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# Multi-Modal Approaches for Transdiagnostic Risk Processes in Youth Psychopathology

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Psychology

by

Elizabeth Caitlin Moroney

2021

ABSTRACT OF THE DISSERTATION

Multi-Modal Approaches for Transdiagnostic Risk Processes

in Youth Psychopathology

by

Elizabeth Caitlin Moroney

Doctor of Philosophy in Psychology

University of California, Los Angeles, 2021

Professor Steve Sung-Yul Lee, Chair

The escalating burden of mental health problems among youth in the U.S. suggests that new approaches to psychopathology are urgently needed. Consistent with the National Institute of Mental Health Research Domain Criteria (RDoC), which prioritizes multi-level, dimensional data to improve traction on etiology and to identify new intervention targets, advanced quantitative methods discerning the underlying structure of psychopathology will accelerate innovations. Replicated evidence shows that a general factor (*p*-factor) nonspecifically confers liability to psychopathology, independent of specific internalizing and externalizing factors, and also economically characterizes their covariation. Careful evaluation of the *p*-factor in youth and its associations with external criteria is needed given age-related effects on psychopathology and concerns over statistical bias favoring bifactor models. Study I of this dissertation supported a bifactor model in youth with general and specific factors of psychopathology which were

uniquely associated with independent measures of academic, social, and global functioning.

Next, social risk factors and their underlying processes are associated with general and specific forms of psychopathology, as suggested by the system of social processes included in the RDoC construct matrix. To elucidate specific targets for intervention and to inform a nascent evidence base, Study II of this dissertation empirically examined patterns of digital media use with adolescent development. Increasing concerns among parents, educators, and healthcare providers parallel recent evidence that frequent digital media use is positively associated with concurrent and prospective psychopathology in adolescents. In addition to simple bivariate associations, identifying their underlying mediators will reveal logical intervention targets. Study II implicated specific online behaviors (i.e., upward social comparison, receiving negative feedback, risky self-presentation) as unique mediators of the concurrent association of frequency of digital media use with transdiagnostic mental health problems.

Lastly, consistent with the RDoC initiative's prioritization of physiological data for the study of affective systems, biological approaches must be integrated into models of the development of youth psychopathology. Measures of respiratory sinus arrythmia (RSA) during emotionally-challenging tasks are associated with youth internalizing and externalizing psychopathology; RSA is a plausible transdiagnostic biomarker of psychopathology. Study III of this dissertation explored the covariation of internalizing and externalizing problems in school-age girls with RSA during a fear conditioning task. Although unrelated with indicators of psychopathology, likely due to the small sample size, significant variability in RSA was observed and it remains a promising biomarker to be leveraged diversely across intervention and basic science contexts, including predicting risk and resilience processes.

The dissertation of Elizabeth Caitlin Moroney is approved.

Denise A. Chavira

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University of California, Los Angeles

2021

## Dedication

This work is dedicated to my family, my friends, and my husband, who all supported me in innumerable ways throughout this process. Also to my baby girl—this is all for you.

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### PUBLICATIONS

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## SELECTED SYMPOSIA PRESENTATIONS

**Moroney, E.,** Zillmer, N., Luthar, & S., Lee, S. S. (2019, August). Digital media use and internalizing psychopathology in adolescents from high-achieving schools: Mediation by social comparison and self-presentation. In E. Moroney and S.S. Lee (Chairs), *Social and individual-level risk processes in youth anxiety disorders*. Symposium presented at the American Psychological Association (APA) Annual Conference, Chicago, IL.

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## Introduction

Despite significant innovations in the basic science, treatment, and prevention of major forms of psychopathology, their global burden increased nearly 40% between 1990 and 2010 (Whiteford et al., 2013). Developmentally, 15.2% of American youth in 2010 met criteria in the past year for a mental disorder (Merikangas et al., 2010) whereas 13.4% of youth worldwide were diagnosed with a mental health disorder in 2015 (Polanczyk et al., 2015). This escalating burden unambiguously suggests that new conceptual, empirical, and clinical approaches to psychopathology are desperately needed. With goals of (a) incorporating data across multiple levels of analysis to help identify new targets for intervention and prevention, (b) detecting subgroups of individuals that may suggest targeted treatment development and/or delivery, and (c) improving the use and application of empirical evidence for clinical decision making, the National Institute of Mental Health (NIMH)'s 2010 Research Domain Criteria (RDoC; Insel et al., 2010) provides a dimensional, interdisciplinary approach to the study of psychopathology. Consisting of individual differences in constructs within positive and negative valence systems (e.g., acute threat, reward learning), cognitive systems (e.g., attention), social processes (e.g., affiliation and attachment), and arousal/regulatory systems (e.g., circadian rhythms), these constructs transcend traditional diagnostic categories and should be studied within the "essential contexts of developmental trajectories and environmental influences" (Insel et al., 2010). Thus, using multiple units of analysis (e.g., genes, molecules, behaviors, self-reports) and incorporating developmental and environmental influences to study their transdiagnostic associations with psychopathology should be prioritized in future studies.

Improved taxonomy is likely to accelerate discoveries in the etiology and treatment of psychopathology. Recent quantitative advances have facilitated innovations in determining the

latent structure of psychopathology: among adults, there is replicated evidence that a general factor of psychopathology (*p*-factor), independent of specific factors (e.g., internalizing, externalizing), economically characterizes patterns of their covariation (e.g., Caspi et al., 2014; Lahey et al., 2018). Not only is the bifactor model consisting of general and specific factors consistent with RDoC, but it also meaningfully *describes* the underlying structure of psychopathology and thus advances efforts to identify causal influences. Issues such as significant within-disorder heterogeneity and frequent comorbidity among separable taxon have long challenged the validity and utility of categorical models of psychopathology. However, general psychopathology models have been developed and validated primarily in adults and with relatively little regard for developmental influences (e.g., Caspi et al., 2014; Lahey et al., 2012, Wright et al., 2016). Only recently have models evaluated general psychopathology and specific factors in youth. Additionally, beyond its reproducibility based on bifactor models with adults, there remain persistent concerns related to the general factor's construct validity as well as vulnerability to methodological artifacts. Given well-known age-related differences in the phenomenology and underlying architecture of psychopathology, replication and extension of these models with developmentally-sensitive samples, as well as evaluation of criterion validity (e.g., clinical and functional outcomes), is necessary to establish its clinical and public health significance as well as identify targets for intervention during potentially sensitive periods.

Given rapid advances in technology, especially with respect to mobile technology and access to digital media, there are significant opportunities and challenges in understanding how these factors relate to child development. Whereas 5% of American adults used at least one social media platform in 2005, 69% of the American public reported using social media during the last nationally-representative survey conducted by the Pew Research Center (2018). With

95% of American adolescents reporting access to a smartphone and 45% of adolescents describing their internet use as "near-constant" (Pew Research Center, 2018), escalating digital media use is particularly salient to adolescents. In fact, an *American Academy of Pediatrics* report suggested that much of the current generation's social and emotional development would occur online and on cell phones (O'Keeffe & Clarke-Pearson, 2011). In particular, given the increasing accessibility and use of technology among children and adolescents spanning academic and social activities, characterizing the association of digital media use with child and adolescent socio-emotional development, including potential mental health problems, is a priority.

Under conditions of social stress, youth often seek out and use technology, and in particular, social networking sites (Lam et al., 2009; van Deursen et al., 2015); thus, digital interactions may facilitate or aggravate subjective experiences of negative affect. Despite contributing meaningfully to developing and maintaining friendships and identity exploration (Uhls et al., 2017), as well as accessing health information (Chassiakos et al., 2016), high-frequency digital media use is associated with dimensions of adolescent psychopathology including increased depression (e.g., Boers et al., 2019; Lin et al., 2016; Twenge et al., 2018), anxiety (e.g., Vannucci et al., 2017; Woods & Scott, 2016), attention problems (e.g., Nikkelen et al., 2014; Ra et al., 2018), and substance abuse (e.g., Brunborg et al., 2017; Ohannessian et al., 2017). These aggregate patterns may betray more specific associations with vulnerable subgroups: adolescents struggling with their "offline" lives may be more vulnerable to adverse online experiences such as receiving negative feedback on social media, difficulty regulating internet time or use, and spending more time passively viewing others online rather than actively engaging (George & Odgers, 2015; Twenge et al., 2019; Underwood & Ehrenreich, 2017). Given

inconsistent evidence to date and a nascent literature overall, explanatory factors (i.e., mediators) underlying putative associations of digital media use with psychopathology must be elucidated.

Individual differences in psychophysiology are aligned with RDoC given that multiple levels of data are incorporated; inferences are also strengthened by gathering additional information not readily gleaned from behavioral or self-report strategies. Psychophysiological assays are also positioned to inform psychological processes among individuals who may be unable to provide reliable self-reports (e.g., young children), especially for specific phenomena; they may also assess psychological reactivity to stimuli that are not processed consciously. This may be particularly useful in the context of tasks that elicit individual differences in negative affect. For example, fear conditioning and frustrative non-reward tasks previously revealed multivariate profiles of putative biomarkers that meaningfully relate to vulnerability to, or buffer against, psychopathology. High tonic or resting respiratory sinus arrythmia (RSA) was associated with positive psychological outcomes, including behavioral regulation during social challenges (Hastings et al., 2008), empathic responding (Liew et al., 2011), and attachment security (Diamond et al., 2012). In contrast, abnormally low resting RSA and RSA withdrawal during emotionally-challenging tasks were differentially associated with internalizing and externalizing psychopathology (Beauchaine, 2015; Beauchaine & Thayer, 2015; Graziano & Derefinko, 2013; Vasilev et al., 2009). Interestingly, in some studies, co-occurring internalizing and externalizing symptoms were associated with greater reduction of RSA during emotion evocation than either dimension alone (Calkins et al., 2007; Pang and Beauchaine, 2013). This suggests that configurations of psychopathology may be differentially sensitive to RSA. Further, the neurovisceral integration theory (Thayer & Lane, 2009) suggests that RSA peripherally indexes prefrontal cortex functioning, which exerts top-down inhibitory control over subcortical

circuits involved in trait impulsivity and trait anxiety and is thus implicated across psychopathology syndromes. RSA, then, may capture transdiagnostic vulnerability to psychopathology putatively captured by the general psychopathology factor (Beauchaine and Thayer, 2015).

This dissertation is comprised of three studies that collectively and rigorously evaluated contemporary, transdiagnostic risk processes in the development of youth psychopathology. The studies, taken together, are guided by the RDoC framework in incorporating multiple levels of data and with the goal of identifying specific targets for intervention. To rigorously characterize the underlying structure of youth psychopathology, as well as its potential explanatory factors, three specific studies were completed: Study I utilized structural equation modeling (SEM) with a pooled sample of 460 school-age children to evaluate the architecture of common dimensions of child psychopathology and to examine the external validity of the best fitting model with concurrent social, academic, and global impairment. Studies II and III examined transdiagnostic risk processes underlying psychopathology, attending carefully to the general and specific psychopathology factors elucidated in Study I. Study II utilized data from 2,952 adolescents from high-achieving schools to investigate the association of the frequency of digital media use with dimensions of youth psychopathology, including specific online behaviors that mediated observed associations. Lastly, Study III examined the concurrent association of individual differences in RSA during a well-validated fear conditioning task with both specific and general psychopathology dimensions derived from an ongoing study of 6-11-year-old girls. Collectively, these studies aimed to advance the study of contemporary risk processes in youth psychopathology to inform and improve future prevention and intervention efforts.

## Study I: General and Specific Factors of Psychopathology in School-Age Children with and without ADHD: Underlying Architecture and External Validity


Abstract

Innovations in intervention and prevention for psychopathology require a rigorous taxonomy. The general factor of psychopathology (the "*p*"-factor) may represent transdiagnostic liability to psychopathology, separate from the frequent covariation among other, previously-established dimensions (e.g., anxiety, depression symptoms). Despite consistency in the derivation of the *p*-factor in adults, its construct validity requires careful scrutiny, especially among children. We used psychopathology data derived from structured diagnostic interviews gathered in 460 children ages 5-13 (65.65% female; $M_{age}$ = 8.72, $SD_{age}$ = 1.67) with and without attention-deficit/hyperactivity disorder (ADHD). Given its frequent covariation with other psychopathology, ADHD is an appropriate condition with which to pursue two aims: (a) comparing a correlated-factor model with Internalizing and Externalizing latent factors versus a bifactor model including the *p*-factor in addition to the two specific Internalizing and Externalizing factors, and (b) examining each model's concurrent association with academic, social, and global outcomes. The bifactor model significantly improved statistical fit to the data compared to the correlated-factor model. For construct validity, the Externalizing factor explained independent variance in social and global criteria in both models, with the *p*-factor explaining additional variance in the bifactor model. Neither the Internalizing or Externalizing factor were associated with academic functioning in the correlated-factor model, but both the *p*-factor and the Internalizing factor were independently associated with academic functioning in the bifactor model. Future work must continue subjecting the *p*-factor to stringent tests of predictive validity as well as elucidate its neurobiological, genetic, and environmental correlates.

Recent innovations in characterizing the underlying architecture of psychopathology have reliably detected a general factor of psychopathology ("*p*"-factor) that parsimoniously explains covariation among common dimensions of psychopathology. The *p*-factor parallels the taxonomy of human cognitive ability (Spearman, 1904), in which a latent general factor (*g*-factor) is separable from lower order, specific factors (e.g., visuospatial, verbal; Gustafsson & Balke, 1993), with each facet independently explaining variance in intelligence and related criteria. In other words, perhaps comparable to how *g* underlies covariation in performance across multiple tests of cognitive ability (Jensen, 1998), *p* may explain covariation among dimensions of psychopathology and important external criteria (e.g., functional impairment).

Bifactor models, in particular, have featured prominently in efforts to understand the basic structure of psychopathology. Lahey et al. (2012) first proposed that common dimensions of psychopathology comprised a *p*-factor (see also Caspi et al., 2014). Conventional approaches to psychopathology consist of separable (but correlated) internalizing (e.g., mood) and externalizing (e.g., aggression) problems that may reflect underlying constructs such as negative affect and disinhibition, respectively (Achenbach, 1966; for a review, see Kruger & Markon, 2006). Thought disorders, psychosis, and mania symptoms are rare in children but have emerged as another specific factor in bifactor models of adult psychopathology (e.g., Caspi et al., 2014). Since the initial proposal of a *p*-factor, bifactor models provided strong fit to psychopathology data in adults (Lahey et al., 2018; Pettersson et al., 2016), adolescents (Laceulle et al., 2015; Patalay et al., 2015; Stochl et al., 2015), and children (Lahey et al., 2015; Martel et al., 2017; Murray et al., 2016), including in children as young as three (Olino et al., 2014), prompting further study into the clearest meaning of the *p*-factor and its external validity.

Consistent with the Research Domain Criteria (RDoC; Insel et al., 2010), which prioritizes dimensional models of psychopathology, the *p*-factor represents general liability to developing psychopathology. Hierarchical models, including those with the *p*-factor, are well-positioned to reconcile longstanding concerns about DSM-based designations and their considerable heterogeneity. For example, DSM-5 major depressive disorder requires any five of nine symptoms, including opposite ends of the same construct (e.g., psychomotor retardation vs. agitation; Goldberg, 2011). This confers *within group* heterogeneity, complicating accurate predictions of outcome and treatment recommendations. In addition, the frequent co-occurrence of DSM diagnoses (i.e., comorbidity) suggests that there are likely more parsimonious and meaningful taxonomies of psychopathology. In fact, almost all DSM-based disorders co-occur at rates exceeding chance, within and across internalizing and externalizing domains, in nationally-representative samples (Kessler et al., 2005). This pattern has spurred terms such as "multi-morbidity" (Forbes et al., 2019). Alternatively, hierarchical systems that reclassify mental disorders and represent general liability to psychopathology may more effectively and efficiently explain psychopathology.

Developmental psychopathology principles such as multifinality (Cicchetti & Rogosch, 1996) are consistent with diversely predicting multiple forms of psychopathology and dysfunction. For example, child maltreatment is a potent, transdiagnostic risk factor for psychopathology, including psychosis (Varese et al., 2012), depression and anxiety disorders (Lindert et al., 2014), and substance problems (Enoch, 2011). Exposure to maltreatment in childhood may increase liability to psychopathology *overall*, putatively through an increased *p*-factor (Caspi et al., 2014). Similarly, prenatal stress may increase susceptibility to psychopathology through elevation of the *p*-factor rather than specific dimensions (Huizink et

al., 2004). Lahey et al. (2012) found that the *p*-factor was strongly associated with physical/ sexual abuse and neglect, but maltreatment was only nominally associated with the specific fear, distress, and externalizing factors when the *p*-factor was included in the model. The *p*-factor may represent a plausible explanation for longstanding evidence that particular risk factors, such as maltreatment and exposure to prenatal stress, transdiagnostically predict later psychopathology.

Despite the rich theoretical and empirical basis supporting the plausibility of the *p*-factor across development, as well as across informants and measurement approaches, persistent concerns remain about its construct validity and vulnerability to methodological artifacts (Greene et al., 2019; Watts et al., 2019). Bifactor models specify that the covariance among a set of item responses is accounted for by a single general factor that reflects the common variance among all scale items, plus group factors that reflect additional common variance among clusters of items, typically with highly similar content (Reise, 2012). Statistically, these fit psychopathology data better than other models including (a) those for which the *p*-factor subsumes specific factors or (b) correlated-factor models that exclude the *p*-factor (that is, those which only include the specific factors; e.g., Laceulle et al., 2015; Martel et al., 2017; Patalay et al., 2015). In fact, statistical simulations suggest that bifactor models generally fit human individual difference (e.g., cognitive performance; Murray & Johnson, 2013) data better than other types of data.

Crucially, however, Greene et al. (2019) found that robust weighted least squares and robust maximum likelihood—two statistical estimators commonly used with psychopathology data—were biased in favor of the bifactor model. Watts et al. (2019) similarly demonstrated a bias toward bifactor modeling in psychopathology, generating recommendations for those using a bifactor framework applied to psychopathology data and advising that general and specific factors within the model should be reliable and well-represented by their respective indicator

variables (i.e., high factor loadings). They also proposed that including the *p*-factor should improve upon a correlated-factor model's external validity, rather than relying solely on statistical fit indices to demonstrate improved model fit. Overall, then, inferences about the validity of the *p*-factor must employ rigorous tests of external and construct validity.

Preliminary evidence suggests that the *p*-factor is moderately to highly heritable (Waldman et al., 2016; Neumann et al., 2016; Harden et al., 2019). Selzam et al. (2018) employed multiple genomic methods and observed convergent evidence for a latent psychopathology factor underlying common dimensions of psychopathology. With respect to neural correlates, the *p*-factor was associated with reduced gray matter volume in prefrontal areas; however, the specific internalizing factor was also associated with reduced gray matter volume in limbic/paralimbic areas (Snyder et al., 2017). Among a large sample of college students, the *p*-factor was associated with gray matter volume in regions functionally connected with those supporting cognitive control (e.g., corticocerebellar circuitry; Romer et al., 2018). In short, identifying external correlates of the *p*-factor is not only necessary to establishing its construct validity but also facilitates efforts aimed toward understanding of the underlying mechanisms eventuating in explicit psychopathology.

We sought to build on promising preliminary evidence for a *p*-factor in samples of youth by transcending approaches based purely on statistical derivation, instead prioritizing evaluating its association with key external criteria. Consistent with recent recommendations, we evaluated a correlated-factor model with Internalizing and Externalizing factors as well as a bifactor model with those specific factors as well as the *p*-factor. Specifically, using two independent samples of school-age children, we derived statistical fit indices *and* evaluated model facets relative to their association with external criteria. The samples consisted of independent, methodologically-

parallel studies consisting of youth with and without attention-deficit/hyperactivity disorder (ADHD). These two samples were intensively characterized across psychopathology, social, functional, and academic domains. Key features of this study included the use of multiple methods (i.e., clinical interviews, questionnaires, psychoeducational assessments) and informants (i.e., parent, teacher, interviewer, child) to assess psychopathology, impairment, and associated outcomes. We hypothesized that the bifactor model would significantly improve statistical fit to the data relative to the correlated-factor model. With respect to external validity, we hypothesized that the Internalizing and Externalizing factors in the correlated-factor model would be correlated with external outcomes but that those associations would be subsumed by the *p*-factor when all included in the same model (i.e., the bifactor model), such that the *p*-factor alone would show independent variance in predicting academic, social, and global outcomes.

## Methods

### Participants

We pooled data from two independent samples of school-age children with (*n* = 261) and without *(n* = 199) DSM-IV ADHD, for a total of 460 children (*n* = 232 from Shemmassian & Lee, 2012*; n* = 228 from Hinshaw, 2002). Given that ADHD often co-occurs with other problems, there was expected variability across externalizing (e.g., aggression) and internalizing (e.g., anxiety) dimensions. Inclusion criteria were broad: English fluency, residing with at least one biological parent at least half of the time, and full-time enrollment in school. Exclusion criteria were an IQ below 70 or a neurological, pervasive developmental, or seizure disorder. Families were recruited, screened, and assessed using nearly-identical procedures in both studies (see below for details about assessment procedures).

Table 1.1 summarizes demographic information of the sample. Children and families spanned two diverse metropolitan regions on the West Coast of the United States. Participants were recruited from mental health clinics and pediatric offices, as well as through flyers posted in local elementary schools and other public locations. Expanded details about both sample's recruitment, ascertainment, and participant characteristics are explained elsewhere (Hinshaw, 2002; Shemmassian & Lee, 2012). Children in the sample ranged from age 5.26-13.42 years, with a mean age of 8.72 (*SD* = 1.67). There were more girls in the pooled sample, given that one study focused exclusively on school-age girls: 302 (65.65%) girls and 158 (34.35%) boys. Although the pooled sample consisted of a majority of girls, previous studies in children have demonstrated that the *p*-factor fits equally well for boys and girls (Carragher et al., 2016; Patalay et al., 2015). Race-ethnicity of the overall sample was as follows: 51.5% White, 17.8% Black, 10.7% Latinx, 6.1% Asian-American, 0.22% Native American, 11.7% mixed-race, and 1.96% missing.

**Measures**

**Diagnostic Interview.** Parents were administered the fully structured National Institute of Mental Health (NIMH) Diagnostic Interview Schedule for Children Version IV (NIMH DISC-IV; Shaffer et al., 2000). The interview assesses for ten major disorders from the *Diagnostic and Statistical Manual for Mental Disorders*, 4th edition (DSM-IV; American Psychiatric Association, 1994): major depressive disorder (MDD), generalized anxiety disorder (GAD), panic disorder, separation anxiety disorder, social phobia, specific phobia, obsessive-compulsive disorder (OCD), ADHD, oppositional defiant disorder (ODD), and conduct disorder (CD). The computerized DISC-IV (Shaffer et al., 2000) probes symptom level/severity, age of onset, and functional impairment. Computerized scoring is summarized in the DISC-IV Scoring Manual

(Shaffer et al., 2007). We utilized past-year symptom counts for each of the ten disorders listed above. Although we gathered data on other dimensions of psychopathology (e.g., bipolar disorder), to facilitate comparisons with other taxonomic studies of school-age children (e.g., Laceulle et al., 2015; Murray et al., 2016; Olino et al., 2014) and given very low symptom base rates for certain disorders (e.g., post-traumatic stress disorder) in this age group, we used the ten disorders listed above. Of note, the DISC-IV computerized scoring protocol disaggregates some symptoms into multiple variables (e.g., same symptom for two different interview questions), periodically resulting in symptom counts that may exceed the actual DSM-IV symptom counts.

Symptom count ranges, means, and Pearson correlations between disorders appear in Table 1.2. Inattention and hyperactivity symptom counts within ADHD were considered separately. As expected, children demonstrated significant rates of ADHD-related symptoms; however, they also showed elevations in other dimensions (e.g., $M = 6.52$ symptoms for ODD; $M = 4.42$ symptoms for MDD) and exhibited variability across all disorders. All symptom dimensions were significantly intercorrelated (*r's* ranged from 0.15 to 0.71).

**Global Functioning: Achenbach Child Behavior Checklist (6-18).** Parents completed the Child Behavior Checklist 6-18 (CBCL; Achenbach & Rescorla, 2001), which consists of 120 items about their child's social, emotional, and academic functioning scored on a three-point scale from 0 (*not true*) to 2 (*very true or often true*). Standardized *T*-scores designate clinical, borderline clinical, and typical functioning. We utilized the CBCL Total Competence to estimate global functioning, which consists of parent-rated competence across extracurricular activities, social, and educational domains. Higher *T*-scores reflect better overall functioning on this scale.

**Social Functioning: Achenbach Teacher Report Form (6-18).** Primary teachers for children in the sample were asked to complete the 120-item Teacher Report Form (TRF;

Achenbach & Rescorla, 2001), which yields subscales of child psychopathology, social problems, and academic functioning. Responses are scored on the same 3-point scale as the CBCL and yield parallel scales. From this measure, we utilized the Social Problems subscale, which consists of items probing social difficulties in the school environment (e.g., peer conflict). Higher *T*-scores reflect worse social functioning. 83% (383 of 460) of the sample had teacher data. Missing data procedures are described below.

**Dishion Social Acceptance Scale**. Teachers also completed the Dishion Social Acceptance Scale (DSAS; Dishion, 1990), rating the proportion of peers in their class who accepted, rejected, or ignored the child in from the sample. Questions were rated on a 5-point Likert scale (e.g., 1 = very few: less than 25%; 5 = almost all: more than 75%). The DSAS demonstrated moderate to strong convergent validity with peer sociometric data (Dishion & Kavanagh, 2003) as well as predictive validity in 10-year-old boys (Dishion, 1990). Following previous evidence, we estimated negative social preference by subtracting the rejection from the acceptance rating and then reverse scoring it; this approach previously was sensitive to ADHD diagnostic status (e.g., Lahey et al., 2004; Lee & Hinshaw, 2006). Scores ranged from -5 to 5, with higher scores reflecting more negative social preference. We then added a positive constant (10) to each score so that every value would be positive for best interpreting the latent social functioning variable described below.

**Academic Functioning: Weschler Individual Achievement Test.** All youth completed two subtests of the Weschler Individual Achievement Test, 2nd edition (WIAT-II; Wechsler, 2001), a well-normed academic achievement test. We administered the Word Reading and Math Reasoning subtests to each participant and then calculated standard scores in order to better understand participants' academic functioning in math and reading domains compared to peers.

Standard scores have a mean of 100 and a standard deviation of 15; mean standard scores in our sample were 107.94 (*SD* = 15.05) for reading and 106.39 (*SD* = 16.40) for math.

**TRF Academic Performance Rating.** We also utilized teacher ratings of youth academic performance on the TRF. Teachers rated the student's academic performance across all of the subjects in which they instructed the student; for each subject, rankings ranged from 1 ("far below grade") to 5 ("far above grade"). Rankings were summed and students were given a *T*-score based on the ratings in the number of subjects in which they were evaluated.

**Data Analytic Procedures**

First, we used structural equation modeling (SEM) to create separate latent variables for the social and academic measures. For social functioning, we utilized the observed TRF Social Problems scale and DSAS negative social preference score. For both scales, higher scores reflect worse social functioning. Both indicators loaded significantly on the latent factor; standardized factor loadings were 0.74 (Dishion negative social preference) and 0.97 (TRF Social Problems *T*-score). Second, the latent academic functioning variable was derived from the two objective WIAT achievement scores (Reading, Math) and the child's academic performance from the TRF. All three indicators significantly loaded on the latent academic functioning factor, with nearly equivalent standardized loadings that ranged from 0.77 (TRF Academic Performance) to 0.78 (WIAT Math score, WIAT Reading score). For global functioning, we used only the CBCL Total Competence scale; thus, SEM was not required for this single variable.

Next, following standard procedures (Shaffer et al., 2007), we generated symptom counts for each of the ten disorders, which produced 11 symptom clusters (ADHD consisted separately of inattention and hyperactivity). We employed SEM to analyze the independent association of child psychopathology, derived from the DISC-IV, as well as general and specific latent factors

(described below), with concurrent social, academic, and global functioning via Mplus version 8 (Muthén & Muthén, 2017). We first estimated the simplest model, then incrementally saturated the model. That is, we examined a model with one factor comprising all symptom clusters, then a correlated-factor model with two factors (i.e., at the same level), and finally evaluating a bifactor model (Reise, 2012), in which the *p*-factor was added at the same level as specific factors.

Because the symptom count data were often positively skewed, we utilized robust maximum likelihood (MLR) estimation, which performs well with nonnormal data (Chou et al., 1991). In Mplus 8, MLR automatically employs full information maximum likelihood (FIML) estimation to combat missing data. FIML enhances accuracy and power relative to other approaches (Enders, 2010; Schafer & Graham, 2002). Goodness of fit of each model was assessed using the maximum-likelihood $\chi^2$ statistic, the comparative fit index (CFI), the root mean squared error of approximation (RMSEA), and the standardized root mean square residual (SRMR). The CFI ranges from 0 to 1 and reflects the improvement in the fit of the hypothesized model over a model of complete independence among the measured variables (Bentler, 2006); CFI values approaching 0.95 or greater are desirable. The RMSEA is a measure of fit per degrees of freedom, controlling for sample size; RMSEA values below 0.06 indicate relatively good fit (Hu & Bentler, 1999). Finally, the SRMR is an absolute measure of fit and is defined as the standardized difference between the observed correlation and the predicted correlation; a value of zero indicates perfect fit, and a value below 0.08 is generally considered good (Hu & Bentler, 1999). To evaluate fit improvement between models, we utilized the Satorra-Bentler scaled chi-square difference test for nested models that use the MLR estimator (Satorra & Bentler, 2001).

Given above-noted concerns about statistical bias favoring the bifactor model (e.g., Greene et al., 2019; Murray & Johnson, 2013)—and given the centrality of utilizing external

criteria—we prioritized evaluation of models based on their concurrent associations with social, academic, and functional impairment. After initial examination of model fit, we estimated concurrent correlations of general and specific factors with the impairment variables.

## Results

*One-factor model*

We first evaluated a model in which all dimensions of psychopathology were explained by a single latent factor. For this model, all eleven symptom clusters significantly loaded on the latent factor, with standardized factor loadings ranging from 0.38 (social phobia) to 0.85 (MDD). Overall, however, this model was a poor fit to the data ($\chi^2[44] = 253.07$, $p < 0.001$; CFI = 0.84; RMSEA = 0.10 [0.09-0.11]; SRMR = 0.064). Fit indices for all models appear in Table 1.3.

*Model 1: Correlated two-factor model*

We next evaluated a model in which symptom counts loaded onto one of two latent specific factors. Inattention, hyperactivity/impulsivity, ODD, and CD loaded on an Externalizing factor whereas MDD, GAD, social phobia, separation anxiety, specific phobia, OCD, and panic disorder loaded on an Internalizing factor. All dimensions significantly loaded on their respective latent factors, with standardized factor loadings ranging from 0.52 (CD) to 0.82 (inattention) for the Externalizing factor and 0.41 (social phobia) to 0.82 (MDD) for the Internalizing factor. Full loading information is summarized in Figure 1.1. The Internalizing and Externalizing factors were strongly intercorrelated ($r = 0.736$, $p < 0.001$). Compared to the one-factor model, the correlated-factor model significantly improved fit ($\chi^2$ [1] = 73.61, $p < 0.001$; see Table 1.3). Still, the fit was still not excellent ($\chi^2[43] = 150.16$, $p < 0.001$; CFI = 0.92; RMSEA = 0.07 [0.06-0.09]; SRMR = 0.05), as only the SRMR index indicated good fit.

*Model 2: Bifactor model*

The bifactor model specified the same Internalizing and Externalizing factors from the two-factor model, and then included the *p*-factor, on which all psychopathology dimensions load. All three factors were entered at the same level in the model (see Figure 1.2 for a visual representation). The Internalizing and Externalizing factors were constrained not to covary with the *p*-factor, but they were allowed to correlate with each other. Given the structure, this model assumed that the *p*-factor directly influences all symptom dimensions, in addition to the Internalizing and Externalizing factors which influence only certain dimensions, respectively. As with previous studies (e.g., Caspi et al., 2014; Laceulle et al., 2015), the model initially failed to converge. We then systematically isolated variables loading on the *p*-factor, finding that CD prevented convergence when included in both the externalizing specific factor and *p*-factor. This finding parallels Caspi et al. (2014), where paths from Thought Problems to the specific factor were removed, given their explanation by the *p*-factor. However, here, the CD variable was explained only by the specific, and not general, factor, possibly due to the very low rate of CD symptoms in this sample. We followed a similar strategy to the above study and removed CD from loading on the *p*-factor, meaning that its variance was completely explained by the specific Externalizing factor versus by both the *p*-factor and the Externalizing factor.

Once the *p*-factor was added to the model at the same level, the correlation between the Internalizing and Externalizing specific factors decreased but remained robust ($r = 0.54$, $p < 0.01$). Standardized factor loadings of inattention, hyperactivity, and ODD on the externalizing factor similarly decreased but remained significant; ADHD symptoms, in particular, decreased from 0.82 (inattention) and 0.82 (hyperactivity/impulsivity) to 0.34 and 0.41, respectively, suggesting an important role for general psychopathology in explaining variance in ADHD

symptoms in this sample. The lone exception remained CD, the variance of which was explained specifically by the Externalizing factor (not the *p*-factor). As a result, the factor loading of CD on the Externalizing factor increased compared to the correlated two-factor model. Some factor loadings for the Internalizing factor decreased with the *p*-factor included, but the magnitude of reduction was more modest relative to the Externalizing specific factor (e.g., loadings of MDD on the Internalizing factor decreased from 0.82 to 0.60 in the bifactor model). Loadings for some dimensions were nearly constant (e.g., separation anxiety decreased from 0.75 to 0.71).

OCD and panic disorder did not significantly load onto the *p*-factor in the bifactor model, perhaps reflecting low variance/base rates for those symptoms in the overall sample. However, standardized factor loadings for the other disorders on the *p*-factor were all significant, ranging from 0.33 (ODD) to 0.82 (inattention); all loadings for the bifactor model appear in Figure 1.2. Model fit was good ($\chi^2[33] = 80.57$, $p < 0.001$; CFI = 0.96, RMSEA = 0.06 [0.04-0.07]; SRMR = 0.04) and significantly improved fit over the two-factor model ($\chi^2[10] = 67.01$, $p < 0.001$). Even with inclusion of the *p*-factor, factor loadings on the specific Internalizing and Externalizing factors remained significant (although decreased in some cases), suggesting that the specific factors retained explanatory utility with simultaneous inclusion of the *p*-factor.

*External validity*

Although the bifactor model fit the data better than the correlated two-factor model, in order to combat methodologic and statistical concerns about potential biases (e.g., Greene et al., 2019; Watts et al., 2019), we prioritized model evaluation based on associations with academic achievement, social functioning, global impairment. Fit statistics and regression coefficients for general and specific factors with these criteria appear in Table 1.4.

**Models 1A and 2A: Academic Functioning.** In the correlated two-factor model (excluding the *p*-factor), the Internalizing and Externalizing factors were marginally associated with youth academic functioning (Model 1A; β = -0.17; *SE* = 0.09; *p* = 0.06 and β = -0.17; *SE* = 0.10; *p* = 0.09, respectively). For the bifactor model (2A), the *p*-factor was significantly and negatively related to academic functioning (β = -0.43; *SE* = 0.06; *p* < 0.001); the Internalizing factor was similarly negatively associated (β = -0.21; *SE* = 0.10; *p* = 0.03), whereas the Externalizing factor (β = 0.07; *SE* = 0.11; *p* = 0.52) was not significantly related to youth academic functioning with inclusion of the other factors.

**Models 1B and 2B: Social functioning.** For the social functioning variable, within the two-factor model (1B), the Externalizing factor (β = 0.58; *SE* = 0.10; *p* < 0.001) but not the Internalizing factor (β = 0.08; *SE* = 0.10; *p* = 0.44) was significantly associated with youth social functioning. When the *p*-factor was added for the bifactor model (2B), the *p*-factor and the Externalizing factor were each significantly and positively associated with social functioning (β = 0.48; *SE* = 0.11; *p* < 0.001 and β = 0.32; *SE* = 0.15; *p* = 0.03, respectively). However, the Internalizing factor was statistically unrelated to youth social functioning (β = 0.11; *SE* = 0.08; *p* = 0.17).

**Models 1C and 2C: Global functioning.** As with social functioning, in the correlated two-factor model (1C), the Externalizing factor (β = -0.56; *SE* = 0.08; *p* < 0.001), but not the Internalizing factor (β = 0.01; *SE* = 0.09; *p* = 0.92), was significantly and negatively associated with global functioning. For the bifactor model (2C), the *p*-factor and Externalizing factor were both significantly and negatively associated with global functioning (β = -0.47; *SE* = 0.05; *p* < 0.001 and β = -0.23; *SE* = 0.08; *p* = 0.004, respectively). Once again, the Internalizing factor was not significantly associated with global functioning (β = -0.07; *SE* = 0.07; *p* = 0.31).

## Discussion

We investigated two models of psychopathology structure, a correlated-factor model and a bifactor model, using cross-sectional psychopathology data from 460 ethnically diverse school-age children with *(n* = 261) and without *(n* = 199) ADHD. Given persistent concerns over statistical bias favoring the bifactor model with respect to human individual difference data, we evaluated the relative model fit of separate correlated-factor and bifactor models with ten DSM-IV disorders (i.e., MDD, GAD, panic disorder, separation anxiety disorder, social phobia, specific phobia, OCD, ADHD, ODD, and CD)—and then examined associations with latent variables derived from multi-method measures of social, academic, and global functioning. First, we derived a correlated two-factor model (Model 1) with Internalizing (MDD, GAD, panic disorder, separation anxiety disorder, social phobia, specific phobia, OCD) and Externalizing (ADHD, ODD, and CD) factors. All dimensions significantly loaded on their respective latent factors, and the Internalizing and Externalizing factors were strongly intercorrelated. However, the bifactor model (Model 2), which included the *p*-factor at the same level as the Internalizing and Externalizing factors, fit the data significantly better than the correlated-factor model. However, this finding was expected based on previous evidence, including potential statistical bias in favor of bifactor models.

Our second aim was to examine associations with external criteria for each of the two models to transcend reliance on only statistical fit indices. For the correlated-factor model, the Internalizing and Externalizing factors were not significantly related to academic functioning (Model 1A). For the social (1B) and global functioning (1C) models, only the Externalizing factor was inversely associated with social and global functioning. In the bifactor model, the *p*-factor was strongly associated with youth academic functioning (2A), with the Internalizing

factor also showing independent associations. Similarly, the *p*-factor was uniquely associated with social (2B) and global (2C) functioning; the Externalizing factor also explained independent variance with a significant association with these outcomes. The Internalizing factor was unrelated to social and global functioning in the bifactor model. Given significant factor loadings on the Internalizing and Externalizing factors as well as concurrent validity for the Externalizing factor, even with inclusion of the *p*-factor, these data suggested that specific and general factors of psychopathology both usefully explained variation in symptom patterns and external criteria.

Herein, we used two independent, case-control studies of childhood ADHD. Not surprisingly, there was significant co-occurring psychopathology among ADHD youth, particularly with respect to externalizing symptoms. The patterns of psychopathology, including comorbidity, may differ here from unselected samples (e.g., population-based). Nevertheless, these results were consistent with the large community sample of school-age youth where the *p*-factor and Externalizing factor were each significantly and inversely associated, both concurrently and prospectively, with external criteria, including school functioning (e.g., special services, school impairment; Lahey et al., 2015). Interestingly, Brikell et al. (2018) recently showed that common genetic risk variants associated with ADHD also increased genetic liability toward general psychopathology in childhood (in addition to a specific association with hyperactivity and impulsivity symptoms), suggesting that examining the structure of psychopathology in children with ADHD symptoms may effectively capture the *p*-factor. We also observed that factor loadings on the specific Externalizing factor decreased by 50% with inclusion of the *p*-factor, suggesting that the general psychopathology factor was more strongly associated with externalizing symptoms relative to internalizing symptoms. See also Laceulle et al. (2014), who found that factor loadings of attention problems on the latent externalizing factor

reduced by about half after accounting for the *p*-factor. Whereas the present results were consistent with other studies regarding associations with external criteria, they diverged from others. For example, Martel et al. (2017) reported that executive functioning was unrelated to externalizing problems with inclusion of the *p*-factor, suggesting the predictive primacy of the general psychopathology factor in that sample. In all, the inconsistency with which the *p*-factor is associated with external criteria, independent of specific factors, may reflect important sample differences (e.g., age range and mean). Our study is unique in examining external criteria for each of the two structural models, and, along with other developmental studies cited here, supports the *p*-factor in predicting external outcomes in school-aged youth, with additional variance explained by the Externalizing factor, particularly for social and global outcomes.

Findings from the current study were consistent with previous evidence on the utility of a bifactor model to characterize the underlying architecture of psychopathology in school-age children. Independent associations of the *p*-factor with clinically meaningful external criteria, even with inclusion of specific Internalizing and Externalizing facets, suggest that the *p*-factor is unlikely to be purely artifactual. Innovations in the taxonomy of psychopathology have significant implications for assessment and intervention. For example, the Hierarchical Taxonomy of Psychopathology (HiTOP) integrates dimensional psychological phenomena, covariation and comorbidity, and general and specific factors of psychopathology to improve the utility of the diagnosis of mental disorders (Kotov et al., 2017). The HiTOP framework supports a general psychopathology factor at the highest level, decomposed into Internalizing and Externalizing "transdiagnostic spectra." "Subspectra" within those domains (e.g., fear, distress, substance use) are also present, along with further "differentiated syndromes" with more specific symptoms within each subspectra (e.g., phobic anxiety, aggression, impulsivity). Clinical

implications are discussed below, but the framework attempts to incorporate recent evidence challenging traditional nosologies to propose a more cohesive and applicable approach; our results support considering a framework such as HiTOP in children as young as school-age.

With respect to implications of the general psychopathology factor for intervention, Forbes et al. (2019) proposed a model for developmentally informed and transdiagnostic stepped-care intervention that highlights the importance of the *p*-factor early in life. The adaptation involves targeting general psychopathology at ages 3-6 with interventions becoming more specific from transdiagnostic spectra to differentiated syndromes from adolescence to adulthood. Rather than treatment protocols tailored to specific problems, transdiagnostic and developmentally-informed interventions (e.g., psychoeducation, parenting behavior, emotion regulation strategies) may prevent trajectories of illness, including emergent comorbidity. Next, a general psychopathology framework is well-positioned to guide implementation of interventions that could be ideographically tailored contingent upon emergence of specific syndromes. For example, elements of cognitive behavioral therapy could supplement risk for internalizing and externalizing domains in middle childhood followed by selective interventions for specific symptom domains in adolescence (e.g., fear, distress, substance use, antisocial behavior; Forbes et al., 2019). In adults, Hopwood et al. (2019) discussed how the HiTOP structure could effectively align with three clusters of psychotherapy approaches, including common factors, cognitive-behavioral techniques, and relational techniques. These models are consistent with calls to prioritize prevention (Ialongo et al., 2015; Rishel, 2007) and transdiagnostic care (e.g., Unified Protocol for treatment of emotional disorders in youth; Ehrenreich et al., 2009). The present findings suggest that the *p*-factor is evident in school-age youth, separable from internalizing and externalizing facets, associates meaningfully with important indicators of

social, academic, and overall development. Reducing risk factors for the *p*-factor, and/or implementing prevention or intervention programs targeted at reducing it, may usefully improve academic, social, and global impairment in school-age children.

Despite providing important preliminary data on the external validity of the *p*-factor, this study also includes several limitations. Although strengthened by its multi-informant/method design, all data were cross-sectional, precluding inferences of predictive validity (see Cervin et al., 2020; Patalay et al., 2015; and Lahey et al., 2015 for data with longitudinal samples). Next, the current sample size was adequate for SEM, but the modest sample size may help explain some inconsistencies observed in this study relative to previous reports. For example, a significant correlation between the Internalizing and Externalizing factors remained even with inclusion of the *p*-factor, whereas previous bifactor studies revealed nonsignificant associations in the bifactor model (Caspi et al., 2014; Laceulle et al., 2015; Olino et al., 2014). Finally, the pooled sample from the current study, while intentionally selected to sample a range of school-aged youth, may reflect unmeasured developmental influences that may affect factor loadings. Historically, factor analytic studies demonstrate that internalizing symptoms are best characterized as a single dimension for school-age youth but split into two dimensions (anxiety and depression) by middle school (Cole et al., 1998). Similarly, Lahey et al. (2004) showed that items measuring ODD and hyperactivity/impulsivity loaded on the same factor in young children but on different factors in older children. Future studies reflecting diverse sampling strategies may optimally characterize developmental aspects of psychopathology and implications for discerning its latent structure.

With respect to future directions, there is an acute need to extend and deepen validation efforts to improve traction on the predictors and sequelae of the *p*-factor. In particular,

prospective longitudinal design would refine directional and reciprocal associations with other risk factors and related processes. Similarly, further diversifying external correlates of the *p*-factor, including genetic and neurobiological correlates, would be valuable (Romer et al., 2018; Selzam et al., 2018; Snyder et al., 2017). At the same time, applying existing knowledge about the *p*-factor and hierarchical structures that include such a factor represent novel directions for future psychiatric neuroimaging and genetic research. For example, heterogeneity and comorbidity within existing diagnostic categories have increasingly focused biological studies on narrow groupings of symptoms or functional constructs rather than categorical diagnoses. Applying a hierarchical approach may aid in identifying neural substrates that nonspecifically contribute to multiple symptoms and forms of psychopathology, further guiding targeted prevention and intervention efforts (Bilder, 2017; Krueger & DeYoung, 2016; Zald & Lahey, 2017). Overall, a comprehensive understanding of the architecture of developmental patterns of psychopathology, including the role of the *p*-factor, should help to reconcile existing taxonomic challenges and ultimately to decrease the burden of mental health problems.

Table 1.1. Demographic information for the study sample.

| | |
|---|---|
| Age in years (*SD*) | 8.72 (1.67) |
| Female | 65.65% |
| Ethnicity | 51.52% White<br>17.83% Black<br>10.65% Latinx<br>6.09% Asian-American<br>0.22% Native American<br>11.74% mixed-race<br>1.96% did not report |
| WIAT Reading Standard Score (*SD*) | 107.94 (15.05) |
| WIAT Math Standard Score (*SD*) | 106.39 (16.40) |

Table 1.2. Means, standard deviations, and Pearson correlations between symptom counts for disorders.

| | Mean (SD) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. ADHD: Inattention (0-11) | 5.68 (3.71) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2. ADHD: Hyperactivity/ Impulsivity (0-11) | 4.34 (3.53) | 0.707** | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 3. ODD (0-12) | 6.52 (3.16) | 0.447** | 0.485** | -- | -- | -- | -- | -- | -- | -- | -- |
| 4. CD (0-8) | 1.07 (1.56) | 0.355** | 0.405** | 0.492** | -- | -- | -- | -- | -- | -- | -- |
| 5. MDD (0-15) | 4.42 (3.64) | 0.618** | 0.550** | 0.515** | 0.410** | -- | -- | -- | -- | -- | -- |
| 6. GAD (0-11) | 2.63 (2.37) | 0.439** | 0.378** | 0.270** | 0.286** | 0.608** | -- | -- | -- | -- | -- |
| 7. Social phobia (0-13) | 1.77 (2.89) | 0.251** | 0.191** | 0.145** | 0.116* | 0.276** | 0.400** | -- | -- | -- | -- |
| 8. Separation anxiety (0-10) | 2.46 (2.33) | 0.402** | 0.340** | 0.320** | 0.305** | 0.580** | 0.610** | 0.316** | -- | -- | -- |
| 9. Specific phobia (0-7) | 1.31 (1.37) | 0.335** | 0.349** | 0.250** | 0.244** | 0.405** | 0.412** | 0.221** | 0.438** | -- | -- |
| 10. OCD (0-4) | 0.34 (0.72) | 0.196** | 0.251** | 0.159** | 0.289** | 0.373** | 0.340** | 0.137** | 0.342** | 0.239** | -- |
| 11. Panic disorder (0-3) | 0.22 (0.52) | 0.174** | 0.151** | 0.172** | 0.154** | 0.358** | 0.346** | 0.162** | 0.407** | 0.195** | 0.262** |

*Note*. *$p < 0.05$; **$p < 0.01$. ADHD = attention-deficit/hyperactivity disorder, ODD = oppositional defiant disorder, CD = conduct disorder, MDD = major depressive disorder, GAD = generalized anxiety disorder, OCD = obsessive-compulsive disorder

Table 1.3. Fit for evaluated models.

| | **Chi-square** | **df** | **CFI** | **RMSEA** | **SRMR** | **S-B $\chi^2$ diff** |
|---|---|---|---|---|---|---|
| **Model** | | | | | | |
| 1. One factor model | 253.071*** | 44 | 0.843 | 0.102 [0.090- 0.114] | 0.064 | -- |
| 2. Correlated two-factor model | 150.161*** | 43 | 0.920 | 0.074 [0.061- 0.087] | 0.049 | 2 vs. 1: 73.605*** |
| 3. Bifactor model | 80.565*** | 33 | 0.964 | 0.056 [0.041- 0.072] | 0.037 | 3 vs. 2: 67.005*** |

*Note*. *$p < 0.01$; **$p < 0.05$; ***$p < 0.001$. S-B $\chi^2$ diff = Satorra-Bentler chi-square difference test for the specified model comparison.

Table 1.4. Correlated two-factor and bifactor models predicting social, academic, and global functioning outcomes including fit indices and regression coefficients for general and specific factors.

| | **Chi-square** | **df** | **CFI** | **RMSEA** | **SRMR** | ***P*** | ***INT*** | ***EXT*** | **$R^2$** |
|---|---|---|---|---|---|---|---|---|---|
| **Model** | | | | | | | | | |
| 2a. Two-factor model predicting academic functioning | 254.182*** | 74 | 0.895 | 0.073 [0.063-0.083] | 0.085 | -- | -0.169 | -0.169 | 0.10* |
| 2b. Two-factor model predicting social functioning | 174.826*** | 62 | 0.931 | 0.063 [0.052-0.074] | 0.048 | -- | 0.078 | 0.580*** | 0.41*** |
| 2c. Two-factor model predicting global functioning | 183.192*** | 52 | 0.912 | 0.074 [0.063-0.086] | 0.050 | -- | 0.009 | -0.558*** | 0.30*** |
| 3a. Bifactor predicting academic achievement | 152.523*** | 63 | 0.953 | 0.056 [0.044-0.067] | 0.047 | -0.430*** | -0.210* | 0.072 | 0.21*** |
| 3b. Bifactor predicting social functioning | 106.459*** | 51 | 0.966 | 0.049 [0.036-0.062] | 0.042 | 0.476*** | 0.106 | 0.324* | 0.38*** |
| 3c. Bifactor predicting global functioning | 97.752*** | 41 | 0.962 | 0.055 [0.041-0.069] | 0.036 | -0.471*** | -0.069 | -0.227** | 0.30*** |

*Note.* *$p < 0.01$; **$p < 0.05$; ***$p < 0.001$

Figure 1.1. Correlated two-factor model with standardized factor loadings.

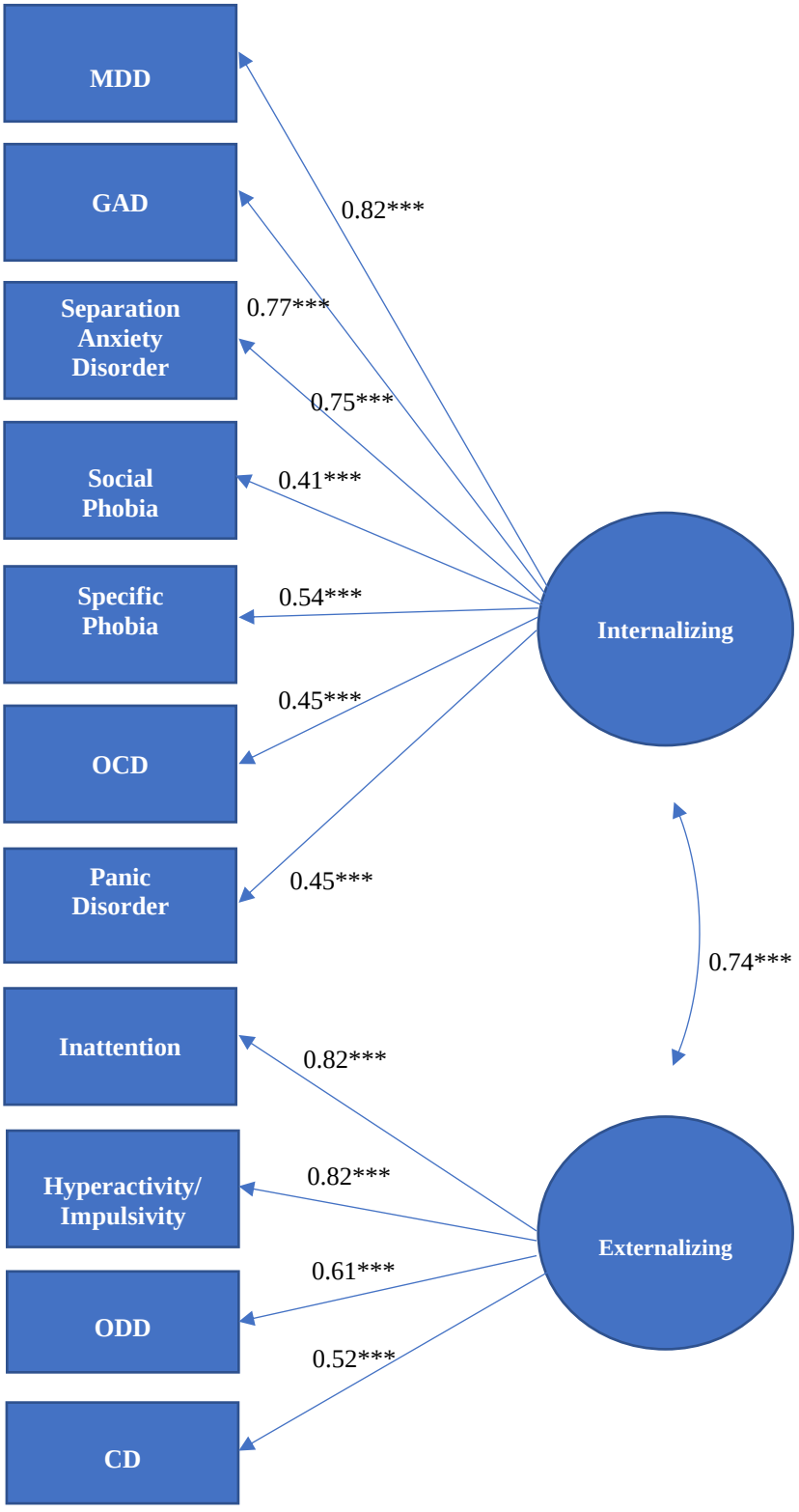
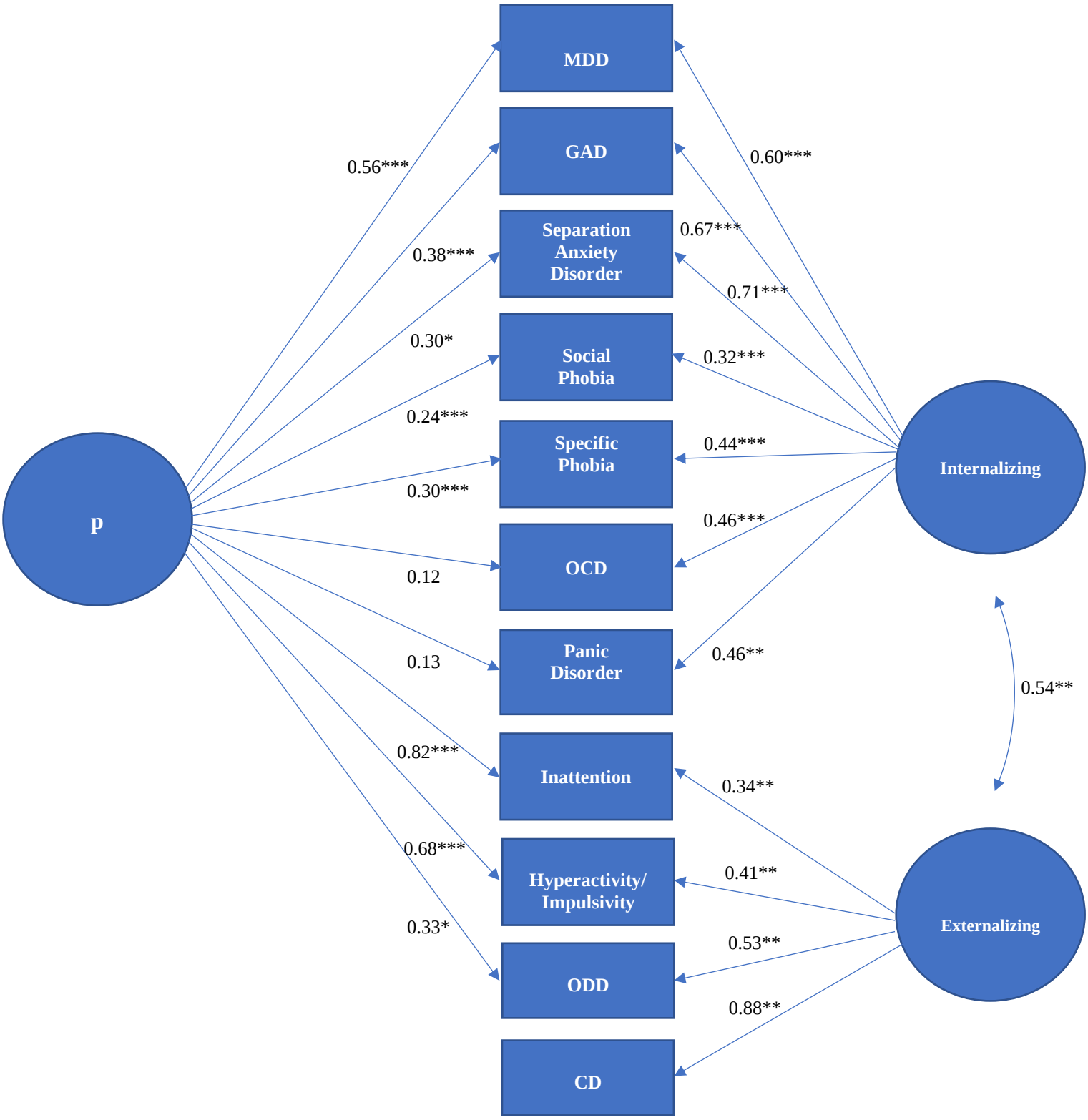


Figure 1.2. Bifactor model with standardized factor loadings.



## Study II: Digital Media Use Frequency, Online Behaviors, and Risk for Psychopathology in Adolescents in High Achieving Schools


Abstract

There is replicated evidence that adolescents enrolled in high achieving schools (HAS) exhibit elevated psychopathology (e.g., anxiety, depression, substance use) relative to national norms; influences such as achievement pressures, affective characteristics, and peer relationships may be important risk factors. Similarly, the frequency of digital media (e.g., social networking) use is a potential risk factor for psychopathology, particularly among vulnerable subgroups of adolescents, although mediators of this association have not been clearly identified. 2,952 HAS youth drawn from three U.S. high schools self-reported the frequency (i.e., number of hours/day) of their digital media use across platforms as well as internalizing and externalizing problems and substance use; hypothesized mediators consisted of the frequency of social comparisons with peers, receiving negative feedback from others, and presenting themselves in a risky way on digital media. Models were examined in boys and girls to look for potential gender differences in digital media habits and impact on mental health symptoms. Using a multiple mediation framework, the frequency of social comparison, receiving negative feedback, and risky self-presentation each uniquely mediated the association of digital media use with internalizing and externalizing problems in boys and girls; with respect to substance use, risky self-presentation mediated this association in both boys and girls and negative feedback additionally mediated substance use in girls but not boys. Measurable online behaviors in the form of social comparison, negative feedback, and self-presentation may constitute crucial links in the association of digital media use frequency with socio-emotional development in adolescents.

In 2011, an *American Academy of Pediatrics* report suggested that much of the current generation's social and emotional development would occur online and on cell phones (O'Keeffe & Clarke-Pearson, 2011). Given that youth are increasingly able to access and use technology across academic and social activities, characterizing the association of digital media use with the development of mental health problems is a priority. Despite documented social and health benefits of digital media use in youth (Chassiakos et al., 2016; Rideout et al., 2018; Best et al., 2014; & Uhls et al., 2017), digital media use has also been associated with cyberbullying (Patchin & Hinduja, 2006), early sexual experimentation (i.e., "sexting"; Lenhart et al., 2009; Rice et al., 2012), and compromised personal privacy (O'Keeffe & Clarke-Pearson, 2011). The availability and convenience of digital media may exacerbate socio-emotional problems among some youth: for example, the frequency of digital media use was positively associated with adolescent anxiety (Vannucci et al., 2017; Woods & Scott, 2016) and depression (Boers et al., 2019; Lin et al., 2016; Twenge et al., 2018), including a systematic review of 13 studies linking time spent on social media with adolescent anxiety and depression (Keles et al., 2020). Frequent digital media use was also positively associated with attention problems (Nikkelen et al., 2014; Ra et al., 2018), heavy episodic drinking, and drug use (Brunborg et al., 2017; Ohannessian et al., 2017). These patterns are evident prospectively, including between- and within-person covariation of self-reported digital media use with increased depressive symptoms across four years (Boers et al., 2019). Finally, adjusting for clinical and demographic factors, including baseline mental health, three plus hours of daily social media use prospectively predicted internalizing and comorbid internalizing and externalizing problems (Riehm et al., 2019).

However, the recent review by Odgers and Jensen (2020) revealed that digital media was unrelated to youth psychopathology in many studies. For example, digital-screen engagement,

derived from time-use-diary measures, was nominally associated with adolescent well-being measures such as self-esteem and depression (Orben & Przybylski, 2019). Similarly, ecological momentary assessments of mobile phone use across 14 days were unrelated to subsequent mental health (Jensen et al., 2019) in a different sample of adolescents. The precise association between frequency of digital media use with concurrent or prospective adolescent well-being remains inconsistent, which likely reflects methodological differences and specific patterns in subgroups of (vulnerable) adolescents. Crucially, characterizing explanatory factors (i.e., mediators) of putative associations is necessary to begin to establish the causal validity of digital media use as a risk factor for psychopathology; it will also help to identify potential intervention targets. Plausible mediators of this association include disrupted sleep (Lemola et al., 2015; Woods & Scott, 2016) and impaired executive functioning and/or inhibited learning (Chen & Yan, 2016; Park et al., 2011). However, social and behavioral mediators remain largely unknown.

Initially, time spent on online social platforms was implicated as an ineffective coping strategy for adolescent daily stress (Caplan, 2010; LaRose et al., 2003). Recent work suggested cognitive rumination and avoidance (McNicol & Thorsteinsson, 2017) and passively viewing online (rather than actual interactions with others; George & Odgers, 2015; Twenge et al., 2019; Underwood & Ehrenreich, 2017) were maladaptive responses secondary to digital media use. Among the 1,058 adolescents from the 2018 Pew Research Center survey on teens and digital media use, 45% of youth reported feeling overwhelmed by online "drama," 43% felt pressure to only post content that makes them look good to others, and 37% felt pressure to post content that would garner likes and positive comments. These studies support the plausibility that social influences online may help explain putative associations of digital media use frequency with

mental health problems among adolescents; also, salient personality factors may identify which adolescents differentially struggle with mental health secondary to online engagement.

While some digital interactions mirror "offline" social processes, there is also evidence that contemporary digital media settings constitute a distinct and unique interpersonal context, particularly for adolescent socio-emotional development (Nesi et al., 2018). Adolescents often engage in upward social comparison using digital media, including incurring negative affect subsequent to these evaluations (Lee, 2014). Recently, upward social comparison on social media was concurrently (Virgil & Wu, 2015) and prospectively associated with decreased life satisfaction (Frison & Eggermont, 2016), body dissatisfaction (Ho et al., 2016; Rousseau et al., 2017), and depressive symptoms (Li, 2019; Nesi & Prinstein, 2015). In fact, greater exposure to upward social comparisons on social media mediated the association of frequent Facebook use with self-esteem in young adults (Vogel et al., 2014); similarly, frequency of social comparison to others that were perceived to be better off predicted major depressive disorder among college students (Robinson et al., 2019). Adolescents' comparisons with others via digital media, and the links to decreased well-being therein, may be affected by their own presence on social media (e.g., the number of likes they get on a post; Burrow & Rainone, 2017) or by judging their own lives versus the quality of others' perceived on public sites (Vogel et al., 2014).

Adolescents also self-report experiencing pressure to post content that will earn them positive feedback on digital media platforms (Pew Research Center, 2018). Studies of "offline" relational processes suggest frequency of receiving negative feedback is associated with high distress among adolescents, including feeling victimized by being left out of an activity or being the target of gossip (Murray-Close et al., 2017). Receiving negative feedback directly (e.g., in comments) or indirectly (e.g., not getting the desired number of likes) online was positively

associated with low self-esteem (Thomaes et al., 2010). In fact, negative online feedback may be more harmful to adolescents compared to face-to-face negative feedback given that it is public, can be distributed widely, and endures long after it has been communicated (Boyd, 2008). The potential consequences of receiving such feedback may be particularly salient for adolescents who are acutely sensitive to and internalize feedback from others (Rodman et al., 2017).

Lastly, Vogel and Rose (2016) described how social comparison relative to others' unrealistic self-presentations and framing one's own presentation with those expectations online was associated with negative outcomes. Risky self-presentation, defined in one study as posting pictures with a strong focus on sexuality and physical attractiveness (e.g., wearing provocative or revealing clothing) predicted receiving more negative feedback on digital media (Koutamanis et al., 2015). Risky self-presentation may thus indirectly contribute to low self-esteem through negative feedback, although it may also more directly affect adolescent well-being (Fullwood et al., 2016; Yau & Reich, 2019). Risky self-presentation may also be correlated with digital status seeking, defined as the investment of significant effort to accumulate online indicators of peer status and approval (Nesi & Prinstein, 2019). However, risky self-presentation can be particularly salient if frequent risky posting is an effort to manage impressions and improve online popularity (Dhir et al., 2016). In fact, college students who were less likely to post pictures of themselves along with other people (e.g., "selfies"), possibly representing risky self-presentation, were more likely to meet criteria for major depressive disorder (Robinson et al., 2019). Nesi and Prinstein (2019) demonstrated that adolescents engaged in digital status seeking also exhibited higher levels of substance use and sexual risk behaviors one year later. Taken together, upward social comparison, receiving negative feedback, and risky self-presentation all

constitute strong candidates as specific mediators of psychopathology from digital media use with mental health symptoms.

*Adolescents in high achieving school environments*

There is replicated evidence that students in high achieving schools (HAS) concurrently and prospectively exhibit heightened psychopathology compared to national norms, including substance use, depression, anxiety, and non-suicidal self-injury (Ebbert et al., 2019; Luthar & Barkin, 2012; Luthar et al., 2019; Luthar et al., 2017; Luthar et al., 2020; Yates et al., 2008). In fact, the National Academies of Science, Engineering, and Medicine (NASEM; 2019) identified HAS students as an at-risk group, along with historically vulnerable groups (e.g., children living in poverty, foster care youth). The Robert Wood Johnson Foundation also identified poverty, trauma, discrimination, and excessive achievement pressures (usually seen in affluent communities) as the top four environmental threats to adolescent well-being in 2018 (Geisz & Nakashian, 2018). As summarized by Ebbert et al. (2019), large nationally representative samples have shown that "school-level affluence" (i.e., high density of high-income families), not individual family-level affluence, connotes risk (Coley et al., 2018; Lund et al., 2017) among these populations in considering achievement pressures and risk within HAS students.

Several possible risk factors for poor socio-emotional outcomes in youth in HAS have emerged, including achievement pressures, perceived isolation from parents, and high rates of unique personality characteristics (e.g., perfectionism, envy; Ebbert et al., 2019). Achievement pressures among HAS adolescents may potentiate heightened competition and comparisons among peers (Luthar et al., 2019). The "Big Fish Little Pond Effect" of being educated amongst high performers may negatively affect academic self-concept for some HAS students (Becker & Neumann, 2018; Fang et al., 2018); this may also reflect comparisons with talented peers and

increase anxiety and distress related to achievement. Together with evidence of heightened envy across multiple domains (e.g., popularity, sports; Lyman & Luthar, 2014), including its positive association with externalizing problems and poor relatedness with others, especially among girls (Lyman & Luthar, 2014), HAS students may frequently compare themselves to peers. That frequent upward comparisons and social comparisons on social media may be associated with self-esteem and depression suggest that these factors should be assessed with HAS youth.

Other aspects of peer relationships among HAS youth also warrant study, including identity formation/presentation and feedback from peers. Luthar et al. (2020) reported that receiving negative feedback on social media was positively associated with somatic symptoms and rule-breaking behaviors in separate HAS samples. Negative feedback from others, including relational victimization, was associated with high distress in adolescents more broadly (Murray-Close et al., 2017). Also, adolescence is a period of elevated valuation of social status and acceptance influences (e.g., De Bruyn & Van Den Boom, 2005); these factors may be particularly relevant to HAS youth with respect to predictions of psychopathology. For example, youth with persistently high substance use trajectories in one suburban high school had higher peer acceptance relative to low substance using youth (McMahon & Luthar, 2006). Lastly, digital status seeking, which may reflect some of these offline phenomena, prospectively predicted adolescent substance use and sexual risk behaviors (Nesi & Prinstein, 2019), which again may be particularly relevant to psychopathology in HAS youth given their vulnerability to these problems (e.g., Händel et al., 2013; Luthar et al., 2019). Taken together, adolescents in HAS, who consistently demonstrate elevated psychopathology, must be intensively characterized across theoretically-relevant family, social, and academic factors; moreover, plausible sex differences in patterns of association suggest that this, too, should be prioritized in future studies.

*Present study*

Increasing access to and frequent digital media may increase vulnerability to psychopathology (and perhaps transactionally). This may be particularly true in key subgroups of the population, including students attending HAS. To facilitate innovations in assessment and intervention for an understudied population, this study examined the concurrent association of digital media use with self-reported psychopathology among HAS youth, its mediation *through* specific online behaviors, and potential gender differences. Luthar et al. (2020) suggested that social comparisons on social media were associated with internalizing problems and negative feedback on social media with rule-breaking behavior among HAS youth. The present study increments this emerging evidence by (a) using 3 different HAS samples; and (b) including an outcome known to be problematic in this population—substance use—while examining potential mediation by specific online behaviors. Given that upward social comparison and negative feedback were previously associated with self-esteem and depression (Li, 2019; Luthar et al., 2020; Nesi & Prinstein, 2015; Thomaes et al., 2010), we hypothesized that these factors would significantly mediate associations with internalizing problems, and risky self-presentation would mediate associations with substance use given that peer acceptance and status seeking were associated with increased substance use in HAS populations (McMahon & Luthar, 2006).

## Methods

### Participants

Participants were 2,952 students from three different high schools across the United States. Schools self-identified as "high achieving" based on having high standardized test scores, enriched extracurricular and academic offerings, and graduates heading to elite colleges. Schools typically elected to participate in the study based on their desire to understand student well-being, including proactively addressing academic pressures. Schools included an independent

boarding school in the Northeast (*n* = 638; School 1 in Table 2.1), a private day school in the Midwest (*n* = 739; School 2), and a public day school in the Pacific Northwest (*n* = 1738; School 3). All data used in the study were collected in 2016 (School 3) and 2017 (Schools 1 and 2). Across all schools, 53.2% of the sample self-reported their gender identity as male (*n* = 1571) and 46.8% (*n* = 1381 including *n* = 3 transgender) identified as female. Students self-reported their race and ethnicity as follows: 57.7% White, 4.43% Black, 3.76% Latinx, 20.13% Asian/Asian-American, 6.71% bi/multiracial, 4.96% "other", and 2.31% unreported.

**Procedures**

Within each school, all students were invited to participate in the study, but only those students who returned consent and assent forms were enrolled. All data for the study was collected through the High Achieving Schools (HAS) Survey (Kumar, 2019), which students completed online at school in a single sitting (see details below).

**Measures**

**Independent Variable: Digital Media Use Frequency.** Students self-reported how frequently in a typical day they used texting/messaging, Snapchat, Facebook, Instagram, Twitter, YouTube, and visited forums/chatrooms (e.g., Reddit). Seven items (e.g., On a typical day, how much time do you spend on Snapchat?) were rated on an 8-point scale (i.e., 0 = No use; 1 = Less than 30 minutes; 2 = 30 minutes; 3 = 1 hour; 4 = 2 hours; 5 = 3 hours; 6 = 4 hours; 7 = 5+ hours) for each platform and then summed across all media forms to estimate overall digital media use frequency ($\alpha = 0.71$). Further details about digital media use appear in Table 2.1.

**Mediator: Negative Feedback.** Students rated four questions about the frequency of receiving negative feedback in response to messages or pictures they posted on digital media platforms from good friends, people they did not know, and people they knew but who they were

not friends with, as well as how often people said mean things to them or about them online. Items were scored on a 5-point Likert scale, ranging from 0 = Never to 4 = Very Often. Responses from all four items were summed to estimate negative feedback ($\alpha = 0.84$).

**Mediator: Social Comparison.** Students answered four questions, all of which began with: "After viewing other people's digital media accounts, how often do you feel…?" Students answered how frequently they felt that their life is not as exciting, interesting, and/or happy as others', as well as assessments of their own attractiveness when viewing others' digital media content. Items were scored on a 5-point Likert scale, ranging from 0 = Never to 4 = Very Often. All responses were summed to estimate overall social comparison on digital media ($\alpha = 0.90$).

**Mediator: Risky Self-Presentation.** Participants rated five items on the frequency with which they posted "risky" pictures (e.g., in which they showed their body, that they would "NOT" want their parents to see). Items were scored on a 5-point Likert scale from 0 = Never to 4 = Very Often. Responses to the five items were summed for an overall measure of risky self-presentation ($\alpha = 0.80$).

**Dependent Variables: Psychopathology.** Youth completed 89 items from the Youth Self Report (YSR) for 11-18-year-old youth (Achenbach et al., 2004). Items were rated on a 3-point Likert scale (i.e., 0 = "Not True"; 1 = "Somewhat or Sometimes True"; 2 = "Very True or Often"). Raw sum scores for the Internalizing (e.g., anxiety, depression, and somatic concerns) and Externalizing (e.g., rule-breaking and aggressive behaviors) subscales were used, although models controlled for age. A priori, analyses were conducted separately for boys and girls, so *T*-scores were not used. The YSR is well-validated and psychometrically sound across diverse samples (e.g., Ebesutani et al., 2011; Ivanova et al., 2007).

Students also self-reported their substance use by completing 3 items from the Monitoring the Future Study (National Institute on Drug Abuse, 2019); they rated frequency of past year cigarette use, alcohol use, and marijuana use on a 7-point Likert scale (i.e., 0 = Never; 6 = 40+ times). Responses were summed for a total composite substance use variable ($\alpha = 0.82$).

### Data Analytic Procedures

To examine the association of digital media use frequency with self-reported internalizing, externalizing, and substance abuse problems, as well as mediation by negative feedback, social comparison, and self-presentation, we evaluated a multiple mediation model separately in boys and girls. Multiple mediation with bootstrapping is a powerful, nonparametric resampling procedure that evaluates multiple individual mediators simultaneously and adjusts for covariates (MacKinnon et al., 2000; Preacher & Hayes, 2008). Unlike traditional mediation, mediation with bootstrapping does not require a significant total effect of the predictor on the outcome (MacKinnon et al., 2000; Preacher & Hayes, 2008; Zhao et al., 2010). Multiple mediation discerns the unique role of each individual mediator and is more powerful than traditional methods (i.e., Sobel test; Zhao et al., 2010). We conducted mediation analyses using Mplus version 8.3 (Muthén & Muthén, 2017). Parameter estimates and 95% confidence intervals for total and specific indirect effects were generated based on 10,000 bootstrap simulation samples (Preacher & Hayes, 2008). We ran three separate multiple mediation models, separately for boys and girls, across internalizing problems, externalizing problems, and substance use outcomes. All models controlled for age and school (using dummy codes) given that raw YSR scores were used for the internalizing and externalizing outcomes (i.e., not *T*-scores).

## Results

### Group differences

Boys versus girls and the three schools were compared on all predictor, mediator, and dependent variables. There were gender differences in time spent on digital media use, risky self-presentation, and all psychopathology variables. Compared to boys, girls reported more internalizing problems, but less substance use and fewer externalizing problems; girls also spent more time on digital media and engaged in more risky self-presentation. There was also a main effect of school on all variables. Thus, mediation was tested separately in boys versus girls with school covaried. See Table 2.1 for descriptive statistics for study variables by gender and school.

**Mediation models**

To review, we evaluated social comparison, negative feedback, and risky self-presentation as mediators of the association of digital media use frequency with internalizing and externalizing problems and substance use, separately for boys and girls. Each model estimated the following parameters (Preacher & Hayes, 2008): (a) the total effect of digital media use frequency on symptoms of psychopathology (i.e., relationship between predictor and outcome or the sum of direct and indirect effects; *c* path), (b) specific effects of digital media use frequency on each online behavior mediator (*a* paths), (c) specific effects of each mediator on symptoms of psychopathology (*b* paths), (d) specific indirect effects for each mediator, and (e) the direct effect of digital media use frequency with respect to symptoms of psychopathology *absent* the proposed mediators (*c'* path). To improve model fit, certain variables were allowed to covary, if supported theoretically, including the three mediators. All six models demonstrated good fit across multiple indices (i.e., for all models, RMSEA < 0.04; CFI > 0.99; SRMR < 0.02). Parameter estimates of the effects for all six models appear in Table 2.2.

The pattern of results was the same across boys and girls for internalizing problems. First, in both boys and girls, controlling for age and school, there was a significant total effect of

digital media use frequency on internalizing problems (*c* path). Digital media use frequency was positively associated with the social comparison, negative feedback, and risky self-presentation mediators ($a_1$, $a_2$, $a_3$ paths). Social comparison and negative feedback were each positively associated with youth internalizing problems whereas risky self-presentation negatively predicted internalizing problems ($b_1$, $b_2$, $b_3$ paths). We observed significant indirect effects for all three mediators in predictions of the internalizing outcome. Specific indirect effects for social comparison and negative feedback were positively whereas risky self-presentation was negatively associated with internalizing problems. We observed a significant direct effect after accounting for the mediators in both genders. Mediation figures appear in Figures 2.1A (boys) and 2.1B (girls).

Next, these same models were reproduced with externalizing problems; the pattern of results was again the same for boys and girls. There was a significant total effect on externalizing problems from digital media use frequency. Paths from the predictor (digital media use frequency) to the mediators were the same as in the internalizing problems models as those variables did not change. For the *b* paths, social comparison and negative feedback were positively associated with externalizing problems; however, here, risky self-presentation was positively associated with externalizing problems. Again, all three online behaviors significantly mediated the relationship between digital media use frequency and externalizing problems. However, whereas risky self-presentation showed an inverse effect for internalizing problems, risky self-presentation positively mediated effects for externalizing problems. Direct effects remained significant for both boys and girls. Mediation figures appear in Figures 2.2A (boys) and 2.2B (girls).

Lastly, this same model evaluated past year substance use. Mediation figures appear in Figures 2.3A (boys) and 2.3B (girls). There was a significant total effect of digital media use frequency on substance use in both boys and girls. *A* paths were again the same in this model. For the *b* paths from mediator(s) to outcome, in boys, only risky self-presentation was positively associated with substance use; for girls, both negative feedback and risky self-presentation were positively associated with substance use. Social comparison did not mediate effects in boys or girls. Negative feedback positively mediated effects in girls, but not boys; risky self-presentation positively mediated effects in boys and girls. Direct effects were significant in both the boy and girl models.

We also investigated the size of the mediation effect across models, based on the $R^2$ mediation effect size method ($R^2_{med}$), which is the portion of variance in the outcome explained by the indirect (mediated) effect in each model (Fairchild et al., 2009). Because effect size estimation for the total mediator effect is not possible using this method, each mediator was examined independently per outcome to give an idea of the size of the significant effect. According to Fairchild et al. (2009), simulation studies of $R^2$ effect sizes for mediation were small, ranging from 0.001-0.280 in their mean estimates. Estimates from this study were small and within this window, ranging from 0.003 (risky self-presentation for internalizing problems in girls) to 0.06 (negative feedback for externalizing problems in both boys and girls). All $R^2_{med}$ effect sizes appear in Table 2.2.

## Discussion

To better understand the association of the frequency of digital media use with adolescent internalizing problems, externalizing problems, and substance use, as well as their mediation by specific online behaviors (i.e., social comparison, negative feedback, risky self-presentation), we

leveraged a large sample of adolescents ($n$ = 2952) attending three HAS, given their increased risk for psychopathology (Ebbert et al., 2019). Controlling for age and school, several important patterns emerged: first, self-reported frequency of social comparison, negative feedback, and risky self-presentation on digital media all uniquely mediated the association of digital media use frequency with internalizing problems in both boys and girls. Digital media use was positively associated with the social comparison, negative feedback, and risky self-presentation mediators; however, social comparison and negative feedback were positively whereas risky self-presentation was negatively associated with internalizing problems. Patterns were similar in predictions of externalizing problems in boys and girls, although risky self-presentation was positively associated with externalizing problems. Lastly, for substance use, social comparison did not significantly mediate effects; negative feedback significantly and positively mediated the association of digital media use frequency with substance use in girls, but not boys; finally, risky self-presentation significantly and positively mediated this relationship in boys and girls.

To improve traction on *how* risk factors contribute to negative outcomes, explanatory mechanisms must be identified (Rutter, 2012). These preliminary findings suggest that specific social behaviors are sensitive to frequent digital media use, which may in turn potentiate psychopathology. Although cross-sectional, these mediation results converge with previous studies linking upward social comparison with decreased life satisfaction (Frison & Eggermont, 2016) and depression (Li, 2019; Nesi & Prinstein, 2015); social comparison also mediated Instagram use with depressive symptoms in young adults (Lup et al., 2015). Notably, HAS students display elevated rates of envy compared to peers in different school environments, as well as high rates of achievement pressures (Lyman & Luthar, 2014), which may increase comparison with peers on digital media platforms and subsequent psychopathology. Although

social comparison did not mediate predictions of substance use from digital media use, it mediated associations with externalizing problems (i.e., attention, rule-breaking, and aggressive behaviors) in girls and boys.

Previously, self-esteem was inversely associated with receiving negative feedback online (Thomaes et al., 2010); receiving frequent negative feedback on social media also predicted depression symptoms one year later, particularly among adolescent girls (Nesi & Prinstein, 2015). Negative social experiences more broadly, including peer rejection and victimization, predicted poor physiological stress responses in adolescents (for a review, see Murray-Close, 2013), supporting their potential influence on emergent anxiety. As with the social comparison, negative feedback also positively mediated associations with externalizing problems. In a recent study with HAS adolescents, Luthar et al. (2020) reported that receiving negative feedback on digital media was associated with rule-breaking behaviors, with similar results in the current study. DeWall and Bushman (2011) described how social rejection reliably increases negative affect and aggression, which may help explain this finding; adolescents who received criticism or negative comments online may react with anger, frustration, and aggression. Similarly, in the current study, negative feedback positively mediated the association of frequent digital media use with substance use in girls, but not boys. In considering how receiving negative feedback may contribute to daily changes in negative affect, which may then impact substance use, in adolescent girls, for example, greater baseline levels of negative affect variability predicted increased cigarette smoking over time (Weinstein & Mermelstein, 2013). The peer context appears integral in this vein: greater daily fluctuations in feelings of worry predicted increased daily substance use, consistent with a self-medication hypothesis, and greater daily fluctuations in negative affect were a stronger predictor of daily use than a total level of daily negative affect;

however, strong peer social support protected against self-medication (Shadur et al., 2015). Given that receiving negative feedback fluctuates over time and potentiates negative affect, mechanisms similar to a self-medication hypothesis should be examined.

Lastly, risky self-presentation significantly negatively predicted internalizing problems and positively predicted externalizing problems and substance use. Although risky online self-presentation previously predicted receiving more negative feedback online (Koutamanis et al., 2015), and thus is plausibly associated with adolescent internalizing problems, less is known about the direct impact of this association. Digital status seeking (Nesi & Prinstein, 2019) shares some overlap with risky self-presentation, including measuring how frequently adolescents post "selfies", which elicit positive comments and curate a personal image (Katz & Crocker, 2015); this construct may be particularly salient if the motivation for more frequent risky posts is to manage impressions and improve popularity (e.g., Dhir et al., 2016). Nesi and Prinstein (2019) found that adolescents who engaged in digital status seeking also exhibited elevated substance use and sexual risk behaviors one year later. In the current study, risky self-presentation was positively associated with substance use in boys and girls, which may parallel processes described in digital status seeking predicting substance use. Previously, high peer status positively predicted alcohol use in HAS youth, suggesting potential social conformity effects on substance use, particularly among males (McMahon & Luthar, 2006). As digital media platforms continue to evolve, digital status seeking, including risky self-presentation, and its relation to health behaviors and psychopathology in HAS populations will be an important future direction, particularly in identifying and replicating specific mechanisms that are amenable to prevention and intervention efforts.

Across prospective and cross-sectional designs, the frequency of digital media use is inconsistently associated with psychopathology. There is evidence of positive associations with depression (Boers et al., 2019; Lin et al., 2016; Twenge et al., 2018), anxiety (Woods & Scott, 2016), and attention problems (Nikkelen et al., 2014; Ra et al., 2018). Yet, other studies, perhaps reflecting methodological differences (e.g., EMA time-use-diary methods), found no association between frequency of use and negative mental health symptom (Jensen et al., 2019; Orben & Przybylski, 2019). Though the current study did find positive associations between frequency of use and increased self-reported internalizing/externalizing problems and substance use across domains, consistent with Prinstein et al.'s (2020) commentary on the Odgers and Jensen (2020) review of digital media use and adolescent development, the primary goal of the current study was to test specific explanatory mechanisms. This approach is necessary to identify putative mechanisms that are compelling intervention targets.

This study demonstrated a number of strengths, including a large sample size across three HAS, as well as statistical sophistication geared toward most effectively contextualizing the results: for example, (1) models were examined a priori separately in boys and girls and controlled for age and school; (2) we transcended simple reliance on tests of significance by incorporating fit indices and estimated effect sizes for mediated effects ($R^2_{med}$), which is the portion of variance in the outcome explained by the indirect (mediated) effect in each model (Fairchild et al., 2009). Effects were small overall, suggesting that there are other mechanisms explaining this relationship, perhaps in the neurobiological domain. Despite its many strengths, a notable limitation in this study is that youth self-reported all data, constituting a single-method and single-informant approach. Although adolescent self-reported digital media use is certainly valid, future research should also employ in-vivo measures of online behavior (e.g., screen time

reports, time-use data from specific platforms, coding of online behaviors from social media profiles) that may characterize this construct more richly and dynamically. Additionally, all data was collected during a single time-point, precluding any definitive causal conclusions; inferring mediation from cross-sectional data also incurs uncertainty about bi-directional influences. For example, aggressive and rule-breaking adolescents may receive more negative feedback on digital media as a result; latent anxious or depressive vulnerabilities and traits may similarly increase social comparisons in competitive, achievement-focused environments. Longitudinal, temporally-ordered designs will improve traction on these constructs.

If replicated and extended across diverse designs/strategies, the three mediators in this study may hold important implications for intervention. For example, helping adolescents establish contingencies for digital media use (e.g., not following peers who provide frequent negative feedback; making profiles "private" or disabling comment functions), supporting alternative coping strategies, cognitive restructuring strategies focused on upward social comparison, and giving less weight to direct or indirect (e.g., number of likes) negative feedback could reduce internalizing and/or externalizing problems. Similarly, common behavioral interventions for anxiety and depression symptoms (e.g., behavioral activation, exposure practices) could readily integrate these digital media behaviors by helping adolescents find off-line activities to improve mood or engage in facing fears related to these behaviors to change their worries around digital interactions. Given that the data for this study was collected in the school setting in HAS, these interventions may be generically implemented in schools by counselors, administrators, or teachers, as recently suggested in a commentary focused on how teachers may promote mental health in HAS (Luthar et al., 2020).

In a recent review on adolescent peer relationships and psychopathology, Prinstein and Giletta (2020) emphasized that digitally-mediated peer communication was an important emerging research area; this reinforces the notion that adolescent experiences with technology do not seem to simply reflect offline peer relationships, but instead function uniquely for youth social interactions and expectations (Nesi et al., 2018). This study contributes to the nascent literature on the social context of frequent digital media use, improving understanding of potential mechanisms underlying associations with psychopathology. In particular, we presented evidence that when adolescents at risk for psychopathology frequently engage in social comparison with peers on digital media sites, frequently receive negative feedback on these sites (from friends, acquaintances, and strangers), and frequently present themselves in "risky" ways, it may potentiate increased risk for these problems. Future studies should replicate these findings in other samples of adolescents as well as explore other mediators in the relationship between digital media use and psychopathology to best inform prevention and intervention efforts.

Table 2.1. Descriptive statistics for key variables in study, by school and gender.

| | School 1 (Northeast) | | | | School 2 (Midwest) | | | | School 3 (Northwest) | | | | School | | Gender | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Boys (N = 292) | | Girls (N = 279) | | Boys (N = 372) | | Girls (N = 314) | | Boys (N = 907) | | Girls (N = 788) | | *F* | $\eta^2$ | *F* | $\eta^2$ |
| Variable | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | | | | |
| Average time spent on digital media | 11.91 | 6.39 | 12.49 | 6.46 | 12.21 | 6.17 | 13.12 | 6.11 | 12.79 | 8.02 | 15.24 | 8.26 | 14.86*** | 0.01 | 32.41*** | 0.01 |
| Social comparison on digital media | 4.92 | 3.84 | 8.09 | 3.72 | 5.14 | 4.01 | 7.52 | 4.01 | 4.82 | 4.29 | 7.25 | 4.30 | 3.01 | 0.002 | 256.59*** | 0.09 |
| Negative feedback on digital media | 1.85 | 2.52 | 1.49 | 2.10 | 1.62 | 2.04 | 1.04 | 1.70 | 1.76 | 2.84 | 1.22 | 2.30 | 1.96 | 0.001 | 29.61*** | 0.01 |
| Risky self-presentation on digital media | 4.74 | 3.65 | 6.50 | 3.71 | 2.85 | 2.91 | 4.58 | 2.71 | 2.62 | 3.40 | 4.34 | 3.43 | 86.72*** | 0.06 | 169.63*** | 0.06 |
| YSR Internalizing raw score | 10.18 | 9.48 | 15.33 | 11.06 | 11.10 | 10.25 | 14.09 | 10.13 | 12.52 | 11.05 | 18.14 | 12.60 | 16.30*** | 0.01 | 140.03*** | 0.05 |
| YSR Externalizing raw score | 9.41 | 8.93 | 8.66 | 7.45 | 9.68 | 8.37 | 8.01 | 6.20 | 10.98 | 9.25 | 10.33 | 9.45 | 12.913*** | 0.01 | 8.01** | 0.003 |
| Yearly drug use | 2.61 | 4.20 | 2.24 | 3.50 | 2.57 | 3.77 | 2.45 | 3.59 | 1.90 | 3.91 | 1.60 | 3.53 | 14.334*** | 0.01 | 4.64* | 0.002 |

*Note.* $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

Table 2.2. Multiple mediation by three online behaviors on adolescent internalizing, externalizing, and substance use problems from digital media use, by gender.

| Model | | Boys | | | | | | Girls | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 95% bootstrapped CI | | | | | | 95% bootstrapped CI | | | | |
| DV | Mediators | Point est. | SE | Lower | Upper | $R^2_{med}$ | Mediators | Point est. | SE | Lower | Upper | $R^2_{med}$ |
| YSR Internalizing | | | | | | | | | | | | |
| | Social comparison*** | 0.14 | 0.02 | 0.11 | 0.18 | 0.04 | Social comparison*** | 0.11 | 0.02 | 0.07 | 0.14 | 0.02 |
| | Negative feedback** | 0.07 | 0.02 | 0.04 | 0.11 | 0.03 | Negative feedback*** | 0.08 | 0.02 | 0.05 | 0.12 | 0.03 |
| | Risky self-presentation** | -0.05 | 0.02 | -0.08 | -0.03 | 0.005 | Risky self-presentation*** | -0.09 | 0.02 | -0.12 | -0.06 | 0.003 |
| | Total indirect effect*** | 0.16 | 0.03 | 0.10 | 0.21 | -- | Total indirect effect** | 0.10 | 0.03 | 0.04 | 0.15 | -- |
| | Direct effect* | 0.13 | 0.05 | 0.05 | 0.22 | -- | Direct effect** | 0.15 | 0.05 | 0.07 | 0.24 | -- |
| | | | | | | | | | | | | |
| YSR Externalizing | | | | | | | | | | | | |
| | Social comparison*** | 0.05 | 0.01 | 0.03 | 0.07 | 0.04 | Social comparison*** | 0.03 | 0.01 | 0.02 | 0.05 | 0.02 |
| | Negative feedback** | 0.07 | 0.02 | 0.04 | 0.11 | 0.06 | Negative feedback** | 0.07 | 0.02 | 0.04 | 0.11 | 0.06 |
| | Risky self-presentation* | 0.03 | 0.02 | 0.01 | 0.06 | 0.05 | Risky self-presentation** | 0.05 | 0.02 | 0.03 | 0.08 | 0.05 |
| | Total indirect effect*** | 0.15 | 0.03 | 0.11 | 0.20 | -- | Total indirect effect*** | 0.15 | 0.02 | 0.12 | 0.19 | -- |
| | Direct effect*** | 0.25 | 0.05 | 0.17 | 0.34 | -- | Direct effect** | 0.19 | 0.06 | 0.10 | 0.28 | -- |
| | | | | | | | | | | | | |
| Substance Use | | | | | | | | | | | | |
| | Social comparison | -0.004 | 0.003 | -0.01 | 0.002 | 0.004 | Social comparison | 0.000 | 0.002 | -0.003 | 0.003 | 0.006 |
| | Negative feedback | 0.003 | 0.01 | -0.01 | 0.01 | 0.02 | Negative feedback** | 0.02 | 0.01 | 0.01 | 0.03 | 0.03 |
| | Risky self-presentation*** | 0.04 | 0.01 | 0.03 | 0.05 | 0.03 | Risky self-presentation*** | 0.03 | 0.01 | 0.02 | 0.04 | 0.05 |
| | Total indirect effect*** | 0.04 | 0.01 | 0.02 | 0.05 | -- | Total indirect effect*** | 0.05 | 0.01 | 0.04 | 0.06 | -- |
| | Direct effect** | 0.06 | 0.02 | 0.03 | 0.10 | -- | Direct effect*** | 0.07 | 0.02 | 0.03 | 0.10 | -- |

Note. DV = dependent variable; YSR = Youth Self Report (Achenbach et al., 2004); Point est. = point estimate of the indirect effect; SE = standard error; CI = confidence interval; $R^2_{med}$ = portion of variance in outcome explained by the indirect effect (Fairchild et al., 2009). All models controlled for youth age and school; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Figure 2.1. Multiple mediation: Prediction of youth internalizing problems from digital media use frequency through digital media behaviors (social comparison, negative feedback, and risky self-presentation) in boys and girls.

Figure 2.1A. Boys.

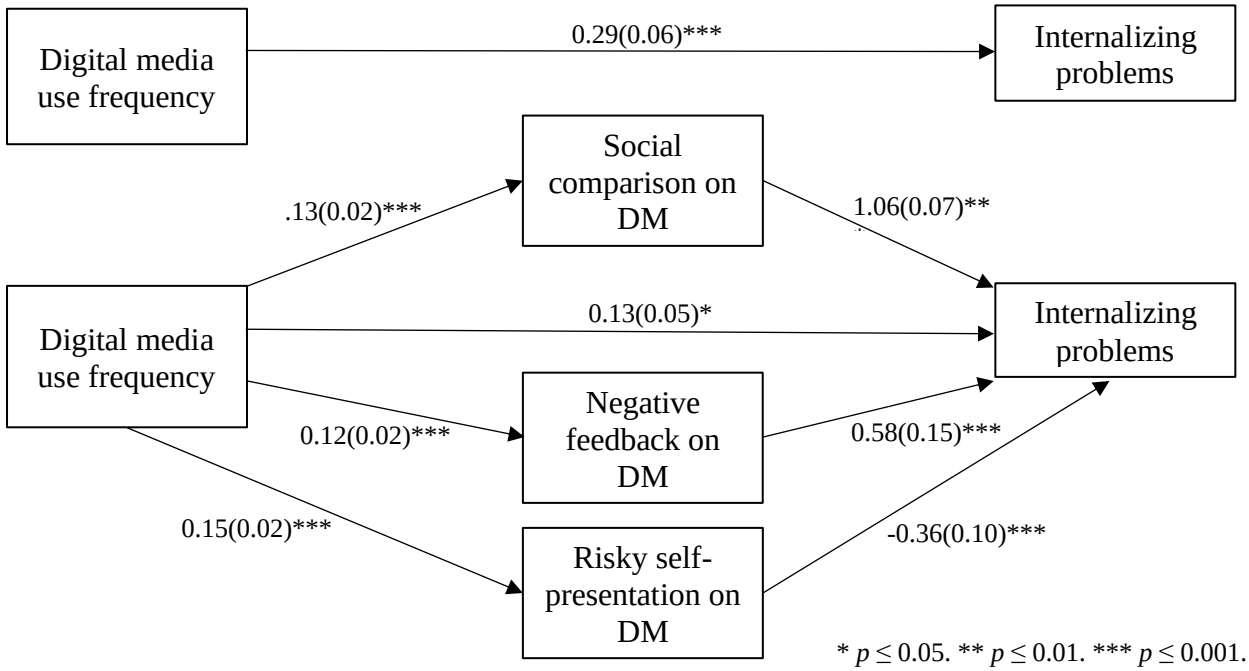



Figure 2.1B. Girls.

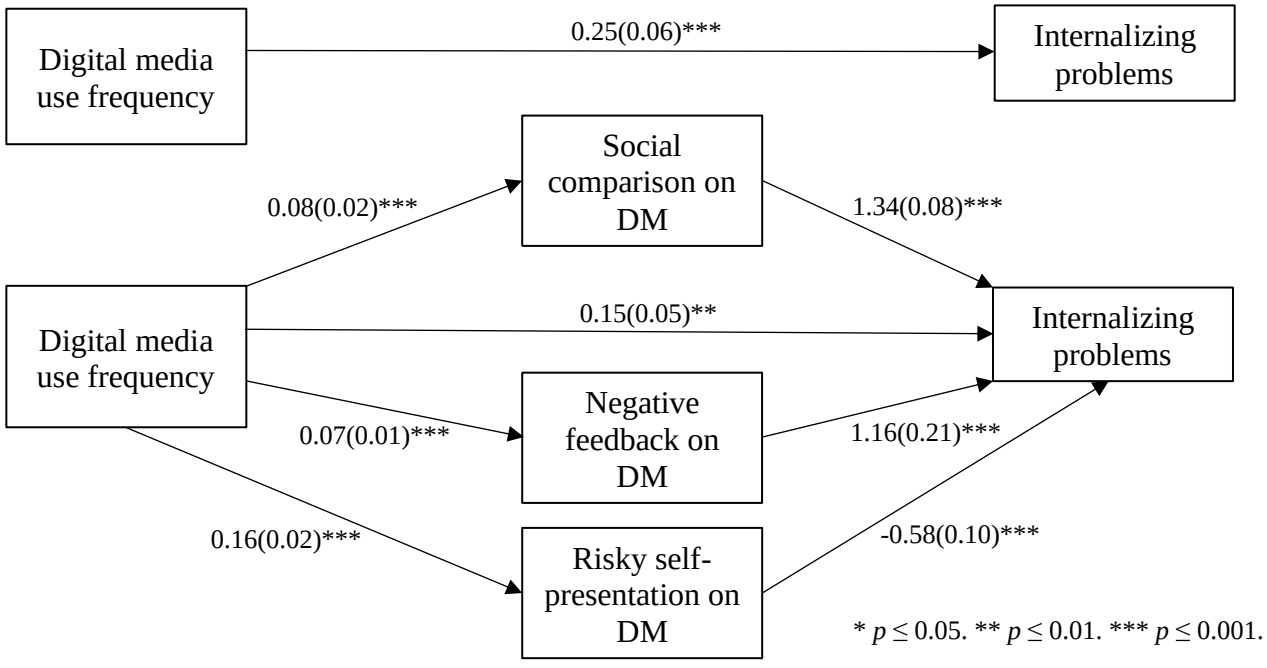


Figure 2.2. Multiple mediation: Prediction of youth externalizing problems from digital media use frequency through digital media behaviors (social comparison, negative feedback, and risky self-presentation) in boys and girls.

Figure 2.2A. Boys.

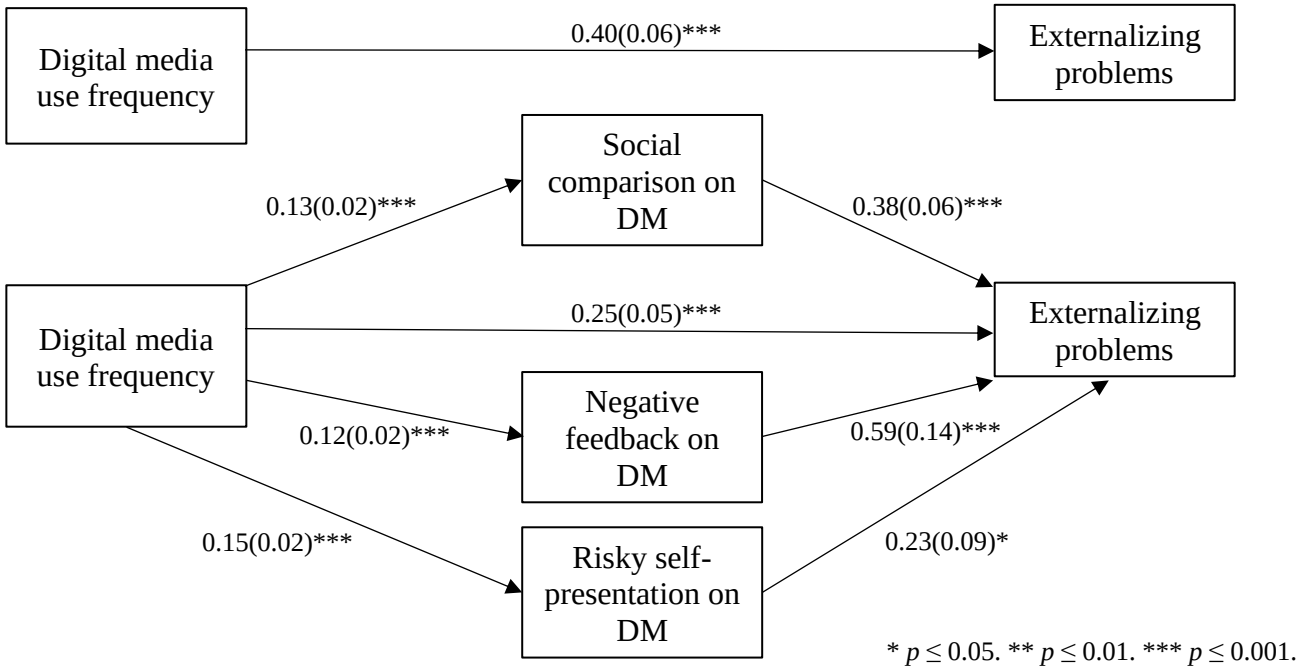



Figure 2.2B. Girls.

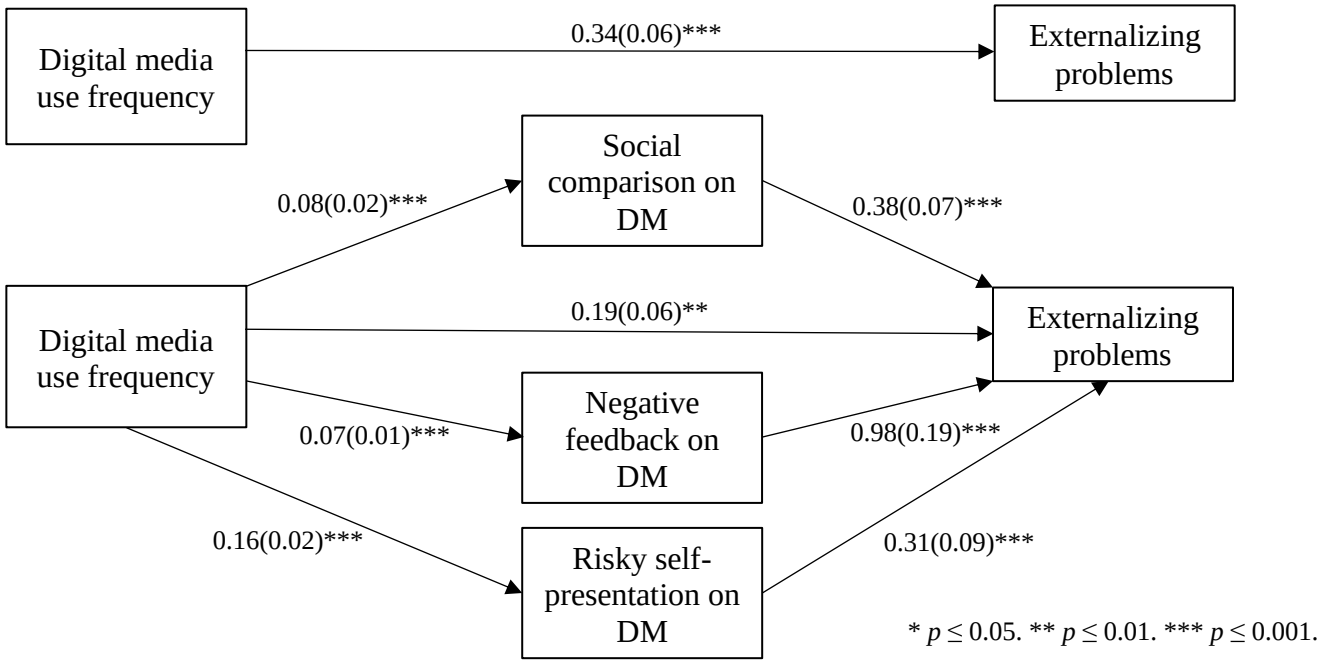


Figure 2.3. Multiple mediation: Prediction of youth substance use from digital media use frequency through digital media behaviors (social comparison, negative feedback, and risky self-presentation) in boys and girls.

Figure 2.3A. Boys.

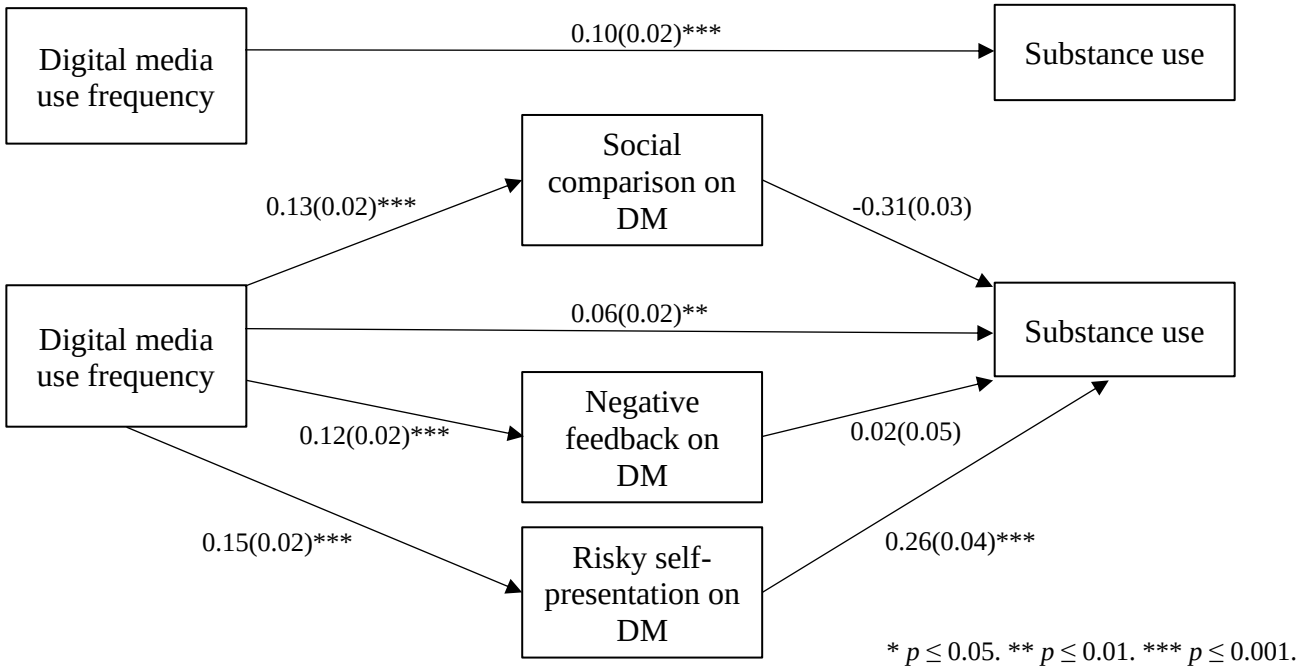
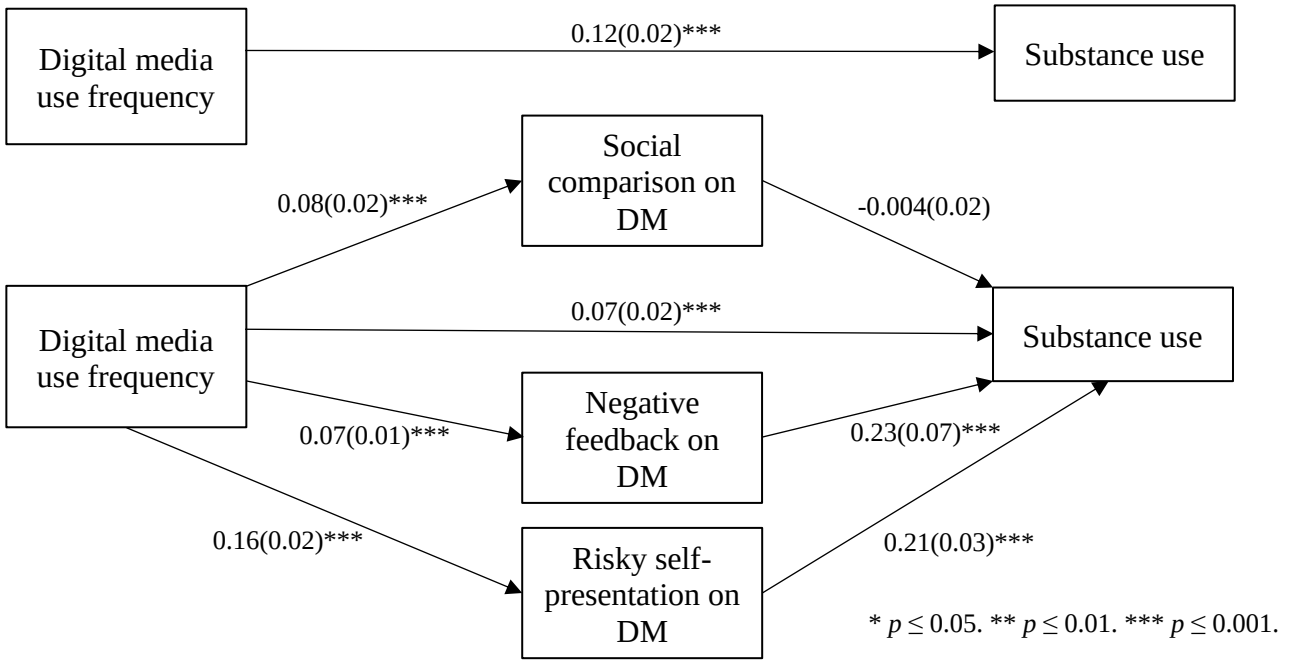



Figure 2.3B. Girls.



## Study III: Psychophysiological Correlates of Self-Regulation and Psychopathology during Fear Conditioning in Children


### Abstract

Psychophysiological studies are well-aligned with mental health research priorities focused on utilizing multi-level data to study basic and applied constructs; in particular, the fear learning paradigm richly elicits learning processes toward threat and safety cues, but they are infrequently employed in youth samples. Although vagal withdrawal, represented by a decrease in respiratory sinus arrythmia (RSA) from baseline in response to an emotional challenge, is generally considered adaptive, the magnitude of RSA withdrawal is inconsistently associated with internalizing and externalizing problems; this association is poorly characterized in children. This exploratory study examined internalizing and externalizing problems relative to change in RSA over three phases of a well-validated differential fear conditioning task. Based on a preliminary sample of 31 preadolescent girls recruited for trait negative emotionality, overall, RSA decreased from the pre-acquisition to the acquisition phase of the fear conditioning task and increased from the acquisition to the extinction phase. While participants self-reported more fear toward the danger versus safety cue, there was no definitive evidence that girls were differentially (fear) conditioned using self-reported or physiological indices. In addition, median-split internalizing nor externalizing scores predicted patterns of RSA using repeated measures ANOVA. Results likely reflect some influence of the small sample size and moderate levels of psychopathology overall; given these factors, however, RSA responses in the study may represent normative trajectories during this task. Future work can further examine physiological indices of self-regulation in fear learning tasks to best understand regulation of fear during acquisition of learning and its relation to mental health problems in youth.

The National Institute of Mental Health Research Domain Criteria (RDoC; Insel et al., 2010) constitutes a dimensional, interdisciplinary approach to psychopathology designed to: (a) integrate data across multiple levels of analysis to identify new targets for intervention and prevention, (b) detect subgroups of individuals that may require targeted treatment development and/or delivery, and (c) improve the use and application of empirical evidence to clinical decision making. RDoC prioritizes the study of individual differences in constructs within negative and positive valence systems (e.g., acute threat, reward anticipation), cognitive systems (e.g., attention), social processes (e.g., affiliation), and arousal/regulatory systems (e.g., circadian rhythms) that transcend traditional diagnostic categories. RDoC further suggests that these constructs be studied within the "essential contexts of developmental trajectories and environmental influences" (Insel et al., 2010). Thus, leveraging multiple units of analysis and incorporating developmental and environmental influences in psychopathology are priorities.

Psychophysiology has a rich tradition in psychopathology and it is a central strategy in RDoC (Miller et al., 2016). Spanning methods such as pupillometry, skin conductance response (SCR), and respiratory sinus arrhythmia (RSA), these approaches reliably measure physiological responses, reactivity, and functioning that are separable from behavioral observations and self-report ratings; they may also be sensitive to processes not considered consciously (Zisner & Beauchaine, 2016). Within the autonomic nervous system, psychophysiological recording methods for negative valence systems (e.g., fear conditioning, frustrative non-reward) have identified biomarkers that differentially confer risk for and resilience to psychopathology (e.g., Blandon et al., 2008; Shannon et al., 2007). For example, heart rate variability (HRV) and vagal tone reflect variation in self-regulation from infancy (Bornstein & Suess, 2000) to adulthood (McCraty & Shaffer, 2015; Thayer et al., 2012; Williams et al., 2015). Respiratory sinus

arrythmia (RSA) refers to the ebb and flow of the heart rate across the respiratory cycle and indexes HRV at high frequencies (which accounts for respiration). The cyclical pattern evident in RSA occurs from increased inhibitory parasympathetic efference during exhalation and decreases in inhibitory parasympathetic efference during inhalation (Beauchaine, 2001; Porges, 1995). Within the high frequency band, other cardiac influences (e.g., sympathetic, diurnal) are filtered out, allowing for isolation of parasympathetic activity, which controls physiological functions while the body is at rest.

RSA changes contingently in response to an emotional, cognitive, or behavioral challenge; these patterns are consistently evident in children as young as toddlers during laboratory tasks (e.g., Calkins & Keane, 2004; Cho et al., 2017; Doussard-Roosevelt et al., 2003). According to polyvagal theory (Porges, 1995, 2007), RSA withdrawal (i.e., decrease in vagal tone from baseline) in response to challenge reflects successful vagal regulation by increasing heart rate to mediate metabolic output. Alternatively, RSA augmentation lowers cardiac arousal and supports social engagement and prepares for calm interaction (Porges, 1995, 2007). Consistent with this formulation, RSA withdrawal is associated with observed emotion regulation and active coping skills during stressful or frustrating tasks as early as infancy (Cui et al., 2015; Gentzler et al., 2009; Huffman et al., 1998). According to neurovisceral integration theory, RSA may reflect prefrontal cortex functioning (Thayer et al., 2012; Thayer et al., 2009; Thayer & Lane, 2000, 2009), which broadly enacts executive control over behavior and which can thus non-specifically increase vulnerability to psychopathology (Maren et al., 2013; Menon, 2011). Perhaps parallel to the transdiagnostic associations of prefrontal dysfunction, resting (i.e., tonic) RSA and RSA changes during specific emotion evocation tasks are plausible biomarkers of emotion dysregulation that are diversely associated with psychopathology (Beauchaine, 2015).

Although RSA withdrawal in response to challenge is generally considered adaptive, the simple magnitude of RSA withdrawal is inconsistently associated with psychopathology (i.e., increasing vulnerability or conferring resilience). That is, the precise nature of this association, including potential non-linear patterns, is not well-characterized, particularly not in children. Meta-analytically, RSA withdrawal was inversely associated with externalizing problems, and children from clinical or at-risk samples demonstrated lower levels of resting RSA and RSA withdrawal compared to children in community and healthy samples (Fanti et al., 2019; Graziano & Derefinko, 2013). For internalizing problems, Graziano and Derefinko's (2013) meta-analysis similarly found that RSA withdrawal was overall inversely associated with internalizing problems, suggesting similar patterns across internalizing and externalizing problems. However, low resting RSA and/or large *reductions* in RSA (i.e., withdrawal) during emotion evocation were associated with internalizing and also externalizing psychopathology in other studies (Beauchaine, 2012, 2015; Pang & Beauchaine, 2007). Additionally, across several studies, concurrent clinical internalizing and externalizing symptoms were associated with a greater reduction in RSA during emotion evocation (e.g., frustration, sadness) than for either domain alone (Calkins et al., 2007; Pang and Beauchaine, 2013). This evidence is consistent with heterotypic comorbidity, or covariation of problems across diagnostic "groupings" (Angold et al., 1999), which may reflect stronger physiological response relative to individual psychopathology dimensions. These mixed results suggest that a moderate level of vagal regulation (Beauchaine, 2001) may be optimally associated with preparedness to respond to environmental challenge; for example, low levels of RSA withdrawal may suggest poor regulation whereas excessive withdrawal during challenge tasks may reflect greater emotional lability. Taken together, these inconsistent results also attest to the need for greater refinement of

RSA with respect to psychopathology including investigation of non-linear (e.g., quadratic) associations, evaluation of patterns specific to clinical profiles, considering unmeasured developmental influences, and use of well-specified challenge tasks (e.g., emotion evocation).

Fear conditioning tasks elicit physiological and neural processes underlying associative learning about danger and safety cues. Typically, a neutral stimulus is repeatedly paired with an aversive, fear-inducing unconditioned stimulus (UCS), resulting in a conditioned stimulus (CS). Discrimination learning tasks employ two CS wherein participants learn to differentiate between the CS paired with the aversive stimulus (CS+) and one that is not (CS-) via a conditioned response allowing for optimal anticipation and threats in the future. During the extinction phase of discrimination fear conditioning tasks, the CS+ is repeatedly presented in the absence of the UCS, leading to a decline in the conditioned response over time. However, inhibitory learning theory contends that the CS-UCS association acquired during fear conditioning is not erased during extinction, but rather a new "safety memory" develops for the CS-noUCS association (Craske et al., 2012). In non-human animals, whereas fear conditioning emerges early in life, this recall of extinction memories appears later in development and recruits later-developing neural regions (e.g., prefrontal cortex, hippocampus; Kim & Richardson, 2010). In the laboratory, fear conditioning tasks rapidly induce fear learning, thus facilitating inferences about fear acquisition, autonomic nervous system activity (e.g., heart rate) and related psychophysiological correlates of emotion processing (e.g., startle, LeDoux, 2000). Despite this rich tradition, developmental aspects of fear conditioning are poorly characterized, including identifying when learning and discrimination processes occur and elucidating how fear conditioning and extinction adaptively and maladaptively affects developmental milestones. In a recent meta-analysis on fear conditioning and extinction (Dvir et al., 2019), only seven studies focused on children and

adolescents, likely reflecting ethical challenges associated with employing a sufficiently potent and biologically-relevant UCS (see Shechner et al., 2014 for a review of developmental considerations in fear conditioning). The existing pediatric fear conditioning studies have revealed differential conditioning to the CS+ compared to the CS- utilizing SCR, fear-potentiated startle, and/or explicit subjective ratings of fear (e.g., Britton et al., 2013; Gao et al., 2010; Lau et al., 2011; Michalska et al., 2017). Overall, given the information provided by fear conditioning studies and the relative lack of exigent research, this work should be expanded further into pediatric samples, examining various psychophysiological assays that may help researchers to best understand biological responses to fear learning.

Acute fear acquisition and conditioning processes can be adaptive given their role in protecting organisms from perceived danger. However, this type of associative learning is problematic when fear becomes pervasive, interferes with normal functioning, and develops without adaptive compensatory behaviors (e.g., when fear responses are triggered without a fear learning contingency). Acute threat/fear is a negative valence RDoC construct, suggesting its importance across typical and atypical development. Given that fear conditioning paradigms effectively elicit fear and corresponding biological and psychological correlates, they constitute a salient emotional-challenge task, particularly during initial acquisition and extinction phases when the conditioned response is potent. Consequently, these are compelling tasks to study the association of self-regulation with dimensions of psychopathology. To our knowledge, no study has examined RSA change (i.e., from baseline) across phases of a fear conditioning paradigm in children. Two recent studies examined associations of *resting* RSA in the context of fear conditioning with child psychopathology and found that high resting RSA was associated with lower levels of later psychopathology. Specifically, among youth with an abuse history, high

resting RSA predicted fewer PTSD symptoms and enhanced extinction learning; extinction learning also mediated the association of abuse with PTSD symptoms only among youth with high resting RSA (Jenness et al., 2019). Similarly, tonic RSA moderated the prospective association of violence exposure with PTSD symptoms and transdiagnostic psychopathology (i.e., *p*-factor scores), demonstrating a weaker association among youth with higher RSA; in the same study, higher SCR when viewing a CS+ and CS- during a fear learning task predicted more internalizing symptoms and higher *p*-factor scores, although RSA responses were not examined in the context of the fear learning task (Susman et al., 2021 preprint). These studies provide initial evidence for resting RSA as protective and the role of fear and extinction learning in predicting psychopathology. However, analysis of RSA change with psychopathology may provide more rich information about the nature of self-regulation during fear-inducing and learning tasks.

Differential fear conditioning tasks elicit individual differences in threat and safety learning, which are implicated in risk and resilience processes in children. Self-regulation in the context of emotion evocation, estimated from vagal activity and the potential allocation of metabolic resources to cope with a challenging context, may also be related to vulnerability to psychopathology. This study examined the concurrent association of RSA, a physiological marker of self-regulation, indexed during a valid fear conditioning task, with measures of youth internalizing and externalizing psychopathology. Specifically, we examined RSA across three phases of a differential fear conditioning task previously administered with children (described in detail below) with rigorously ascertained measures of psychopathology in a preliminary sample of 6-11-year-old girls oversampled for trait negative emotionality (e.g., irritability, anger). Given that RSA change has not been previously validated in this specific fear conditioning task in

children, the first aim was to characterize the physiological self-regulation response during the three phases of the task. We hypothesized that children would demonstrate RSA withdrawal from the pre-acquisition phase, where the conditioned stimuli were both neutral, to the emotionally-challenging phases of the fear conditioning task (i.e., acquisition and extinction). A secondary, exploratory aim was to discern if RSA change over the three different phases of the task (e.g., levels of withdrawal or augmentation from one phase to the next) was differentially associated with configurations of internalizing or externalizing psychopathology.

## Methods

### Participants

Data were collected as part of a larger, ongoing study of psychophysiological and familial correlates of trait negative emotionality and psychopathology in preadolescent girls. The study recruited typically-developing girls as well as girls whose parents were concerned about their daughter's trait negative emotionality (e.g., anger, irritability, anxiety). Thus, participants reflected a broad range of individual differences in trait negative emotionality in school-age girls. Eligibility criteria consisted of female sex, 6 to 11 years of age, attending school full-time, and English fluency in the child and parent. Exclusion criteria for all participants consisted of a previously-identified Full Scale IQ less than 70 or a pervasive developmental, seizure, or neurological disorder that prevented full participation in the study. Participants were recruited via flyers in schools, extracurricular organizations (e.g., Girl Scouts of America), pediatrician offices, and via social media posts. Data collection began in 2019, but all research procedures were halted in March 2020 due to the Covid-19 pandemic, resulting in a smaller sample than anticipated. At the time of this manuscript, the study remains closed to in person data collection. The overall study sample consisted of 45 ethnically-diverse girls (32.26% White, 3.23% Black,

3.23% Latina, 22.58% Asian-American, 32.26% mixed) with a mean age of 9.03 years (*SD* = 1.60). 10 girls in the larger sample did not complete the fear conditioning task (described further below) employed in this study either due to time constraints or child or parent opting out of the task[1]. Of the remaining 35 girls, the current study employed data from 31 participants; 3 participants declined completing the task prior to seeing any stimuli and 1 participant's data was excluded for technical issues (i.e., timing between task and physiological software did not match).

**Procedures**

Study eligibility was determined through an initial telephone screening with a parent caregiver. Parents from eligible families were then invited to complete initial rating scales online about family history and demographics, the child's socio-emotional and behavioral functioning, as well as psychosocial functioning in the second parent (if applicable). Families were next invited to participate in a laboratory-based assessment consisting of structured interviews, standardized tests of cognitive ability and academic achievement, and structured family interaction tasks. Whenever possible, children were assessed in the lab without psychotropic medication (e.g., stimulants). If a child was normally medicated, we asked that parents provide ratings based on the child's unmedicated behavior. Examiners consisted of doctoral students in clinical psychology and well-trained BA-level research assistants. Written consent and written assent were collected from all parents and children, respectively. All study procedures were approved by the UCLA Institutional Review Board. Families were compensated $100 for complete participation.

[1] Most families who directly declined participation for the fear learning task (e.g., not an issue of time constraints) declined due to concerns over the emotionally-evocative nature of the paradigm, which was detailed in the consent form.

## Measures

**Fear Conditioning: The Screaming Lady Paradigm (Lau et al., 2008).** In the laboratory, participants were presented with the opportunity to complete the Screaming Lady task, a differential fear conditioning task previously used with children and adults (Britton et al., 2013; Glenn et al., 2012; Lau et al., 2008; Michalska et al., 2017). This task reliably elicited individual differences in youth and adult self-reported fear, during and after the task, as well as key physiological markers of the conditioned response (e.g., elevated SCR, fear-potentiated startle). The entire task was completed during the single study visit. Prior to beginning the task, participants completed pre-task questionnaires, including rating their state anxiety and subjective ratings of fear toward the two female faces they were about to see during the task. This afforded an assessment of baseline differences in fear between the two faces. The task consisted of three phases: pre-acquisition, acquisition, and extinction, with a pause between the last two phases for questionnaires (see Figure 3.1 for visual representation of the task). During the pre-acquisition phase, children passively viewed neutral faces of two women (one blonde and one brunette), including the future CS+ in the absence of the UCS. They viewed each face four times during this phase. During the acquisition phase, one woman (CS+) predicted the UCS, a 1-second image of a fearful face paired with a loud, aversive 95 dB scream while the other woman (CS-) displayed a neutral expression and no scream. The two faces were counterbalanced for CS+ and CS- across participants. The CS+ was followed by the UCS with an 80% reinforcement schedule such that 80% of the CS+ faces in the acquisition phase were paired with the scream and 20% were not. Participants viewed each face ten times during this phase, so eight of the CS+ phases were paired with the scream. Participants were instructed that they could learn to predict when the UCS would occur but were not informed of the CS+/UCS contingency. After the acquisition

phase, participants subjectively rated their anxiety toward each female face, ranging from 1 (not anxious) to 10 (extremely anxious). Fear extinction occurred immediately after participants completed these ratings. During the extinction phase, the CS+ (and CS-) were presented repeatedly in the absence of the UCS (i.e., neutral expressions only). Participants viewed each face eight times during this phase. Across all phases, the CS+ and CS- were presented for 7–8 s, followed by an interstimulus interval (ISI) of a blank, gray screen for 8–21 seconds. The task was presented using E-prime version 3.2.1 on a desktop computer approximately 90 cm from the seated child. Children were asked to complete two rating forms after the extinction phase, including providing their rating of how scared they felt doing the experiment on a 10-point Likert scale (0 = Not at all; 10 = A lot).

Psychophysiological data acquisition was performed using a BIOPAC MP160 system (BIOPAC Systems Inc., Goleta, CA) together with AcqKnowledge 4.3 (BIOPAC) software; electrocardiographic activity (ECG) was recorded with a BIOPAC ECG100C Electrocardiogram amplifier. Ag-AgCL electrodes on the left and right collarbones and left rib provided ECG activity that was sampled at 1,000 Hz while participants sat upright. While participants completed pre-task ratings, the electrode gel adhered to the skin to facilitate conductivity and to provide a rest period prior to physiological data collection. SCR to the task stimuli was recorded from two additional Ag-AgCl electrodes on the middle and ring finger of the nondominant hand also continuously sampled at 1,000 Hz and communicating with the BIOPAC and AcqKnowledge systems. The experimenter sat approximately five feet away from the participant to monitor the physiological data acquisition as the participant completed the task. Stimulus software presentation (E-Prime v3.2.1, Psychology Software Tools, Inc., Pittsburgh, PA)

interfaced with the BIOPAC MP160 system to time stamp the collection of physiological data and provided trigger codes when the images and sound clips were presented on the screen.

21 of the 31 girls completed the Screaming Lady task; 10 discontinued the task during administration by verbally communicating their desire to stop to the examiner. In all cases, participants saw *at least* one CS+ face with the loud scream before terminating; thus, physiological data were recorded during the acquisition phase; however, given that children who completed versus terminated the task expectedly differed in the length of time for that phase, children who terminated early were not included in the main ANOVA analyses. Crucially, completion versus discontinuation status on the tasks was unrelated to internalizing or externalizing problems (see below) or RSA during the pre-acquisition phase.

**Child Psychopathology: Achenbach Child Behavior Checklist 6-18 (CBCL; Achenbach & Rescorla, 2001).** Parents completed 113 items on the CBCL about their child's social, emotional, and academic functioning; each response is scored on a three-point scale ranging from 0 (*not true*) to 2 (*very true or often true*). Standardized scores (*T*-scores and percentiles) are computed separately for competence and clinical domains and are adjusted for age and sex. Following similar work (e.g., Calkins, Graziano, & Keane, 2007), we utilized the Internalizing Problems (e.g., anxious/depressed, withdrawn/depressed) and the Externalizing Problems (i.e., rule-breaking, aggressive behavior) *T*-scores. Overall, according to the CBCL, this sample exhibited relatively low levels of psychopathology with one child scoring in the borderline clinical range for Internalizing Problems and two children scoring in the borderline or clinically significant range for Externalizing Problems.

**Physiological Data Procedures**

Psychophysiological data from the fear conditioning paradigm, including ECG and SCR, were processed using the AcqKnowledge data analysis software that communicates directly with the BIOPAC MP160 hardware. To improve stabilization of the signal and eliminate high-frequency noise, we ran a band pass filter between 1-35 Hz before processing the ECG data. To extract RSA data, we examined the interpolated tachogram generated by the AcqKnowledge program's HRV spectral software which locates R-R intervals throughout the task; artifacts in the tachogram were manually identified and eliminated by amplifying QRS peaks (i.e., adding a constant to improve detection of individual peaks by the software), eliminating noise in between peaks, and defining focus areas during the three phases of the task (i.e., not analyzing data during periods when participants completed self-report ratings) to improve the signal. The high-frequency component of HRV (0.15-0.40 Hz) during each of the three task phases was then extracted using spectral analysis via the HRV/RSA analysis tool in AcqKnowledge; the algorithm conforms to established frequency domain algorithm guidelines (Camm et al, 1996). Of note, frequency domain methods, including spectral analysis, are less impacted by respiration rates, compared to other methods that assess the amplitude of RSA oscillations (Grossman et al., 1990). Following recommendations (e.g., Pang & Beauchaine, 2007; Vasilev et al., 2009), high-frequency HRV values were then log-transformed for measures of RSA in the three phases.

For SCR, baseline (minimum amplitude within 0-1 seconds prior to stimulus onset) and peak (maximum amplitude within 1-5 seconds following stimulus onset) values were extracted from AcqKnowledge for each CS+ and CS- trial presentation across all three phases. We used the maximum value within the stimulus period to represent the response magnitude for each trial (Balderston & Helmstetter, 2010; Michalska et al., 2017). Next, to estimate SCR across stimuli,

raw values for each trial were expressed as a percent change from the baseline value. Signal change values were averaged for each phase (i.e., pre-acquisition, acquisition, and extinction) and stimulus type (i.e., CS+, CS-). Percent signal change values more than 2 *SDs* above the mean signal change for that participant were replaced with the upper (i.e., 2 *SD*s above the mean) or lower (i.e., 2 *SD*s below the mean) values. Participants who completed the entire task had 44 percent signal change values. On average, only 4.32% of SCR values required distributional adjustment through substitution.

## Results

Table 3.1 summarizes descriptives and correlations among key variables. For the primary analyses, we utilized repeated measures ANOVA to test differences in mean RSA scores across phases of the task. Although we were underpowered to test group differences based on the CBCL, we explored associations between high versus low CBCL Internalizing and then Externalizing scores and phase of the task in predicting RSA levels. Given low levels of internalizing and externalizing symptoms overall, we used a median split as a between-subject factor for CBCL Internalizing Problems raw score (*Mdn* = 7.00) to contrast RSA values across the three phases; we then reproduced the same model using CBCL Externalizing raw scores (*Mdn* = 2.50) as the grouping variable.

### Descriptive analyses

Mean RSA scores over the three phrases of the task, pre-acquisition, acquisition, and extinction, were 7.19 (*SD* = 0.89), 7.21 (0.91), and 7.10 (0.84), respectively. These values approximate RSA studies with similarly aged children; for example, 8–12-year-old children (see Pang & Beauchaine, 2013) with conduct disorder and depression problems exhibited a mean RSA of 7.06 (1.10) during a baseline period and an increase to 7.09 (0.94) during emotion

evocation. It is important to note that the pre-acquisition phase cannot be considered a baseline period. Children were shown pictures of faces during this phase of the task and while the UCS was not paired with any of the photos, participants may already have been experiencing and/or regulating emotion, compared to a true resting period where children were not shown any stimuli. As suggested by the difference scores presented in Table 3.1, on average, children's RSA scores increased from pre-acquisition to acquisition ($M$ = 0.02, $SD$ = 0.44), suggesting RSA augmentation, and decreased from acquisition to extinction ($M$ = -0.31, $SD$ = 0.61), suggesting RSA withdrawal. RSA trajectories for each participant are visually represented in Figure 3.2.

As expected, CBCL Internalizing and Externalizing scores were significantly correlated, $r$ = 0.53, $p$ < 0.01. RSA scores were also significantly correlated across all task phases. Self-reported anxiety toward the CS+ after the acquisition phase correlated significantly with pre-acquisition and extinction RSA scores, but not acquisition RSA, and also significantly correlated with the difference score from pre-acquisition to acquisition, $r$ = -0.47, $p$ < 0.05. Specifically, participants who reported higher subjective fear toward the CS+ also demonstrated a larger decrease in their RSA from pre-acquisition to acquisition. Self-reported fear during the experiment correlated significantly with extinction RSA ($r$ = 0.44, $p$ < 0.05), ratings of anxiety toward the CS+ ($r$ = 0.71, $p$ < 0.001) and CS- ($r$ = 0.48, $p$ < 0.05) after the acquisition phase, and the change in RSA from pre-acquisition to acquisition ($r$ = -0.40, $p$ < 0.05). Similar to self-reported anxiety toward the CS+ after acquisition, children who reported more fear about the experiment also showed a larger decrease in RSA from pre-acquisition to acquisition. CBCL Internalizing and Externalizing scores were unrelated to fear ratings or RSA.

**Evidence of conditioning**

We examined whether children were differentially conditioned to fear the CS+ face versus the CS- face using both subjective fear ratings and a physiological measure, SCR percent signal change to the different stimuli. There was no bias toward either stimuli in terms of fear ratings; prior to the task, self-reported fear for the blonde versus brunette woman's face was comparable [$t(25) = 0.24$, $p = 0.82$]. After the acquisition phase, participants self-reported their subjective anxiety toward each female face. As expected, mean ratings of anxiety were higher for the CS+ [$M = 3.82$. $SD = 3.50$] versus the CS- [$M = 2.74$, $SD = 2.69$], which was marginally significant [$t(24) = 2.01$, $p = 0.056$, Cohen's $d = 0.40$]. After the extinction phase, mean ratings of anxiety toward the CS+ decreased and there were still no significant differences between the CS+ and CS- [$t(21) = 0.84$, $p = 0.41$, Cohen's $d = 0.18$]. We also examined percent signal change for SCR values to the CS+ compared to the CS- for evidence of differential conditioning. For SCR, the percent signal change did not differ significantly between the CS+ ($M = 48.60\%$; $SD = 94.27$) and CS- ($M = 11.66\%$; $SD = 167.66$) stimuli overall, $t(30) = 1.31$, $p = 0.20$, likely given the large variability in signal change values across participants. Similarly, there was no significant stimulus (i.e., CS type) x phase (i.e., pre-acquisition, acquisition, extinction) interaction for SCR percent signal change, $F(2,40) = 0.47$, $p = 0.55$. Results did not change when SCR was examined to only the first half of acquisition and extinction stimuli, a method recent studies have used given that fear responses tend to habituate relatively quickly (McLaughlin et al., 2016; Shechner et al., 2015). Overall signal change to CS+ stimuli and overall signal change to CS- stimuli were correlated, $r = 0.39$, $p < 0.05$.

Given that one aim of this study was to examine whether children show evidence of regulating emotion when presented with fearful stimuli via RSA change over time, and whether

patterns were associated with Internalizing and/or Externalizing problems, we pursued the primary analyses despite preliminary findings contraindicating evidence of differential conditioning for this task. We await planned, future data collection that will increase the sample size and better position evaluation of differential conditioning for this task.

**Primary analysis**

To review, the primary analysis consisted of repeated-measures ANOVA where CBCL Internalizing and Externalizing problems median split scores were treated as between-subjects factors and RSA responses across the three phases constituted the repeated measures factor. This analysis employed the portion of the sample ($n$ = 21) with complete data, given that those who aborted in the acquisition phase did not have an extinction RSA score. Mauchly's Test of Sphericity was not violated, $\chi^2(2) = 1.15$, $p = 0.56$, allowing us to accept the null hypothesis that the variances of the group differences across phases of the task were equal. There was no significant phase x Internalizing problems interaction [$F(2) = 1.56$, $p = 0.23$] nor between phase and externalizing scores [$F(2, 32) = 3.02$, $p = 0.06$]. Additionally, there was no main effect of phase, $F(2, 32) = 2.30$, $p = 0.12$. ANOVA results are summarized in Table 3.2. RSA scores across each phase by high and low Internalizing scores can be seen in Figure 3.3, and by high and low Externalizing scores in Figure 3.4.

## Discussion

RSA withdrawal during conditions in which an individual must generate a response to an emotional or behavioral challenge is thought to reflect appropriate self-regulation (Porges, 2007) by supporting increased heart rate and mobilization for coping with a challenging state. However, it is unclear to what extent RSA withdrawal is adaptive in the context of development and psychopathology, given that both low (Graziano & Derefinko, 2013) and high (Beauchaine,

2012; Pang & Beauchaine, 2007) reductions in RSA previously predicted internalizing and externalizing psychopathology. Given emerging evidence of its transdiagnostic significance, this exploratory study examined internalizing and externalizing problems in predicting RSA during a fear conditioning task in a pilot study of preadolescent girls recruited for trait negative emotionality. Although RSA patterns, derived across different types of emotional challenge tasks, were previously associated with youth psychopathology, and that fear conditioning tasks improve traction about children's threat and safety learning, to our knowledge, this is the first study examining changes in self-regulation measures within a fear conditioning task.

To characterize a physiological index of emotion regulation, the first aim of the study was to examine how RSA changed over three phases of a fear learning task previously used with children. Overall, children exhibited an increase in RSA from the pre-acquisition, where two neutral women's faces were presented, to the acquisition phase of the task, where one of the faces was paired 80% of the time with an aversive scream and fearful facial expression. Although the pre-acquisition period cannot be definitively considered a true baseline period, we hypothesized that RSA would decrease from pre-acquisition to acquisition, given evidence supporting RSA withdrawal in the context of fear induction tasks (Cho et al., 2017; Gentzler et al., 2009). This pattern of RSA activity was evident in some children (Figure 3.2), but overall, children's RSA increased from pre-acquisition to acquisition. This pattern is instead consistent with RSA augmentation, suggesting increased parasympathetic activity. Youth whose RSA increased from pre-acquisition to acquisition (i.e., maintained greater parasympathetic "rest and digest" influence) may not have had significantly induced fear to warrant sympathetic mobilization; for example, the safe/non-threatening environment in which the task was completed may have attenuated emotional evocation. Consistent with this formulation, youth

self-reported anxiety toward the CS+ after the acquisition period was positively correlated with overall fear following task completion and decreased RSA from the pre-acquisition to acquisition period (i.e., vagal withdrawal). That is, children who reported more anxiety toward the conditioned stimulus (CS+), but not the safety stimulus (CS-), after acquisition, as well as more overall fear after the task may have exhibited vagal withdrawal relative to youth who were not sufficiently fear-induced and thus did not recruit regulatory capacities.

Interestingly, participants demonstrated an overall decrease from the acquisition to the extinction (i.e., faces were paired in the absence of the aversive stimuli) phase of the task to a mean value below the pre-acquisition RSA, indicating RSA withdrawal/vagal regulation from the acquisition phase. Although we hypothesized that children would exhibit vagal regulation in the acquisition phase when presented with the UCS, children may have actually regulated their fear during the extinction learning period. Poor extinction of conditioned responses may occur with social stimuli (e.g., affect faces in this task) that feel less neutral compared with other stimuli (Britton et al., 2013; Shechner et al., 2014). Of note, Michalska et al. (2017) observed that children continued to report fear toward the CS+ versus CS- into the extinction period of the Screaming Lady task, unlike their SCR values, which leveled off in the extinction phase. Together, this evidence suggests that children in this study were still fearful in the extinction phase and exhibited RSA responses consistent with vagal regulation; however, this does not explain why this pattern was not evident from pre-acquisition to acquisition. Given the role of inhibitory learning in fear extinction in creating a safety memory to compete with the fear memory in extinction phases (Craske et al., 2012), an alternative hypothesis may have actually supported RSA augmentation from acquisition to extinction, as children learned the safety memory and recruited increased parasympathetic activity for social engagement. Unlike the

pattern from pre-acquisition to acquisition RSA, self-reported fear regarding the CS+ or experiment overall was unrelated to change in RSA from acquisition to extinction.

Next, RSA variability over the three phases of the fear conditioning task was unrelated to dichotomized (i.e., median split) Internalizing or Externalizing problems. These results likely reflect important facets of the participants in this preliminary study. Whereas atypical patterns of RSA (e.g., reduced tonic RSA, excessive RSA withdrawal) are well-established in *clinical* samples during emotion evocation tasks (Beauchaine, 2015; Graziano & Derefinko, 2013; Zisner & Beauchaine, 2016), moderate variation in psychopathology is periodically correlated with greater tonic RSA, less RSA withdrawal during different lab tasks, or no RSA withdrawal. For example, tasks that do not elicit strong emotional responses (e.g., attention task) or samples with moderate variation in internalizing or externalizing problems (relative to clinical samples) have shown this inconsistency as well (e.g., Dietrich et al., 2007; Hinnant & El-Sheikh, 2009). It may be that the mechanisms of RSA withdrawal differ for clinically significant internalizing or externalizing problems; normative variation in psychopathology may instead reflect temperamental exuberance, positive affectivity, or adaptive engagement with the environment (Degnan et al., 2011). These patterns may be appropriately associated with modest RSA withdrawal. For the current study, which over-sampled trait negative emotionality (e.g., anger, irritability) as a transdiagnostic predictor of psychopathology, there were few exclusion criteria (i.e., IQ < 70, major neurological, developmental, or seizure disorder, neither parent fluent in English), which may have resulted in lower levels of psychopathology within a small, initial sample. Additionally, given the length of the fear conditioning task, it is possible that levels of psychopathology were higher in the girls who did not participate in that particular task, for example, if assessors implemented behavioral management strategies such as frequent breaks or

reward systems for children exhibiting externalizing symptoms and ran out of time for the fear learning task during the laboratory assessment. Coupled with the small sample size, there was only modest clinically significant psychopathology, which likely affected associations between configurations of psychopathology symptoms and RSA patterns over the course of the task.

Given that internalizing and externalizing problems were unrelated to RSA activity, it is difficult to ascertain whether RSA withdrawal, and across which phases, may be adaptive for this task. However, given that levels of psychopathology were modest in the sample overall, the patterns observed may have reflected normative RSA reactivity to a fear conditioning task. In terms of the level of vagal withdrawal that may be optimal for psychological wellness overall, potential non-linear (e.g., quadratic) associations may be explanatory such that moderate levels of withdrawal during emotional challenge tasks may be most adaptive. There is recent evidence attesting to the possibility of nonlinear relationships between RSA and positive outcomes in children, particularly for studies examining resting RSA. For example, a negative quadratic association has been consistently demonstrated between resting RSA and prosocial behaviors in children (Ackland et al., 2019; Kogan et al., 2014; Miller et al., 2017; Zhang & Wang, 2020), such that moderate, compared to high and low, levels of baseline RSA are associated with more prosocial behaviors. In terms of vagal withdrawal, moderate levels of withdrawal have been associated with optimal performance on executive functioning tasks in preschool-aged children (Marcovitch et al., 2010). Lastly, children exhibiting moderate levels of both baseline RSA and RSA reactivity were most likely to follow a “normal” trajectory of internalizing and externalizing problems (Hinnant & El-Sheikh, 2013). While these findings together are not specific to one developmental stage or even specific dimensions of psychopathology studied here, they nevertheless provide initial support for the notion that a particular biological process

may become less adaptive at extreme levels. For example, the concept of optimal balance between positive and negative affect/emotions (e.g., Fredrickson & Losada, 2005; Schwartz et al., 2002) as well as under (Beauchaine, 2001, 2015) or overregulation (Kogan et al., 2014; Miller et al., 2017) of negative emotion as maladaptive is sensitive to context, particularly for prosocial behavior (Zhang & Wang, 2020). With a larger sample, future studies examining RSA withdrawal during fear conditioning tasks could examine whether they observe a similar pattern across phases for children with non-clinical levels of symptoms as this study and whether moderate RSA withdrawal in the later phases of the task is more adaptive compared to high or low levels.

Despite its importance to physiological processing of threat cues (Lonsdorf et al., 2017) and recent models supporting exploration of autonomic emotion responses separately, rather than expecting coherence (Glenn & Michalska, 2018 preprint), we did not find conclusive evidence of fear conditioning/learning in this small sample given the absence of a phase x CS type interaction for SCR or subjective fear ratings. Previous, larger studies with the Screaming Lady task in children have consistently demonstrated conditioning. However, the three components widely thought to represent the fear emotion (following Lang's tripartite model of fear: physiological arousal, cognitive or subjective distress, and behavioral avoidance; Lang, 1967, 1979; Lang et al., 1998; Lang et al., 1983) sometimes work in harmony but can also be discordant (Hodgson & Rachman, 1974). In the Screaming Lady studies conducted with children that examined at least two components of fear conditioning, Britton et al. (2013) and Michalska et al. (2017) found overall concordance between self-report and SCR conditioning; Glenn et al. (2012) found a larger magnitude startle response toward the CS+ versus CS- but only a marginal relationship toward greater self-reported fear expressed toward the CS+. Although we did not

specifically examine within-subject concordance in this study, we explored two measures of the tripartite model: self-reported subjective distress and physiological arousal (SCR to conditioned stimuli). Girls self-reported marginally more anxiety toward the CS+ versus the CS- after the acquisition phase; the relationship was only marginally significant but yielded a small-medium effect size ($d$ = 0.40). Additionally, the percent change in SCR was unrelated to the CS+ compared to the CS-, perhaps reflecting high variance in these values. Taken together, the data suggest that children experienced some level of fear during the task (i.e., evocation), despite not necessarily effectively differentiating facial stimuli. However, evidence of fear conditioning in at least one index (e.g., self-report and SCR) is necessary to make strong inferences about regulation, even if the two measures do not support concordance.

The current, all-female preadolescent sample, recruited for trait negative emotionality, may reflect previous evidence of sex differences in both fear conditioning and vagal regulation during negative challenge tasks. First, biological sex is inconsistently associated with RSA reactivity including evidence of greater reactivity in women (e.g., Yaroslavsky et al., 2013), some in men (e.g., Jönsson & Sonnby-Borgström, 2003), and still others no differences (e.g., Hamilton & Alloy, 2016). In a recent meta-analysis of physically healthy adults, however, women showed greater RSA reactivity compared to men (Beauchaine et al., 2019). In adults, autonomic control in female cardiac systems is characterized by greater relative parasympathetic control; despite higher mean heart rates, then, women show more parasympathetic activity than men (Koenig et al., 2016). Problematically, evidence is limited in youth: in a prospective study, increased vagal reactivity to emotional challenge in infancy predicted more toddler oppositional defiant disorder (ODD) symptoms in girls, but inversely predicted ODD symptoms in boys (Vidal-Ribas et al., 2017). Gray et al. (2017) observed that in girls with high levels of potentially

traumatic events, higher RSA withdrawal predicted higher internalizing problems; the opposite was observed for girls with low potential trauma exposure. Somewhat similarly, Hinnant and El-Sheikh (2013) found that girls with strong RSA withdrawal were more likely to exhibit a low externalizing trajectory and moderately elevated internalizing symptoms *or* a high externalizing and high internalizing trajectory. Together, these findings suggest complex interactions for RSA reactivity in preadolescent girls compared to boys in predicting both internalizing and externalizing problems and suggests more work in this area focused specifically on sex differences in youth in order to most effectively predict and prevent the development of internalizing and externalizing problems.

Unlike nonhuman animals and adults, where fear conditioning and sex differences are relatively well-characterized, the evidence is somewhat limited for youth. Key exceptions include Gao et al. (2010) and Michalska et al. (2017), who reported finding no sex differences with respect to fear acquisition or extinction using either self-report or physiological measures. Among children attempting the Screaming Lady task in Glenn et al. (2012), participants who aborted the task early were more likely to be female than those who completed the task. Girls showed less discrimination between danger (CS+) and safety (CS-) signals, relative to boys, using SCR and startle responses in another study (Gamwell et al., 2015). We await future studies, better positioned to examine sex differences in subjective and physiological fear conditioning indices, as well as intensively ascertained samples of girls across development and clinical risk status, to improve traction on potential similarities and differences with respect to fear conditioning, extinction, and its physiological correlates. This evidence will further refine models of psychopathology onset and development.

This study provides preliminary evidence on physiological correlates of self-regulation (i.e., RSA) in response to fear conditioning among pre-adolescent girls. Given modest levels of clinically significant internalizing and externalizing problems in this sample, RSA responses may represent normative parasympathetic response to this fear conditioning task. Fear conditioning paradigms afford the opportunity to study autonomic nervous system activity and related psychophysiological correlates of emotion processing in the laboratory. In addition, tasks such as the Screaming Lady paradigm are non-invasive and tolerated in pediatric samples, although it remains a challenging paradigm to administer, thus affecting the size of samples collected. Nevertheless, there are important opportunities to understand fear learning and generalization in relation to normal and abnormal development. Lastly, examining self-regulation indices during these paradigms provide key information on how children are able to manage negative emotions (namely, fear and anxiety) independently over the course of a task and how that may relate to internalizing and/or externalizing symptomatology. Ultimately, the goal of this and related studies are to characterize how children acquire and manage fear and related emotions in their environment and how we can translate this knowledge into prevention and intervention efforts to promote resilience in the context of acute threat and stress.

Table 3.1. Descriptive statistics and correlations between study variables.

| | *M (SD)* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Child age | 9.03 (1.60) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2. CBCL Internalizing Raw Score | 6.57 (4.26) | 0.07 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 3. CBCL Externalizing Raw Score | 5.00 (5.72) | -0.14 | 0.53** | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 4. Pre-acquisition RSA | 7.16 (0.89) | 0.33 | 0.09 | -0.08 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 5. Acquisition RSA | 7.21 (0.89) | 0.33 | 0.14 | 0.06 | 0.85** | -- | -- | -- | -- | -- | -- | -- | -- |
| 6. Extinction RSA ($n$ = 21) | 7.11 (0.82) | 0.21 | 0.06 | -0.19 | 0.74** | 0.74** | -- | -- | -- | -- | -- | -- | -- |
| 7. Anxiety rating to CS+ after ACQ ($n$ = 25) | 3.82 (3.50) | 0.06 | -0.08 | -0.31 | 0.51* | 0.31 | 0.64** | -- | -- | -- | -- | -- | -- |
| 8. Anxiety rating to CS- after ACQ ($n$ = 25) | 2.74 (2.69) | -0.12 | -0.28 | -0.25 | 0.18 | 0.13 | 0.36 | 0.65** | -- | -- | -- | -- | -- |
| 9. Difference score: ACQ RSA – PRE RSA | 0.06 (0.49) | 0.004 | 0.09 | 0.24 | -0.27 | 0.27 | -0.05 | -0.48* | -0.12 | -- | -- | -- | -- |
| 10. Difference score: EXT RSA – ACQ RSA | -0.30 (0.60) | -0.27 | -0.20 | -0.31 | -0.17 | -0.36 | 0.37 | 0.37 | 0.38 | -0.36 | -- | -- | -- |
| 11. SCR percent signal change to CS+ | 48.60% (94.27) | 0.13 | -0.21 | -0.10 | 0.22 | 0.17 | 0.23 | 0.04 | 0.17 | -0.10 | 0.11 | -- | -- |
| 12. SCR percent signal change to CS- | 11.66% (167.66) | -0.03 | -0.10 | 0.07 | 0.02 | 0.03 | -0.01 | 0.13 | 0.14 | 0.02 | 0.11 | 0.39* | -- |
| 13. Overall fear rating after task ($n$ = 24) | 3.08 (3.46) | -0.11 | -0.08 | -0.22 | 0.37 | 0.10 | 0.44* | 0.71*** | 0.48* | -0.40* | 0.10 | -0.07 | 0.05 |

*Note.* * $p \leq .05$. ** $p \leq .01$.

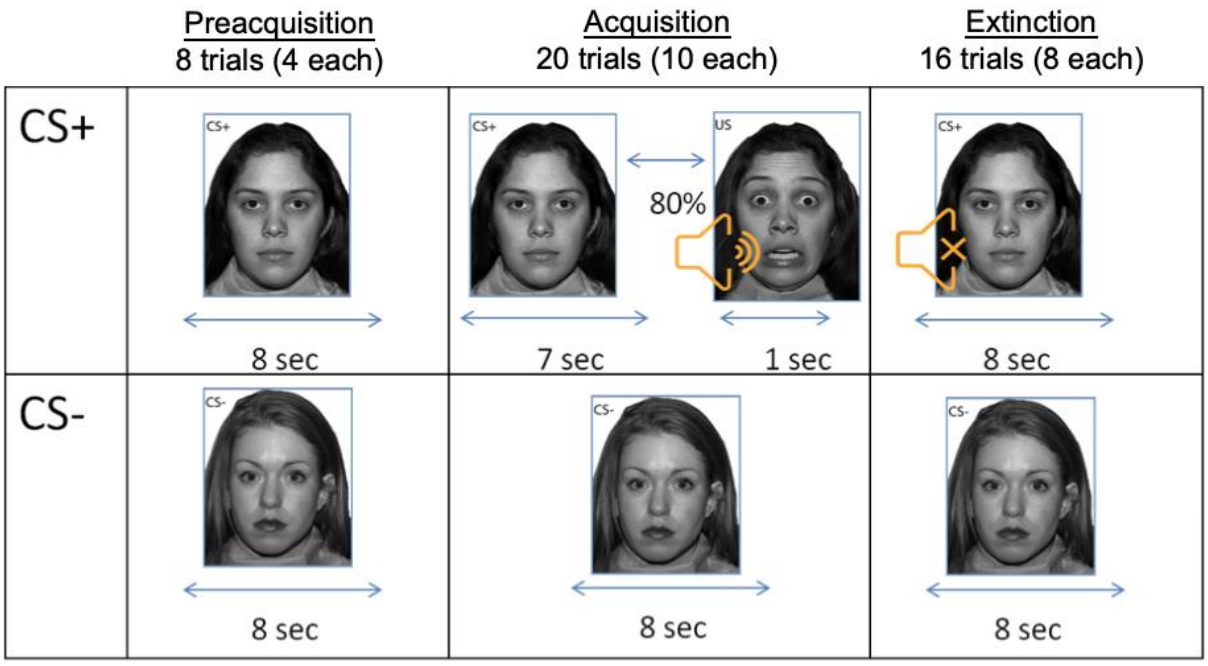
CBCL = Child Behavior Checklist 6-18 (Achenbach & Rescorla, 2001); RSA = respiratory sinus arrythmia; CS+ = differentially-conditioned stimulus; CS- = non-differentially-conditioned stimulus; ACQ = acquisition phase; PRE = pre-acquisition phase; EXT = extinction phase; SCR = skin conductance response. Matrix includes full sample (N = 31), even those who aborted the task before the extinction phase.

Table 3.2. Repeated-measure ANOVA results for RSA during three task phases.

| | ***Sum of squares*** | ***df*** | ***Mean square*** | ***F*** | ***p*** | $\eta^2$ |
|---|---|---|---|---|---|---|
| **Phase** | 0.65 | 2 | 0.33 | 2.30 | 0.12 | 0.13 |
| **Phase*Age** | 0.76 | 2 | 0.38 | 2.70 | 0.09 | 0.14 |
| **Phase*Internalizing** | 0.44 | 2 | 0.22 | 1.56 | 0.23 | 0.09 |
| **Phase*Externalizing** | 0.85 | 2 | 0.43 | 3.02 | 0.06 | 0.16 |
| **Phase*INT*EXT** | 0.24 | 2 | 0.12 | 0.86 | 0.43 | 0.05 |
| **Error** | 4.51 | 32 | 0.14 | | | |

*Note*. Phase = phase of Screaming Lady task (i.e., pre-acquisition, acquisition, extinction); INT = Internalizing median split; EXT = Externalizing median split.

Figure 3.1. The Screaming Lady paradigm (Lau et al., 2008)




During the pre-acquisition phase, children passively viewed neutral faces of two women, including the conditioned stimulus (CS) in the absence of the unconditioned stimulus (UCS). During the acquisition phase, one woman, the CS+, predicted the UCS, a 1-second image of a fearful face paired with a loud, aversive 95 dB scream, while the other woman, the CS-, did not. During extinction, the CS+ (and CS-) were presented repeatedly in the absence of the UCS.

Figure 3.2. Individual RSA trajectories during three phases of the Screaming Lady task.

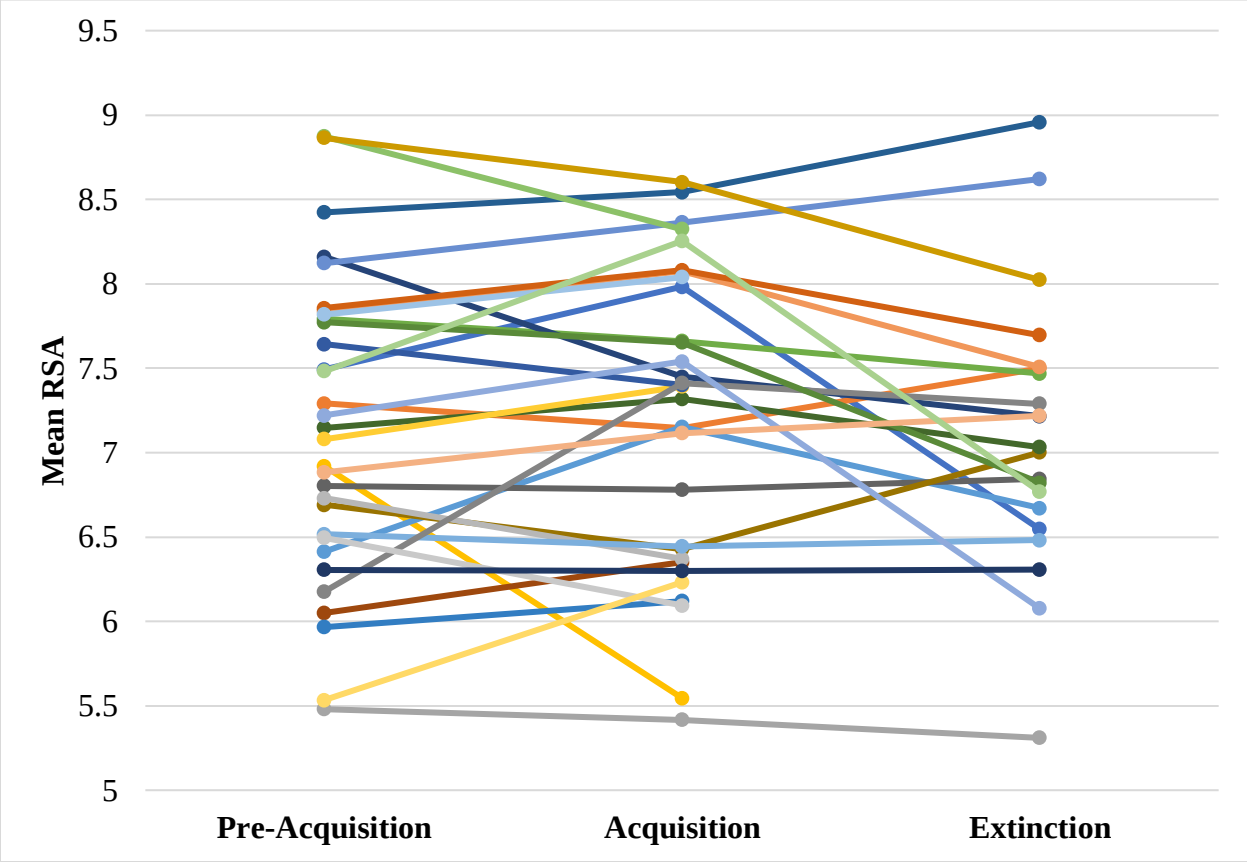


Figure 3.3. RSA values over the three phases of the task by high and low Internalizing median split scores.

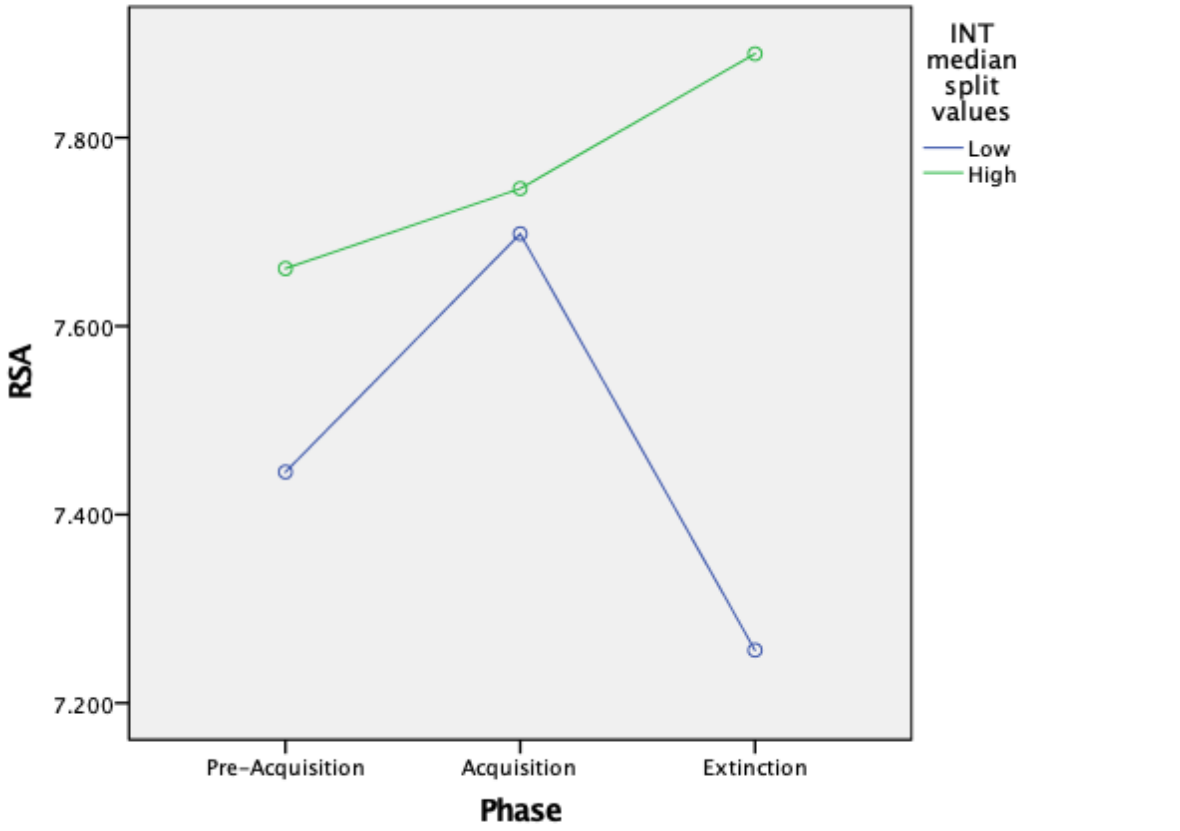
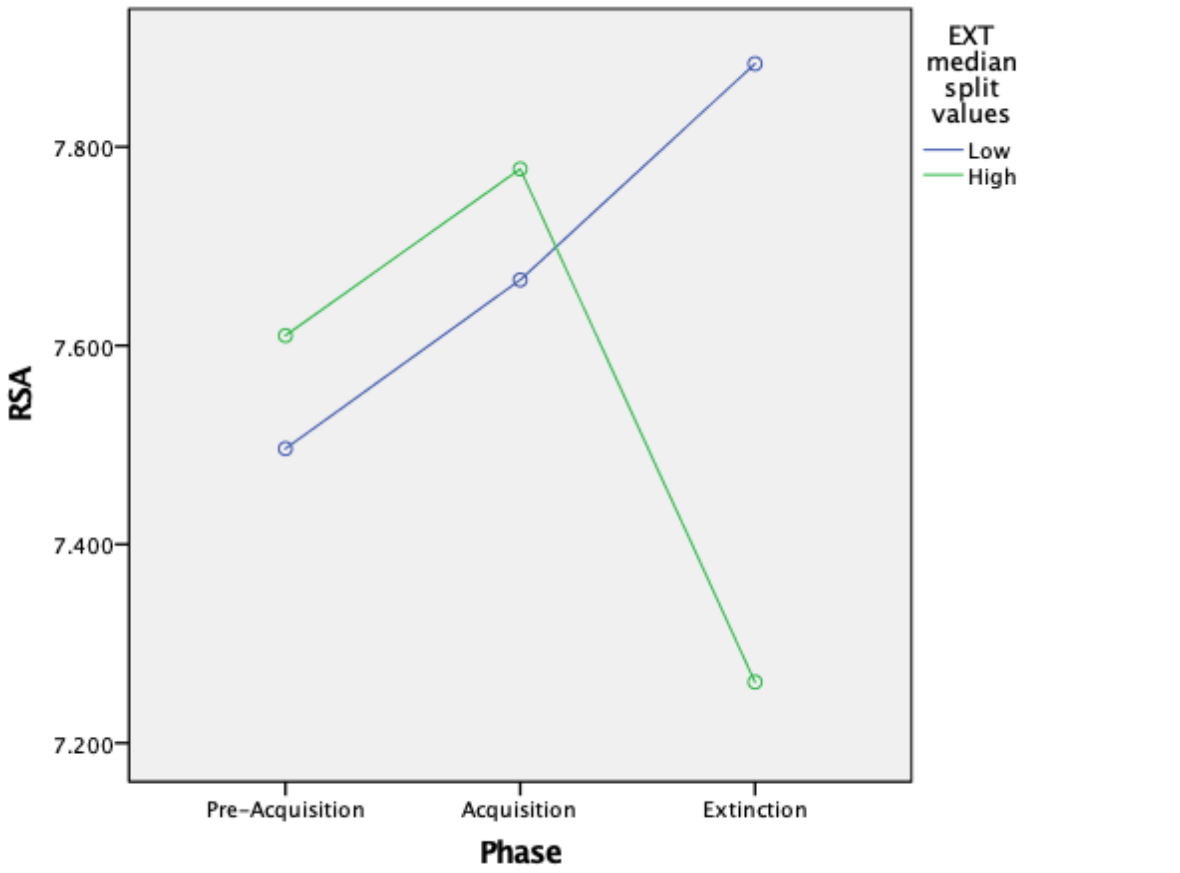


Figure 3.4. RSA values over the three phases of the task by high and low Internalizing median split scores.



## Conclusions

This dissertation utilized multiple methods to examine transdiagnostic psychopathology in youth, through examining associations of general and specific factors of psychopathology with relevant criteria as well as their social (i.e., behaviors on digital media) and biological (i.e., physiological regulation in the context of threat) correlates. Across diversely recruited and ascertained samples, including school- and laboratory-based assessments, the results of these studies contribute to a framework for examining psychopathology in children and adolescents, including highlighting potential intervention targets in preventing youth psychopathology and underscoring the need for developmental perspectives.

This work is guided by dimensional, transdiagnostic models reflected in the NIMH Research Domain Criteria (RDoC; Insel et al., 2010) and the Hierarchical Taxonomy of Psychopathology (HiTOP; Hopwood et al., 2020). We incorporated methods across multiple units of analysis (e.g., physiology, self-report, paradigms), examined transdiagnostic risk factors, and intentionally sampled key developmental periods from school-aged children to preadolescence and high school. Although RDoC was primarily designed as a research framework placing particular emphasis on the neurobiological basis of psychopathology, and HiTOP as a framework predominantly focused on clinical manifestations, recent work has linked these two systems and identified core connections that may serve as the foundation for a unified nosological system integrating etiology and clinical presentation (Michelini et al., 2020 preprint). Further, Forbes et al. (2019) extended these frameworks to propose an integrated model including developmental stages and considerations and interventions at each level of their model. Influenced heavily by the HiTOP model, we similarly frame the results of this dissertation and consider implications. Figure 4.1 represents a visual interpretation of our discussion below.

*P-factor model as a framework*

In Study I, we fit a bifactor model to symptoms of psychopathology in *n* = 460 school-age children with and without attention-deficit/hyperactivity disorder (ADHD), examining two specific (i.e., internalizing and externalizing) and a general factor of psychopathology (i.e., *p*-factor) for potential concurrent associations with independent assessments of academic, social, and global functioning. Results from this study suggest that internalizing and general factors were associated with academic functioning whereas externalizing and general factors were associated with social and global functioning.

These results substantiate that a general factor of psychopathology is evident in pre-adolescence and is associated with important outcomes; it also justifies the need for further evaluations of this model (e.g., predictive validity), especially across developmental periods. The general factor has been detected in children as young as preschool (e.g., Olino et al., 2014); in fact, Forbes et al. (2019) contend that targeting general psychopathology in early childhood, for example, through universal interventions delivered to young children, may increase protective factors associated with positive mental health and functioning. Relevant intervention targets include parent education/optimizing parent-child relationships, prosocial peer relationship skills, coping strategies for emotion regulation, and, of course, social efforts to reduce abuse and poverty that convey risk for general psychopathology. Further, results from Study I align with Forbes et al. (2019) on transdiagnostic spectra in middle childhood, given the independent association of specific factors, beyond the general psychopathology factor, with academic, social, and global functioning. That is, the model recommends universally implementing key behavioral approaches in early childhood as well as additional targeted modules for children with prominent internalizing or externalizing problems. Taken together, these results suggest that

school-based curricula in middle childhood may yield improved benefits across multiple domains of functioning. To thematically and programmatically integrate the results of all three studies, we consider below how constructs as diverse as behaviors on digital media and physiological self-regulation may be integrated into a transdiagnostic stepped care intervention.

*Integration of digital media use behaviors with the p-factor model of psychopathology*

The potential association of frequent digital media use with elevated psychopathology (i.e., *p*-factor scores and/or specific internalizing and externalizing symptoms) may operate via specific behaviors online, including frequently receiving negative feedback, presenting oneself in a risky fashion, and comparing oneself to others in an upward direction. Although Study II consisted of middle and high school youth, an older cohort relative to the school-age sample for Study I, previous evidence supports the utility of the general factor in adolescence and young adulthood (Laceulle et al., 2015; Patalay et al., 2015; Lahey et al., 2018). Thus, consistent with Forbes et al. (2019), interventions at this stage could focus on effective monitoring and possible reduction of digital media use, and more specific interventions could include cognitive restructuring for challenging thoughts around social comparison, behavioral activation strategies for students engaging in digital media too frequently or maladaptively to help identify other prosocial activities, and psychoeducation focused on the risks of risky self-presentation and digital privacy. Despite the Children's Online Privacy Protection Act enacted in 1998 which requires certain websites, including social media platforms, to set their user age limit at 13+, recent reports suggest that the average age for a child getting their first smartphone is now 10.3 years, and 40% of children in a sample of 500 representative youth reported having a social media account by 11.4 years old (Influence Central, 2016). Although results from Study II were

focused on adolescents, preventative programs could even include elements of these interventions through the CBT framework in elementary school.

*Physiological self-regulation and contribution to p-factor model*

Study III examined vagal regulation during a fear conditioning task and associations with internalizing and externalizing problems in a pilot study of preadolescent girls recruited for negative emotionality. Although patterns of RSA change were unrelated to internalizing and externalizing problems, likely due to the small sample size and modest levels of clinically-significant psychopathology, previous work consistently implicates RSA withdrawal in response to emotional challenge as a correlate and risk factor for psychopathology in children as young as toddlers (Calkins & Keane, 2004; Cho et al., 2017). In fact, RSA has been proposed as a transdiagnostic biomarker of psychopathology, given these findings, although the level of RSA withdrawal that is most adaptive during emotional challenge tasks remains to be specified, including potential nonlinear associations. RSA is thought to index prefrontal cortex (PFC) function given that there are (a) inhibitory efferent pathways from the medial PFC to the parasympathetic nervous system, measured by RSA; (b) positive associations between resting RSA and performance on executive functioning tasks; and (c) positive associations between RSA and PFC activity during neuroimaging paradigms (Beauchaine & Thayer, 2015). Thus, consistent with Thayer and Lane's (2009) neurovisceral integration theory, RSA may reflect similarly reflect non-specific vulnerability to psychopathology as the *p*-factor.

Although resting RSA and RSA withdrawal patterns may represent a transdiagnostic biomarker of psychopathology, it is unclear whether these facets can be meaningfully affected via prevention or intervention in childhood. As a hypothesized indicator of physiological capacity for self-regulation, we contend that some of the elements of the universal interventions

for limited-modifiable risk factors proposed in early childhood by Forbes et al. (2019) would improve such factors as harsh parenting and emotion regulation, which may have downstream effects. Similarly, recent work by Hastings et al. (2019) demonstrated that a parent training intervention for families recently investigated for maltreatment improved toddlers' parasympathetic regulation (measured by RSA reactivity to tasks). Preterm infants who received a novel in-hospital intervention focused on emotionally connecting infants and mothers to offset traumatic effects of early separation showed increased RSA during sleep compared to the control group (Porges et al., 2019), further highlighting the importance of sensitive parenting interventions and the potential role of modified RSA in subsequent improved functioning.

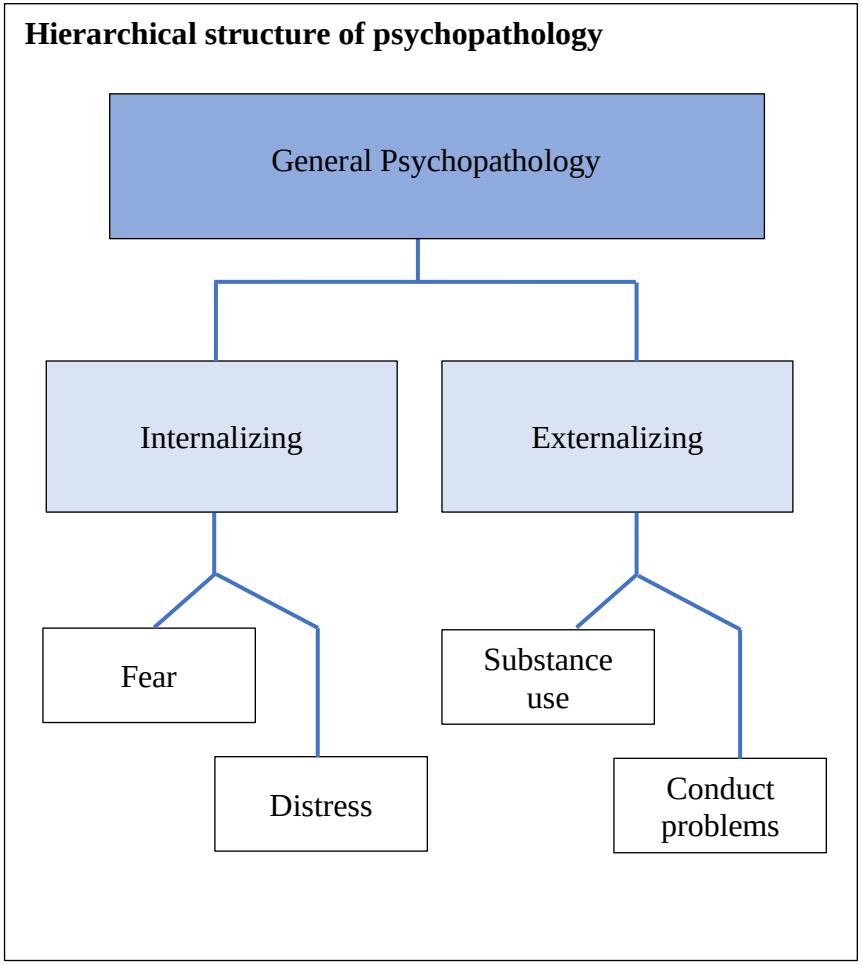
In addition to intervention, RSA as a biomarker may be usefully added to clinical assessment. Study III examined a novel task in the context of RSA reactivity, additional emotion or behavior challenge tasks have been utilized repeatedly in studies of RSA withdrawal (e.g., adaptations of the Laboratory Temperament Assessment, Goldsmith & Rothbart, 1993; see Buss & Goldsmith, 2000, Calkins et al., 2007). If adaptive and maladaptive patterns of RSA reactivity can be reliably established via behavioral and/or emotional evocation, early interventions could target children exhibiting these patterns to help prevent general liability to psychopathology.

*General conclusions*

Taken together, these three dissertation studies exemplify key characteristics of modern clinical science approaches to developmental psychopathology: use of multiple methods and multiple levels for constructs as well as integration of both dimensional and hierarchical approaches to the underlying architecture of common youth psychopathology. We identified several factors warranting further study that span statistical, interpersonal, and biological domains. Our hope is that this work contributes toward prevention and intervention efforts that

will ultimately help to identify youth at risk for psychopathology in childhood or adolescence and aid in identifying novel treatment targets for reaching them with clinical services.

Figure 4.1. Discussion figure incorporating hierarchical structure of psychopathology (with general and specific factors), potential biological and social risk factors as outlined in dissertation studies, and proposed interventions at each developmental stage. Adapted from Forbes et al. (2019): transdiagnostic stepped care intervention model.




| | Risk factors | Interventions |
|---|---|---|
| **Early childhood (3-6 years)** | Vagal regulation (RSA at rest and reactivity assessment)<br>Parent-child relationships | **Universal interventions**: Parent-child relationship, positive parenting, parental sensitivity, emotion regulation skills |
| **Middle childhood (7-10 years)** | Vagal regulation (RSA at rest and reactivity assessment)<br>Digital media use frequency | **Add CBT elements (e.g., Unified Protocol):** cognitive restructuring, mindfulness, fostering social support, self-monitoring |
| **Adolescence (11-17 years)** | Vagal regulation (RSA at rest and reactivity assessment)<br>Digital media use frequency and behaviors | **Add selective interventions for teens exhibiting specific symptom clusters** (include interventions specific to digital media) |

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