Similarly, results were consistent when parental education was split into those who had not graduated high school, had graduated from high school, or had obtained more than a high school degree. Data collection site (Louisiana, California, or Pennsylvania) was also used as a control variable.

Neighborhood Quality

Neighborhood quality was assessed as a continuous measure using a self-report questionnaire adapted for the Crossroads study designed to assess observable signs of physical and social disorder in the adolescent's neighborhood (Sampson & Raudenbush, 1999). Youth reported on how frequently they observed both physical disorder (9 items; e.g. *graffiti or tags*, *boarded up windows on buildings*) and social disorder (12 items; e.g., *adults fighting or arguing loudly*) in their neighborhood using a 4-point Likert scale from "Never" to "Often". Average scores across both scales provide an index of overall neighborhood quality, where higher scores indicate worse neighborhood quality. The neighborhood quality scale demonstrated excellent internal consistency (Cronbach's α=0.94).

History of Self-Reported Offending

At baseline, youth self-reported participating in criminal activities at any point prior to their arrest using the Self-Report of Offending measure (SRO; Huizinga, Esbensen, & Weiher,

1991). Participants were informed that their responses would remain confidential, ensuring that law enforcement officials would not be notified of any previously undisclosed offending behavior. Participants reported if they had or had not participated in any of 24 criminal acts at any point prior to their arrest, with offenses ranging in severity from selling drugs to homicide. A summed variety score across all different types of criminal acts was generated to obtain an overall index of offending, where higher scores indicate greater offending. Variety scores are often used in criminological research to provide a self-report across a heterogeneous mix of criminal behaviors (Sweeten, 2012). For Aim 1, total self-reported offending prior to arrest (or SRO ever) served as the outcome variable of interest. Items indicating that youth engaged in violent behaviors (e.g. *assault, getting into fights, shot at someone*; 10 total violent act questions) were summed together to create a violent offending SRO category as done previously (Fine, Simmons, Cavanagh, Rowan, & Cauffman, 2020). Violent SRO items largely capture low-level aggression; getting into fights accounts for most of the variance in this measure.

Post-Baseline Self-Reported Offending

Youth completed the SRO at every follow-up interview, reporting on offenses committed in the prior 6 months. For Aim 3, analyses examined self-reported re-offending over the year following first arrest, calculated as a summed variety score. It is important to note that youth did not specify when in the previous 6-month period they had committed offenses; therefore, precise details regarding the timing between self-reported offenses and re-arrest cannot be determined.

Official Re-Arrest Record

Data from official records were obtained from the Department of Probation from all sites to indicate the number of times youth were re-arrested for either misdemeanor or felony charges

during the year after first arrest. The outcome of interest was dichotomized into whether or not youth were re-arrested.

Processing Status

After the youth's first arrest, the youth in this study were either formally or informally processed within the justice system. Informal processing involves youth being diverted from juvenile court and could include a probationary ("wait and see") status or community service. Formal processing, on the other hand, involved being sanctioned through the juvenile court system, and subsequently being placed on probation or referred to a juvenile correctional institution. Youth who are formally processed are required to attend a series of court hearings, and if they are sanctioned with community probation, they are required to check in with both the judge and a probation officer. As such, formal processing constitutes a more intensive form of juvenile justice system treatment. Initial processing decisions following arrest for each youth were obtained from official records from the probation department.

Institutional Time

Youth self-reported the number of days during the recall period they spent in a detox/drug-treatment program, psychiatric hospital, residential treatment program, or secure institution. As spending time in such facilities can limit the opportunity youth have to engage in antisocial acts (Piquero et al., 2001), we use institutional time as a control variable. Youth spent a small proportion of each study recall period in facilities (0.09 months across 1 year in 14.7% of the study population).

Behavioral Data Analysis

Aim 1: Relationship between Race and Entry into the Juvenile Justice System

We first investigated whether race predicted the history of self-reported offending prior to the adolescents' first arrest, over and above the effects of parental education, neighborhood quality, age at arrest, and data collection site. To compare across all racial groups, we ran separate models with White youth as the reference group and Black youth as the reference group. As demographic variables such as parental education, neighborhood quality, and age have been linked to offending behaviors (Peeples & Loeber, 1994; Rekker et al., 2015) and may differentially affect racial groups, we controlled for these factors in our analysis to better isolate how race relates to entry into the justice system. Finally, as these data were collected across multiple states and race may differentially impact justice system involvement in different areas of the United States, we controlled for data collection site in addition to demographic factors. To compare across all data collection sites, we ran separate models with California as the reference group and Pennsylvania as the reference group. Self-reported offending, the outcome of interest and our dependent variable, is a count variable with a skewed distribution. Negative binomial regression is optimal for analyzing skewed dependent variables (which prevents the need to log-transform the dependent variable to address skew), over-dispersed data (i.e., variance of the dependent variable exceeds its mean), and data where there are several "0" values for the dependent variable (i.e., no prior self-reported offending) (Long & Freese, 2001). Table 5.1.2 lists model fit indices across all multiply imputed datasets, demonstrating that the negative binomial hurdle model had the best model fit. Results from this analysis will help identify any differences in the amount of offenses committed prior to arrest across racial groups, providing crucial insight into potential racial discrimination behind biased entry into the juvenile justice system. Supplementary analyses were conducted to specifically examine whether race predicted the amount of self-reported violent offenses committed prior to arrest. Table 5.1.3 lists model fit

indices across all multiply imputed datasets, demonstrating that the negative binomial hurdle model had the best model fit.

Some youth did not provide parental education data (n=49). Maximum likelihood estimation (the default for linear regression) uses list-wise deletion to eliminate cases with missing data. Therefore, we imputed 20 datasets using a Markov chain Monte Carlo sequence in Mplus (Muthén & Muthén, 2017). Results did not differ when including these 49 youth in the analysis; therefore, these cases were included for completeness.

Aim 2: Relationship between Race and Processing Decision for Initial Arrest

Once juveniles are arrested, they are either processed formally or informally. The dependent variable for this analysis is whether or not youth were formally processed; formality of processing was assessed via official records. The second analysis used a logistic regression to investigate whether race predicted whether youth were formally or informally processed, controlling for history of self-reported offending, parental education, neighborhood quality, age at arrest, data collection site, and whether or not youth were arrested for a violent offense. To compare across all racial groups, we ran separate models with White youth as the reference group and Black youth as the reference group. Similarly, to compare across all data collection sites, we ran separate models with California as the reference group and Pennsylvania as the reference group. Results from this logistic regression will help identify whether race relates to formality of justice processing, over and above other relevant factors (e.g., type of offense).

Aim 3: Relationship between Race and Re-Arrest

The third analysis used a logistic regression to investigate whether race predicted which youth were re-arrested following their first arrest. The dependent variable for this analysis is whether or not youth were arrested within a year after first arrest; re-arrest data were assessed via

official records. This analysis also controlled for parental education, neighborhood quality, age at arrest, and data collection site; post-baseline self-reported offending was also included in the model. Importantly, post-baseline SRO measures the amount of offending youth self-report at their follow-up visits following their first arrest. As such, post-baseline SRO – offending after first arrest – is distinct from the history of SRO which was assessed in the first analysis. To compare across all racial groups, we ran separate models with White youth as the reference group and Black youth as the reference group. Similarly, to compare across all data collection sites, we ran separate models with California as the reference group and Pennsylvania as the reference group. Further, initial justice system processing decisions were also included in the model, as a host of evidence suggests that receiving formal justice system processing relates to greater future re-offending (Fine et al., 2017; Morris & Piquero, 2013) and that earlier justice system proceedings can have a cumulative impact on later judicial outcomes (Rodriguez 2010). Finally, this analysis also controlled for institutional time, given that youth in facilities may have fewer opportunities to engage in criminal behavior compared to youth who are not incarcerated (Piquero et al., 2001). Supplementary analyses were conducted to specifically examine whether race predicted the amount of post-baseline self-reported offenses committed, and post-baseline self-reported violent offenses committed, to ensure that higher likelihood of re-arrest would not be driven by higher or more severe SRO. Results from this logistic regression will help identify whether race predicts criminal targeting once youth have already entered the justice system, regardless of re-offending behaviors or other prior justice system-related factors.

Some youth did not provide self-reported offending data (n=91) and/or were missing official arrest data (n=4) at six months or one year after initial arrest. We imputed 20 datasets using a Markov chain Monte Carlo sequence in Mplus (Muthén & Muthén, 2017). Results did

not differ when including these 95 youth in the re-arrest analysis; therefore, these cases were included for completeness.

Variance inflation factors (VIF) were calculated to examine collinearity amongst predictor variables, where variables with a VIF greater than 10 indicates collinearity in the model (Miles, 2014). Predictor collinearity makes it difficult to assess the unique contribution of each predictor to the overall model prediction and decrease the stability of predictor coefficients. In our models, no variables had VIF values greater than 2.89, well below the recommended threshold.

RESULTS: STUDY 1

Aim 1: Relationship between Race and Entry into the Juvenile Justice System

Negative binomial hurdle regression was used to investigate whether race relates to history of self-reported offending prior to arrest when accounting for parental education, neighborhood quality, age at arrest, and data collection site (Table 5.1.4). The probability of reporting no prior offending was predicted by neighborhood quality and data collection site, such that youth were more likely to self-report zero offenses (n=63) if neighborhood quality was worse and less likely to self-report zero offenses if they lived in Pennsylvania. Amongst youth who did self-report prior offending, parental education, neighborhood quality, age, and data collection site were predictive of greater self-reported offending. Specifically, youth were arrested after the fewest offenses in Pennsylvania relative to both California and Louisiana. However, even after controlling for these variables, results indicate that race predicted the amount that youth offended prior to arrest (Figure 1). Relative to White youth, Black youth committed fewer offenses prior to arrest (β = -0.30, *SE* = 0.10, p = 0.002, 95% CI [-0.49, -0.11]).

At a trend level, Latino youth committed more offenses relative to Black youth prior to arrest (β = 0.17, *SE* = 0.09, p = 0.06, 95% CI [-0.004, 0. 34]) There were no significant differences between White and Latino youth (β = -0.13, *SE* = 0.09, p = 0.15, 95% CI [-0.23, 0.04]). A negative binomial hurdle regression was used to investigate whether race specifically related to violent offending committed prior to arrest to ensure that Black youth were not simply committing more severe offenses prior to arrest (offenses warranting more police intervention), albeit committing fewer of them. Results of the negative binomial hurdle regression controlling for the same demographics demonstrated that race no longer predicted self-reported offending when only considering violent offenses. Specifically, Black youth did not commit more self-reported violent offenses prior to arrest compared to White youth (β = 0.12, *SE* = 0.18, p = 0.50, 95% CI [-0.47, 0.23]). At a trend level, Black youth committed more violent offenses relative to Latino youth (β= 0.27, *SE* = 0.16, p = 0.08, 95% CI [-0.03, 0.58]). Overall, results from these analyses indicate that Black youth were arrested after committing fewer offenses, and that this lower barrier to arrest was not driven by a higher degree of violent offending.

Aim 2: Relationship between Race and Processing Decision for Initial Arrest

The second set of analyses examined how processing decisions relate to youths' race (Table 5.1.5). These analyses controlled for history of self-reported offending prior to arrest, parental education, neighborhood quality, age at arrest, data collection site, and whether or not youth were arrested for a violent offense. Committing a violent index offense and a greater history of self-reported offending predicted formal processing. The likelihood of formal processing was lowest in Pennsylvania relative to both California and Louisiana. Over and above these associations, results of the logistic regression demonstrated that race predicts whether youth are formally or informally processed, such that both Black and Latino youth are more

likely to be formally processed relative to White youth (Figure 2). The odds of being formally arrested was 66.6% higher for Black youth relative to White youth (IRR = 1.67, β = 0.51, *SE* = 0.21, p = 0.02, 95% CI [0.10, 0.92]), and 66.8% higher for Latino youth relative to White youth (IRR = 1.67, β= 0.51, *SE* = 0.20, p = 0.01, 95% CI [0.12, 0.90]). The odds of being formally arrested did not differ between Black and Latino youth (β = 0.002, *SE* = 0.18, p = 0.99, 95% CI [-0.36, 0.36]).

Aim 3: Relationship between Race and Re-Arrest

The third set of analyses sought to examine the association between race and re-arrest in the year following youths' first arrest (Table 5.1.6). These analyses controlled for post-baseline self-reported offending, parental education, neighborhood quality, age at arrest, data collection site, whether or not youth were formally processed at their first arrest, whether or not youth were arrested for a violent offense at their first arrest, and institutional time. Spending more time within institutions and higher post-baseline self-reported offending predicted greater likelihood of re-arrest; being formally processed at initial arrest was associated with greater likelihood of re-arrest at a trend level. Higher parental education and data collection site predicted lower likelihood of re-arrest. Specifically, likelihood of re-arrest was lower for youth in Pennsylvania and Louisiana relative to California; there were no differences between re-arrests in Pennsylvania and Louisiana. Over and above these associations, results of the logistic regression demonstrated that race was predictive of who would be re-arrested (Figure 3). The odds of being re-arrested were 71.1% higher for Black youth relative to White youth (IRR = 1.71, β = 0.54, *SE* = 0.25, p = 0.04, 95% CI [0.04, 1.04]), and 75.9% higher for Black youth relative to Latino youth (IRR = 0.57, β = 0.57, *SE* = 0.22, p = 0.01, 95% CI [-1.01, -0.13]. There were no significant differences between White and Latino youth (IRR = 0.97, β = -0.03, *SE* = 0.24, p = 0.91, 95% CI

[-0.49, 0.44]. Importantly, the finding that Black youth were more likely to be re-arrested relative to White or Latino youth was not driven by differences in post-baseline self-reported offending, or self-reported violent offending. Specifically, Black youth did not offend more than White (IRR = 0.42, β= -0.87, *SE* = 0.55, p = 0.11, 95% CI [-1.94, 0.20]) or Latino youth (IRR = 0.69, β= -0.37, *SE* = 0.53, p = 0.48, 95% CI [-1.41, 0.67]) in the year following first arrest. Black youth also did not commit more violent offenses relative to White (IRR = 1.12, β= 0.11, *SE* = 0.14, p = 0.43, CI [-0.16, 0.38]) or Latino youth (IRR = 1.19, β= 0.17, *SE* = 0.14, p = 0.21, CI [-0.10, 0.44]).

DISCUSSION: STUDY 1

The goal of the present study was to examine the mechanisms underlying disproportionate minority contact (DMC) in the juvenile justice system. Prior efforts have highlighted that DMC can occur due to legal factors such as the severity and amount of criminal offending, in addition to extralegal factors such as race, socioeconomic status, neighborhood quality, and age at arrest (McCarter, 2009). In this study, we isolated the specific role of race among Black, White, and Latino youth in the justice system by accounting for both legal and other extralegal factors. We investigated 3 specific aims: 1) whether racial disparities were related to biased entry into the justice system at the time of first arrest, 2) whether level of contact with the system (e.g., formality of processing) differed across racial groups, and 3) whether the likelihood of re-arrest differed across racial groups. In line with the differential selection and processing hypothesis, Black youth in our sample were arrested after committing significantly fewer crimes compared to White youth, even after controlling for the effects of parental education, neighborhood quality, and age at arrest. Similarly, both Black and Latino

youth were more likely to be processed formally (rather than informally) as compared to White youth, regardless of the severity of the offense (i.e., whether or not the offense for which they were arrested was violent) or amount of self-reported offending prior to first arrest. Finally, Black youth were significantly more likely to be re-arrested compared to White and Latino youth, despite no differences in self-reported offenses, both violent and non-violent, across racial groups. This paper presents a critical view of racial disparities present across several stages of the juvenile justice system, highlighting that minority youth are overrepresented in the system despite similar or lower levels of involvement in criminal behavior.

Aim 1: Relationship between Race and Entry into the Juvenile Justice System

First, we aimed to identify whether self-reported offending prior to arrest differed by race. Results of this study indicate that Black youth were arrested after committing fewer and no more violent crimes than White youth, while a significant effect was not observed for Latino youth in line with prior findings (Andersen, 2015). Importantly, racial differences persisted over and above the effects of contextual variables including parental education, neighborhood quality, age at arrest, and data collection location. A recent longitudinal study demonstrated that the likelihood of arrest has increased over time for all levels of self-reported offending, suggesting that arrest rates are becoming increasingly de-coupled from levels of criminality (Weaver, Papachristos, & Zanger-Tishler, 2019). In particular, this divide between self-reported offending and arrests has become greatest for Black individuals (Weaver et al., 2019).

One potential reason that Black youth may be arrested despite lower levels of offending could stem from higher levels of police monitoring that tend to occur in Black (Hinton, 2015) and low-income neighborhoods (Brunson & Weitzer, 2009). While the stated purpose of such "hot spots policing" (Rinehart Kochel, 2011) is to improve neighborhood safety (Clarke &

Cornish, 1985), proactive policing tactics result in disproportionately higher levels of police contact with minority youth (Fagan, 2017). Qualitative accounts of police-youth interactions describe negative experiences involving substantial surveillance and harassment (Brunson & Miller, 2006; Payne, Hitchens, & Chambers, 2017), both in schools and throughout their neighborhoods, presuming criminality in the absence of crime (Vera Sanchez & Adams, 2011). In contrast, White youth report receiving more "chances" compared to minority youth after being questioned by police for repeat offending (Feinstein, 2015), such that police are more likely to release White youth but arrest minority youth (Rinehart Kochel, Wilson, & Mastrofski, 2011). White youth in disadvantaged neighborhoods also report less frequent contact with police relative to Black youth in comparable neighborhoods (Brunson & Weitzer, 2009).

It is unclear why a similar effect of lower offending prior to arrest was not observed for Latino youth in our sample, as Latino communities encounter "hot spots policing" as well (Solis, Portillos, & Brunson, 2009; Toro et al., 2019). However, this is in line with prior work showing that Latino youth are not more likely than White youth to be arrested after accounting for self-reported delinquency (Andersen, 2015). The findings that Black and Latino youth both experience DMC, albeit to varying degrees, has led some to argue for the presence of a "racial gradient" (Weitzer & Tuch, 2008). This "racial gradient" describes the phenomenon whereby Black youth tend to receive the harshest sanctions and be monitored to a higher extent than Latino youth, while Latino youth may likewise be treated differently than White youth (Fader, Kurlychek, & Morgan, 2014; Rodriguez, 2010). Black youth are often described and perceived as more threatening to authority figures compared to Latino youth, potentially leading to differential levels of scrutiny and arrest for Black youth (Feinstein, 2015; Hagan, Shedd, & Payne, 2005).

Indeed, we find in our sample that while Latino youth do not offend significantly less than White youth prior to first arrest, they do (at a trend level) offend more than Black youth, falling along a "racial gradient." It is also important to note that, as with any self-report measure, there is the possibility that youth did not provide a full account of their offending behaviors for fear of retribution. Racial differences in self-reports of offending may limit our conclusions; however, discrepant results from prior studies temper the conclusion that there are definitive differences in the validity of self-reported offending data by race (Thornberry & Krohn, 2000). Furthermore, only 63 (out of 1,216) youths in this sample reported no prior offenses at baseline, and race did not predict whether youth reported no prior offenses, suggesting that most youths were comfortable disclosing at least some of their offenses. Regardless, while youth were ensured that their responses would be anonymized and kept in strict confidence, it is still possible that youth – in particular Black youth – were hesitant to provide full accounts of their offending behavior, which might also help explain discrepancies between Black and Latino youth.

Altogether, our finding that Black youth commit fewer (and not more violent) crimes than White youth prior to arrest suggests that Black youth are disproportionately targeted by policing, thereby facing a lower barrier to entry into the juvenile justice system than their peers. While in this sample we do not find that Latino youth face a similarly lower barrier to entry into the system, this should not be taken to demonstrate that Latino communities do not experience disproportionate policing as well. While we do not have data regarding community policing in our sample of youth, these results suggest that heightened police presence in minority communities needs to be addressed. Subjecting disadvantaged communities to heightened police contact can have long-lasting effects. Hot spots policing may promote negative perceptions of police, and of the justice system more broadly (Wiley & Esbensen, 2016), thus relating to greater

delinquent behavior and the formation of a deviant identity over time (Lemert, 1951). Moreover, selective police contact of predominantly disadvantaged youths can propagate infrequent offending into systematic patterns of delinquency, spurred on by self-perceptions of deviance (H. S. Becker, 1963; Tannenbaum, 1957). Perceptions of racial biases during initial arrest and sentencing may influence later criminal activity and negative attitudes regarding the justice system (Bishop, Leiber, & Johnson, 2010; Hawkins, Kempf-Leonard, & Bishop, 2013). Future work should investigate whether adaptations to hot spots policing, such as reforms aimed at increasing citizen perception of police legitimacy (Weisburd, 2016), may address DMC in entry into the juvenile justice system. In addition, the juvenile justice system needs to address and decrease implicit biases involved in police interactions with youth (Peck, 2018).

Aim 2: Relationship between Race and Processing Decision for Initial Arrest

Second, we aimed to identify whether formality of processing after initial arrest differed by race. Here, we demonstrate that Latino and Black youth experience higher stringency in juvenile processing once arrested. Once youth are arrested, law enforcement officials such as police and probation officers often have the authority to determine whether cases will be formally or informally processed (Snyder, 1996), a determination which we find relates to recidivism in the present study, as have others (Fine et al., 2017; Petitclerc, Gatti, Vitaro, & Tremblay, 2013). Formal processing also relates to more negative attitudes about the juvenile justice system (Liberman, 2008). In the present study, all participants were included on the basis of committing midrange level crimes of similar severity. That is, they were all arrested for an offense that had a 0.35-0.65 probability of being formally versus informally processed. This ensured that any observed differences in relation to processing type were not likely to be driven by severity of arrestable offense. We demonstrate that both Black and Latino youth are at a

greater risk of receiving formal processing, even when controlling for whether or not the arrestable offense was violent and for the amount of self-reported offending prior to arrest. These findings are in line with prior evidence demonstrating that Latino youth are 20% more likely than White youth to be referred to juvenile court (Hockenberry & Puzzanchera, 2016), and Black youth are similarly more likely than White youth to be referred to juvenile court (Schlesinger, 2018).

While some structured guidelines exist for making case determinations (e.g., Borum, Lodewijks, Bartel, & Forth, 2011; Howell & Lipsey, 2004), probation officers in several jurisdictions report often disregarding these recommendations in favor of their own judgments (Shook & Sarri, 2007), sometimes retroactively referring to recommendations to justify processing decisions (Sarri & Hasenfeld, 1976). The subjective nature of determining whether or not a case should be formally processed relies on a number of factors, including perceptions of a youth's risk to public safety and of recidivism (Shook & Sarri, 2007), two variables often conflated with a child's race (Bishop & Frazier, 1995). For instance, probation officers report relying on youth's disposition or level of remorse toward a crime, but White youth are often perceived as more remorseful or as a victim of their circumstances, whereas minority youth are often seen as not remorseful (and thus likely to re-offend) (Bridges & Steen, 1998). Subjectivity in case assignment can thus unintentionally be influenced by implicit racial biases amongst police and probation officers. One study suggests that cultural differences in displays of respect or contrition, such as avoiding direct eye contact in many Latin cultures, might be regarded by authority figures as disrespectful (Villarruel et al., 2002). Such inter-cultural miscommunications may result in Latino youth receiving stricter sentencing, as authority figures rely in part on

interactions with youth to determine whether they seem remorseful enough to not engage in future delinquent behaviors (Bridges & Steen, 1998; Hanan, 2018).

Given that we find minority youth at a greater risk of having cases undergo formal processing regardless of crime severity, subjective case assignment practices potentially hinging on racial biases put minority youth at greater risk of negative life outcomes. Youth with formally processed cases display worse outcomes, such that they are more likely to reoffend (Petrosino, Turpin-Petrosino, & Guckenburg, 2010), reoffend more violently (Beardslee et al., 2019), have difficulty in school (Hjalmarsson, 2008; Sweeten, 2006), and face a greater barrier to employment later in life (Apel & Sweeten, 2010). Formal processing relates to increased self-reported offending and higher re-arrest rates even after accounting for a child's environment, suggesting a criminogenic effect of formal processing (Robertson, 2018).

These results strongly suggest the need for evidence-based and standardized risk assessment tools for determining whether cases should be formally processed (Piquero, 2008), practices that are not adopted in all courts (Mulvey & Iselin, 2008). Minority youth are at a disadvantage during prosecutorial charging when comparing across comparable cases (Bishop et al., 2010), and this is especially true for mid-adolescent youth (ages 14-15) with minor charges (Evangelist, Ryan, Victor, Moore, & Perron, 2017). Minority youth are particularly impacted, as assumptions about a youth's family can influence diversion recommendations despite evidence suggesting that living arrangements do not relate to completion of diversion programs (Love & Morris, 2019). However, even the use of standardized measurements for diversion decisions does not remove minority overrepresentation in secure placement (Mallett & Stoddard-Dare, 2010). These tools need further modification to accurately convey risk factors across diverse populations, as predictions are inconsistent with offending and re-arrest records for minority

youth in particular (Schwalbe, Fraser, Day, & Cooley, 2006; Vincent, Chapman, & Cook, 2011). Thus, future work is needed to generate culturally competent assessment tools to help mitigate the issue of minority youth being disproportionately formally processed.

Aim 3: Relationship between Race and Re-Arrest

Third, we aimed to identify whether likelihood of re-arrest would differ by race. We found that Black youth are at an even greater likelihood of being re-arrested than White or Latino youth, mirroring prior work (McGovern, Demuth, & Jacoby, 2009), even after controlling for the effects of being formally processed, as well as other legal factors that might relate to re-arrest (e.g., self-reported offending after first arrest) and extralegal factors (e.g., neighborhood quality and parental education). Re-arrest results here closely parallel our earlier findings; we find that Black youth are more likely to be re-arrested despite similar levels of post-baseline self-reported offenses as their peers, demonstrating that there is little connection between offending and arrests after accounting for relevant environmental influences.

These results provide further evidence suggesting increased police monitoring amongst minority youth. Black youth were more likely to be re-arrested relative to White youth, despite no differences in self-reported offenses prior to re-arrest. Experiences with the juvenile justice system, especially at the time of first contact (Fine et al., 2017), relate to increased risk for future offending as well as increased likelihood of re-arrest (Beardslee et al., 2019). A longitudinal study investigating the impact of juvenile justice system contact amongst low-income youth demonstrated that more interactions with law enforcement related to a seven times greater likelihood of committing crimes as an adult (Gatti, Tremblay, & Vitaro, 2009). Youth may be monitored more closely following initial justice system contact (Fine et al., 2017); in particular, minority youth may experience even greater monitoring (Rios, 2007), which may explain how

Black youth are more likely to be re-arrested. In line with the recommendations from Aim 1, policy changes should be explored to reduce the burden of proactive policing on communities of color.

Implications of Data Collection Site

Results from this study also demonstrate that geographic location relates to youths' interactions with the juvenile justice system. This may result from unclear specifications regarding how to appropriately address DMC across states and jurisdictions (Jones, 2012). Here, we find that youth in Philadelphia were arrested after committing the fewest offenses but were the least likely to be formally processed or re-arrested. Pennsylvania courts have demonstrated lower levels of both Black and Hispanic youths throughout multiple stages of the juvenile justice system following implementation of the DMC mandate (Donnelly, 2017). That youth were at greater risk of arrest relative to their self-reported offending suggests that DMC reforms in Philadelphia have not effectively addressed police-youth interactions (Peck, 2018). However, it remains unclear why biases would be present at the initial arrest stage and not at re-arrest. Amongst police officers, interview data suggest that while they acknowledge higher rates of arrest in minority youth, these heightened arrest rates reflect the perception of greater crimes committed by minority youth (Dawson-Edwards, Tewksbury, & Nelson, 2020). Altogether, our results in conjunction with prior work suggest that diminishing minority overrepresentation at the earliest stage of juvenile system processing in Philadelphia will require working with police officers to reduce biases.

The likelihood of re-arrest was highest in Orange County. Again, inconsistencies in addressing DMC nationwide (Jones, 2012) may explain these results. Prior work investigating re-arrest risk amongst serious juvenile offenders in California notes that behavior such as gang

involvement and violence while incarcerated strongly predicts re-arrest (Lattimore, MacDonald, Piquero, Linster, & Visher, 2004). As such characteristics may influence perceived risk of recidivism, these youth may be more likely to be monitored after initial arrest. Similar to how greater police presence may increase risk for initial arrest, greater monitoring may yield similar results for risk for re-arrest.

In our diverse sample of adolescents living across multiple states, Black youth report committing the fewest crimes before their initial arrest, report no differences in offending after initial arrest, and commit no more violent crimes than those committed by other youth, yet are nevertheless more likely to be re-arrested. While it is not possible to definitively state that these results are driven by racial bias amongst those in power in the juvenile justice system, the evidence strongly suggests that DMC across all stages of the juvenile justice system may be reinforced by either implicit or explicit racial biases. Indeed, it is important to note that using race as a predictor is not the same as looking at the effects of racism itself *per se* (Jee-Lyn García & Sharif, 2015). Based on arrest records alone, the fact that Black youth are re-arrested at a higher rate than any other group may result in perceptions of Black youth as criminals. However, this study highlights the importance of considering the relationship between youths' self-reports of their offending versus official arrest records. Institutionalized and structural racism inherent in children's neighborhoods and communities contribute to biased police strategies that can reinforce racial differences in arrest and incarceration rates. Thus, it is crucial that future research strongly consider children's socioeconomic status and neighborhood quality as we have done here, as well as numerous other contextual factors such as the proportion of single-parent households, to help disentangle the forces of structural racism in the broader community from racial biases in the justice system. Future research should be careful to consider both the

perceptions and potential biases of those in the justice system, as well as the lived experience of youths themselves.

In addition to shedding light on the factors influencing contact with the juvenile justice system, this line of work also has practical implications for providers who work in or tangentially with the juvenile justice system. Here, we demonstrate that minority youth may be experiencing differential treatment within, and crucially before entry into, the juvenile justice system as a function of racial biases. Future research identifying the mechanisms by which bias is transmitted throughout the justice system will be imperative to successfully combat DMC, benefit minority communities, and promote more favorable perceptions of police and justice system legitimacy.

Table 5.1.1
Participant Descriptive Statistics

	Sample
Black	n = 449, 37.9%
Latino	n = 557, 47.0%
White	n = 180, 15.1%
Age at Arrest *M (SD)*	15.7 (1.31)
History of Self-Reported Offending (SRO) *M (SD)*	3.42 offenses (3.10)
Range	0-19 offenses
SRO in Year After First Arrest *M (SD)*	2.45 offenses (6.14)
Range	0-29.5 offenses
Institutional Time	0.09 months
Violent Index Offense	n = 217, 18.3%
Formal Processing	n = 535, 45.1%
Parental Education	
Has not Completed High School	n = 311, 26.2%
Completed High School	n = 427, 36.0%
More than a High School Diploma	n = 448, 37.8%
Neighborhood Quality	2.07 (0.68)
Data Collection Site	
California	n = 515, 43.4%
Pennsylvania	n = 524, 44.2%
Louisiana	n = 147, 12.4%

Table 5.1.2 Model fit indices for Aim 1: history of self-reported offending

	AIC	BIC	RMSE
Negative Binomial [A]	5131.71	5177.41	0.9958
Poisson [B]	5480.38	5521.00	1.3647
Hurdle	5468.05	5549.29	1.4479
Negative Binomial Hurdle	5033.19	5119.50	1.0434
Poisson Hurdle	5468.05	5549.29	1.4479
OLS	5582.30	5627.62	2.7954

Model fit indices were averaged across 20 imputed data sets to include missing data. Results indicate that the negative binomial hurdle model had the best model fit.

[A] Ordinary count negative binomial model had significantly better fit than the zero-inflated negative binomial model (Vuong test $p = 0.12$)

[B] Ordinary count poisson model had significantly better fit than the zero-inflated poisson model (Vuong test $p = 0.20$)

Table 5.1.3 Model fit indices for Aim 1: self-reported violent offending

	AIC	BIC	RMSE
Negative Binomial [A]	3345.09	3390.79	0.8889
Poisson [B]	3343.08	3383.70	0.8889
Hurdle	3102.72	3183.96	1.2118
Negative Binomial Hurdle	2987.75	3074.07	0.9855
Poisson Hurdle	3103.17	3184.41	1.2121
OLS	3588.78	3634.48	1.0917

Model fit indices were averaged across 20 imputed data sets to include missing data. Results indicate that the negative binomial hurdle model had the best model fit.

[A] Ordinary count negative binomial model had significantly better fit than the zero-inflated negative binomial model (Vuong test $p = 0.25$)

[B] Ordinary count poisson model had significantly better fit than the zero-inflated poisson model (Vuong test $p = 0.25$)

Table 5.1.4 Negative Binomial Hurdle Regression Results for History of Self-Reported Offending Prior to Arrest

	Coefficient *(SE)*	**95% CI**	**Incidence Risk Ratio**
Prior SRO			
Black [A]	-0.30** (0.10)	-0.49, -0.11	0.74
Latino [A]	-0.13 (0.09)	-0.004, 0.34	0.88
Latino [B]	0.17† (0.09)	-0.31, 0.05	1.19
Parental Education	0.06*** (0.02)	0.03, 0.09	1.07
Neighborhood Quality	0.63*** (0.05)	0.54, 0.73	1.88
Age at Arrest	0.14*** (0.02)	0.10, 0.19	1.16
Pennsylvania [C]	-0.51*** (0.09)	-0.68, -0.33	0.60
Louisiana [C]	0.08 (0.11)	-0.14, 0.29	1.08
Louisiana [D]	0.58*** (0.10)	0.38, 0.78	1.79
No prior SRO			
Black [A]	0.61 (0.43)	-0.23, 1.45	1.84
Latino [A]	0.07 (0.40)	-0.72, 0.86	1.07
Latino [B]	-0.54 (0.41)	-1.33, 0.26	0.58
Parental Education	0.10 (0.07)	-0.04, 0.24	1.10
Neighborhood Quality	1.39*** (0.28)	0.85, 1.94	4.02
Age at Arrest	0.07 (0.10)	-0.12, 0.27	1.07
Pennsylvania [C]	-0.79* (0.38)	-1.53, -0.05	0.45
Louisiana [C]	-0.08 (0.48)	-1.02, 0.87	0.93
Louisiana [D]	0.71 (0.45)	-0.17, 1.60	2.04

† denotes $p < 0.10$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$
[A] Reference group is White
[B] Reference group is Black
[C] Reference group is California
[D] Reference group is Pennsylvania

Table 5.1.5 Logistic Regression Results for Formal vs. Informal Processing

	Coefficient *(SE)*	**95% CI**	**Incidence Risk Ratio**
Black [A]	0.51* (0.21)	0.10, 0.93	1.67
Latino [A]	0.51* (0.20)	0.12, 0.90	1.67
Latino [B]	0.002 (0.18)	-0.36, 0.36	1.00
Violent Index Offense [C]	0.66*** (0.16)	0.35, 0.97	1.94
History of Self-Reported Offending	0.08*** (0.02)	0.03, 0.12	1.08
Parental Education	-0.04 (0.03)	-0.10, 0.02	0.96
Neighborhood Quality	-0.04 (0.11)	-0.25, 0.17	0.96
Age at Arrest	0.01 (0.05)	-0.08, 0.10	1.01
Pennsylvania [D]	-0.42* (0.19)	-0.77, -0.05	0.66
Louisiana [D]	0.42 (0.23)	-0.03, 0.87	1.52
Louisiana [E]	0.83 (0.21)	0.42, 1.24	2.30

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

[A] Reference group is White
[B] Reference group is Black
[C] Reference group is "Nonviolent Index Offense"
[D] Reference group is California
[E] Reference group is Pennsylvania

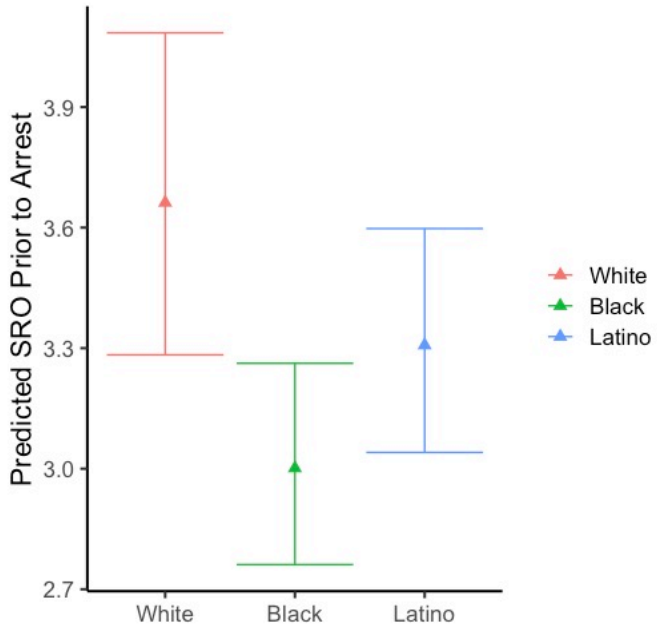
Table 5.1.6 Logistic Regression Results for Probability of Re-Arrest

	Coefficient *(SE)*	**95% CI**	**Incidence Risk Ratio**
Black [A]	0.54* (0.25)	0.04, 1.04	1.71
Latino [A]	-0.03 (0.24)	-0.49, 0.44	0.97
Latino [B]	-0.57* (0.22)	-1.01, -0.13	0.57
Violent Offense [C]	-0.04 (0.18)	-0.40, 0.31	0.96
Formal Processing [D]	0.26† (0.14)	-0.02, 0.54	1.30
Institutional Time	1.87*** (0.28)	1.33, 2.41	6.48
Post-Baseline Self-Reported Offending	0.09*** (0.02)	0.06, 0.13	1.10
Parental Education	-0.08* (0.04)	-0.15, -0.01	0.92
Neighborhood Quality	0.10 (0.12)	-0.12, 0.33	1.11
Age at Arrest	0.002 (0.06)	-0.10, 0.11	1.00
Pennsylvania [E]	-0.67** (0.22)	-1.11, -0.23	0.51
Louisiana [E]	-0.58* (0.28)	-1.12, -0.04	0.56
Louisiana [F]	0.09 (0.25)	-0.40, 0.57	1.09

† denotes $p < 0.10$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

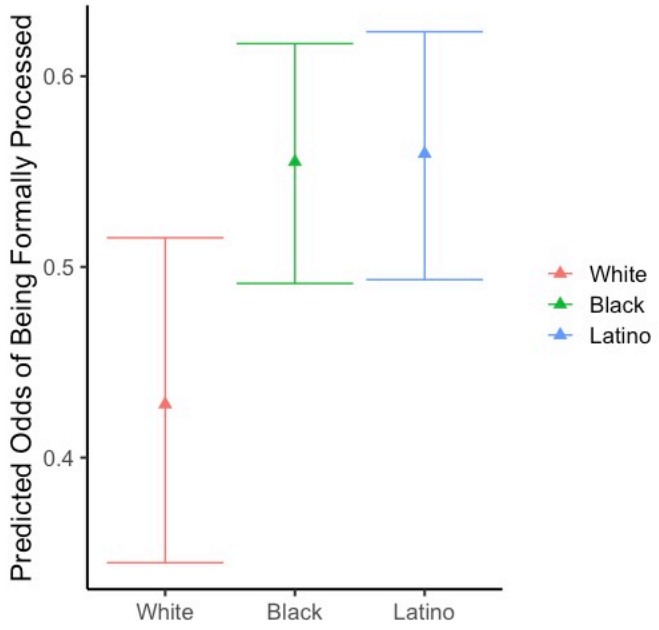
[A] Reference group is White
[B] Reference group is Black
[C] Reference group is "Nonviolent Index Offense"
[D] Reference group is "Informal Processing"
[E] Reference group is California
[F] Reference group is Pennsylvania

Figure 5.1.1



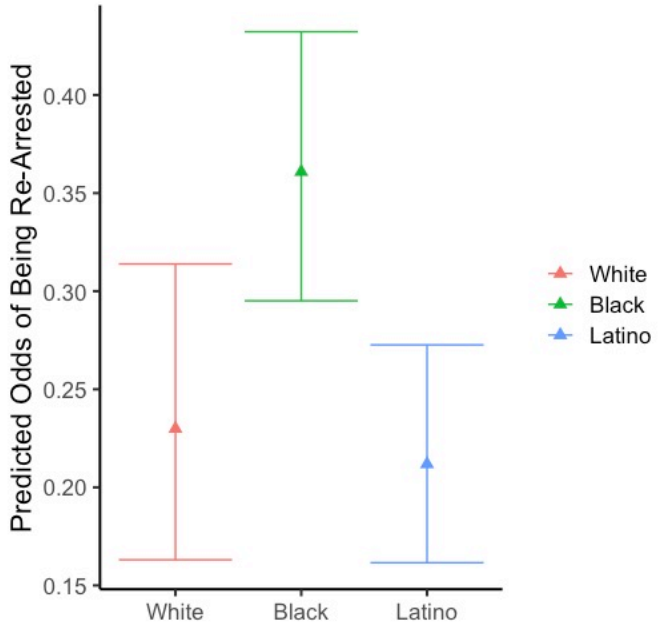
Estimated mean of self-reported offending (SRO) prior to first arrest, controlling for parental education, neighborhood quality, age at arrest, and data collection site. Estimated means are shown for White youth (dashed line), Black youth (solid line), and Latino youth (dot-dashed line). Results from the negative binomial hurdle regression demonstrate that race significantly predicts offending prior to arrest, such that Black youth commit fewer offenses prior to arrest compared to White youth. There were no significant differences between Black and Latino youth, or between White and Latino youth.

Figure 5.1.2



Estimated predicted odds of being formally versus informally processed, controlling for parental education, neighborhood quality, age at arrest, data collection site, history of self-reported offending, and whether the index offense was violent. Estimated odds are shown for White youth (dashed line), Black youth (solid line), and Latino youth (dot-dashed line). Results from the logistic regression demonstrate that race significantly predicts whether youth are formally processed, such that both Black and Latino youth are more likely to be formally processed relative to White youth.

Figure 5.1.3



Estimated predicted odds of being re-arrested, controlling for parental education, neighborhood quality, age at arrest, data collection site, whether youth were formally processed, whether the index offense was violent, and time spent in facilities. Estimated odds are shown for White youth (dashed line), Black youth (solid line), and Latino youth (dot-dashed line). Results from the logistic regression demonstrate that race significantly predicts whether youth are re-arrested, such that Black youth are more likely to be re-arrested than either White or Latino youth.

REFERENCES: STUDY 1

Aizer, A., & Doyle, J. J. (2015). Juvenile Incarceration, Human Capital, and Future Crime: Evidence from Randomly Assigned Judges. *The Quarterly Journal of Economics*, *130*(2), 759–803. https://doi.org/10.1093/qje/qjv003

Andersen, T. S. (2015). Race, Ethnicity, and Structural Variations in Youth Risk of Arrest: Evidence From a National Longitudinal Sample. *Criminal Justice and Behavior*, *42*(9), 900–916. https://doi.org/10.1177/0093854815570963

Apel, R., & Sweeten, G. (2010). The Impact of Incarceration on Employment during the Transition to Adulthood. *Social Problems*, *57*(3), 448–479. https://doi.org/10.1525/sp.2010.57.3.448

Beardslee, J., Miltimore, S., Fine, A., Frick, P. J., Steinberg, L., & Cauffman, E. (2019). Under the radar or under arrest: How is adolescent boys' first contact with the juvenile justice system related to future offending and arrests? *Law and Human Behavior*, *43*(4), 342–357. https://doi.org/10.1037/lhb0000340

Becker, H. S. (1963). *Outsiders*. New York: New York Free Free.

Bishop, D. M. (2016). Juvenile Offenders in the Adult Criminal Justice System. *Crime and Justice*. https://doi.org/10.1086/652199

Bishop, D. M., & Frazier, C. E. (1995). Race Effects in Juvenile Justice Decision-Making: Findings of a Statewide Analysis. *Journal of Criminal Law and Criminology*, *86*(2), 393–414. Retrieved from https://heinonline.org/HOL/Page?handle=hein.journals/jclc86&id=404&div=29&collection=journals

Bishop, D. M., Leiber, M., & Johnson, J. (2010). Contexts of Decision Making in the Juvenile Justice System: An Organizational Approach to Understanding Minority Overrepresentation. *Youth Violence and Juvenile Justice*, *8*(3), 213–233. https://doi.org/10.1177/1541204009361177

Black, J. A. (2016). *Understanding the effectiveness of incarceration on juvenile offending through a systematic review and meta-analysis: do the "get tough" policies work?* Nova Southeastern University. Retrieved from https://nsuworks.nova.edu/cgi/viewcontent.cgi?referer=https://scholar.google.com/&httpsredir=1&article=1001&context=cahss_jhs_etd/

Borum, R., Lodewijks, H., Bartel, P. A., & Forth, A. E. (2011). Structured assessment of violence risk in youth (SAVRY). In R. K. Otto & K. S. Douglas (Eds.), *Handbook of Violence Risk Assessment* (pp. 73–90). Routledge.

Bridges, G. S., & Steen, S. (1998). *Racial Disparities in Official Assessments of Juvenile Offenders: Attributional Stereotypes as Mediating Mechanisms*. *Source: American Sociological Review* (Vol. 63). Retrieved from https://www.jstor.org/stable/pdf/2657267.pdf?refreqid=excelsior%3Aed2de1ff2d2cbbb22be5a26503c2171c

Brunson, R. K., & Miller, J. (2006). Young Black Men and Urban Policing in the United States. *The British Journal of Criminology*, *46*(4), 613–640. https://doi.org/10.1093/bjc/azi093

Brunson, R. K., & Weitzer, R. (2009). Police Relations with Black and White Youths in Different Urban Neighborhoods. *Urban Affairs Review*, *44*(6), 858–885. https://doi.org/10.1177/1078087408326973

Clarke, R. V., & Cornish, D. B. (1985). Modeling Offenders' Decisions: A Framework for

Research and Policy. *Crime and Justice: An Annual Review of Research*, *6*, 147–185. Retrieved from https://heinonline.org/HOL/Page?handle=hein.journals/cjrr6&div=8&g_sent=1&casa_token=&collection=journals

Dawson-Edwards, C., Tewksbury, R., & Nelson, N. T. (2020). The Causes and Pervasiveness of DMC: Stakeholder Perceptions of Disproportionate Minority Contact in the Juvenile Justice System. *Race and Justice*, *10*(2), 223–242. https://doi.org/10.1177/2153368717735365

Dmitrieva, J., Monahan, K. C., Cauffman, E., & Steinberg, L. (2012). Arrested development: The effects of incarceration on the development of psychosocial maturity. *Development and Psychopathology*, *24*(3), 1073–1090. https://doi.org/10.1017/S0954579412000545

Donnelly, E. A. (2017). The Disproportionate Minority Contact Mandate: An Examination of Its Impacts on Juvenile Justice Processing Outcomes (1997-2011). *Criminal Justice Policy Review*, *28*(4), 347–369. https://doi.org/10.1177/0887403415585139

Evangelist, M., Ryan, J. P., Victor, B. G., Moore, A., & Perron, B. E. (2017). Disparities at Adjudication in the Juvenile Justice System: An Examination of Race, Gender, and Age. *Social Work Research*, *41*(4), 199–212. https://doi.org/10.1093/swr/svx017

Fader, J. J., Kurlychek, M. C., & Morgan, K. A. (2014). The color of juvenile justice: Racial disparities in dispositional decisions. *Social Science Research*, *44*, 126–140. https://doi.org/10.1016/j.ssresearch.2013.11.006

Fagan, J. (2017). Response to Ridgeway: Allocating Police. *Journal of Policy Analysis and Management*, *36*(3), 703–707. https://doi.org/10.1002/pam.21998

Federal Register. (1991). Notice of FY 1991 competitive discretionary grant programs and availability of the Office of Juvenile Justice and Delinquency Prevention Program

announcement application kit. Washington, D.C.: Office of Juvenile Justice and Delinquency Prevention.

Feinstein, R. (2015). A Qualitative Analysis of Police Interactions and Disproportionate Minority Contact. *Journal of Ethnicity in Criminal Justice*, *13*(2), 159–178. https://doi.org/10.1080/15377938.2014.936645

Fine, A., Donley, S., Cavanagh, C., Miltimore, S., Steinberg, L., Frick, P. J., & Cauffman, E. (2017). And Justice for All: Determinants and Effects of Probation Officers' Processing Decisions Regarding First-Time Juvenile Offenders. *Psychology, Public Policy, and Law*, *23*(1), 105–117. https://doi.org/10.1037/law0000113

Fine, A., Simmons, C., Cavanagh, C., Rowan, Z., & Cauffman, E. (2020). Implications of Youths' Perceptions of Police Bias and the Code of the Street for Violent Offending. https://doi.org/10.1037/vio0000286.supp

Galobardes, B., Lynch, J., & Smith, G. D. (2007). Measuring socioeconomic position in health research. *British Medical Bulletin*, *81–82*(1), 21–37. https://doi.org/10.1093/bmb/ldm001

Gatti, U., Tremblay, R. E., & Vitaro, F. (2009). Iatrogenic effect of juvenile justice. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*. https://doi.org/10.1111/j.1469-7610.2008.02057.x

Hagan, J., Shedd, C., & Payne, M. R. (2005). Race, Ethnicity, and Youth Perceptions of Criminal Injustice. *American Sociological Review*, *70*(3), 381–407. https://doi.org/10.1177/000312240507000302

Hanan, M. E. (2018). Remorse Bias. *Missouri Law Review*, *83*. Retrieved from https://heinonline.org/HOL/Page?handle=hein.journals/molr83&id=317&div=17&collection=journals

Hawkins, D. F., Kempf-Leonard, K., & Bishop, D. M. (2013). The Role of Race and Ethnicity in Juvenile Justice Processing. In *Our Children, Their Children*. https://doi.org/10.7208/chicago/9780226319919.003.0002

Hinton, E. (2015). Creating Crime. *Journal of Urban History*, *41*(5), 808–824. https://doi.org/10.1177/0096144215589946

Hjalmarsson, R. (2008). Criminal justice involvement and high school completion. *Journal of Urban Economics*, *63*(2), 613–630. https://doi.org/10.1016/J.JUE.2007.04.003

Hockenberry, S., & Puzzanchera, C. (2016). Delinquency Cases Involving Hispanic Youth. Retrieved October 24, 2019, from http://www.ncjj.org/Publication/Delinquency-Cases-Involving-Hispanic-Youth-2013.aspx

Howell, J. C., & Lipsey, M. W. (2004). *A practical approach to linking graduated sanctions with a continuum of effective programs*.

Huizinga, D., Esbensen, F.-A., & Weiher, A. W. (1991). Are There Multiple Paths to Delinquency. *Journal of Criminal Law and Criminology*, *82*. Retrieved from https://heinonline.org/HOL/Page?handle=hein.journals/jclc82&id=95&div=13&collection=journals

Jee-Lyn García, J., & Sharif, M. Z. (2015). Black Lives Matter: A Commentary on Racism and Public Health. *American Journal of Public Health*, *105*(8), e27-30. https://doi.org/10.2105/AJPH.2015.302706

Johnson, L. M., Simons, R. L., & Conger, R. D. (2004). Criminal Justice System Involvement and Continuity of Youth Crime. *Youth & Society*, *36*(1), 3–29. https://doi.org/10.1177/0044118X03260323

Jones, E. N. (2012). Disproportionate Representation of Minority Youth in the Juvenile Justice

System: A Lack of Clarity and Too Much Disparity among States "Addressing" the Issue. *UC Davis J. Juv. L. & Pol'y*, *16*, 155–202. Retrieved from http://www.ojjdp.gov/ojstatbb/ezacjrp/asp/Offense_Race.asp

Kiessl, H., & Würger, M. (2002). Victimization of incarcerated children and juveniles in South Africa. *International Review of Victimology*. https://doi.org/10.1177/026975800200900305

Lambie, I., & Randell, I. (2013). The impact of incarceration on juvenile offenders. *Clinical Psychology Review*, *33*(3), 448–459. https://doi.org/10.1016/j.cpr.2013.01.007

Lattimore, P. K., MacDonald, J. M., Piquero, A. R., Linster, R. L., & Visher, C. A. (2004). Studying the Characteristics of Arrest Frequency among Paroled Youthful Offenders. *Journal of Research in Crime and Delinquency*, *41*(1), 37–57. https://doi.org/10.1177/0022427803256094

Leiber, M. J., Bishop, D., & Chamlin, M. B. (2011). Juvenile Justice Decision-Making Before and After the Implementation of the Disproportionate Minority Contact (DMC) Mandate. *Justice Quarterly*, *28*(3), 460–492. https://doi.org/10.1080/07418825.2010.516005

Leiber, M. J., & Fix, R. (2019). Reflections on the Impact of Race and Ethnicity on Juvenile Court Outcomes and Efforts to Enact Change. *American Journal of Criminal Justice*, *44*(4), 581–608. https://doi.org/10.1007/s12103-019-09479-3

Lemert, E. M. (1951). Social pathology; A systematic approach to the theory of sociopathic behavior. - PsycNET. Retrieved July 17, 2019, from https://psycnet.apa.org/record/1951-08006-000

Liberman, A. M. (Ed.). (2008). *The Long View of Crime: A Synthesis of Longitudinal Research*. Washington, D.C.: Springer.

Lien, N. (2001). Adolescents' proxy reports of parents' socioeconomic status: How valid are

they? *Journal of Epidemiology & Community Health*, *55*(10), 731–737. https://doi.org/10.1136/jech.55.10.731

Long, J. S., & Freese, J. (2001). *Predicted probabilities for count models*. *The Stata Journal* (Vol. 1).

Love, T. P., & Morris, E. W. (2019). Opportunities Diverted: Intake Diversion and Institutionalized Racial Disadvantage in the Juvenile Justice System. *Race and Social Problems*, *11*(1), 33–44. https://doi.org/10.1007/s12552-018-9248-y

Lowery, P. G., Burrow, J. D., & Kaminski, R. J. (2018). A Multilevel Test of the Racial Threat Hypothesis in One State's Juvenile Court. *Crime & Delinquency*, *64*(1), 53–87. https://doi.org/10.1177/0011128716678192

Maggard, S. R. (2015). Assessing the Impact of the Juvenile Detention Alternatives Initiative (JDAI): Predictors of Secure Detention and Length of Stay Before and After JDAI. *Justice Quarterly*, *32*(4), 571–597. https://doi.org/10.1080/07418825.2013.783610

Mallett, C. A., & Stoddard-Dare, P. (2010). Predicting Secure Detention Placement for African-American Juvenile Offenders: Addressing the Disproportionate Minority Confinement Problem. *Journal of Ethnicity in Criminal Justice*, *8*(2), 91–103. https://doi.org/10.1080/15377931003761011

McGovern, V., Demuth, S., & Jacoby, J. E. (2009). Racial and Ethnic Recidivism Risks. *The Prison Journal*, *89*(3), 309–327. https://doi.org/10.1177/0032885509339507

Mendel, R. A. (2009). Two decades of JDAI: from demonstration project to national standard. Baltimore, MD: The Annie E. Casey Foundation.

Mendel, R. A. (2011). No place for kids: The case for reducing juvenile incarceration. *Annie E. Casey Foundation*. https://doi.org/10.1021/jp109041y

Mendel, R. A. (2014). *Juvenile Detention Alternatives Initiative Progress Report*. Retrieved from http://www.aecf.org/work/juvenile-justice/jdai/

Miles, J. (2014). Tolerance and Variance Inflation Factor. In *Wiley StatsRef: Statistics Reference Online*. Chichester, UK: John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118445112.stat06593

Mitchell, O. (2005). A meta-analysis of race and sentencing research: Explaining the inconsistencies. *Journal of Quantitative Criminology*. https://doi.org/10.1007/s10940-005-7362-7

Moore, J. (2007). And Justice for Some - Differential Treatment of Youth of Color in the Justice System. *Youth Today*. https://doi.org/http://dx.doi.org/10.1108/17506200710779521

Morris, R. G., & Piquero, A. R. (2013). For Whom Do Sanctions Deter and Label? *Justice Quarterly*, *30*(5), 837–868. https://doi.org/10.1080/07418825.2011.633543

Mulvey, E. P., & Iselin, A.-M. R. (2008). Improving Professional Judgments of Risk and Amenability in Juvenile Justice. *The Future of Children*, *18*(2), 35–57. https://doi.org/10.1353/foc.0.0012

Muthén, L. K., & Muthén, B. O. (2017). Mplus User's Guide. Los Angeles, CA: Muthén & Muthén.

Onifade, E., Barnes, A., Campbell, C., & Mandalari, A. (2019). Risk assessment as a mechanism for reducing differential treatment of minorities by a juvenile justice system. *Journal of Ethnicity in Criminal Justice*, *17*(3), 203–227. https://doi.org/10.1080/15377938.2019.1619647

Payne, Y. A., Hitchens, B. K., & Chambers, D. L. (2017). "Why I Can't Stand Out in Front of My House?": Street-Identified Black Youth and Young Adult's Negative Encounters With

Police. *Sociological Forum*, *32*(4), 874–895. https://doi.org/10.1111/socf.12380

Peck, J. H. (2018). The Importance of Evaluation and Monitoring Within the Disproportionate Minority Contact (DMC) Mandate. *Race and Justice*, *8*(4), 305–329. https://doi.org/10.1177/2153368716675923

Peeples, F., & Loeber, R. (1994). Do individual factors and neighborhood context explain ethnic differences in juvenile delinquency? *Journal of Quantitative Criminology*. https://doi.org/10.1007/BF02221156

Petitclerc, A., Gatti, U., Vitaro, F., & Tremblay, R. E. (2013). Effects of juvenile court exposure on crime in young adulthood. *Journal of Child Psychology and Psychiatry*, *54*(3), 291–297. https://doi.org/10.1111/j.1469-7610.2012.02616.x

Petrosino, A., Turpin-Petrosino, C., & Guckenburg, S. (2010). *Formal System Processing of Juveniles: Effects on Delinquency*. *Campbell Systematic Reviews* (Vol. 6). John Wiley & Sons, Ltd. https://doi.org/10.4073/csr.2010.1

Piquero, A. R. (2008). Disproportionate minority contact. *Future of Children*. https://doi.org/10.1353/foc.0.0013

Piquero, A. R., Blumstein, A., Brame, R., Haapanen, R., Mulvey, E. P., & Nagin, D. S. (2001). Assessing the impact of exposure time and incapacitation on longitudinal trajectories of criminal offending. *Journal of Adolescent Research*. https://doi.org/10.1177/0743558401161005

Rekker, R., Pardini, D., Keijsers, L., Branje, S., Loeber, R., & Meeus, W. (2015). Moving in and out of poverty: The within-individual association between socioeconomic status and juvenile delinquency. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0136461

Rinehart Kochel, T. (2011). Constructing Hot Spots Policing: Unexamined Consequences for

Disadvantaged Populations and for Police Legitimacy. *Criminal Justice Policy Review*, *22*(3), 350–374. https://doi.org/10.1177/0887403410376233

Rinehart Kochel, T., Wilson, D. B., & Mastrofski, S. D. (2011). Effect of Suspect Race on Officers' Arrest Decisions. *Criminology*, *49*(2), 473–512. https://doi.org/10.1111/j.1745-9125.2011.00230.x

Rios, V. M. (2007). The Hypercriminalization of Black and Latino Male Youth in the Era of Mass Incarceration. In *Racializing Justice, Disenfranchising Lives* (pp. 17–33). New York: Palgrave Macmillan US. https://doi.org/10.1057/9780230607347_2

Robertson, E. (2018). The Potential Iatrogenic Effects of Formal vs. Informal Juvenile Justice System Processing: The Moderating Influence of Callous-Unemotional Traits. *LSU Master's Theses*. Retrieved from https://digitalcommons.lsu.edu/gradschool_theses/4747

Rodriguez, N. (2010). The Cumulative Effect of Race and Ethnicity in Juvenile Court Outcomes and Why Preadjudication Detention Matters. *Journal of Research in Crime and Delinquency*, *47*(3), 391–413. https://doi.org/10.1177/0022427810365905

Sarri, R. C., & Hasenfeld, Y. (1976). *Brought to justice?: Juveniles, the courts, and the law*. National Assessment of Juvenile Corrections, University of Michigan.

Schlesinger, T. (2018). Decriminalizing racialized youth through juvenile diversion. *The Future of Children*, *28*(1), 59–82.

Schwalbe, C. S., Fraser, M. W., Day, S. H., & Cooley, V. (2006). Classifying Juvenile Offenders According to Risk of Recidivism. *Criminal Justice and Behavior*, *33*(3), 305–324. https://doi.org/10.1177/0093854806286451

Shook, J. J., & Sarri, R. C. (2007). Structured decision making in juvenile justice: Judges' and probation officers' perceptions and use. *Children and Youth Services Review*, *29*(10), 1335–

1351. https://doi.org/10.1016/J.CHILDYOUTH.2007.05.008

Snyder, H. N. (1996). The Juvenile Court and Delinquency Cases. *The Juvenile Court*, *6*(3), 53–63. Retrieved from http://www.ncjj.org/PDF/Howardpubs/Snyder_Future_of_Children_1996_vol6no3ART4.pdf

Solis, C., Portillos, E. L., & Brunson, R. K. (2009). Latino Youths' experiences with and perceptions of involuntary police encounters. *Annals of the American Academy of Political and Social Science*, *623*(1), 39–51. https://doi.org/10.1177/0002716208330487

Sweeten, G. (2006). Who Will Graduate? Disruption of High School Education by Arrest and Court Involvement. *Justice Quarterly*, *23*(4), 462–480. https://doi.org/10.1080/07418820600985313

Sweeten, G. (2012). Scaling Criminal Offending. *Journal of Quantitative Criminology*, *28*(3), 533–557. https://doi.org/10.1007/s10940-011-9160-8

Tannenbaum, F. (1957). *Crime and the Community*. Columbia University Press.

Thompson, K. C., & Morris, R. J. (2016). Characteristics of Juvenile Delinquents. In *Juvenile Delinquency and Disability. Advancing Responsible Adolescent Development.* (pp. 9–30). Springer, Cham. https://doi.org/10.1007/978-3-319-29343-1_2

Thornberry, T., & Krohn, M. (2000). The self-report method for measuring delinquency and crime. *Criminal Justice*.

Thornton, L. C., Frick, P. J., Shulman, E. P., Ray, J. V, Steinberg, L., & Cauffman, E. (2015). Callous-unemotional traits and adolescents' role in group crime. *Law and Human Behavior*, *39*(4), 368–377. https://doi.org/10.1037/lhb0000124

Toro, J. Del, Lloyd, T., Buchanan, K. S., Robins, S. J., Zhang Bencharit, L., Gamson Smiedt,

M., … Goff, P. A. (2019). The criminogenic and psychological effects of police stops on adolescent black and Latino boys. *PNAS*, *116*(17), 8261–8268. https://doi.org/10.1073/pnas.1808976116

Unnever, J., Owusu-Bempah, A., & Deryol, R. (2019). A Test of the Differential Involvement Hypothesis. *Race and Justice*, *9*(2), 197–224. https://doi.org/10.1177/2153368717697104

Vera Sanchez, C. G., & Adams, E. B. (2011). Sacrificed on the Altar of Public Safety: The Policing of Latino and African American Youth. *Journal of Contemporary Criminal Justice*, *27*(3), 322–341. https://doi.org/10.1177/1043986211412565

Villarruel, F. A., Walker, N. E., Minifee, P., Rivera-Vázquez, O., Peterson, S., & Perry, K. (2002). *"Dónde está la justicia?" A Call to Action on Behalf of Latino and Latina Youth in the U.S. Justice System*. Retrieved from http://www.buildingblocksforyouth.org.

Vincent, G. M., Chapman, J., & Cook, N. E. (2011). Risk-Needs Assessment in Juvenile Justice. *Criminal Justice and Behavior*, *38*(1), 42–62. https://doi.org/10.1177/0093854810386000

Weaver, Papachristos, & Zanger-Tishler. (2019). The Great Decoupling: The Disconnection Between Criminal Offending and Experience of Arrest Across Two Cohorts. *RSF: The Russell Sage Foundation Journal of the Social Sciences*, *5*(1), 89. https://doi.org/10.7758/rsf.2019.5.1.05

Weisburd, D. (2016). Does Hot Spots Policing Inevitably Lead to Unfair and Abusive Police Practices, or Can We Maximize Both Fairness and Effectiveness in the New Proactive Policing. *University of Chicago Legal Forum*, *661*. Retrieved from https://heinonline.org/HOL/Page?handle=hein.journals/uchclf2016&id=667&div=19&collection=journals

Weitzer, R., & Tuch, S. A. (2008). Race and Policing in America: Conflict and Reform - Ronald

Weitzer, Steven A. Tuch - Google Books. *American Journal of Sociology*, *114*(1), 254–256. Retrieved from https://books.google.com/books?hl=en&lr=&id=xM-YAZsBuqkC&oi=fnd&pg=PR7&dq=Race+and+policing+in+America:+conflict+and+reform&ots=Iq_L5zDFQw&sig=m7S17i07q4Q0765WxcwwLNgySRI#v=onepage&q=Race and policing in America%3A conflict and reform&f=false

Wiley, S. A., & Esbensen, F.-A. (2016). The Effect of Police Contact. *Crime & Delinquency*, *62*(3), 283–307. https://doi.org/10.1177/0011128713492496

Zane, S. N., Mears, D. P., & Welsh, B. C. (2020). How Universal Is Disproportionate Minority Contact? An Examination of Racial and Ethnic Disparities in Juvenile Justice Processing Across Four States. *Justice Quarterly*, *37*(5), 817–841. https://doi.org/10.1080/07418825.2020.1766544

ABSTRACT: STUDY 2

Youth in the juvenile justice system evince high rates of mental health symptoms, including anxiety and depression. How these symptom profiles change after first contact with the justice system and—importantly—how they are related to re-offending remains unclear. Here, we use latent growth curve modeling to characterize univariate and multivariate growth of anxiety, depression, and re-offending in 1,216 male adolescents over 5 years following their first arrest. Overall, the group showed significant linear and quadratic growth in internalizing symptoms and offending behaviors over time such that levels decreased initially after first arrest followed by a small but significant upturn occurring a few years later. Crucially, multivariate growth models revealed a strong positive relationship between the rates of growth in all processes, such that improvements in mental health related to greater decreases in offending, and vice versa. These results highlight the reciprocal nature of internalizing and externalizing problems in adolescence, underscoring the importance of considering mental health alongside offending in the juvenile justice system.

INTRODUCTION: CHAPTER 2

Youth in the juvenile justice system experience higher rates of internalizing symptoms such as anxiety and depression than their non-system-involved peers (Atkins et al., 1999; Cauffman, 2004; Dierkhising et al., 2013; Lemos & Faísca, 2015; Schubert, Mulvey, & Glasheen, 2011; Teplin, Abram, McClelland, Dulcan, & Mericle, 2002; Vermeiren, 2003; Wasserman, McReynolds, Schwalbe, Keating, & Jones, 2010). While justice-involved youth report higher rates of all mental health symptoms (Wasserman et al., 2010), rates of anxiety and depression in this population are especially concerning: nearly half of justice-involved youth

screened from a national database meet clinical criteria for internalizing problems (Dierkhising et al., 2013), and roughly half of justice-involved males who experience mental health disorders while incarcerated continue to have these impairments once released (Teplin, Welty, Abram, Dulcan, & Washburn, 2012). Furthermore, mental health problems go hand-in-hand with criminological outcomes: individuals who continue offending after adolescence are nearly three times more likely to experience mental health problems (Reising, Ttofi, Farrington, & Piquero, 2019). Despite the high prevalence of persistent mental health concerns in this population, youth in the juvenile justice system rarely receive treatment (Zajac, Sheidow, & Davis, 2015).

Above-average rates of internalizing symptoms coupled with lack of treatment is itself a cause for concern for youth development, as untreated internalizing disorders in youth have been linked to increased risk for negative outcomes such as substance abuse, academic failure, and emotional disorders in adulthood (Child Mind Institute, 2018; Colman, Wadsworth, Croudace, & Jones, 2007; Essau, Lewinsohn, Lim, Ho, & Rohde, 2018). Moreover, the cumulative impact of externalizing behaviors (e.g., criminal offending) and internalizing symptoms can be especially detrimental for youth academic and global functioning (Lewinsohn, Rohde, & Seeley, 1995), leading to further justice system contact (Sampson & Laub, 2005) and increased risk for suicide (Perry & Morris, 2014; Ruchkin, Schwab-Stone, Koposov, Vermeiren, & King, 2003). Most psychiatric disorders onset during adolescence or young adulthood (Meyer & Lee, 2019), a period in which risk-taking behaviors such as offending peak as well (Moffitt, 2018; Sweeten, Piquero, & Steinberg, 2013). When considering the unique compounding vulnerabilities that justice-involved youth may also face—including the experience of being labeled as "delinquent" (McLeod, Uemura, & Rohrman, 2012) and incarceration (Barnert, Perry, & Morris, 2016)—the

risk for atypical emotional development in these youth is further increased (Dmitrieva, Monahan, Cauffman, & Steinberg, 2012).

Mental health needs have been studied alongside criminological needs in the risk-needs-responsivity (RNR) model, a correctional psychology framework aimed at assessing the risks and needs of a person related to reducing recidivism (Andrews, Bonta, & Hoge, 1990). In the RNR model, mental health symptoms do not themselves serve a causal role in the development of delinquency, but rather can moderate the efficacy of rehabilitation services aimed at decreasing recidivism (McCormick, Peterson-Badali, & Skilling, 2017). Consideration and treatment of mental health concerns may contribute to enhanced engagement in services; thus, an understanding of how mental health symptoms and offending behaviors develop in parallel is crucial for facilitating ideal rehabilitation. A recent cross-sectional study found limited evidence that prior anxiety and depression are related to later self-reported offending, and stronger evidence that self-reported offending predicts later anxiety and depression (Jolliffe et al., 2019). However, a cross-sectional design can obscure the relationship between internalizing symptoms and offending behaviors and may not capture the true impact of mental health symptoms over time—especially for disorders such as depression that can manifest cyclically (Rubenstein et al., 2015). Longitudinal studies that follow youth from adolescence to young adulthood are necessary for understanding how mental health and offending change together during this crucial developmental period.

Previous developmental research has highlighted bidirectional associations between internalizing symptoms and externalizing behaviors from childhood to adolescence that help explain the high rates of mental health problems seen in arrested youth. Results from a longitudinal prospective study suggest a temporal cascade whereby conduct problems in

childhood contribute to depression symptoms in adolescence because of the many impairments and conflicts caused by the adolescent's behavior and the depression can then further contribute to delinquency in later adolescence by fostering a pessimistic outlook towards the future (Fontaine et al., 2019). Similarly, externalizing behaviors in childhood can predict other internalizing symptoms in adolescence as well, due to the consequences of the adolescent's behavior, and this distress again may lead to further externalizing behaviors due to the higher rates of negative affect that reduce the ability of the youth regulate behavior (Yong et al., 2014). In a community sample followed longitudinally for 6 years, youth exhibiting high depression symptoms were at risk for increasing disruptive behavior, and youth exhibiting high levels of disruptive behavior were at risk for developing higher depression symptoms (Reinke, Eddy, Dishion, & Reid, 2012). While these studies provide valuable information for predicting adolescent outcomes, mental health problems tend to increase the longer youth stay in the juvenile justice system (Wasserman et al., 2010) and have been linked to continued offending into adulthood (Reising et al., 2019). A close examination of how internalizing symptoms and offending behaviors develop in parallel after youth first enter the juvenile justice system is a crucial next step for identifying youths' mental health and criminogenic needs and promoting healthy adolescent development.

The present study employed latent growth curve modeling of repeated assessments of adolescents' emotions and behavior to examine longitudinal trajectories of internalizing symptoms and criminal offending behaviors in 1,216 male adolescents across 3 cities in the United States over the five years following their first arrest. Crucially, latent growth curve modeling allows for examining individual starting points (intercepts) and rates of change (slopes) across different processes, as well as describing the multivariate growth of multiple processes in

relation to one another. In Aim 1, we sought to characterize the average trajectories of internalizing symptoms and offending behaviors in this sample after first contact with the justice system, accounting for between-person differences in a range of key demographic variables. As the prevalence of mental health disorders tends to increase after first contact with the justice system (Wasserman et al., 2010), we hypothesized that the group would show average increases in internalizing symptoms over time. Given the increase in offending behavior across adolescence and into young adulthood (Loeber, Stouthamer-Loeber, Tonry, & Morris, 1986), we also hypothesized increases in offending over time. In addition to these group trajectories, we expected there would be significant variability in starting points and growth patterns across participants, highlighting the role of individual differences in the development of internalizing and externalizing problems in youth after their first arrest, even after considering relevant demographic characteristics including age, race/ethnicity, neighborhood context, data collection location, and parental education.

In Aim 2, we sought to characterize the co-development of internalizing symptoms and offending behaviors over time by examining whether change in mental health is related to change in offending, and vice versa. Because little is known about trajectories of internalizing symptoms in this population, we investigated the role of depression and anxiety symptoms separately. We hypothesized that these constructs would develop together over time, such that worsening mental health symptoms would co-occur with greater criminal offending, highlighting the intertwined nature of internalizing and externalizing processes during adolescence and underscoring the importance of mental health when considering youth recidivism.

MATERIALS AND METHODS: STUDY 2

Study Participants

Data for this project were collected as part of the Crossroads Study, an on-going multi-site longitudinal assessment of 1,216 male adolescents ages 13-18 at baseline (M_{Age} = 15.80, *SD* = 1.28; Table 5.2.1) who were arrested for moderate offenses (i.e., misdemeanors) in either Jefferson Parish, Louisiana (*N* = 151), Orange County, California (*N* = 532), or Philadelphia, Pennsylvania (*N* = 533). These study sites were selected to represent culturally and demographically distinct regions of the country (South, West, and East). Youth were enrolled in the study at the time of their first arrest for midrange, non-felony crimes such as theft of goods, simple battery (e.g., offensive physical contact such as punching), and vandalism (e.g., graffiti); these are distinct from felony-level offenses (e.g., armed robbery, homicide). Detailed information regarding sampling procedures and data collection methodology can be found via the study website: https://sites.uci.edu/crossroadsinfo/about-the-study/study-design/ and in prior publication (Cavanagh & Cauffman, 2017). Briefly, arrested youth with pending intake hearings were screened for eligibility (e.g., no prior arrests) by research associates and invited to participate in the study following informed consent and assent regarding study involvement. Youth were provided $50 for completion of the first interview; an additional $15 was provided at follow-up interviews as retention incentive up to $140. The current study focuses on data from the baseline interview following first official contact with the juvenile justice system and from eight follow-up interviews conducted over the next five years.

Behavioral Measures

Demographic information

Participants self-reported demographic information regarding their age, parents' highest level of education (used as a proxy for socioeconomic status; Galobardes, Lynch, & Smith,

2007), and race/ethnicity. Prior research supports the validity of child report of parental education in adolescent samples (Lien, Friestad, & Klepp, 2001). In the current sample, 26.9% of participants had parents who had not graduated high school, 34.8% had parents with a high school diploma or GED, and 38.3% had parents who had pursued further education after high school. Participants in this sample self-reported their ethnicity as Latino (45.8%), Black (36.9%), White (14.8%), or Other (2.5%). Of note, approximately 78% of youth in California reported their ethnicity as Latino, while approximately 65% of youth in Pennsylvania reported their ethnicity as Black. Therefore, race/ethnicity and data collection site are confounded in this sample, so caution must be taken when interpreting results involving these variables.

Neighborhood quality

Neighborhood quality was assessed using a self-report questionnaire adapted for the Crossroads Study designed to assess observable signs of physical and social disorder in the participant's neighborhood (Sampson & Raudenbush, 1999). Youth reported on how frequently they observed both physical (9 items; e.g. *graffiti or tags*, *boarded up windows on buildings*) and social (12 items; e.g., *adults fighting or arguing loudly*) disorder in their neighborhood using a 4-point Likert scale ranging from 1 (*never*) to 4 (*often*). Average scores across both scales were used as a continuous index of overall neighborhood quality, where higher scores indicate worse neighborhood quality. Neighborhood quality scores for this sample of participants at baseline ranged from 1 to 3.95 ($M = 2.07$, $SD = 0.68$).

Internalizing symptoms

The Revised Child Anxiety and Depression Scale (RCADS; Chorpita, Yim, Moffitt, Umemoto, & Francis, 2000) was used to measure internalizing symptoms associated with anxiety and depression. Anxiety was assessed using the Generalized Anxiety Disorder (GAD)

subscale of the RCADS, which includes 6 items about worries (e.g., "I worry about what is going to happen."). Depression was assessed using the Major Depressive Disorder (MDD) subscale of the RCADS, which includes 10 items measuring depression symptoms such as feelings of worthlessness and anhedonia (e.g., "Nothing is much fun anymore."). Participants rated each item on a 4-point Likert scale ranging from 0 (*never*) to 3 (*always*) according to how often they experience each item. Items for each scale were summed to achieve overall indices of anxiety and depression symptomatology, with higher scores indicating more symptoms of anxiety (max score possible = 18) and depression (max score possible = 30). At baseline, participants scored an average of 5.28 on the GAD subscale (*SD* = 3.76, range: 0-18) and 5.80 on the MDD subscale (*SD* = 4.70, range: 0-30). Baseline anxiety and depression scores demonstrated a significant positive correlation (r (1214) = .55, $p < .001$).

Self-reported offending

Participants' offending behaviors were tracked using the Self-Report of Offending scale (SRO; Huizinga et al., 1991), a self-report measure in which participants indicated their involvement in 24 types of criminal activity ranging from selling drugs to homicide over the previous 6-month period. Responses were summed together to create variety scores (# of different types of criminal acts over the past six months/# of different types of criminal acts ever endorsed by participant), which are often used in criminological research as they correlate well with official reports of offending (Thornberry & Krohn, 2000) and are more resilient to recall bias than are self-reports of frequency of antisocial behavior (Eve, 1984; Osgood, McMorris, & Potenza, 2002). Variety scores are the preferred method for estimating overall offending because they take into account heterogeneity in crime types and seriousness of offense (Sweeten, 2012).

Participants in this sample engaged in an average of 1.09 offenses for every 6-month period (*SD* = 1.44) after initial arrest.

Time in facility

Incarceration can reduce the opportunities an individual has to engage in criminal behavior (Piquero et al., 2001), and time spent incarcerated may also affect internalizing symptom severity. Therefore, we accounted for the proportion of each recall period in which participants reported they were in a secure institution, locked facility, detention, jail, or residential treatment center. On average, participants spent 5.31% of each recall period in a facility (*SD* = 11.64%).

Official re-arrest records

In addition to self-report data from participants, this study also obtained official records from the Department of Probation from all data collection sites to indicate the number of times that youth were re-arrested for either misdemeanor or felony charges over the five years following their first arrest. Across the three data collection sites, 611 participants were re-arrested at least once over the 5-year period, while 556 participants had no record of re-arrest during the period of the study. Forty-nine participants were missing re-arrest data entirely or lacked sufficient re-arrest data to determine whether or not re-arrest occurred.

Behavioral Data Analysis

Latent growth curve analyses were employed in Mplus version 8.2 (Muthén & Muthén, 2017) to examine trajectories of internalizing symptoms and offending behaviors from baseline through the 8 follow-up interviews. Latent growth curve modeling allows for examination of abstract variables over time such as group starting points (intercepts) and growth factors (slopes), as well as their simultaneous growth over time. Furthermore, by modeling different processes

explicitly and simultaneously, we can assess how development in one process relates to development in the other. Although anxiety and depression often co-occur and correlate positively in adolescents (Lewinsohn, Zinbarg, Seeley, Lewinsohn, & Sack, 1997), they are distinct disorders and, by modelling separate growth patterns, we were able to determine if there were differences in their influences on offending behaviors.

Univariate growth curve models were fit for each process of interest (anxiety, depression, offending) to assess average initial levels and trajectories over time. Good model fit for the internalizing univariate models was assessed using the following criteria (Hu & Bentler, 1999): comparative fit index (CFI) greater than or equal to .95, Tucker–Lewis index (TLI) greater than or equal to .95, root mean squared error of approximation (RMSEA) less than or equal to .06, and standardized root mean squared residual (SRMR) less than or equal to .08. Self-reported offending is a count variable with a right-skewed distribution, so a negative binomial model was specified in the offending growth models. Negative binomial regression is optimal for analyzing skewed dependent variables (which prevents the need to log-transform the dependent variable to address skew) and over-dispersed data (Long & Freese, 2001). As standard model fit indices are not provided in Mplus when using count variables, fit was assessed using the Akaike and Bayesian information criterion (AIC and BIC, respectively). Lower AIC and BIC values indicate better model fit. Once the functional form of the growth models (linear and/or quadratic growth) was established, demographic covariates were added into the model to examine the influence of age, neighborhood quality, race/ethnicity, and data collection site on developmental patterns. For models with both linear and quadratic growth factors, the linear slope describes initial growth patterns, while the quadratic slope tends to describe change occurring later in the trajectory.

Associations between internalizing symptoms and offending behaviors over time were assessed using multivariate growth curve modeling (Duncan, Duncan, & Strycker, 2013). Multivariate growth models provide estimates of the covariation among individual differences in initial levels of each variable, covariation in rates of change (both linear and quadratic), and the predictive associations between initial levels in one variable and subsequent change in another (Duncan et al., 2013). The intercept indicates the status immediately after first arrest and first contact with the justice system, while growth coefficients indicate the change that occurred in 1-year increments after arrest. The first 6 follow-up visits occurred in 6-month increments, after which visits were spaced by one year. Therefore, time points were specified as follows: 0, .5, 1, 1.5, 2, 2.5, 3, 4, 5.

Missing data handling

Maximum likelihood estimation with robust standard errors was used to account for missing data in anxiety, depression, and offending, a technique that uses all available data to identify highly probable parameter estimates for a particular data set and reduces sample bias related to attrition (Baraldi & Enders, 2010). Mplus does not allow for missing values in covariates; therefore, multiple imputation (10 imputations) was used to account for missing parental education data from 50 participants.

Internalizing, offending, and re-arrest

In an exploratory analysis, independent samples t-tests were used to compare average growth model estimates for anxiety, depression, and offending derived from the univariate growth models between participants who were (n = 611) and were not (n = 556) re-arrested at least once during the 5-year period to determine how initial levels and changes in these variables may differ in those who are rearrested and those who are not.

RESULTS: STUDY 2

Unconditional growth models

Anxiety

An initial unconditional growth model for anxiety symptoms with only an intercept and linear growth factor was fit to examine the overall trajectory of anxiety symptom development over the 5 years following first arrest. While anxiety symptoms showed a significant linear decrease over the 5-year period (mean linear slope = -0.052, $p < .05$), the model did not fit the data well (χ^2 (40, N = 1216) = 351.31, $p < .001$; RMSEA = 0.08; CFI = 0.92, TLI = 0.93; SRMR = 0.11). A quadratic growth factor was added to the model, significantly improving model fit (χ^2 (36, N = 1216) = 188.30, $p < .001$; RMSEA 0.06; CFI = 0.96, TLI = 0.96; SRMR = 0.07).

As Table 5.2.2 indicates, the current sample demonstrated significant linear and quadratic change in anxiety symptoms over time such that anxiety declined initially after first arrest, followed by an upwards turn occurring a few years after first arrest. Furthermore, the intercept and each growth factor demonstrated significant variance across participants, highlighting significant individual variability in both starting points and growth trajectories of anxiety in this population. There was significant covariance between the intercept and the quadratic slope factor and between the slope factors; however, the intercept did not significantly covary with the linear slope. This suggests that starting points for anxiety were not significantly related to linear change but were related to quadratic change in anxiety over time.

Depression

Next, an initial unconditional growth model for depression symptoms with only an intercept and linear growth factor was fit to examine the overall trajectory of depression

symptom development over the 5 years following first arrest. Unlike anxiety, depression did not show significant linear change on average (mean linear slope = 0.002, $p = .95$). Additionally, the model did not fit the data well (χ^2 (40, N = 1216) = 323.15, $p < .001$; RMSEA = 0.08; CFI = 0.93, TLI = 0.94; SRMR = 0.11). A quadratic growth factor was added to the model, significantly improving model fit (χ^2 (36, N = 1216) = 181.04, $p < .001$; RMSEA 0.06; CFI = 0.96, TLI = 0.96; SRMR = 0.07).

As Table 5.2.3 indicates, the current sample demonstrated significant linear and quadratic change in depression symptoms over time such that depression declined initially after first arrest, followed by an upwards turn occurring a few years after first arrest. Furthermore, the intercept and each growth factor demonstrated significant variance across participants, highlighting significant individual variability in both starting points and growth trajectories of depression in this population. There was significant covariance between the intercept and the quadratic slope factor and between the slope factors; however, the intercept did not significantly covary with the linear slope. This suggests that starting points for depression were not significantly related to linear change but were related to quadratic change in depression over time, perhaps suggesting that internalizing starting points relate to long-term (rather than short-term) change in development following first arrest.

Offending

Next, an initial unconditional growth model for offending behaviors with only an intercept and linear growth factor was fit to examine the overall trajectory of offending development over the 5 years following first arrest. We also accounted for the proportion of time in each recall period participants spent in a secure facility by regressing offending at each time point on time spent in facility. Offending showed a significant linear decrease on average (mean

linear slope = -.27, $p < .001$; AIC = 24756.97, BIC = 24874.35). A quadratic growth factor was next added to the model, improving model fit (AIC = 24507.06, BIC = 24644.85).

As Table 5.2.4 indicates, the current sample demonstrated significant linear and quadratic change in offending behaviors over time such that offending declined steeply after first arrest, followed by an upwards turn occurring a few years after first arrest. Furthermore, the intercept and each growth factor demonstrated significant variance across participants, highlighting significant individual variability in both starting points and growth trajectories of offending in this population. Offending intercepts demonstrated significant covariance with linear and quadratic growth factors, suggesting that offending behaviors at the time of first arrest are related to growth trajectories over time.

Conditional growth models

Anxiety

Covariates were next added to the anxiety growth model to examine effects of demographic variables on starting points (intercepts) and growth (linear and quadratic slopes) in anxiety over time (Table 5.2.5; Figure 5.2.1). Specifically, the latent factors were regressed on the following covariates: age at baseline, neighborhood quality, parental education, race/ethnicity, and data collection site. Model fit indices demonstrated that the conditional model fit the data better than the unconditional model (χ^2 (84, N = 1216) = 235.10, $p < .001$; RMSEA = 0.04; CFI = 0.96, TLI = 0.95; SRMR = 0.05). Age at baseline and neighborhood quality were significantly related to anxiety intercepts such that older age and worse neighborhood quality were associated with higher anxiety symptoms at baseline. None of the covariates significantly predicted linear or quadratic slopes. After inclusion of demographic factors in the conditional model, the covariance between anxiety intercepts and slopes was no longer significant,

suggesting that intercepts were related to slopes in the unconditional model through the influence of shared demographic factors.

Depression

Covariates were also added to the depression growth model (Table 5.2.6; Figure 5.2.2). Specifically, the latent factors were regressed on the following covariates: age at baseline, neighborhood quality, parental education, race/ethnicity, and data collection site. Model fit indices demonstrated that the conditional model fit the data better than the unconditional model (χ^2 (84, N = 1216) = 245.63, $p < .001$; RMSEA = 0.04; CFI = 0.96, TLI = 0.95; SRMR = 0.05). Neighborhood quality and race/ethnicity were both significantly related to depression intercepts such that higher neighborhood quality was related to worse depression, while Black youth (as compared to white youth) demonstrated lower depression at baseline. Race/ethnicity was also related to depression linear slopes, with Latino youth (as compared to white youth) demonstrating greater decreases in depression over time. After inclusion of demographic factors in the conditional model, the covariance between depression intercepts and slopes was no longer significant, suggesting that intercepts were related to slopes in the unconditional model through the influence of shared demographic factors.

Offending

Covariates were also added to the offending growth model (Table 5.2.7; Figure 5.2.3). Specifically, the latent factors were regressed on the following covariates: age at baseline, neighborhood quality, parental education, race/ethnicity, and data collection site. Model fit indices suggested that the conditional model fit the data better than the unconditional model (AIC = 24339.31, BIC = 24599.58). Neighborhood quality, parental education, data collection site, and race/ethnicity were all significantly related to offending intercepts. Specifically, worse

neighborhood quality and higher parental education were related to greater offending at baseline, while youth living in Pennsylvania (as compared to youth in California) and Black and Latino youth (as compared to white youth) demonstrated lower offending at baseline. Age at baseline predicted both linear and quadratic offending slopes, with older age relating to greater linear decreases in offending and quadratic increases in offending over time. Average offending trajectories for different ages are visualized in Figure 5.2.4.

Multivariate growth models

Finally, anxiety, depression, and offending growth models were combined in a multivariate growth model to examine the development of internalizing symptoms and offending behaviors in relation to one another. As anxiety and depression are highly related processes and scores are derived from the same measure, we accounted for the similarity between the two by allowing values to covary at each time point. Anxiety and depression demonstrated significant covariance at each time point (Table 5.2.8). Average group trajectories for anxiety, depression, and offending are displayed together in Figure 5.2.5.

To assess the relationships between the different processes in our multivariate latent growth curve model, we examined the magnitude and direction of the covariance parameters between factors (Table 5.2.9), as well as the correlations between factors (Table 5.2.10). Covariance between factors indicates the extent to which two random variables change in tandem. Therefore, a significant covariance between growth factors suggests that the two constructs change together over time. Correlation between factors indicates how starting points and growth of the different processes relate to one another on a standard scale. It is important to note that these modeling procedures explain overall growth in a process; as such, linear and quadratic trajectories need to be interpreted simultaneously.

Results from the multivariate growth models demonstrate significant covariation between the starting points for anxiety, depression, and offending, suggesting that individuals demonstrating higher depression at baseline also tend to demonstrate higher anxiety and greater offending frequency. Furthermore, the linear and quadratic slopes covaried positively across processes such that change in one process related to similar change in the others in magnitude and direction (i.e., greater improvements in internalizing symptoms related to greater decreases in offending, and vice versa).

Finally, we added all demographic covariates to our multivariate model to control for the confounding effects of external factors such as neighborhood quality that can influence both offending and internalizing processes. The residual covariance between growth processes remained significant when accounting for demographic variables. Residual covariance and correlation matrices for the latent variables are displayed in Tables 5.2.11 and 5.2.12, respectively.

Model estimates by youth re-arrest

Results of an exploratory analysis probing how model estimates related to youth re-arrest outcomes demonstrated that mean growth estimates of internalizing symptoms and offending behaviors in this sample differed based on whether or not youth were re-arrested at least once during the 5-year period. While the mean anxiety intercept did not differ significantly based on youth re-arrest, starting points for depression were significantly higher in the re-arrest group than in the no re-arrest group, suggesting that higher levels of depression at baseline relate to future re-arrest. The mean offending intercept showed a similar pattern: starting points for offending were significantly higher in the re-arrest group than in the no re-arrest group, suggesting that higher baseline offending was related to future re-arrest.

Trajectories of anxiety, depression, and offending all showed significant differences by youth re-arrest. Specifically, youth in the no re-arrest group showed significantly greater declines in anxiety, depression, and offending over time. Taken together, these results suggest that lower depression symptoms and offending behaviors at baseline, as well as declines in anxiety, depression, and offending after first arrest were related to youth avoiding re-arrest.

DISCUSSION: STUDY 2

Mental health problems such as anxiety and depression are common in the juvenile justice system (Dierkhising et al., 2013), tend to increase at each stage of system processing (Wasserman et al., 2010), and have been linked to continued offending into adulthood (Reising, Ttofi, Farrington, & Piquero, 2019). Despite the high symptom burden among justice-involved youth and the potential relevance of mental health for healthy rehabilitation, very little research has examined how anxiety and depression change after youth enter the justice system, and—importantly—how symptom trajectories may be related to re-offending patterns over time. Results from the current study indicate that anxiety and depression change alongside offending behaviors in male adolescents after their first arrest, such that greater improvements in mental health relate to greater decreases in offending, and vice versa. These findings highlight the intertwined nature of internalizing symptoms and externalizing behaviors in adolescence and underscore the importance of considering mental health in studies of juvenile recidivism.

Trajectories of internalizing symptoms among justice-involved youth

While the high prevalence of internalizing disorders among youth in the justice system has been well established in the current literature (Atkins et al., 1999; Dierkhising et al., 2013; Lemos & Faísca, 2015; Schubert, Mulvey, & Glasheen, 2011; Teplin, Abram, McClelland,

Dulcan, & Mericle, 2002; Vermeiren, 2003; Wasserman, McReynolds, Schwalbe, Keating, & Jones, 2010), less is known about how subclinical internalizing symptoms change once youth enter the system, or how individual differences may influence symptom trajectories over time. In the current sample of 1,216 male adolescent first-time offenders tracked over five years, we report initial decreases in anxiety and depression following first arrest followed by an increase in symptoms a few years later.

The initial decline in anxiety and depression observed in this sample was contrary to our hypotheses; we had hypothesized increases in internalizing symptoms over time, as the prevalence of mood and anxiety disorders increases from adolescence into young adulthood (Merikangas et al., 2010), and youth in the justice system may be especially affected. However, the uptick in symptom severity we observed after the initial decline suggests that justice system involvement may influence symptom trajectories and relate to worsening symptoms as youth continue developing. Furthermore, youth were assessed every six months for the first 3 years of study participation, after which interviews were spaced annually. As the uptick in symptom severity occurred around when interviews were spaced further apart, is possible that frequent check-ins through study participation had a positive effect on mental health, and greater changes occurred once visits were spaced more infrequently.

Despite significant group-level trajectories in internalizing symptom development over the 5-year period, there was significant variability in starting points and growth of both anxiety and depression across participants. Individual differences in demographic factors played a role in this variability: older age at baseline was associated with higher baseline anxiety but not depression, replicating previous work suggesting that youth in transition from adolescence to young adulthood may be at higher risk for anxiety disorders (Abuse, 2012; Teplin et al., 2002;

Zajac et al., 2015). Poorer neighborhood quality was associated with greater severity in both anxiety and depression, which is in line with previous work highlighting that neighborhood disorganization and exposure to violence can increase risk for mental health problems in adolescents (Kerig, Ward, Vanderzee, & Moeddel, 2009). Black youth also reported lower baseline depression than white youth, and Black and Latino youth demonstrated greater linear declines in depression than white youth over time. When interpreting these results, it is important to be mindful that ethnic minority youth may face additional burdens to reporting and receiving treatment for mental health concerns (Planey, Smith, Moore, & Walker, 2019), and further research is needed to probe the mechanisms driving internalizing symptom development within diverse populations. Consideration of key demographic variables such as age and neighborhood context will be crucial for identifying at-risk youth. Mental health screenings, especially for older youth who report worse living conditions, may help target limited mental health resources toward those most in need. Providing such support can help improve mental health, which may lead to improved justice system outcomes as well.

Previous research examining recidivism among serious adolescent offenders found no direct association between mental health symptoms and risk for re-arrest in male youth (El Sayed et al., 2016; Schubert et al., 2011). However, amongst the current sample of male adolescents arrested for moderate crimes, increases in internalizing symptom *was* related to re-arrest outcomes. Specifically, youth in the current sample who were re-arrested at least once over the 5-year study period reported significantly higher depression at baseline than those who were not re-arrested, suggesting that baseline depression symptoms may be informative—and more informative than anxiety—when assessing likelihood of youth re-arrest. Furthermore, re-arrested

youth exhibited smaller reductions in anxiety and depression over time, suggesting that accumulated justice-system involvement may relate to less improvements in mental health.

Trajectories of offending behaviors among justice-involved youth

In addition to symptoms of anxiety and depression, youth also reported on their frequency of engaging in a variety of criminal offending behaviors at each study timepoint. Over the five years following their first arrest, youth reported steep initial declines in self-reported offending behavior giving way to an uptick in offending a few years later. This overall decline in offending is hopeful and suggestive of justice system involvement deterring recidivism; these results are also in line with recent work showing declines in juvenile offending, particularly for males (Becker, Kerig, Lim, & Ezechukwu, 2012; Snyder & Office of Justice Programs, 2008). However, just as with the internalizing results, the increase in offending observed years after first arrest could signify the negative impact of more extended time juvenile justice system.

Despite these significant group patterns in offending behaviors over time, there was significant variability in starting points and growth of offending across participants. Greater offending at baseline was associated with smaller declines in offending over time, suggesting that offending frequency at the time of first arrest may be indicative of fluctuations in offending over the following years. Numerous demographic factors influenced baseline levels of offending and offending trajectories in the current sample: worse neighborhood quality and higher parental education were associated with greater baseline offending, while Black and Latino (compared to white) youth and youth in Pennsylvania (compared to California) evinced lower baseline offending. Developmental trends emerged in offending development such that older youth demonstrated greater declines in offending following first arrest. This replicates prior work suggesting that youth who are arrested at a young age more likely to recidivate than older youth

(Becker et al., 2012) and highlights the unique challenges facing youth who enter the justice system at an earlier developmental stage. As with the internalizing results, the significant relationships between demographic variables and offending trajectories suggest that individualized attention is crucial for supporting justice-involved youth.

It is notable that poor neighborhood quality was related to higher baseline anxiety, depression, and offending. Justice-involved youth often live in disorganized neighborhoods with high rates of poverty and violence that increase their risk for developing mental health problems in adolescence and influence criminogenic outcomes (Gorman-Smith & Loeber, 2005; Ingoldsby & Shaw, 2002; Kirk, 2008). While worse neighborhood quality was related to higher baseline levels of anxiety, depression, and offending in this sample, it did not directly influence mental health or offending trajectories over time, suggesting that neighborhood quality may be especially important for youth development prior to entering the juvenile justice system. This is in line with previous work suggesting that middle childhood may be a sensitive period for effects of neighborhood context on youth development (Ingoldsby & Shaw, 2002) and highlights a need for community-based care for youth living in disorganized or dangerous neighborhoods.

Perhaps unsurprisingly, individual differences in offending trajectories were associated with youth re-arrest outcomes in this sample: youth who were re-arrested at least once demonstrated greater offending at baseline and showed the smallest declines in offending behaviors over time. This association warrants further investigation into the factors driving recidivism in this subset of re-arrested youth and suggests that the level of involvement youth have with the juvenile justice system may relate to changes in their tendency to offend. As this study only examined male juvenile offenders, it is unclear whether other genders would demonstrate the same pattern.

Cross-domain associations between mental health and offending

In the current sample of participants, internalizing symptoms and offending behaviors were positively correlated at time of first arrest such that youth displaying higher baseline levels of anxiety and depression also showed high levels of offending at baseline. Offending frequency at baseline was related to the growth of depression, but not anxiety, symptoms over the following five years such that those who offended the most at baseline showed the smallest changes in depression symptoms over time. In contrast, neither baseline anxiety nor baseline depression related to change in offending behaviors over time, suggesting that while high baseline offending may directly impact some aspects of internalizing symptom development, baseline internalizing symptoms do not directly predict offending development. Prior work examining the directionality in the relationship between offending and internalizing has similarly demonstrated that, for males adolescents specifically, earlier offending behaviors predict later depression symptoms (Jolliffe et al., 2019; Kim, Gilman, Kosterman, & Hill, 2019) and anxiety symptoms (Jolliffe et al., 2019) rather than the inverse. Our results also highlight the importance of screening across multiple dimensions of mental health as our observed relationships were specific to depression and not anxiety, though this may vary across youth.

Anxiety, depression, and offending were positively associated in the current sample at baseline; even further, internalizing symptoms and offending behaviors fluctuated together over time such that greater declines in offending were mirrored by greater declines in internalizing, and vice versa. While previous work examining the association between internalizing symptoms and risk-taking behaviors in adolescence is mixed, the positive relationships between anxiety, depression, and offending over time suggests that increases in anxiety and depression were associated with increases in offending. Factors such as poor neighborhood quality have been

associated with both recidivism and internalizing disorders, which could indicate that such demographic factors may account for the association between externalizing and internalizing problems. However, the associations between internalizing and offending observed in this sample remained even when accounting for demographic factors, indicating that the associations between internalizing symptoms and offending behaviors were not solely due to outside influences.

The observed co-development of internalizing symptoms and offending behaviors suggests that the mental health needs of justice involved youth are inextricable from criminogenic needs. These findings give further support for the consideration of mental health needs within the risk-needs-responsivity framework, by considering mental health symptoms in conjunction with other factors relating to recidivism. By treating mental health concerns alongside criminogenic concerns, practitioners can address factors that might otherwise preclude sufficient engagement in treatments addressing criminogenic needs (McCormick, Peterson-Badali, & Skilling, 2015) leading to potential reductions in recidivism rates and time to recidivism (Zeola, Guina, & Nahhas, 2017). In addition, even if treatment for mental health concerns does not directly reduce recidivism, supporting healthy mental health development is an important goal in and of itself (Jolliffe et al., 2019), and is crucial for youth rehabilitation and well-being in the transition from adolescence into adulthood.

It is important to acknowledge the limitations of the current study. Firstly, as this study consisted of an all-male cohort, we cannot generalize these results to other genders. Furthermore, anxiety and depression were measured via self-report as opposed to full clinical interviews, and therefore should not be used to diagnose clinical anxiety and depression. Nevertheless, youth in the juvenile justice system—and especially males—report more symptoms via self-report

compared to clinical interviews (Vermeiren, Jespers, & Moffitt, 2006), suggesting that data from clinical interviews may underestimate youths' symptom burden. Relatedly, while youth were ensured that their records would remain anonymous and protected from law enforcement subpoena through a Certificate of Confidentiality, it is possible that youth did not disclose the full extent of their offending for fear of punishment. Finally, previous research has implicated factors in driving mental health problems and later re-offending; however, in this study, we do not probe factors mediating this process, and therefore cannot speak to the mechanisms driving changes in mental health and offending at each time point.

This project advances past work by examining both internalizing and externalizing trajectories in youth after their first arrest. The analytic framework allows us to examine how internalizing symptoms and offending behaviors change together over time, rather than focusing exclusively on the predictive validity of either, as is typically done in the literature. Here, we showcase the reciprocal relationship between internalizing and offending in adolescence and highlight that even amongst boys—who typically express fewer internalizing symptoms than girls—subclinical internalizing symptomatology can increase risk for recidivism, even after accounting for relevant demographic factors. Taken together, these results underscore the importance of considering both mental health and criminogenic concerns in decisions regarding how youth are treated in the juvenile justice system and, in particular, highlighting the importance addressing the mental health needs of youth in order to reduce their risk for future antisocial behavior and offending.

Table 5.2.1 Subject demographics

	Sample
Black	n = 449, 36.9%
Latino	n = 557, 45.8%
White	n = 180, 14.8%
Other	n = 30, 2.5%
Age at Arrest *M (SD)*	15.8 (1.28)
Average SRO in Years After First Arrest *M (SD)*	1.09 offenses (1.44)
Time in Facility per 6-mo Recall Period *M (SD)*	5.31% (11.64%)
Number of Youth Re-Arrested Once after First Arrest	611 (50.2%)
Parental Education	
Has not Completed High School	n = 327, 26.9%
Completed High School or GED	n = 423, 34.8%
More than a High School Diploma	n = 465, 38.3%
Generalized anxiety symptom severity *M (SD)*	5.28 (3.76)
Major depressive disorder severity *M (SD)*	5.80 (4.70)
Neighborhood Quality *M (SD)*	2.07 (0.68)
Data Collection Site	
California	n = 532, 43.8%
Pennsylvania	n = 533, 43.8%
Louisiana	n = 151, 12.4%

Table 5.2.2 Unconditional anxiety growth model

	Estimate	***S.E.***	***p-value***
Intercept			
Mean	5.092[A]	0.092	0.000
Variance	4.335[B]	0.441	0.000
Linear slope			
Mean	-0.518[C]	0.072	0.000
Variance	1.472[B]	0.281	0.000
Quadratic slope			
Mean	0.093[D]	0.014	0.000
Variance	0.050[B]	0.010	0.000
Linear slope with:			
Intercept	0.304[E]	0.286	0.287
Quadratic slope with:			
Intercept	-0.108[E]	0.051	0.036
Linear slope	-0.249[E]	0.052	0.000

A. Average value of anxiety when Time = 0.
B. Does the parameter vary significantly across individuals?
C. Average linear change in anxiety for one year of Time.
D. Average quadratic change in anxiety for one year of Time.
E. Covariance between growth factors.

Table 5.2.3 Unconditional depression growth model

	Estimate	***S.E.***	***p-value***
Intercept			
Mean	5.571[A]	0.113	0.000
Variance	7.060[B]	0.674	0.000
Linear slope			
Mean	-0.348[C]	0.090	0.000
Variance	2.565[B]	0.434	0.000
Quadratic slope			
Mean	0.069[D]	0.017	0.000
Variance	0.091[B]	0.016	0.000
Linear slope with:			
Intercept	0.637[E]	0.428	0.136
Quadratic slope with:			
Intercept	-0.159[E]	0.077	0.040
Linear slope	-0.448[E]	0.081	0.000

A. Average value of depression when Time = 0.
B. Does the parameter vary significantly across individuals?
C. Average linear change in depression for one year of Time.
D. Average quadratic change in depression for one year of Time.
E. Covariance between growth factors.

Table 5.2.4 Unconditional offending growth model

	Estimate	***S.E.***	***p-value***
Intercept			
Mean	0.013[A]	0.042	0.756
Variance	0.863[B]	0.066	0.000
Linear slope			
Mean	-0.743[C]	0.051	0.000
Variance	0.638[B]	0.075	0.000
Quadratic slope			
Mean	0.108[D]	0.011	0.000
Variance	0.021[B]	0.003	0.000
Linear slope with:			
Intercept	0.157[E]	0.051	0.002
Quadratic slope with:			
Intercept	-0.043[E]	0.010	0.000
Linear slope	-0.109[E]	0.014	0.000
Offending on Time in Facility			
Baseline	2.036	0.711	0.004
Follow-up 1	1.087	0.289	0.000
Follow-up 2	0.534	0.173	0.002
Follow-up 3	0.192	0.170	0.260
Follow-up 4	-0.044	0.182	0.807
Follow-up 5	0.057	0.182	0.755
Follow-up 6	-0.096	0.253	0.704
Follow-up 7	0.606	0.273	0.027
Follow-up 8	-0.077	0.234	0.742

A. Average value of offending when Time = 0.
B. Does the parameter vary significantly across individuals?
C. Average linear change in offending for one year of Time.
D. Average quadratic change in offending for one year of Time.
E. Covariance between growth factors.

Table 5.2.5 Conditional anxiety growth model

	Estimate	*S.E.*	*p-value*
Mean when covariates = 0[G]			
Intercept	5.341	0.279	0.000
Linear slope	-0.348	0.223	0.119
Quadratic slope	0.082	0.042	0.052
Intercept on:			
Age	0.186	0.072	0.010
Neighborhood quality	0.612	0.148	0.000
Parental education	-0.039	0.046	0.391
Data collection site			
Pennsylvania	-0.495	0.271	0.068
Louisiana	-0.116	0.344	0.735
Race/ethnicity			
Black	-0.145	0.311	0.641
Latino	0.094	0.296	0.751
Other	-0.422	0.617	0.495
Linear slope on:			
Age	-0.024	0.057	0.680
Neighborhood quality	0.007	0.118	0.954
Parental education	0.009	0.036	0.815
Data collection site			
Pennsylvania	0.016	0.217	0.942
Louisiana	-0.135	0.275	0.623
Race/ethnicity			
Black	-0.196	0.248	0.430
Latino	-0.212	0.236	0.370
Other	0.369	0.485	0.447
Quadratic slope on:			
Age	-0.011	0.011	0.290
Neighborhood quality	0.002	0.022	0.920
Parental education	-0.003	0.007	0.682
Data collection site			
Pennsylvania	0.004	0.041	0.913
Louisiana	0.013	0.052	0.797
Race/ethnicity			
Black	0.019	0.047	0.689
Latino	0.007	0.045	0.874
Other	-0.103	0.091	0.257

A. Age, parental education, and neighborhood quality are centered at the group mean. Reference group for categorical variables: Site: California, Race: White.

Table 5.2.6 Conditional depression growth model

	Estimate	*S.E.*	*p-value*
Mean when covariates = 0[G]			
Intercept	6.298	0.345	0.000
Linear slope	0.129	0.279	0.644
Quadratic slope	0.004	0.052	0.941
Intercept on:			
Age	0.021	0.089	0.811
Neighborhood quality	0.818	0.183	0.000
Parental education	0.053	0.057	0.355
Data collection site			
Pennsylvania	-0.510	0.335	0.127
Louisiana	-0.121	0.425	0.776
Race/ethnicity			
Black	-0.891	0.384	0.020
Latino	-0.328	0.367	0.371
Other	-0.486	0.763	0.525
Linear slope on:			
Age	0.044	0.072	0.538
Neighborhood quality	0.086	0.147	0.561
Parental education	-0.012	0.046	0.794
Data collection site			
Pennsylvania	0.058	0.271	0.832
Louisiana	-0.013	0.345	0.969
Race/ethnicity			
Black	-0.577	0.310	0.063
Latino	-0.618	0.296	0.037
Other	-0.112	0.607	0.853
Quadratic slope on:			
Age	-0.018	0.013	0.180
Neighborhood quality	-0.015	0.028	0.588
Parental education	0.003	0.009	0.757
Data collection site			
Pennsylvania	-0.001	0.051	0.992
Louisiana	0.002	0.065	0.977
Race/ethnicity			
Black	0.095	0.058	0.104
Latino	0.067	0.056	0.231
Other	-0.038	0.114	0.739

A. Age, parental education, and neighborhood quality are centered at the group mean. Reference group for categorical variables: Site: California, Race: White.

Table 5.2.7 Conditional offending growth model

	Estimate	*S.E.*	*p-value*
Mean when covariates = 0[A]			
Intercept	0.460	0.103	0.000
Linear slope	-0.724	0.110	0.000
Quadratic slope	0.098	0.022	0.000
Intercept on:			
Age	0.046	0.026	0.075
Neighborhood quality	0.673	0.057	0.000
Parental education	0.068	0.017	0.000
Data collection site			
Pennsylvania	-0.493	0.102	0.000
Louisiana	0.089	0.115	0.440
Race/ethnicity			
Black	-0.353	0.111	0.001
Latino	-0.229	0.109	0.035
Other	-0.324	0.235	0.168
Linear slope on:			
Age	-0.147	0.027	0.000
Neighborhood quality	-0.091	0.062	0.146
Parental education	-0.001	0.019	0.955
Data collection site			
Pennsylvania	-0.076	0.107	0.478
Louisiana	-0.252	0.139	0.068
Race/ethnicity			
Black	0.016	0.119	0.894
Latino	0.072	0.111	0.516
Other	0.337	0.223	0.131
Quadratic slope on:			
Age	0.025	0.006	0.000
Neighborhood quality	0.008	0.012	0.521
Parental education	0.000	0.004	0.905
Data collection site			
Pennsylvania	0.040	0.021	0.051
Louisiana	0.052	0.027	0.051
Race/ethnicity			
Black	-0.015	0.023	0.524
Latino	-0.017	0.022	0.444
Other	-0.066	0.041	0.103

A. Age, parental education, and neighborhood quality are centered at the group mean. Reference group for categorical variables: Site: California, Race: White.

Table 5.2.8 Covariance between anxiety and depression at each time point

	Estimate	***S.E.***	***p-value***
Anxiety with Depression:			
Baseline	8.605	0.812	0.000
Follow-up 1	4.618	0.516	0.000
Follow-up 2	4.097	0.489	0.000
Follow-up 3	3.860	0.407	0.000
Follow-up 4	3.733	0.408	0.000
Follow-up 5	3.750	0.476	0.000
Follow-up 6	4.630	0.494	0.000
Follow-up 7	6.811	0.801	0.000
Follow-up 8	3.907	0.797	0.000

Table 5.2.9 Estimated covariance matrix for the latent variables

		Intercept			*Linear*			*Quadratic*		
		Anx	*Dep*	*Off*	*Anx*	*Dep*	*Off*	*Anx*	*Dep*	*Off*
Intercept	*Anx*	4.44***								
	Dep	3.61***	7.13***							
	Off	0.87***	1.12***	0.85***						
Linear	*Anx*	0.26	0.43	0.07	1.48***					
	Dep	0.60†	0.57	0.17	1.45***	2.61***				
	Off	-0.18	-0.23	0.15**	0.55***	0.66***	0.62***			
Quadratic	*Anx*	-0.10†	-0.08	-0.03	-0.25***	-0.27***	-0.09***	0.05***		
	Dep	-0.15*	-0.15	-0.05*	-0.24***	-0.46***	-0.10***	0.05***	0.09***	
	Off	0.02	0.05	-0.04***	-0.10***	-0.13***	-0.10***	0.02***	0.02***	0.02***

Anx = anxiety; Dep = depression; Off = offending. † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 5.2.10 Estimated correlation matrix for the latent variables

		Intercept			*Linear*			*Quadratic*		
		Anx	*Dep*	*Off*	*Anx*	*Dep*	*Off*	*Anx*	*Dep*	*Off*
Intercept	*Anx*	1***								
	Dep	0.64***	1***							
	Off	0.45***	0.46***	1***						
Linear	*Anx*	0.10	0.13	0.06	1***					
	Dep	0.18	0.13	0.12	0.74***	1***				
	Off	-0.11	-0.11	0.21**	0.58***	0.52***	1***			
Quadratic	*Anx*	-0.21	-0.13	-0.13	-0.92***	-0.74***	-0.50***	1***		
	Dep	-0.23*	-0.18	-0.19*	-0.65***	-0.93***	-0.42***	0.76***	1***	
	Off	0.07	0.14†	-0.32***	-0.57***	-0.57***	-0.94***	0.56***	0.53***	1***

Anx = anxiety; Dep = depression; Off = offending. † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 5.2.11 Estimated residual covariance matrix for the latent variables (with covariates)

		Intercept			*Linear*			*Quadratic*		
		Anx	*Dep*	*Off*	*Anx*	*Dep*	*Off*	*Anx*	*Dep*	*Off*
Intercept	*Anx*	4.18***								
	Dep	3.36***	6.75***							
	Off	0.67***	0.85***	0.64***						
Linear	*Anx*	0.26	0.40	0.08	1.48***					
	Dep	0.57†	0.50	0.14	1.44***	2.57***				
	Off	-0.10	-0.18	0.18***	0.53***	0.67***	0.60***			
Quadratic	*Anx*	-0.09	-0.07	-0.03†	-0.25***	-0.27***	-0.09***	0.05***		
	Dep	-0.13*	-0.13	-0.04*	-0.24***	-0.45***	-0.10***	0.05***	0.09***	
	Off	0.01	0.05†	-0.04***	-0.10***	-0.13***	-0.10***	0.02***	0.02***	0.02***

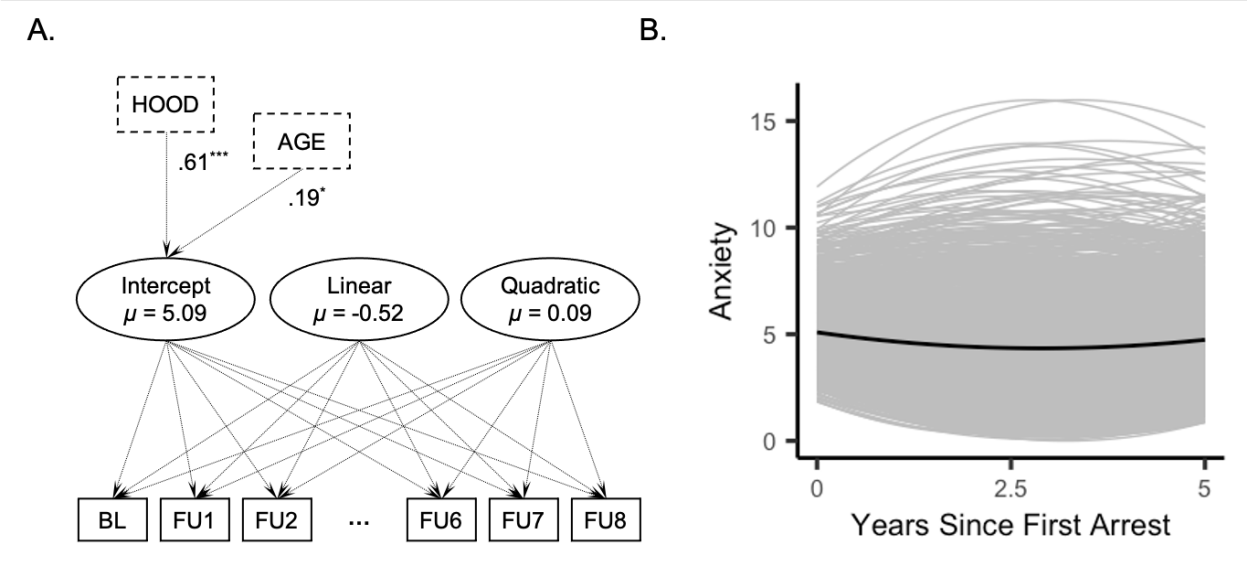
Anx = anxiety; Dep = depression; Off = offending. $^{\dagger}p < .1$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table 5.2.12 Estimated residual correlation matrix for the latent variables (with covariates)

		Intercept			*Linear*			*Quadratic*		
		Anx	*Dep*	*Off*	*Anx*	*Dep*	*Off*	*Anx*	*Dep*	*Off*
Intercept	*Anx*	1***								
	Dep	0.63***	1***							
	Off	0.41***	0.41***	1***						
Linear	*Anx*	0.10	0.13	0.08	1***					
	Dep	0.17	0.12	0.11	0.74***	1***				
	Off	-0.06	-0.09	0.29**	0.56***	0.54***	1***			
Quadratic	*Anx*	-0.20	-0.12	-0.15†	-0.92***	-0.75***	-0.50***	1***		
	Dep	-0.21†	-0.16	-0.18*	-0.66***	-0.93***	-0.44***	0.77***	1***	
	Off	0.04	0.11	-0.39***	-0.57***	-0.59***	-0.95***	0.56***	0.54***	1***

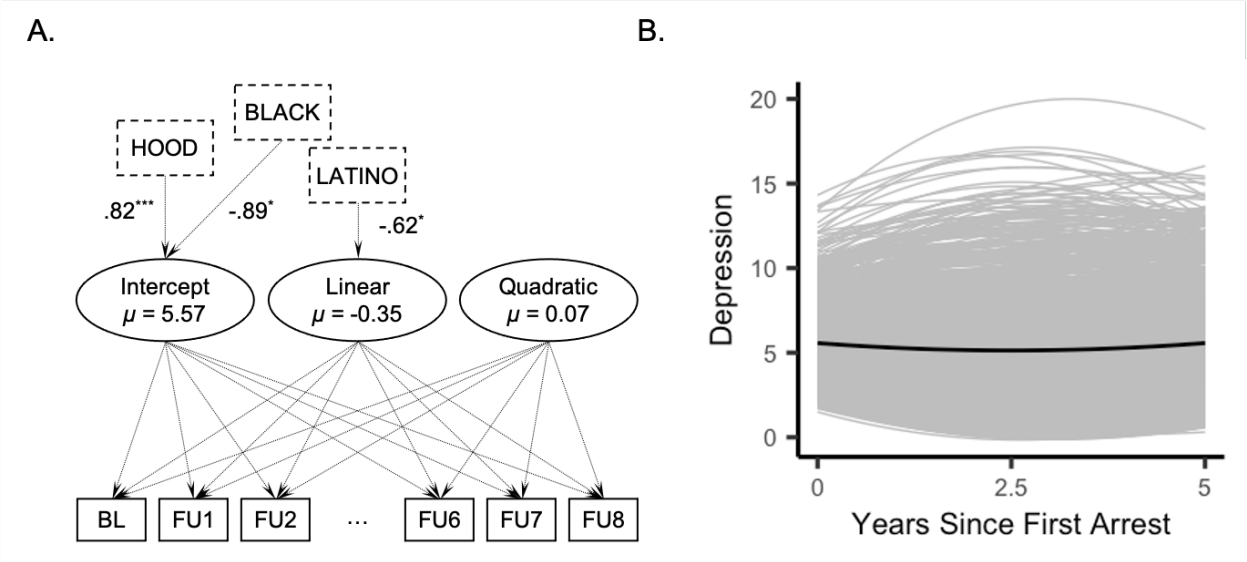
Anx = anxiety; Dep = depression; Off = offending. † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 5.2.1 Trajectories of anxiety following youths' first arrest



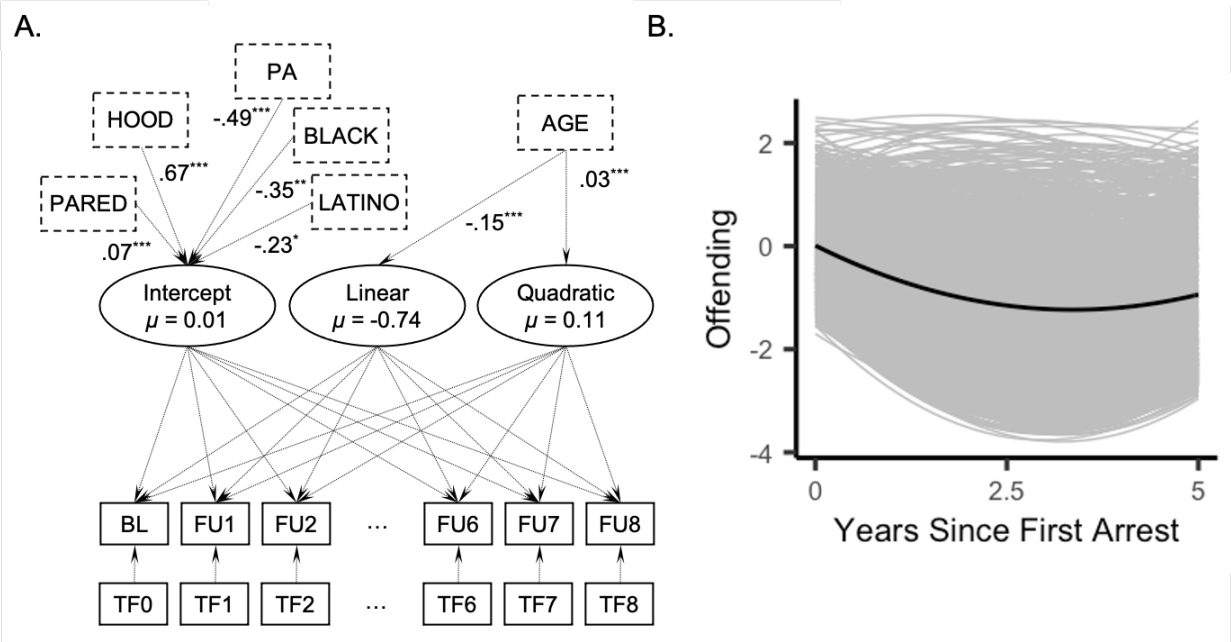
A) Conditional anxiety growth model. *Note:* only covariates with significant effects are shown. Hood = neighborhood quality; BL = baseline; FU = follow-up; μ = estimated conditional mean derived from model. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$. B) Visual depiction of anxiety symptoms over time. Grey lines depict individual growth trajectories in anxiety with the average group trajectory overlayed in black.

Figure 5.2.2 Trajectories of depression following youths' first arrest



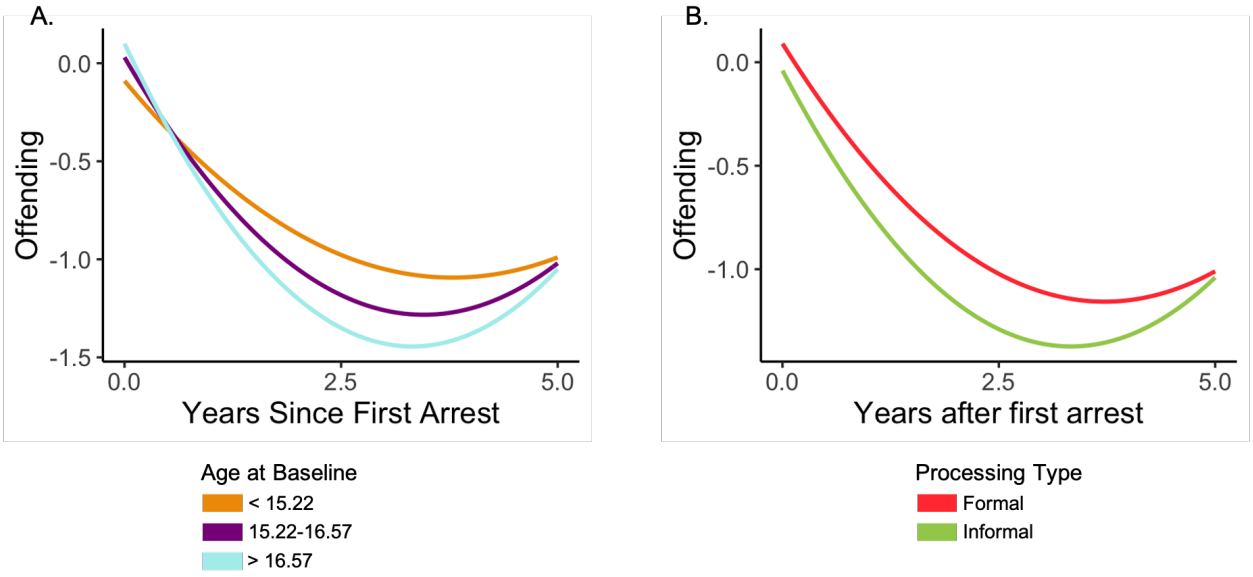
A) Conditional depression growth model. *Note:* only covariates with significant effects are shown. Hood = neighborhood quality; BL = baseline; FU = follow-up; μ = estimated conditional mean derived from model. Reference group for race: white. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$. B) Visual depiction of depression symptoms over time. Grey lines depict individual growth trajectories in depression with the average group trajectory overlayed in black.

Figure 5.2.3 Trajectories of offending following youths' first arrest



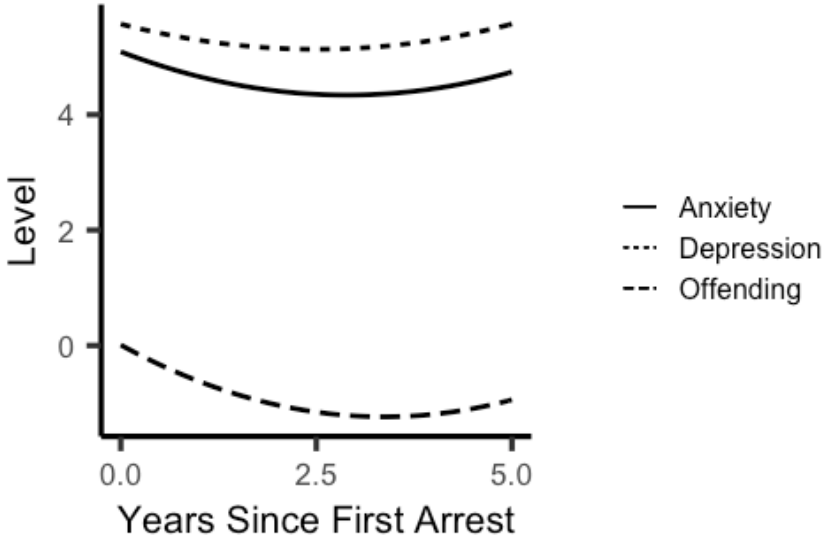
A) Conditional offending growth model. *Note:* only covariates with significant effects are shown. Pared = parental education; Hood = neighborhood quality; PA = Pennsylvania; BL = baseline; FU = follow-up; TF = time in facility; μ = estimated conditional mean derived from model. Reference groups for data collection site and race: California and white. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$. B) Visual depiction of offending behaviors over time. Grey lines depict individual growth trajectories in depression with the average group trajectory overlayed in black.

Figure 5.2.4 Average offending trajectories by age group and processing status



A) Visual depiction of average offending trajectories by age group at baseline. Older participants demonstrated greater declines in offending after first arrest. B) Visual depiction of average offending trajectories by processing status at baseline.

Figure 5. Average group trajectories of anxiety, depression, and offending.



REFERENCES: STUDY 2

Abuse, S.-U.S.D. of H. and H.S., 2012. Results from the 2011 national survey on drug use and health: mental health findings. hsdl.org.

Andrews, D.A.., Bonta, J., Hoge, R.D., 1990. Classification for Effective Rehabilitation. Crim. Justice Behav. 17, 19–52. https://doi.org/10.1177/0093854890017001004

Atkins, D.L., Pumariega, A.J., Rogers, K., Montgomery, L., Nybro, C., Jeffers, G., Sease, F., 1999. Mental health and incarcerated youth. I: Prevalence and nature of psychopathology. J. Child Fam. Stud. 8, 193–204. https://doi.org/10.1023/A:1022040018365

Barnert, E.S., Perry, R., Morris, R.E., 2016. Juvenile Incarceration and Health. Acad. Pediatr. 16, 99–109. https://doi.org/10.1016/j.acap.2015.09.004

Becker, S.P., Kerig, P.K., Lim, J.Y., Ezechukwu, R.N., 2012. Predictors of Recidivism among Delinquent Youth: Interrelations among Ethnicity, Gender, Age, Mental Health Problems, and Posttraumatic Stress. J. Child Adolesc. Trauma. https://doi.org/10.1080/19361521.2012.671798

Cauffman, E., 2004. A Statewide Screening of Mental Health Symptoms Among Juvenile Offenders in Detention. J. Am. Acad. Child Adolesc. Psychiatry 43, 430–439. https://doi.org/10.1097/00004583-200404000-00009

Child Mind Institute, 2018. Understanding Anxiety in Children and Teens, 2018 Children's Mental Health Report.

Colman, I., Wadsworth, M.E.J., Croudace, T.J., Jones, P.B., 2007. Forty-year psychiatric outcomes following assessment for internalizing disorder in adolescence. Am. J. Psychiatry. https://doi.org/10.1176/ajp.2007.164.1.126

Dierkhising, C.B., Ko, S.J., Woods-Jaeger, B., Briggs, E.C., Lee, R., Pynoos, R.S., 2013. Trauma

histories among justice-involved youth: Findings from the National Child Traumatic Stress Network. Eur. J. Psychotraumatol. https://doi.org/10.3402/ejpt.v4i0.20274

Dmitrieva, J., Monahan, K.C., Cauffman, E., Steinberg, L., 2012. Arrested development: The effects of incarceration on the development of psychosocial maturity. Dev. Psychopathol. https://doi.org/10.1017/s0954579412000545

El Sayed, S., Piquero, A.R., Schubert, C.A., Mulvey, E.P., Pitzer, L., Piquero, N.L., 2016. Assessing the Mental Health/Offending Relationship Across Race/Ethnicity in a Sample of Serious Adolescent Offenders. Crim. Justice Policy Rev. 27, 265–301. https://doi.org/10.1177/0887403415575145

Essau, C.A., Lewinsohn, P.M., Lim, J.X., Ho, M.R., Rohde, P., 2018. Incidence, recurrence and comorbidity of anxiety disorders in four major developmental stages. J. Affect. Disord. 228, 248–253. https://doi.org/10.1016/j.jad.2017.12.014

Fontaine, N.M.G., Brendgen, M., Vitaro, F., Boivin, M., Tremblay, R.E., Côté, S.M., 2018. Longitudinal associations between delinquency, depression and anxiety symptoms in adolescence: Testing the moderating effect of sex and family socioeconomic status. J. Crim. Justice. https://doi.org/10.1016/J.JCRIMJUS.2018.09.007

Gorman-Smith, D., Loeber, R., 2005. Are developmental pathways in disruptive behaviors the same for girls and boys? J. Child Fam. Stud. https://doi.org/10.1007/s10826-005-1109-9

Hu, L.T., Bentler, P.M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct. Equ. Model. 6, 1–55. https://doi.org/10.1080/10705519909540118

Ingoldsby, E.M., Shaw, D.S., 2002. Neighborhood contextual factors and early-starting antisocial pathways. Clin. Child Fam. Psychol. Rev. 5, 21–55.

https://doi.org/10.1023/A:1014521724498

Jolliffe, D., Farrington, D.P., Brunton-Smith, I., Loeber, R., Ahonen, L., Palacios, A.P., 2019. Depression, anxiety and delinquency: Results from the Pittsburgh Youth Study. J. Crim. Justice 62, 42–49. https://doi.org/10.1016/j.jcrimjus.2018.08.004

Kerig, P.K., Ward, R.M., Vanderzee, K.L., Moeddel, M.A., 2009. Posttraumatic stress as a mediator of the relationship between trauma and mental health problems among juvenile delinquents. J. Youth Adolesc. 38, 1214–1225. https://doi.org/10.1007/s10964-008-9332-5

Kim, B.K.E., Gilman, A.B., Kosterman, R., Hill, K.G., 2019. Longitudinal associations among depression, substance abuse, and crime: A test of competing hypotheses for driving mechanisms. J. Crim. Justice 62, 50–57. https://doi.org/10.1016/j.jcrimjus.2018.08.005

Kirk, D.S., 2008. The Neighborhood Context of Racial and Ethnic Disparities in Arrest. Demography. https://doi.org/10.1353/dem.2008.0011

Lemos, I., Faísca, L., 2015. Psychosocial adversity, delinquent pathway and internalizing psychopathology in juvenile male offenders. Int. J. Law Psychiatry 42–43, 49–57. https://doi.org/10.1016/j.ijlp.2015.08.007

Lewinsohn, P.M., Rohde, P., Seeley, J.R., 1995. Adolescent Psychopathology: III. The Clinical Consequences of Comorbidity. J. Am. Acad. Child Adolesc. Psychiatry 34, 510–519. https://doi.org/10.1097/00004583-199504000-00018

Lewinsohn, P.M., Zinbarg, R., Seeley, J.R., Lewinsohn, M., Sack, W.H., 1997. Lifetime comorbidity among anxiety disorders and between anxiety disorders and other mental disorders in adolescents. J. Anxiety Disord. 11, 377–394. https://doi.org/10.1016/S0887-6185(97)00017-0

Loeber, R., Stouthamer-Loeber, M., Tonry, M., Morris, N., 1986. Crime and justice: An annual

review of research. Chicago.

McCormick, S., Peterson-Badali, M., Skilling, T.A., 2017. The Role of Mental Health and Specific Responsivity in Juvenile Justice Rehabilitation. Law Hum. Behav. 41, 55–67. https://doi.org/10.1037/lhb0000228

McCormick, S., Peterson-Badali, M., Skilling, T.A., 2015. Mental health and justice system involvement: A conceptual analysis of the literature. Psychol. Public Policy, Law 21, 213–225. https://doi.org/10.1037/law0000033

McLeod, J.D., Uemura, R., Rohrman, S., 2012. Adolescent mental health, behavior problems, and academic achievement. J. Health Soc. Behav. 53, 482–497. https://doi.org/10.1177/0022146512462888

Merikangas, K.R., He, J., Burstein, M., Swanson, S.A., Avenevoli, S., Cui, L., Benjet, C., Georgiades, K., Swendsen, J., 2010. Lifetime Prevalence of Mental Disorders in U.S. Adolescents: Results from the National Comorbidity Survey Replication–Adolescent Supplement (NCS-A). J. Am. Acad. Child Adolesc. Psychiatry 49, 980–989. https://doi.org/10.1016/J.JAAC.2010.05.017

Meyer, H.C., Lee, F.S., 2019. Translating Developmental Neuroscience to Understand Risk for Psychiatric Disorders. Am. J. Psychiatry 176, 179–185. https://doi.org/10.1176/appi.ajp.2019.19010091

Moffitt, T.E., 2018. Male antisocial behaviour in adolescence and beyond. Nat. Hum. Behav. https://doi.org/10.1038/s41562-018-0309-4

Perry, R.C.W., Morris, R.E., 2014. Health care for youth involved with the correctional system. Prim. Care 41, 691–705. https://doi.org/10.1016/j.pop.2014.05.007

Planey, A.M., Smith, S.M.N., Moore, S., Walker, T.D., 2019. Barriers and facilitators to mental

health help-seeking among African American youth and their families: A systematic review study. Child. Youth Serv. Rev. https://doi.org/10.1016/j.childyouth.2019.04.001

Reinke, W.M., Eddy, J.M., Dishion, T.J., Reid, J.B., 2012. Joint trajectories of symptoms of disruptive behavior problems and depressive symptoms during early adolescence and adjustment problems during emerging adulthood. J. Abnorm. Child Psychol. 40, 1123–1136. https://doi.org/10.1007/s10802-012-9630-y

Reising, K., Ttofi, M.M., Farrington, D.P., Piquero, A.R., 2019. Depression and anxiety outcomes of offending trajectories: A systematic review of prospective longitudinal studies. J. Crim. Justice 62, 3–15. https://doi.org/10.1016/j.jcrimjus.2018.05.002

Rubenstein, L.M., Hamilton, J.L., Stange, J.P., Flynn, M., Abramson, L.Y., Alloy, L.B., 2015. The cyclical nature of depressed mood and future risk: Depression, rumination, and deficits in emotional clarity in adolescent girls. J. Adolesc. 42, 68–76. https://doi.org/10.1016/j.adolescence.2015.03.015

Ruchkin, V. V., Schwab-Stone, M., Koposov, R.A., Vermeiren, R., King, R.A., 2003. Suicidal ideations and attempts in juvenile delinquents. J. Child Psychol. Psychiatry 44, 1058–1066. https://doi.org/10.1111/1469-7610.00190

Sampson, R.J., Laub, J.H., 2005. A life-course view of the development of crime, in: Annals of the American Academy of Political and Social Science. https://doi.org/10.1177/0002716205280075

Schubert, C.A., Mulvey, E.P., Glasheen, C., 2011. Influence of mental health and substance use problems and criminogenic risk on outcomes in serious juvenile offenders. J. Am. Acad. Child Adolesc. Psychiatry 50, 925–937. https://doi.org/10.1016/j.jaac.2011.06.006

Snyder, H.N., Office of Justice Programs, U.S.D. of J., 2008. Juvenile Arrests 2006, Juvenile

Justice Bulletin.

Sweeten, G., Piquero, A.R., Steinberg, L., 2013. Age and the Explanation of Crime, Revisited. J. Youth Adolesc. https://doi.org/10.1007/s10964-013-9926-4

Teplin, L.A., Abram, K.M., McClelland, G.M., Dulcan, M.K., Mericle, A.A., 2002. Psychiatric Disorders in Youth in Juvenile Detention. Arch. Gen. Psychiatry 59, 1133. https://doi.org/10.1001/archpsyc.59.12.1133

Teplin, L.A., Welty, L.J., Abram, K.M., Dulcan, M.K., Washburn, J.J., 2012. Prevalence and persistence of psychiatric disorders in youth after detention: A prospective longitudinal study. Arch. Gen. Psychiatry 69, 1031–1043. https://doi.org/10.1001/archgenpsychiatry.2011.2062

Vermeiren, R., 2003. Psychopathology and delinquency in adolescents: A descriptive and developmental perspective. Clin. Psychol. Rev. 23, 277–318. https://doi.org/10.1016/S0272-7358(02)00227-1

Wasserman, G.A., McReynolds, L.S., Schwalbe, C.S., Keating, J.M., Jones, S.A., 2010. Psychiatric Disorder, Comorbidity, and Suicidal Behavior in Juvenile Justice Youth. Crim. Justice Behav. 37, 1361–1376. https://doi.org/10.1177/0093854810382751

Zajac, K., Sheidow, A.J., Davis, M., 2015. Juvenile justice, mental health, and the transition to adulthood: A review of service system involvement and unmet needs in the U.S. Child. Youth Serv. Rev. 56, 139–148. https://doi.org/10.1016/j.childyouth.2015.07.014

Zeola, M.P., Guina, J., Nahhas, R.W., 2017. Mental Health Referrals Reduce Recidivism in First-Time Juvenile Offenders, But How Do We Determine Who is Referred? Psychiatr. Q. https://doi.org/10.1007/s11126-016-9445-z

CHAPTER DISCUSSION

In this chapter, we investigated real-world risk-taking (e.g., self-reported offending) and internalizing symptoms in a sample of youth in the juvenile justice system. Study 1 investigated discrimination in the juvenile justice system through biased entry into the system, stringency of system processing, and risk for re-arrest. Study 2 investigated how internalizing symptoms co-develop alongside offending patterns. Findings from these studies offer two main insights. First, results from Study 1 indicate that Black and Latino youth face discrimination in the justice system. Second, results from Study 2 indicate that the trajectory of mental health symptoms and self-reported offending after first arrest are inextricably linked, thereby suggesting that the mental health needs of justice-involved youth are important to address.

Minority youth have been overrepresented in the juvenile justice system since its inception in the late 1800s – chiefly described as a manner of keeping minority youth, who were at risk for offending due to negative influences in their families and communities, out of trouble (Platt, 1977). Persistent overrepresentation of minorities in legal systems through arrests, court proceedings, and incarceration prompted the passage of the Juvenile Justice and Delinquency Prevention Act in 1974 to track, and since 1984 to combat, disproportionate minority presence in the juvenile justice system. Since its passage, empirical work demonstrates that disproportionate minority contact (DMC) has not declined (Leiber & Fix, 2019). In Study 1, we demonstrate the myriad ways in which DMC affects the lives of minority youth. Specifically, Black youth enter the juvenile justice system after committing fewer offenses than both Latino and white youth, both Black and Latino youth are more likely to be formally processed through the courts once in the system, and Black youth are most likely to be re-arrested up to 1 year after initial arrest after committing the fewest offenses in the interim.

One candidate driver of DMC, amongst several others, is racism – both implicit and explicit – present across all stages of the juvenile justice system (Cabaniss, Frabutt, Kendrick, & Arbuckle, 2007). While this claim does not suggest that DMC can be blamed on individuals, it is meant to question the role of racism in policies and practices within society broadly, and the juvenile justice system specifically, that may have consequences for racial minority youth. Within society at large for example, minority youth often experience an education system that is more punitive and less supportive in nature (e.g., expulsions, detentions, lack of materials and quality instruction) than non-minority peers (Schiff, 2018), contributing to high levels of student drop-out and overall greater involvement with law enforcement (Christle, Jolivette, & Nelson, 2005), termed the "school to prison pipeline." Within law enforcement policies for example, "hot spots policing," a purported "data-driven" approach to allocating limited police resources to areas of criminality, contributes to high levels of contact between law enforcement officers and minority youth (Fagan, 2017). Taken together, societal practices in conjunction with law enforcement policies and practices can result in minority youth facing significant hardships even prior to any contact with the justice system. Once in the system, as we and others have demonstrated, these racist forces have even greater impact on continued justice involvement.

Greater involvement within the justice system is detrimental to youth because of how it relates to continued and worsening criminal activity and the implications of incarceration, but also because it can contribute to new, or exacerbated, mental health concerns (Wasserman et al., 2010b). Indeed, we found that after first arrest, patterns of internalizing show linear declines but also quadratic increases over time, in parallel with linear declines and quadratic increases in criminal offending. Given that mental health services are rarely offered to youth in the juvenile system (Zeola et al., 2017a), increased mental health services are required for these youths to

experience healthy transitions out of the juvenile system (Binswanger et al., 2011). Our results also indicate that current practices that do not consider the mental health needs of youth in the system are insufficient at rehabilitating youth. Indeed, our characterization of youth internalizing symptoms alongside offending demonstrated significant co-development of these processes, which suggests that services are required for both decreasing offending and improving well-being. Demographic considerations, such as the age of youth when they first encounter system contact, can be helpful to determine youth most at risk.

How can practitioners and policymakers make use of these results? The first and foremost recommendation is to re-align the juvenile justice system goals to emphasize rehabilitation of youth. Indeed, holistic approaches to considering youth are strongly needed; color-blind practices and lack of attention to mental health will only exacerbate existing inequities and lead to greater levels of criminal offending as youth enter adulthood. Implicit bias training, while necessary, will not be sufficient. Instead, the juvenile justice system as a whole needs to commit to anti-racist policies and training of law enforcement. Further, mental health screening need to become commonplace at time of arrest and every stage of juvenile processing onward to appropriately assess and address youth needs. It is important to consider the results from both studies with some limitations in mind. The Crossroads dataset consists of male adolescents, and thus how these findings extend to females in the juvenile justice system is still an open question, and in general, females are often overlooked in this field (Bloom & Covington, 2001). Data are also collected mainly through self-report, both for offending and internalizing; given that both constructs are highly personal, there is the potential for reporting bias. Overall, however, data from both studies demonstrate significant problems in the juvenile justice system,

both in terms of racial discrimination and lack of mental health support, that need to be addressed.

CHAPTER REFERENCES

Binswanger, I.A., Nowels, C., Corsi, K.F., Long, J., Booth, R.E., Kutner, J., Steiner, J.F., 2011. "From the prison door right to the sidewalk, everything went downhill," A qualitative study of the health experiences of recently released inmates. Int. J. Law Psychiatry 34, 249–255. https://doi.org/10.1016/j.ijlp.2011.07.002

Blakemore, S.-J., Mills, K.L., 2014. Is Adolescence a Sensitive Period for Sociocultural Processing? Annu. Rev. Psychol. 65, 187–207. https://doi.org/10.1146/annurev-psych-010213-115202

Bloom, B.E., Covington, S.S., 2001. Effective Gender-Responsive Interventions in Juvenile Justice: Addressing the Lives of Delinquent Girls, in: Annual Meeting of the American Society of Criminology. Atlanta, Georgia.

Cabaniss, E.R., Frabutt, J.M., Kendrick, M.H., Arbuckle, M.B., 2007. Reducing disproportionate minority contact in the juvenile justice system: Promising practices. Aggress. Violent Behav. 12, 393–401. https://doi.org/10.1016/j.avb.2006.09.004

Christle, C.A., Jolivette, K., Nelson, C.M., 2005. Breaking the School to Prison Pipeline: Identifying School Risk and Protective Factors for Youth Delinquency. Exceptionality 13, 69–88. https://doi.org/10.1207/s15327035ex1302_2

Cottle, C.C., Lee, R.J., Heilbrun, K., 2001. The Prediction of Criminal Recidivism in Juveniles. Crim. Justice Behav. 28, 367–394. https://doi.org/10.1177/0093854801028003005

Fagan, J., 2017. Response to Ridgeway: Allocating Police. J. Policy Anal. Manag. 36, 703–707. https://doi.org/10.1002/pam.21998

Farrington, D.P., Piquero, A.R., Jennings, W.G., 2013. Offending from childhood to late middle age: Recent results from the Cambridge study in delinquent development. Spring Science &

Business Media.

Galván, A., 2017. Adolescence, brain maturation and mental health. Nat. Neurosci. https://doi.org/10.1038/nn.4530

Hamilton, J.L., Hamlat, E.J., Stange, J.P., Abramson, L.Y., Alloy, L.B., 2014. Pubertal timing and vulnerabilities to depression in early adolescence: Differential pathways to depressive symptoms by sex. J. Adolesc. 37, 165–174. https://doi.org/10.1016/j.adolescence.2013.11.010

Hoeve, M., Mcreynolds, L.S., Wasserman, G.A., 2013. The Influence of Adolescent PsychiatrIc DIsorder on Young Adult RecIdIvIsm. Crim. Justice Behav. 40, 1368–1382. https://doi.org/10.1177/0093854813488106

Lambie, I., Randell, I., 2013. The impact of incarceration on juvenile offenders. Clin. Psychol. Rev. 33, 448–59. https://doi.org/10.1016/j.cpr.2013.01.007

Leiber, M.J., Fix, R., 2019. Reflections on the Impact of Race and Ethnicity on Juvenile Court Outcomes and Efforts to Enact Change. Am. J. Crim. Justice 44, 581–608. https://doi.org/10.1007/s12103-019-09479-3

McCormick, S., Peterson-Badali, M., Skilling, T.A., 2017. The Role of Mental Health and Specific Responsivity in Juvenile Justice Rehabilitation. Law Hum. Behav. 41, 55–67. https://doi.org/10.1037/lhb0000228

Merikangas, K.R., He, J., Burstein, M., Swanson, S.A., Avenevoli, S., Cui, L., Benjet, C., Georgiades, K., Swendsen, J., 2010. Lifetime Prevalence of Mental Disorders in U.S. Adolescents: Results from the National Comorbidity Survey Replication–Adolescent Supplement (NCS-A). J. Am. Acad. Child Adolesc. Psychiatry 49, 980–989. https://doi.org/10.1016/J.JAAC.2010.05.017

Meyer, H.C., Lee, F.S., 2019. Translating Developmental Neuroscience to Understand Risk for Psychiatric Disorders. Am. J. Psychiatry 176, 179–185. https://doi.org/10.1176/appi.ajp.2019.19010091

Mulder, E., Brand, E., Bullens, R., van Marle, H., 2011. Risk Factors for Overall Recidivism and Severity of Recidivism in Serious Juvenile Offenders. Int. J. Offender Ther. Comp. Criminol. 55, 118–135. https://doi.org/10.1177/0306624X09356683

Platt, A.M., 1977. The child savers: The invention of delinquency. University of Chicago Press.

Romeo, R.D., 2017. The impact of stress on the structure of the adolescent brain: Implications for adolescent mental health. Brain Res. https://doi.org/10.1016/j.brainres.2016.03.021

Schiff, M., 2018. Can restorative justice disrupt the 'school-to-prison pipeline?' Contemp. Justice Rev. 21, 121–139. https://doi.org/10.1080/10282580.2018.1455509

Spear, L.P., 2000. Neurobehavioral Changes in Adolescence. Curr. Dir. Psychol. Sci. 9, 111–114.

Wasserman, G.A., McReynolds, L.S., Schwalbe, C.S., Keating, J.M., Jones, S.A., 2010a. Psychiatric disorder, comorbidity, and suicidal behavior in juvenile justice youth. Crim. Justice Behav. https://doi.org/10.1177/0093854810382751

Wasserman, G.A., McReynolds, L.S., Schwalbe, C.S., Keating, J.M., Jones, S.A., 2010b. Psychiatric Disorder, Comorbidity, and Suicidal Behavior in Juvenile Justice Youth. Crim. Justice Behav. 37, 1361–1376. https://doi.org/10.1177/0093854810382751

Zajac, K., Sheidow, A.J., Davis, M., 2015. Juvenile justice, mental health, and the transition to adulthood: A review of service system involvement and unmet needs in the U.S. Child. Youth Serv. Rev. 56, 139–148. https://doi.org/10.1016/j.childyouth.2015.07.014

Zeola, M.P., Guina, J., Nahhas, R.W., 2017. Mental Health Referrals Reduce Recidivism in

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CHAPTER 6

General Discussion to the Dissertation

Adolescent brain and behavioral development are multi-faceted and dynamic. This dissertation celebrates the variability and diversity of adolescence by investigating many aspects of brain and behavioral development, casting a wide net to better understand how variations in internalizing symptoms and disorders converge to affect the experience of being an adolescent. Not only are internalizing symptoms highly prevalent in this population (Meyer & Lee, 2019), but these disorders often persist into adulthood (Beesdo-Baum & Knappe, 2012) with and without treatment (Ginsburg et al., 2018), which may contribute to the ever-increasing proportion of college students seeking mental health services (Center for Collegiate Mental Health, 2015). In this dissertation, I examined the role of internalizing symptoms in relation to brain connectivity, emotional and reward processing at both the neural and behavioral level, and risk-taking in the real world. Overall, my findings suggest that even symptoms that are below diagnostic threshold can influence development.

In Chapter 2, functional connectivity of the amygdala and its subnuclei were related to internalizing symptomatology in a gender-balanced sample of neurotypical youth. Prior examinations comparing amygdala functional connectivity between youth with and without internalizing disorders have been mixed. For instance, some reports demonstrate weaker connectivity between the amygdala and regions involved in socioemotional processing in youth with depressive symptoms (Scheuer et al., 2017) whereas others demonstrate stronger connectivity (Burghy et al., 2012). Additionally, reports have shown both stronger amygdala-whole brain connectivity with greater anxiety symptoms (Qin et al., 2014) and weaker (Burghy

et al., 2012). Elucidating the relationship between internalizing symptoms and amygdala connectivity prior to disorder onset can serve as one metric for how the relationship between brain networks and symptoms develops. Further, examining how these relationships differ between girls and boys can contribute to understanding the mechanisms behind gender differences in symptom expression. Findings demonstrated that, especially in girls, symptom severity related to connectivity in key emotional processing regions, such as the posterior mid-cingulate cortex. Future work is needed to understand how brain and symptom development occur in tandem; however, the present results highlight that even subclinical symptom severity can modulate brain connectivity at rest, especially in girls. As functional connectivity can index a history of co-activation across brain regions, these results demonstrate that girls with higher symptom severity have more frequent co-activation of the amygdala and the cingulate gyrus which could reflect greater attention toward emotional stimuli

Samples inclusive of a broader range of symptom severity than in the present study are important for capturing the relationships between symptoms and connectivity across a larger group of youth. Similarly, future research investigating the developmental trajectories of symptom severity and functional connectivity are crucial for unpacking the bidirectional relationship between symptoms and brain development. While brain-based biomarkers of youth internalizing disorders have been elusive given the heterogeneity of these conditions across development (Zahn-Waxler, Shirtcliff, & Marceau, 2008) and test-retest reliability issues of brain imaging (Nord, Gray, Charpentier, Robinson, & Roiser, 2017), longitudinal studies examining functional brain networks may prove promising (Chahal et al., 2020). Studies may also benefit from examining fluctuations in functional connectivity through studying dynamic brain states (Chiang et al., 2018) and characterizing the thought processes youth engage in during

resting scans as these can strongly shape functional connectivity measures (Gonzalez-Castillo, Kam, Hoy, & Bandettini, 2021).

The study presented in Chapter 3 examines how youth with and without anxiety regulate emotions, both at the level of the brain and behavior. Prior work has identified similarities and differences between youth with and without anxiety in emotion regulation at the level of behavior (Carthy, Horesh, Apter, Edge, & Gross, 2010; Carthy, Horesh, Apter, & Gross, 2010), however this is the first study to investigate the neural mechanisms which may undergird emotion regulation differences (Young, Sandman, & Craske, 2019). Such work is crucial to improving existing anxiety treatments which, while efficacious in the short-term (Higa-McMillan, Francis, Rith-Najarian, & Chorpita, 2016), are insufficient to achieve full remission (Ginsburg et al., 2018). Youth with anxiety were capable of reappraisal when instructed, but even following reappraisal, youth were more distressed and evinced greater brain activation in and connectivity between frontal and limbic regions. Identifying both that youth with anxiety may require greater effortful regulation and may experience heightened distress can inform clinical practice. Treatments may more efficacious if clinicians help youth manage the initial emotional response in addition to practicing reappraisal in everyday situations.

Future studies with larger sample sizes are crucial for replicating these results. Given that anxiety severity related to task-related functional connectivity in this study, future work examining the role of dimensional anxiety in a larger sample could help further understand the relationship between symptoms and emotion regulation. Like other emotion regulation tasks, the present task employed an event-related design in which reappraisal and non-reappraisal trials were intermixed. The timing involved in the process of initiating an emotional response, bringing awareness to the response, and subsequently reappraising it can vary, emotions can resurge, and

emotions can bleed into subsequent trials (Waugh, Shing, & Avery, 2015). While the reappraisal task used in this study was optimized to withstand such effects through jittered timing of events and long durations for reappraisal, the process of emotion generation and regulation is difficult to neatly package into an fMRI-friendly design. Future studies may consider testing blocked designs to examine whether brain states of reappraisal differ depending on the task design.

Chapter 4 assessed the role of decision value and prediction error on reward learning in a sample of youth across a continuum of anxiety. Youth with anxiety often find changes to their environment or expectations to be distressing (Osmanağaoğlu, Creswell, & Dodd, 2018). Characterizing the relationship between decision value, prediction errors, and anxiety may help explain why youth with anxiety shy away from unpredictable situations. Further, youth with anxiety or at risk-for anxiety demonstrate atypical hyperactivation of reward network regions during anticipation of reward (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Cho et al., 2013; Guyer et al., 2006) and hypoactivation during receipt of reward (Helfinstein et al., 2011; Helfinstein, Fox, & Pine, 2012). Identifying how decision value and prediction error signals relate to neural activation is key to understanding altered brain-based reward processing. All youth learned stimulus-reward associations for more predictable and rewarding stimuli. However, youth with the greatest anxiety displayed the strongest relationships between brain activity and behavior, and youth with the greatest intolerance of uncertainty demonstrated the least activation of the nucleus accumbens when responding correctly.

Future iterations of this reward-learning task can employ loss trials in addition to gain trials to probe further into anxiety-reward relationships, as youth with anxiety tend to ascribe more salience to threatening conditions (Helfinstein et al., 2011). Examining how these associations between brain function and anxiety symptomatology at baseline develop over time

can prove fruitful for identifying youth who may shy away from rewarding experiences in daily life. As youth progress through adolescence, they need to adapt to changes in their environments. Youth with anxiety may face difficulties in adapting, particularly when their expectations of a situation do not match the outcomes.

Real-world risk-taking and its relationship to both race and internalizing symptoms was examined in Chapter 5. Black and Latino youth have disproportionately greater contact with law enforcement and greater representation in the juvenile justice system relative to white youth (Dmitrieva, Monahan, Cauffman, & Steinberg, 2012). Once in the juvenile justice system, all youth have lower access to mental health services despite greater needs than non-system involved peers (Zajac, Sheidow, & Davis, 2015). However, it has remained unclear how youth offending prior to arrest relates to system contact, and how mental health may be affected after first arrest. Results showed that Black youth were most likely to be arrested relative to White and Latino after committing the fewest offenses, both Black and Latino youth were more likely to be formally processed through the court system relative to White youth, and Black youth were the most likely to be re-arrested 1 year after their first arrest after committing the fewest offenses in the interim period. Importantly, internalizing symptoms and self-reported offending varied together over time such that youth who had the most improvements in mental health after first arrest also showed the least offending in that time. These results demonstrate the persistent effects of racism throughout system involvement and demonstrate that mental health concerns are importantly linked to offending outcomes. Strategies designed to reduce police presence in minority communities can help address rampant over-representation of minority youth in the juvenile justice system. For youth who enter into the system, it is vital to conduct thorough

mental health screening at intake and throughout justice system involvement to ensure well-being.

Both offending and internalizing data came from youth self-reports which, especially for lifetime offending, can be subject to recall biases. Offending and internalizing may also differ by gender, which was not examined in the present study. Behavioral measures were also collected at distinct study periods 6 months to 1 year apart; future studies may capitalize on real-time assessments to capture symptomatology closer in time to arrests to better understand the temporal sequencing of symptoms following justice system involvement.

General Limitations

Studies of youth with internalizing symptoms, particularly studies involving brain imaging, can be difficult for youth. The experience of social interaction and evaluation with study staff may itself be an anxiogenic factor. Further, the experience of MRI can be frightening due to the enclosed space and loud noises during imaging. Altogether, this may result in studying a particular sample of anxious youth who are willing and able to withstand such factors; when considering the behavioral performance and brain measures of these youth who are able to participate, it is vital to consider the influence that these external forces may have. Given the caution with which youth may approach new people and environments, it is also important to consider that behavior and brain imaging captured at a single visit may represent youth at their least comfortable.

Concluding Remarks

Internalizing disorders are highly prevalent during adolescence and can affect future development. The studies presented in this dissertation provide a close examination of the role of internalizing symptoms in brain and behavioral development in adolescence. Results

demonstrated that subclinical internalizing symptoms relate to functional connectivity of regions involved in emotion processing. Anxiety can also relate to greater distress during emotion regulation and altered perceptions of stimulus-reward associations. Finally, for youth within the juvenile justice system, the greatest disparities were present for youth of color and, for all youth, mental well-being was inextricable from low recidivism. Taken together, these findings demonstrate that internalizing symptoms affect the lives of adolescents in myriad ways and lay the groundwork for future longitudinal studies investigating the development and treatment of internalizing disorders.

REFERENCES

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M.J., van IJzendoorn, M.H., 2007. Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. Psychol. Bull. 133, 1–24. https://doi.org/10.1037/0033-2909.133.1.1

Beesdo-Baum, K., Knappe, S., 2012. Developmental Epidemiology of Anxiety Disorders. Child Adolesc. Psychiatr. Clin. N. Am. 21, 457–478. https://doi.org/10.1016/j.chc.2012.05.001

Burghy, C.A., Stodola, D.E., Ruttle, P.L., Molloy, E.K., Armstrong, J.M., Oler, J.A., Fox, M.E., Hayes, A.S., Kalin, N.H., Essex, M.J., Davidson, R.J., Birn, R.M., 2012. Developmental pathways to amygdala-prefrontal function and internalizing symptoms in adolescence. Nat. Neurosci. 15, 1736–1741. https://doi.org/10.1038/nn.3257

Carthy, T., Horesh, N., Apter, A., Edge, M.D., Gross, J.J., 2010a. Emotional reactivity and cognitive regulation in anxious children. Behav. Res. Ther. 48, 384–393. https://doi.org/10.1016/j.brat.2009.12.013

Carthy, T., Horesh, N., Apter, A., Gross, J.J., 2010b. Patterns of Emotional Reactivity and

Regulation in Children with Anxiety Disorders. J Psychopathol Behav Assess 32, 23–36. https://doi.org/10.1007/s10862-009-9167-8

Center for Collegiate Mental Health, 2015. Annual Report.

Chahal, R., Weissman, D.G., Hallquist, M.N., Robins, R.W., Hastings, P.D., Guyer, A.E., 2020. Neural connectivity biotypes: associations with internalizing problems throughout adolescence. Psychol. Med. 1–11. https://doi.org/10.1017/S003329172000149X

Chiang, S., Vankov, E.R., Yeh, H.J., Guindani, M., Vannucci, M., Haneef, Z., Stern, J.M., 2018. Temporal and spectral characteristics of dynamic functional connectivity between resting-state networks reveal information beyond static connectivity. PLoS One 13, e0190220. https://doi.org/10.1371/journal.pone.0190220

Cho, Y.T., Fromm, S., Guyer, A.E., Detloff, A., Pine, D.S., Fudge, J.L., Ernst, M., 2013. Nucleus accumbens, thalamus and insula connectivity during incentive anticipation in typical adults and adolescents. Neuroimage 66, 508–521. https://doi.org/10.1016/j.neuroimage.2012.10.013

Dmitrieva, J., Monahan, K.C., Cauffman, E., Steinberg, L., 2012. Arrested development: The effects of incarceration on the development of psychosocial maturity. Dev. Psychopathol. https://doi.org/10.1017/s0954579412000545

Ginsburg, G.S., Becker-Haimes, E.M., Keeton, C., Kendall, P.C., Iyengar, S., Sakolsky, D., Albano, A.M., Peris, T., Compton, S.N., Piacentini, J., 2018. Results From the Child/Adolescent Anxiety Multimodal Extended Long-Term Study (CAMELS): Primary Anxiety Outcomes. J Am Acad Child Adolesc Psychiatry 57, 471–480. https://doi.org/10.1016/j.jaac.2018.03.017

Gonzalez-Castillo, J., Kam, J.W.Y., Hoy, C.W., Bandettini, P.A., 2021. How to Interpret

Resting-State fMRI: Ask Your Participants. J. Neurosci. 41, 1130–1141. https://doi.org/10.1523/JNEUROSCI.1786-20.2020

Guyer, A.E., Kaufman, J., Hodgdon, H.B., Masten, C.L., Jazbec, S., Pine, D.S., Ernst, M., 2006. Behavioral Alterations in Reward System Function: The Role of Childhood Maltreatment and Psychopathology. J. Am. Acad. Child Adolesc. Psychiatry 45, 1059–1067. https://doi.org/10.1097/01.chi.0000227882.50404.11

Helfinstein, S.M., Benson, B., Perez-Edgar, K., Bar-Haim, Y., Detloff, A., Pine, D.S., Fox, N.A., Ernst, M., 2011. Striatal responses to negative monetary outcomes differ between temperamentally inhibited and non-inhibited adolescents. Neuropsychologia 49, 479–485. https://doi.org/10.1016/j.neuropsychologia.2010.12.015

Helfinstein, S.M., Fox, N.A., Pine, D.S., 2012. Approach–withdrawal and the role of the striatum in the temperament of behavioral inhibition. Dev. Psychol. 48, 815–826. https://doi.org/10.1037/a0026402

Higa-McMillan, C.K., Francis, S.E., Rith-Najarian, L., Chorpita, B.F., 2016. Evidence Base Update: 50 Years of Research on Treatment for Child and Adolescent Anxiety. J. Clin. Child Adolesc. Psychol. 45, 91–113. https://doi.org/10.1080/15374416.2015.1046177

Meyer, H.C., Lee, F.S., 2019. Translating Developmental Neuroscience to Understand Risk for Psychiatric Disorders. Am. J. Psychiatry 176, 179–185. https://doi.org/10.1176/appi.ajp.2019.19010091

Nord, C.L., Gray, A., Charpentier, C.J., Robinson, O.J., Roiser, J.P., 2017. Unreliability of putative fMRI biomarkers during emotional face processing. Neuroimage 156, 119–127. https://doi.org/10.1016/j.neuroimage.2017.05.024

Osmanağaoğlu, N., Creswell, C., Dodd, H.F., 2018. Intolerance of Uncertainty, anxiety, and

worry in children and adolescents: A meta-analysis. J. Affect. Disord. 225, 80–90. https://doi.org/10.1016/j.jad.2017.07.035

Qin, S., Young, C.B., Duan, X., Chen, T., Supekar, K., Menon, V., 2014. Amygdala subregional structure and intrinsic functional connectivity predicts individual differences in anxiety during early childhood. Biol. Psychiatry 75, 892–900. https://doi.org/10.1016/j.biopsych.2013.10.006

Scheuer, H., Alarcón, G., Demeter, D. V, Earl, E., Fair, D.A., Nagel, B.J., 2017. Reduced fronto-amygdalar connectivity in adolescence is associated with increased depression symptoms over time. Psychiatry Res. Neuroimaging 266, 35–41. https://doi.org/10.1016/j.pscychresns.2017.05.012

Waugh, C.E., Shing, E.Z., Avery, B.M., 2015. Temporal Dynamics of Emotional Processing in the Brain. Emot. Rev. 7, 323–329. https://doi.org/10.1177/1754073915590615

Young, K.S., Sandman, C.F., Craske, M.G., 2019. Positive and negative emotion regulation in adolescence: links to anxiety and depression. Brain Sci. https://doi.org/10.3390/brainsci9040076

Zahn-Waxler, C., Shirtcliff, E.A., Marceau, K., 2008. Disorders of Childhood and Adolescence: Gender and Psychopathology. Annu. Rev. Clin. Psychol. 4, 275–303. https://doi.org/10.1146/annurev.clinpsy.3.022806.091358

Zajac, K., Sheidow, A.J., Davis, M., 2015. Juvenile justice, mental health, and the transition to adulthood: A review of service system involvement and unmet needs in the U.S. Child. Youth Serv. Rev. 56, 139–148. https://doi.org/10.1016/j.childyouth.2015.07.014