CHILDREN'S INTERNALIZING AND EXTERNALIZING SYMPTOMS:
DEVELOPMENTAL DYNAMICS AND NEURAL INDICES OF
SOCIAL THREAT PROCESSING BIASES

A Dissertation in
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by

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ABSTRACT

Emotional and behavioral problems in childhood can generally be accounted for by two overarching factors: externalizing problems, including aggression and hyperactivity, and internalizing problems, including anxiety and social withdrawal. Comorbidity between internalizing and externalizing problems is surprisingly common and is associated with particularly severe and chronic maladjustment, yet little is known about when and why internalizing-externalizing comorbidity emerges. This dissertation consists of two studies investigating the development of internalizing, externalizing, and comorbid problems in young school-aged children. Both studies drew on a sample of 336 children from an urban school district who were over-sampled for aggressive/oppositional behavior problems and followed longitudinally from kindergarten to 2nd grade.

In Study 1, an exploratory latent transition analysis was conducted to explore the developmental dynamics of aggression/oppositionality, hyperactivity/inattention, anxiety, and social withdrawal in kindergarten through 2nd grade. Four latent profiles were identified: comorbid (48% of the sample in each year), internalizing (19-23%), externalizing (21-22%), and well-adjusted (7-11%). High continuity was observed in symptom profiles across years, particularly for the comorbid profile. Additionally, internalizing children had a 20% probability of remitting by the following year, whereas externalizing children had a 25% probability of transitioning to the comorbid profile. These results are consistent with the hypothesis that a common vulnerability factor contributes to developmentally stable internalizing-externalizing comorbidity, while also suggesting that some children with externalizing symptoms are at risk for subsequently accumulating internalizing symptoms.

Study 2 explored associations between 1st-grade children’s joint internalizing-externalizing symptoms and neural indices of social threat processing biases, measured as event-related potential amplitude differences to threatening versus neutral facial expressions. The results suggested that high-externalizing/low-internalizing children exhibit deficient automatic attentional capture by fearful faces and blunted biases toward sustained perceptual processing of threatening versus neutral faces. In contrast, high-internalizing/low-externalizing children exhibited greater automatic attentional capture by fearful faces. Finally, children with comorbid internalizing-externalizing symptoms exhibited more normative patterns of social threat processing. This suggests that social threat processing biases act as differential risk factors for externalizing versus internalizing problems, and they do not explain internalizing-externalizing comorbidity.
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CHAPTER 1:

Introduction
Numerous children suffer from emotional and behavioral problems that negatively impact their quality of life and impair their social and academic functioning. In nationally-representative samples of children, prevalence rates have been estimated at 7-28% for any anxiety disorder (Costello, Egger, Copeland, Erkanli, & Angold, 2011), 9% for ADHD (Froehlich et al., 2007), and 3% for both oppositional defiant disorder and conduct disorder (Canino, Polanczyk, Bauermeister, Rohde, & Frick, 2010). Rates of emotional and behavioral problems are even higher among low-SES families and within urban communities (Kessler et al., 2012). Comorbidity among these disorders is common and is often associated with greater severity of symptoms and social problems (Angold, Costello, & Erkanli, 1999; Polier, Vloet, Herpertz-Dahlmann, Laurens, & Hodgins, 2011). Factor analyses of psychiatric symptoms and disorders robustly find that two overarching factors, termed internalizing and externalizing, can explain the majority of psychiatric comorbidity (Achenbach & Edelbrock, 1978; Carragher, Krueger, Eaton, & Slade, 2015). The internalizing dimension includes fear- and distress-related disorders such as phobias and generalized anxiety disorder, whereas the externalizing dimension includes primarily behavioral disorders such as oppositional defiant or conduct disorder, as well as substance abuse disorders. Importantly, these overarching dimensions are themselves positively correlated, suggested that there may be common risk factors contributing to the co-occurrence of both dimensions of problems (Krueger & Markon, 2006).

Despite the well-documented positive correlation between the internalizing and externalizing dimensions of psychopathology, they are often considered independently of one another in investigations of etiological processes. However, only through investigating the joint expression of symptoms from both domains within the same individuals can one gain clear insight into the common risk factors that are contributing to the phenomenon of cross-domain comorbidity. It is also important to examine developmental dynamics in the expression of comorbidity in order to better understand the underlying etiological processes. If comorbidity primarily arises due to the presence of common endogenous risk factors that do not change over time, then comorbid symptom manifestations would be expected to be observed early in childhood and to be highly stable over development. On the other hand, comorbidity
may emerge developmentally as part of a developmental cascade whereby symptoms from one dimension yield consequences that, in turn, increase the risk that symptoms from the other dimension will emerge. Only by exploring the dynamic expression of comorbidity over developmental time can these two theoretical etiological pathways be compared.

If comorbidity is strongly influenced by common endogenous risk factors, these risk factors may be particularly strong leverage points for intervention since they are by definition associated with diverse forms of psychopathology. Research has suggested that trait negative affectivity is a particularly strong candidate for a common risk factor for internalizing-externalizing comorbidity (Mikolajewski, Allan, Hart, Lonigan, & Taylor, 2013; Rhee, Lahey, & Waldman, 2015; Schmitz et al., 1999; Tackett et al., 2013). One aspect of trait negative affectivity is a tendency to exhibit negative biases in cognition, including attending preferentially to negative information and interpreting ambiguous information as negative (Watson & Clark, 1984). Indeed, both internalizing and externalizing problems have been linked to negative biases in attention and interpretation, with some research suggesting that such biases occur automatically at the preconscious level (Mogg & Bradley, 1998; Wilkowski & Robinson, 2010). A better understanding of the precise timing and neural processes contributing to these biases can help inform intervention efforts by providing hints at which kinds of interventions are most likely to be effective. For example, early automatic biases may be most easily modified by implicit training whereas conscious cognitive-interpretational biases may benefit most from cognitive-behavioral therapy. Recently, researchers have begun investigating the neural correlates of such negativity biases using event-related potentials (ERPs), which measure neural activity on a millisecond time scale and are therefore ideally suited to addressing questions about the precise timing of the bias, including whether it occurs at automatic/preconscious or later cognitive-elaborative stages of information-processing.

**The present studies**

This dissertation consists of two studies that explore the developmental course and social threat processing correlates of internalizing and externalizing symptoms, including comorbid symptom presentations, in a sample of 336 children followed longitudinally from kindergarten to 2nd grade. All
children were recruited from a single urban school district in southern Pennsylvania and roughly two-thirds of the sample was selected based on high levels of teacher-reported aggressive/oppositional behaviors in kindergarten. Teachers reported on children’s emotional and behavioral symptoms in the classroom in each year, and beginning in 1st grade ERP data were recorded while children completed a go/no-go task with threatening and neutral emotional face stimuli.

**Study 1**

The first study utilized an exploratory latent profile analysis (Collins & Lanza, 2010; Collins & Wugalter, 1992) to identify latent symptom profiles that could account for the co-occurrence of teacher-rated aggression/oppositionality, hyperactivity/inattention, anxiety, and social withdrawal symptoms in the sample. Then, a latent transition analysis was conducted to explore developmental continuities and discontinuities in these symptom profiles across the first three years of school. This paper addressed two primary research aims. The first aim was to identify a discrete number of latent symptom profiles that optimally explain the symptom co-occurrence patterns present in the sample. The second aim was to explore developmental continuities and discontinuities in these symptom profiles across the first three years of school, with particular attention to the developmental dynamics of comorbid internalizing and externalizing symptom presentations.

**Study 2**

The second study examined neural indices of 1st-grade children’s perceptual-attentional processing of threatening (fearful and angry) versus neutral facial expressions on the go/no-go task. Four event-related potentials (ERPs) indexing preconscious and early conscious perceptual-attentional processing of visual stimuli were selected based on prior research suggesting that their amplitudes may be sensitive to the emotional content of the stimulus. Higher amplitudes of these ERPs to threatening versus neutral facial expressions were expected to index greater perceptual-attentional biases toward processing social threat cues. The aim of this study was to explore whether these neural indices of social threat processing biases were associated with children’s internalizing, externalizing, and comorbid symptoms. Two analytic strategies were pursued to achieve this aim. First, building directly on study 1, associations
were examined between children’s ERP threat biases and their latent symptom profiles in 1st grade. Second, children’s ERP threat biases were regressed on dimensional measures of their internalizing and externalizing symptom severity, as well as the interaction between these two symptom domains. Both of these approaches allow for the examination of associations between children’s ERP threat biases and both “pure” and comorbid internalizing-externalizing symptom presentations.
1.1. References


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CHAPTER 2:

The Dynamics of Internalizing and Externalizing Comorbidity

Across the Early School Years

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ABSTRACT

High rates of comorbidity are observed between internalizing and externalizing problems, yet the developmental dynamics of comorbid symptom presentations are not yet well understood. This study explored the developmental course of latent profiles of internalizing and externalizing symptoms across kindergarten, 1st, and 2nd grade. The sample consisted of 336 children from an urban, low-income community, selected based on relatively high (61%) or low (39%) aggressive/oppositional behavior problems at school entry (64% male; 70% African American, 20% Hispanic). Teachers reported on children’s symptoms in each year. An exploratory latent profile analysis of children’s scores on aggression/oppositionality, hyperactivity/inattention, anxiety, and social withdrawal symptom factors revealed 4 latent symptom profiles: comorbid (48% of the sample in each year), internalizing (19-23%), externalizing (21-22%), and well-adjusted (7-11%). The developmental course of these symptom profiles was examined using a latent transition analysis, which revealed remarkably high continuity in the comorbid symptom profile (89% from one year to the next) and moderately high continuity in both the internalizing and externalizing profiles (80% and 71%, respectively). Internalizing children had a 20% probability of remitting to the well-adjusted profile by the following year, whereas externalizing children had a 25% probability of transitioning to the comorbid profile. These results are consistent with the hypothesis that a common vulnerability factor contributes to developmentally stable internalizing-externalizing comorbidity, while also suggesting that some children with externalizing symptoms are at risk for subsequently accumulating internalizing symptoms.
2.1. Introduction

Statistical models of psychiatric comorbidity have consistently revealed two broad-band factors, *internalizing* and *externalizing*, that explain the majority of co-occurrence of psychiatric disorders in adulthood (Carragher, Krueger, Eaton, & Slade, 2015) and of psychiatric symptom manifestations in childhood (Achenbach & Edelbrock, 1978). The externalizing spectrum incorporates a variety of disinhibited or externally-focused behavioral symptoms including aggression, conduct problems, delinquent behavior, oppositionality, hyperactivity, and attention problems, whereas the internalizing spectrum includes a variety of over-inhibited or internally-focused symptoms including anxiety, fear, sadness/depression, social withdrawal, and somatic complaints. Despite the apparent distinctiveness between these domains, most studies of children find them to be positively correlated with one another (Bird, Gould, & Staghezza, 1993; Caron & Rutter, 1991). Because much of the epidemiological research presents only a cross-sectional view of the prevalence of child psychopathology, it is not clear how comorbidity develops over time. It is possible that comorbidity between externalizing and internalizing domains increases probabilistically over time, as initial symptoms become risk factors for the development of additional symptoms from the other domain (i.e., accumulation). Alternatively, it is possible that psychopathology is less differentiated in younger children, such that children may exhibit symptoms from both domains initially that, over time, crystallize into more “pure” internalizing or externalizing presentations in response to environmental contingencies that shape symptom manifestation (i.e., differentiation). Finally, it is possible that comorbidity is stable over time, reflecting the influence of a common underlying trait that increases vulnerability to both domains of psychopathology across the lifespan. In this study, we examine if and how children’s profiles of psychopathology change across the first 3 years of school.

**Theoretical perspectives on comorbidity**

The predominance of comorbidity has been a major concern in clinical science. One of the primary debates is whether the co-occurrence between different syndromes is appropriately termed
“comorbidity,” in the medical application of this term (Lilienfeld, Waldman, & Israel, 1994). Comorbidity refers to the presence of two independent syndromes, which implies that the probability of comorbidity should equal the product of the probabilities of each individual disorder. Data, however, clearly demonstrate that rates of comorbidity between internalizing and externalizing disorders far exceed the rate that would be predicted based on chance co-occurrence of independent syndromes, suggesting that some mechanism must underlie the phenomenon of comorbidity (Beauchaine & McNulty, 2013; Caron & Rutter, 1991).

One of the primary hypotheses put forward is that a common trait imparts vulnerability for symptoms in both domains (Weiss, Süsser, & Catron, 1998). Behavioral genetics models have suggested that a substantial portion of the correlation between externalizing and internalizing disorders is accounted for by a common genetic component (Cosgrove et al., 2011; Lahey, Van Hulle, Singh, Waldman, & Rathouz, 2011). This common genetic liability appears to be at least partially mediated by trait negative affectivity (Mikolajewski, Allan, Hart, Lonigan, & Taylor, 2013; Rhee, Lahey, & Waldman, 2015; Schmitz et al., 1999; Tackett et al., 2013), which is mediated at the neural level by hyperactivation of the threat-response system (Whittle, Allen, Lubman, & Yücel, 2006). Additionally, deficient prefrontal control over limbic system activity contributes to emotion dysregulation and risk for both internalizing and externalizing psychopathology (Beauchaine, 2015). Finally, blunted responsivity of the mesolimbic reward system, which contributes to low positive affectivity and lack of motivation, is another potential common vulnerability factor for externalizing and internalizing psychopathology, particularly depression (Andrews et al., 2011; Brenner & Beauchaine, 2011; Forbes & Dahl, 2005). If a common vulnerability factor underlies both externalizing and internalizing symptoms, comorbidity is more likely to manifest earlier and evidence relative stability over time, as the vulnerability trait arguably confers risk for both conditions simultaneously, and maintains risk across development.

Other theories have posited that comorbidity arises when the symptoms of one disorder increase the risk for the development of another (Caron & Rutter, 1991). With regard to internalizing-externalizing comorbidity, there is substantial empirical evidence suggesting that children initially presenting with
externalizing symptoms are at greater risk for later developing internalizing symptoms, which may emerge in response to adverse consequences of externalizing behaviors such as rejection by peers, academic difficulties, or other stressful life experiences (Burke, Loeber, Lahey, & Rathouz, 2005; Gooren, van Lier, Stegge, Terwogt, & Koot, 2011; Ladd & Troop-Gordon, 2003; Nobile et al., 2013; van Lier & Koot, 2010). In contrast, there is less evidence to suggest that the presence of internalizing symptoms imparts a risk for the emergence of externalizing symptoms (Gilliom & Shaw, 2004; Keiley, Bates, Dodge, & Pettit, 2000). If comorbidity is sequential, it is likely to follow a pattern of symptom accumulation whereby children with “pure” symptom profiles are at greater risk for developing comorbid symptoms over time, a pattern which may be more likely to occur among those initially presenting with externalizing symptoms.

An alternative possibility is that children are more likely than adults to express undifferentiated symptoms of distress that can manifest as symptoms of both externalizing and internalizing domains. Risk for psychopathology that arises from core dispositional traits may differentiate into specific symptom profiles over time through transactional shaping from environmental input (Lahey & Waldman, 2007). Over time, generalized distress may become refined into more “pure” symptom presentations, particularly in response to specific peer or parenting influences that reinforce certain behavioral patterns over others. For example, young children may manifest psychological distress as undifferentiated irritability, which can include symptoms such as temper tantrums, crying, and aggression. Chronic irritability in preschool-aged children has been shown to predict the later onset of both internalizing and externalizing disorders (Dougherty et al., 2015). This perspective of differentiation suggests that comorbidity will be higher among younger children, but will decrease over time as children develop more nuanced emotional reactions and behavioral responses, thus diverging into either an externalizing or internalizing profile.

Defining comorbidity

One of the primary issues in the study of comorbidity is how best to define its existence. Many studies rely on pre-specified cutoffs on dimensional internalizing and externalizing symptom scales that reflect the threshold at which diagnostic “caseness” is met. In studies of comorbidity, this typically
involves identifying children who are above the cutoff on both scales. However, children above the cutoff on one scale but below the cutoff on the other scale are often classified as displaying “pure” internalizing or externalizing disorders, regardless of whether their subthreshold scores reflect meaningful symptom elevation in the other domain. This is especially troubling from a developmental perspective because a restricted focus on children whose symptoms meet or exceed a diagnostic threshold may fail to capture important processes in children who may be on the verge of crossing the clinical threshold in the coming years. This approach also compromises the ability to identify factors that protect or divert high-risk (i.e. subthreshold) children from arriving at a diagnostic outcome.

Maximizing the value of continuous symptom severity can be achieved using latent profile analysis (LPA), a person-centered, multivariate analysis technique for identifying groups of individuals with similar patterns of symptom scores across measures (Collins & Lanza, 2010). This technique is similar in concept to cluster analysis, however, it differs importantly in statistical approach and underlying assumptions. Most importantly, in LPA the grouping variable is latent and individuals have a probability of membership in each latent profile based on their values on the array of indicators. In cluster analysis, individuals are assigned exclusively to one group with which they are deemed to be most similar (DiStefano & Kamphaus, 2006). Thus, in LPA, uncertainty in group assignment is explicitly modeled as measurement error (Collins & Lanza, 2010); by contrast, in cluster analysis, individuals whose profiles do not adequately match any group must either be assigned to a poorly-matched group, thus reducing cluster homogeneity, or be excluded from the analysis sample in order to maintain cluster homogeneity (Edelbrock & Achenbach, 1980).

LPA may be used in an exploratory fashion to reveal profiles of scores within the sample, potentially revealing important profiles that may not have been hypothesized a priori. By capitalizing on information available both across domains (i.e., relative magnitude of scores across a set of indicators) and within the continuum of severity (i.e., absolute magnitude of scores on some or all indicators), this technique facilitates the study of different patterns of comorbidity. For example, LPA may differentiate children with moderate internalizing from those with more severe internalizing symptoms, or identify 2
groups of children equally high in externalizing that are differentiated by their internalizing symptoms. This approach may also reveal whether specific symptoms within the internalizing and externalizing domains are more or less likely to be present in a comorbid symptom profile. For instance, internalizing-externalizing comorbidity may be characterized by high social withdrawal but lower anxiety.

It is important to note that an exploratory LPA reveals the latent groups that best represent a specific sample, and may lack the presumed generalizability of nationally-normed threshold techniques. However, whether developmental patterns of psychopathology are truly generalizable remains poorly understood, and the assessment of sample-specific profiles across a diverse range of samples is important (see Gatzke-Kopp, 2016). By providing characterizations of the development of psychopathology across a range of racially and socioeconomically diverse samples, assumptions of generalizability can ultimately be empirically tested. In examining the literature to date, it is apparent that many latent profiles do replicate across samples, with some key differences emerging as well.

Studies using cluster analysis or latent class analysis to characterize patterns of emotional-behavioral problems spanning the internalizing and externalizing domains have been conducted within large, nationally-representative samples of elementary school-aged children (Basten et al., 2013; Kamphaus et al., 1999; Kamphaus, Huberty, DiStefano, & Petoskey, 1997), samples characterized by high levels of poverty (Bulotsky-Shearer, Fantuzzo, & McDermott, 2010; Tolan & Henry, 1996) and samples of children drawn from clinical treatment centers (Edelbrock & Achenbach, 1980; Frankel, Hanna, Cantwell, Shekim, & Ornitz, 1992). Notably, all of these studies identified at least one class of children exhibiting co-occurring internalizing and externalizing symptoms (Basten et al., 2013; Bulotsky-Shearer et al., 2010; Edelbrock & Achenbach, 1980; Frankel et al., 1992; Kamphaus et al., 1999, 1997; Tolan & Henry, 1996). For many studies, the comorbid group was not only characterized by elevated levels across all internalizing and externalizing syndromes, but also by the degree of symptom severity, even relative to other psychopathology groups (Basten et al., 2013; Frankel et al., 1992; Kamphaus et al., 1999, 1997).
Somewhat surprisingly, several studies failed to identify a group of children exhibiting high levels of externalizing symptoms only. In most cases, the typical comorbid group (with high levels of both externalizing and internalizing symptoms) emerged as a separate class from children characterized by high externalizing symptoms and moderate elevations in at least a subset of internalizing symptoms (Basten et al., 2013; Bulotsky-Shearer et al., 2010; Frankel et al., 1992; Kamphaus et al., 1999, 1997). This pattern again highlights the value of examining the full spectrum of symptom expression rather than relying on arbitrary thresholds. With this approach, it becomes evident that individuals who may be classified as externalizing-only from a diagnostic perspective still evidence meaningful elevations in internalizing symptoms. These findings indicate that comorbidity may even be more prevalent than previously thought, if subthreshold symptom elevations are considered.

Although these studies found a tendency for children with externalizing symptoms to have elevation in at least one domain of internalizing symptoms, the studies were inconsistent in their findings about which internalizing symptoms were most likely to be elevated in this predominantly externalizing class. Basten and colleagues (2013) found that the externalizing group demonstrated elevated levels of social withdrawal but low levels of anxious and depressed symptoms. In contrast, another large-scale study within a U.S. nationally-representative sample that incorporated both parent- and teacher-rated scores found that the externalizing behavior problems were more likely to be comorbid with symptoms of depression than with social withdrawal or anxiety (Kamphaus et al., 1999, 1997). Other studies, however, reported moderate levels of both anxious/depressed and social withdrawal symptoms in their externalizing group, differing from the comorbid group only in severity (Bulotsky-Shearer et al., 2010; Frankel et al., 1992). These findings indicate that it may be important to examine which particular internalizing symptoms are most likely to co-occur with externalizing symptoms.

Importantly, a small number of studies did identify a class of children characterized by high levels of externalizing symptoms and low levels of internalizing symptoms (Edelbrock & Achenbach, 1980; McDermott & Weiss, 1995; Tolan & Henry, 1996). Among a large community sample of urban poor children, a class characterized by clinical-level externalizing severity and low internalizing
symptoms consisted of 6% of the sample (Tolan & Henry, 1996). Membership in this class was related to residence in neighborhoods with a higher density of household poverty, whereas poverty density was not related to membership in the comorbid aggressive-anxious/depressed class. Thus, the inconsistency with which studies have identified an externalizing-only class may be a function of the demographic nature of the sample under study. However, since these authors dichotomized the CBCL scale scores according to whether or not the score fell above the recommended cutoff for clinical significance, it is still possible that the children in this externalizing-only class might have shown elevated but subthreshold levels of anxiety/depression or withdrawal.

Finally, most studies have consistently identified a class of children with high levels of internalizing symptoms including depression, anxiety, and social withdrawal, and with low levels of externalizing symptoms (Basten et al., 2013; Bulotsky-Shearer et al., 2010; Edelbrock & Achenbach, 1980; Kamphaus et al., 1999). This class tended to be more clearly delineated among studies incorporating parent versus teacher ratings, which is consistent with the nature of internalizing symptoms, which may be more difficult for a teacher to detect.

**Developmental perspective on comorbidity**

To date, the majority of research on comorbid symptom profiles has been conducted cross-sectionally. Although studies have been conducted spanning the full range of childhood, little research has examined if/how individuals transition in symptom profiles over time. In the present study, children were first assessed in kindergarten, and followed annually through 2nd grade. Kindergarten represents a valuable starting point because it reflects an age in the earliest phase of reliable symptom identification, as many rating scales are designed to assess children older than age 4. Assessing children at the school age also enables the use of teacher-reported symptoms, which may be beneficial as teachers have extensive experience with same-aged children and are more likely to rate a child in reference to an appropriate comparison group than parents. This developmental step also marks the introduction of new cognitive, social and regulatory demands on children, creating a backdrop of normative development.
against which pathological symptoms are more readily apparent. Finally, the ongoing affective and
cognitive changes underway, as well as the expanding environmental contexts (e.g., the unselected peer
group) create the setting for dynamic developmental changes across these years.

In order to gain insight into the developmental course of emotional and behavioral symptoms, it is
important to move beyond the characterization of static symptom profiles to study continuity and
discontinuity of symptoms over time (Beauchaine & McNulty, 2013; Sroufe, 1997). This goal is met by
latent transition analysis (LTA), which is a longitudinal extension of LCA that models the conditional
probabilities of latent class membership at a later time point, given class membership at the earlier time
point (Collins & Lanza, 2010; Collins & Wugalter, 1992). When emotional and behavioral symptoms are
used to define the classes, this method reveals the likelihood that children exhibiting a particular pattern
of symptoms at one time point will exhibit a similar pattern of symptoms at a later time point (continuity),
as well as the likelihood that they will transition to exhibiting any of the other empirically-identified
symptom patterns at the later time point (discontinuity).

Little research has been conducted longitudinally to assess developmental continuity and
discontinuity in empirically-identified profiles or clusters of symptoms. Only one of the studies described
above conducted a follow up of the participants examined in the initial cross-sectional study (Tolan &
Henry, 1996). From the initial study of children in 1st – 6th grade, these researchers re-assessed a subset of
the 1st-, 2nd-, and 4th-grade samples two years later (n = 946) in order to test for classification stability. Not
surprisingly, 83% of the subsample was in the low probability of clinical-level problems class at both
time points, indicating a high level of stability among typically developing children. Among children
classified with a clinical diagnosis initially, however, only between 21 and 63 percent of children
remained in these same classes at the second time point, indicating at least a moderate degree of change in
symptom class over time. Unfortunately, the authors did not elaborate on which classes had the highest or
lowest stability, nor did they provide the transition probabilities between specific classes. Furthermore,
this study utilized clinical threshold classifications, making it difficult to determine whether subthreshold symptoms at earlier time points contributed to the probability of changing symptom classification.

**Present study**

The present study builds on the sparse pre-existing literature on continuity and discontinuity of childhood emotional-behavioral symptom profiles spanning both externalizing and internalizing symptom domains. LTA (Collins & Lanza, 2010; Collins & Wugalter, 1992) was used to quantify the probabilities of transitioning between latent profiles of psychopathology in a sample of high-risk children, 61% of whom were selected based on early-onset aggressive behaviors. Children were assessed by teacher report in kindergarten, 1st, and 2nd grade. Because aggression has been shown to be associated with higher levels of internalizing and externalizing, this sample is well suited to the study of comorbidity. Symptom profiles were based on multiple externalizing (aggression/oppositionality and hyperactivity/inattention) and internalizing (anxiety and social withdrawal) factors in order to examine whether comorbidity is more likely to occur between specific syndromes within the broader internalizing and externalizing domains.

We hypothesized that continuity would be high among children exhibiting a low-symptom profile initially, since these children’s behaviors should be reinforced by socialization practices in the classroom and at home. We also expected that children exhibiting a comorbid profile would show high continuity over time, with a particularly low probability of transitioning to a low-symptom profile, since internalizing-externalizing comorbidity has been associated with severe and chronic behavior problems (Ialongo, Edelsohn, Werthermer-Larsson, Crockett, & Kellam, 1996; Sourander et al., 2007). We hypothesized that children with an *externalizing* profile would be at increased risk of developing comorbid internalizing symptoms, reflecting the symptom accumulation hypothesis reviewed above. Finally, we expected that children exhibiting an internalizing profile would be most likely to transition toward a low-symptom profile, reflecting a positive adjustment to school.

Following the developmental models of comorbidity described above, we propose that the shared latent vulnerability model would be supported by a pattern of relatively high stability in a comorbid symptom profile across time with few transitions into the comorbid profile between years, whereas the
undifferentiated distress model would be supported by a reduction in the relative size of the comorbidity group across the three years with a moderate probability of children transitioning from the comorbid profile toward more clearly delineated externalizing and internalizing symptom profiles. Finally, the accumulation model would be supported by higher transition probabilities from individual symptom groups toward a comorbid group across time, although this is predicted to be more likely to occur among those with initial externalizing presentations.

2.2. Methods

Participants

The sample consists of children who participated in the PATHS to Success study, which included a randomized controlled trial of a multi-component preventive intervention targeting kindergarten children with early-onset aggressive/oppositional behaviors, as well as a developmental study of a comparison group of children with relatively low levels of aggressive/oppositional behaviors. All children were recruited from elementary schools within a single urban school district in central Pennsylvania. More details regarding recruitment can be found in Gatzke-Kopp et al. (2012). Briefly, at the beginning of the school year in 2008 (Cohort I) and 2009 (Cohort II), all kindergarten teachers completed a 10-item aggressive/oppositional behavior screening questionnaire for each child in their class. For purposes of the intervention, 207 children who had screened in the upper quartile of aggressive/oppositional behaviors within their classroom were enrolled in the study, 100 of whom were randomly assigned to the experimental condition. Children in the experimental group participated in weekly “friendship groups” along with a rotating selection of peers. These sessions took place during the second half of the kindergarten school year and the first half of the 1st-grade school year. In addition, parents of children in the experimental group received home visits by a trained parenting coach approximately once per month during this same period. Additionally, 132 comparison children who scored in the lowest quartile on the screening instrument were selected to be matched with children in the high-aggression groups on sex and classroom. For the present study, all available participants are included in the analysis sample in order to maximize sample size, which impacts the reliability of the latent class and latent transition analysis.
solutions (Yang, 2006). The full study sample thus consists of 339 children, 61% of whom displayed elevated aggressive/oppositional behaviors relative to their classmates at study entry. The analyses were conducted on the 336 children with teacher survey data in any year (see below). Parents provided informed consent and children gave verbal assent for all study procedures. The study procedures were approved by the Pennsylvania State University Internal Review Board.

Sixty-four percent of the children in the sample were male. Consistent with the demographics of the region, 70% of the children were African American, 20% were Hispanic or Latino, 9% were Caucasian, and 1% were Asian. The average age at initial screening was 5.6 years ($SD = .35$, range = $5.0 – 7.0$). Sample children lived in a community with very low socioeconomic resources; 79% of students in the district were classified as low-income (qualifying for free or reduced-price school meals), the majority of households were headed by a single mother (69%), and 79% of parents were estimated to have no more than a high school education. Regional statistics indicated that property crimes were twice as high and violent crimes were 4.5 times as high as comparable statistics for the entire state.

Measures

**Teacher ratings.** Teachers were asked to complete questionnaires regarding each participating child in the winter of the child’s kindergarten school year and in the spring of the child’s 1st- and 2nd-grade years. Teachers who returned their questionnaires received a $15 gift card as compensation for their time. Teacher surveys were completed for 301 children (89% of the sample) in kindergarten, 272 children (80%) in 1st grade, and 240 children (71%) in 2nd grade. One hundred and ninety-two children (57% of the sample) had teacher questionnaire data across all three school years, while another 93 children had data from all but one year. Only three children had no teacher questionnaire data from any school year. Participating children were equally distributed across classrooms such that all teachers had both high- and low-aggression risk children, as well as children in the experimental and control groups. When teachers declined to complete questionnaires, they did so unilaterally for all participants, and thus there is no built-in selection bias for missing teacher reports.
The present analyses utilized teacher reports of children’s externalizing symptoms, including aggressive/oppositional and hyperactive/inattentive behaviors, and internalizing symptoms, including anxiety, emotional distress, and social withdrawal. Since each of these constructs was measured across multiple survey scales (described below), an exploratory factor analysis was conducted on the individual scale items (29 in total) to identify cohesive dimensions of behavior across all survey items. These factor scores were then entered as indicators in the latent profile analysis.

*Strengths and Difficulties Questionnaire (SDQ).* Teachers responded to four behavior-problem subscales from Goodman’s (1997) SDQ: emotional symptoms, conduct problems, hyperactivity/inattention, and peer problems. Each subscale includes 5 items rated on a 3-point scale from 0 (*not true*) to 2 (*certainly true*). The emotional symptoms subscale includes items assessing worry and fearfulness (e.g., “Many worries or often seems worried”), somatic complaints (“Often complains of headaches, stomach-aches or sickness”), and emotional distress (“Often unhappy, depressed, or tearful”). The conduct problems subscale assesses aggression (“Often fights with other children or bullies them”), oppositionality (e.g., “Generally well behaved, usually does what adults request”), and antisocial behaviors (e.g., “Often lies or cheats”). The hyperactivity/inattention subscale assesses hyperactivity (e.g., “Constantly fidgeting or squirming”), impulsivity (e.g., “Thinks things out before acting”), and concentration problems (e.g., “Easily distracted, concentration wanders”). The peer problems subscale assesses the quality of children’s relationships with their peers, including social withdrawal (“Rather solitary, prefers to play alone”), peer acceptance (e.g., “Generally liked by other children”), and victimization (“Picked on or bullied by other children”). The exploratory factor analysis includes all items from the emotional symptoms, conduct problems, and hyperactivity/inattention SDQ subscales, as well as the single item assessing social withdrawal from the peer problems subscale. These items are supplemented by additional items assessing aggression/oppositionality and internalizing symptoms, particularly social withdrawal, drawn from other survey subscales (described below).

Although the SDQ subscale scores were not utilized in the exploratory factor analysis or in the subsequent latent profile analysis, the means and ranges for these scores at each assessment are presented.
in Table 2.1 in order to provide insight into the level and range of behavior problems exhibited by children in the analysis sample. Sample means suggested moderate symptom elevations on average, with particularly high mean levels of hyperactivity/inattention, and relatively high standard deviations indicated a substantial amount of heterogeneity in symptom levels. Symptom scores ranged across the full spectrum of severity on both the conduct problems and hyperactivity subscales in all 3 years. Scores on the peer problems and emotional symptoms scales had a maximum of 9 or 10, out of 10 possible points, in each year.

*Child Behavior Questionnaire (CBQ).* In addition to the SDQ, teachers completed a second behavior questionnaire with many similarly targeted items compiled for the present study. An aggression/oppositionality scale was created using seven items assessing children’s physical aggression (e.g., “Hits, pushes, or shoves”), verbal aggression (e.g., “Yells at others”), and oppositionality (e.g., “Ignores or refuses to obey adults”) drawn from the Teacher Observation of Classroom Adaptation – Revised (TOCA-R; Werthamer-Larsson, Kellam, & Wheeler, 1991). An internalizing scale was created using six items assessing children’s socially withdrawn behaviors (e.g., “Avoids playing with other children”) and internalizing symptoms (e.g., “Sad, unhappy”) drawn from an internalizing/withdrawn scale compiled for the Head Start REDI Project ([http://headstartredi.ssri.psu.edu/](http://headstartredi.ssri.psu.edu/)). All items were rated on a 6-point scale from 1 (almost never) to 6 (almost always) and scale scores were computed as the average across items.

Sample means and ranges for each year on the CBQ scales are also reported in Table 2.1. Means were very similar on both the aggression and internalizing scales and reflected moderately elevated symptoms. The range of observed scores on the aggression scale nearly covered the entire possible range of scores in each year, indicating that the sample reflects a very wide range of symptom severity. Maximum scores on the internalizing scales were slightly lower, ranging from 4.8 – 5.7 (out of a maximum possible score of 6) across years.
2.3. Results

Factor analyses

As a preliminary step, exploratory factor analyses were conducted on the 29 symptom items separately for each grade level to determine the number of factors that optimally account for the pattern of correlations among the teacher survey items. All factor analyses were conducted in Mplus 7.3 on the polychoric correlation matrix of survey items, modeling the full range of observed response categories for each variable, with pairwise deletion of missing data. Two items that exhibited substantial cross-loadings on two or more factors were removed from the analyses, yielding 27 total items contributing to the factor solutions. The appropriate number of factors to retain in each grade level was assessed using parallel analysis (Horn, 1965) and Velicer’s minimum average partial (MAP) test (Velicer, 1976) as implemented in the R psych package by William Revelle (http://personality-project.org/r/psych/). These statistics generally pointed towards a 4-factor solution in all grade levels. In each grade level, these 4 factors could be clearly interpreted as aggression/oppositionality, hyperactivity/inattention, anxiety, and withdrawal.

In order to test the measurement invariance of the 4-factor solution across grade levels, an exploratory structural equation model (ESEM; Asparouhov & Muthén, 2009; Marsh, Morin, Parker, & Kaur, 2014) was fit in Mplus in which four factors were freely estimated for each grade level simultaneously. This method essentially embeds multiple sets of exploratory factor analyses within a single structural equation model. Unlike a traditional confirmatory factor analysis approach in which items are constrained to have zero loadings on the non-hypothesized factors, in ESEM item cross-loadings are freely estimated within the specified sets of factors, allowing for a closer fit of the model to the data (Marsh et al., 2014). Furthermore, within ESEM parameter constraints may be imposed to test hypotheses such as measurement invariance, which is not possible in a traditional EFA.

For the ESEM model, the 27 ordinal survey items were entered in three grade-level blocks with four factors being freely estimated for each block of items, thus yielding three sets of four factors each. The model was conducted on the polychoric correlation matrix including all children with data in any
year \( (n = 336) \). The model was estimated using WLSMV and the resulting factors were rotated using the CF-varimax rotation algorithm (the factor solution using the oblimin rotation algorithm was very similar). Items were allowed to cross-load on all factors within a grade-level set, but item loadings on factors outside the grade-level set were fixed to 0 and no residual correlations were estimated between items within or across grade levels.

In the baseline model, the factor loadings and item thresholds were freely estimated across grade levels, and factor correlations were freely estimated among all 12 factors both within and across grade levels. For model identification purposes, all latent factors and the latent item response variables were standardized to a mean of 0 and standard deviation of 1. The fit of this model was compared to that of a model in which all factor loadings and item response thresholds were constrained to be invariant across grade levels, and the factor variances were fixed to 1 in kindergarten and freely estimated in 1st and 2nd grade. The means of the factors and the means and variances of the latent item response variables remained fixed in all grade levels. A model with invariant factor loadings and freely estimated item thresholds was not examined since the latent item response probability curve is jointly determined by these two parameters (L. K. Muthén & Muthén, 2012, p. 485), and thus both loading and threshold invariance are required if the factors are to be interpreted as reflecting the same construct over time (Marsh et al., 2014; B. Muthén & Asparouhov, 2002). In contrast, invariance of the item residuals over time is not necessary for common interpretation of the underlying factor scores (Marsh et al., 2014), and thus the fit of a model in which the residuals are held invariant over time was not examined.

The fit statistics for the baseline model and the loading- and threshold-invariant model are reported in Table 2.2. Although the \( \chi^2 \) test indicated that neither model fit the data exactly, the RMSEA, CFI, and TLI fit statistics all indicated that both models provided a close approximation of the data (RMSEAs \( \leq .02 \), CFIs > .98, TLIs > .98). Additionally, although the \( \chi^2 \) test of change in model fit was statistically significant, the magnitude of change in the model fit statistics from the baseline to the measurement-invariant model was very small (\( \Delta \text{RMSEA} = 0.002 \), \( \Delta \text{CFI} = -0.004 \), \( \Delta \text{TLI} = -0.003 \)). The \( \chi^2 \) difference test is known to be overly sensitive to minor model misfit in large samples, and therefore it has
been suggested that fit statistics assessing the degree of closeness of the model’s fit, such as RMSEA and CFI, provide more practically useful information (Browne & Cudeck, 1992; Cheung & Rensvold, 2002). Cheung and Rensvold (2002) suggest that it is reasonable to impose measurement invariance if the ΔCFI between the baseline and measurement-invariant model is less than or equal to -0.01, which was indeed the case in the present comparison. Accordingly, the loading- and threshold-invariant model was accepted as providing an acceptable fit to the data.

The factor loadings for the loading- and threshold-invariant model are provided in Table 2.3. The results replicated the overall factor structure that emerged from the within-grade EFAs, with clearly interpretable factors measuring the behavioral dimensions of aggression/oppositionality, hyperactivity/inattention, anxiety, and withdrawal. Item cross-loadings on non-primary factors were generally below 0.4, with the exception of the item assessing the child’s attention span, which loaded primarily on the hyperactivity/inattention factor ($\lambda = -0.748$) with a moderate cross-loading on the withdrawal factor ($\lambda = -0.419$).

Factor scores were calculated from the latent factor model using Mplus. Although factor scores fail to account for measurement error in the factor model, they are generally preferable to simple scale scores because they more closely approximate the dimensions of behavior represented by the latent factors (Marsh et al., 2014). In order to reduce the degree of uncertainty and bias in the estimated factor scores when used as independent variables in the latent profile analyses, factor scores were dropped if over half of the items with a loading of 0.6 or higher on that factor were missing.

Univariate statistics for these factor scores are provided in Table 2.4, and the correlations among factor scores are provided in Table 2.5. Within years, all factor scores tended to be positively correlated (suggesting the presence of a general behavior-problems factor), although the highest correlations were found between the aggression/oppositionality and hyperactivity/inattention factors ($r^{'s} = .55-.65$) and between the anxiety and withdrawal factors ($r^{'s} = .47-.59$). Across years, there was moderately high stability in children’s aggression (kindergarten to 1st grade: $r = .68$; 1st to 2nd grade: $r = .77$) and hyperactivity/inattention (kindergarten to 1st grade: $r = .71$; 1st to 2nd grade: $r = .82$). Relatively lower
cross-year stability was observed for children’s anxiety (kindergarten to 1st grade: $r = .36$; 1st to 2nd grade: $r = .50$) and withdrawal (kindergarten to 1st grade: $r = .53$; 1st to 2nd grade: $r = .56$).

**Latent transition analysis**

An LTA was conducted with the 4 symptom factor scores in order to

1. identify latent groups of children having particular profiles of scores across these four dimensions of behavior, and

2. examine continuity and discontinuity in these behavioral profiles across kindergarten, 1st, and 2nd grade.

**LTA model selection.** The first task was to identify the number of latent profiles that best characterize the children in this sample. This question was addressed in an exploratory fashion by fitting latent profile models with increasing numbers of latent profiles and using relative model information criteria, including Akaike’s Information Criterion (AIC), the Bayesian Information Criterion (BIC), and the sample-size adjusted Bayesian Information Criterion (aBIC), to select the number of profiles that optimizes the balance between model fit and complexity (Akaike, 1974; Schwartz, 1978; Sclove, 1987).

In all models, the same number of profiles was estimated in kindergarten, 1st, and 2nd grade. The factor score means and variances were allowed to vary freely across profiles within a given year, thus allowing the profiles to be distinguished by differences in both mean factor scores and variances around these mean scores. Although LPA studies frequently constrain variances to be equal across profiles in order to reduce the number of parameters that must be estimated, this constraint yielded substantially poorer model fit in the present sample. As is typical in LPA, the correlations between factor scores within each profile were fixed to 0 (i.e., the factor scores were assumed to be independent conditional on latent profile membership).

During model selection, measurement invariance was imposed by constraining the factor score means and variances within each profile to be equal across all years (the appropriateness of this assumption was later tested for the final selected model). The number of random starts was set at 2,000 initial-stage starts and 500 final-stage optimizations in order to obtain a well-identified maximum-
likelihood solution. All models were conducted on the full sample of 336 children who had data in any year using full-information maximum likelihood estimation, which uses all available data assuming data are missing at random.

Model fit information for the 2- through 6-profile solutions are provided in Table 2.6 and the relative information criteria are plotted in Figure 1. BIC values decrease steadily through the 4-profile solution, are essentially the same for the 4- and 5-profile solutions, and increase in the 6-profile solution. Unlike the BIC, the AIC and aBIC values continue to decrease through the 6-profile solution; however, the rate of decrease progressively slows between the 4-, 5-, and 6-profile solutions, indicating smaller relative improvements in model fit. Thus, the relative information criteria point towards either the 4- or the 5-profile model as being optimal.

It is common for relative information criteria to fail to unambiguously select an optimal model in latent profile analysis, and in such cases the interpretability of differences between profiles and the theoretical meaningfulness of the profile solutions must be considered. Therefore, the profile solutions yielded by the 4- and 5-profile models were compared. The 4-profile model yielded the following profiles: (1) well-adjusted, with very low scores on all internalizing and externalizing factors, (2) internalizing, with very low scores on both externalizing factors and elevated scores on both internalizing factors, (3) externalizing, with elevated scores on both externalizing factors and lower scores on both internalizing factors, and (4) comorbid, with high scores on all externalizing and internalizing factors. The 5-profile model yielded profiles that were very similar to those from the 4-profile model except that the comorbid profile was split into two profiles that were characterized by elevations in both externalizing and internalizing scores, one of which had very high externalizing scores (particularly hyperactivity/inattention) and only moderately high internalizing scores, and the other of which had very high internalizing scores, high aggression, and only moderately high hyperactivity/inattention. Thus, both the 4- and 5-profile models provided solutions with interpretable and well-separated profiles. However, the theoretical significance of the distinction between the two comorbid symptom profiles that were identified in the 5-profile solution is not entirely clear.
In order to check the robustness of the 4- and 5-profile solutions, both models were also tested in separate latent profile analyses incorporating two of the three data collection years, i.e., (1) kindergarten and 1st grade, (2) 1st and 2nd grade, and (3) kindergarten and 2nd grade. The 4-profile model was consistently replicated across all three 2-year LPAs, however the 5-profile model was not consistently replicated, with a particularly divergent solution in the 1st- and 2nd-grade LPA. Thus, the 5-profile solution did not appear to be as robust as the 4-profile solution. Based on this observation, as well as the greater parsimony of the 4-profile solution and the conclusion that the 5-profile solution did not make a strong substantive improvement on the 4-profile solution, all further analyses were conducted using the 4-profile solution.

The appropriateness of the measurement-invariance assumption, which constrains within-profile means and variances to be identical in all three years, was tested by comparing the fit of the measurement-invariant model to that of a model in which all within-profile factor score means and variances were freely estimated across all years (i.e., the unconstrained model). The likelihood-ratio test between these models was significant ($\Delta-2LL = 107.1$, $\Delta df = 64$, $p < .001$), indicating a greater-than-zero reduction in absolute model fit to the data as a result of the measurement invariance constraints. However, the AIC, BIC, and aBIC were all higher in the unconstrained model relative to the measurement-invariant model ($\Delta AIC = 20.9$, $\Delta BIC = 265.2$, $\Delta aBIC = 62.2$), suggesting that the measurement-invariant model was the more optimal model in terms of the balance between model fit and parsimony. Additionally, examination of the profile solutions for each year in the model without measurement invariance constraints (not reported) revealed that a remarkably similar solution is reached across all three years, and that this solution was very similar to that obtained in the measurement-invariant model. Therefore, the measurement-invariant model was used for all further analyses. This allows the interpretation of the profiles to remain constant between kindergarten, 1st, and 2nd grade.

The final question to be addressed in selecting the optimal LTA model was that of stationarity of transitions between the profiles over time. The LTA model included first-order autoregressive associations between the profiles such that profile membership probabilities in 1st and 2nd grade were
estimated conditional on profile membership in the prior year. Initially, the probabilities of transitioning from a given profile in one year to each profile in the following year were freely estimated. This model was compared to a stationary model in which the corresponding profile transition probabilities were constrained to be equal across years. The stationary model did not result in significantly poorer fit to the data ($\Delta -2LL = 19.2$, $\Delta df = 12$, $p = .08$), and the AIC, BIC and $\alpha$BIC were all lower in the stationary model relative to the model in which transition probabilities were freely estimated across years ($\Delta$AIC $= -4.8$, $\Delta$BIC $= -50.6$, $\Delta$\alphaBIC $= -12.5$), suggesting that the stationary model provided a more optimal balance between fit and parsimony. Furthermore, given the relatively short developmental duration reflected here, it is not clear whether theoretically meaningful distinctions can be drawn from changes in transition probabilities from kindergarten to 1st grade relative to 1st to 2nd grade. For these reasons, the stationary model was selected for all further analyses.

**LTA results: Profile structure.** The parameter estimates from the 4-profile measurement-invariant LTA solution are reported in Table 2.7. These estimates include the prevalence of each profile in each year and the factor score means and variances that define each profile. To facilitate interpretation of the profiles, the factor score means for each profile are also plotted in Figure 2 (for visual clarity, the factor score variances are not plotted). Tests of the statistical significance of the differences in factor score means across profiles revealed that all factor score means were significantly different between each pair of profiles ($p$’s $< .05$), with the exception of anxiety, which was equivalent in the comorbid and internalizing profiles. In interpreting the factor score means, it is important to note that each factor score has a sample mean of roughly 0. Since 61% of the children in the present study were selected based on teacher reports of early-emerging aggressive behaviors, the sample mean on the aggression/oppositionality factor score in particular reflects elevated levels of aggression relative to a non-selected community sample.

The four profiles can be described as: *comorbid, externalizing, internalizing*, and *well-adjusted*. In the present sample of at-risk children, the *comorbid* profile had by far the highest prevalence, making up 48% of the sample in each year. This profile was characterized by elevated scores across all four
internalizing and externalizing behavior-problem dimensions. Specifically, this profile exhibited the highest scores on aggression/oppositionality, hyperactivity/inattention, and withdrawal, with anxiety scores equal to those of the internalizing profile. The externalizing and internalizing profiles had similar prevalence rates, each composing roughly 20% of the sample in each year. The externalizing profile was characterized by moderate levels of aggression/oppositionality and hyperactivity/inattention, and relatively low levels of anxiety and withdrawal. More specifically, the externalizing profile had mean scores on aggression/oppositionality and hyperactivity/inattention that were lower than those of the comorbid profile but much higher than those of the internalizing and well-adjusted profiles, along with mean scores on anxiety and withdrawal that were lower than those of the comorbid and internalizing profiles but slightly higher than those of the well-adjusted profile. The internalizing profile was characterized by high levels of anxiety, moderately high withdrawal, and low levels of both aggression/oppositionality and hyperactivity/inattention. Specifically, this profile had mean scores on aggression/oppositionality and hyperactivity/inattention that were much lower than those of the comorbid and externalizing profiles but still slightly higher than those of the well-adjusted profile, mean scores on anxiety that were much higher than those of the externalizing and well-adjusted profiles and equivalent to those of the comorbid profile, and mean scores on withdrawal that were much higher than those of the externalizing and well-adjusted profiles but significantly lower than the comorbid profile. Finally, the well-adjusted profile had the lowest prevalence at just 7% to 11% of the sample in each year (ranging from 22 children in kindergarten to 38 children in 2nd grade). This profile was characterized by the lowest scores across all four internalizing and externalizing factors. In addition, the variances around the mean factor scores within this profile were markedly lower than those for any other profile, indicating higher within-profile homogeneity.

**LTA results: Profile transition probabilities.** Continuity and discontinuity in children’s behavioral profiles over time is reflected in the estimated probability of membership in each profile conditional on prior profile membership, i.e., the profile transition probabilities. As described above, the model assumed stationarity of profile transitions over time, and therefore only one set of profile transition
probabilities was estimated across both the kindergarten to 1st-grade and the 1st-grade to 2nd-grade intervals. Sparseness of the conditional profile membership probability matrix was handled by allowing Mplus to fix regression parameters as necessary to estimate 0 probability values for extremely unlikely transitions. The resulting transition probabilities are reported in Table 2.8. In this table, the rows represent prior profile membership and the columns represent later profile membership. The value in each cell represents the probability of being in the column profile conditional on previous membership in the row profile. The top panel of Table 2.8 presents the profile transition probabilities for adjacent years (i.e., 1-year intervals, with the transition probabilities held constant across each interval), which are directly derived from the model-estimated latent logistic regression parameters regressing each year’s profile membership on the prior-year profile membership. The second panel presents the cumulative transition probabilities over the full 2-year interval between kindergarten and 2nd grade (regardless of 1st-grade profile membership). These probabilities were calculated from the cross-tabulation of profile membership probabilities in each year produced by Mplus based on the estimated model. For both panels, continuity in symptom profiles over time is reported in the diagonal cells.

Overall, there was high continuity in symptom profiles over time. The highest continuity was observed for the comorbid profile; from one year to the next, 89% of these children continued to exhibit comorbid symptoms and only 10% transitioned to an externalizing profile. Over the full 2-year interval, 82% of children who were comorbid in kindergarten continued to exhibit comorbidity in 2nd grade. Nearly all cases of discontinuity among children in the comorbid profile were accounted for by transitions into the externalizing profile (16% over the course of 2 years). The probability of children who manifested comorbidity differentiating toward the internalizing profile or remitting to the well-adjusted profile was effectively 0.

The internalizing profile also showed high continuity, although not as high as that of the comorbid profile. From one year to the next, 80% of internalizing children continued to exhibit this profile, with the remainder (20%) remitting to the well-adjusted profile. Across the full 2-year interval, 68% of those who had exhibited internalizing symptoms in kindergarten continued to exhibit this profile.
in 2nd grade, and 29% had remitted to the well-adjusted profile. The probability of internalizing children transitioning to either the externalizing or comorbid profile was effectively 0, indicating that internalizing symptoms did not predict the additional accumulation of externalizing symptoms.

Among children exhibiting an externalizing profile, from one year to the next 71% continued to exhibit this symptom profile, 25% transitioned to a comorbid profile, and 5% showed a remission of symptoms. Across the full 2-year interval, 53% of children classified as externalizing in kindergarten continued to exhibit this profile in 2nd grade. Of the 47% of externalizing children who exhibited symptom profile discontinuity over the 2-year interval, the majority (40%) transitioned to a comorbid profile, thereby evidencing an additional accumulation of internalizing symptoms. Only a small proportion (6%) transitioned from an initial externalizing presentation into the well-adjusted profile by 2nd grade, and essentially none transitioned to an internalizing profile.

Somewhat surprisingly, year-to-year continuity was lowest for the well-adjusted profile. Adjacent-year continuity for this profile was 64%, with moderate probabilities of transitioning to both the internalizing (22%) and externalizing (15%) profiles. Across the full 2-year interval, only 46% of children classified as well-adjusted in kindergarten continued to exhibit this profile in 2nd grade, while 31% had transitioned to the internalizing profile and 20% had transitioned to the externalizing profile. Not surprisingly, the probability of a direct transition from the well-adjusted profile to the comorbid profile was effectively 0. In interpreting these transition probabilities, it is important to note that only 22 children were classified as well-adjusted in kindergarten. Given this low base rate, these transition probabilities reflect the movement of just a few children (e.g., the 31% transitioning to an internalizing profile by 2nd grade reflects only 7 children). Therefore, the precision and replicability of these transition probabilities may be lower for the well-adjusted profile relative to the other profiles.

A schematic diagram of the pattern of transitions between symptom profiles is provided in Figure 3. Each symptom profile is represented by a circle positioned roughly according to the profile’s severity on the externalizing and internalizing dimensions, which constitute the axes of the graph. The size of the circle approximates the prevalence of the profile in the present sample. Transitions between profiles with
a probability of at least 5% (rounding to the nearest whole number) are illustrated by arrows connecting the circles.

2.4. Discussion

Results from the present analyses provide an exploratory and descriptive examination of internalizing and externalizing symptom profile dynamics across the early school years. A latent profile analysis (LPA) conducted on children’s aggression/oppositionality, hyperactivity/inattention, anxiety, and social withdrawal in kindergarten, 1st, and 2nd grade suggested that children’s patterns of symptoms across these factors coalesce into four profiles that are present in all three years. Consistent with both the high-risk sample demographics and the study design, which over-selected children evidencing higher aggressive/oppositional behaviors relative to their peers, two of the four profiles identified were characterized by elevated levels of externalizing symptoms and collectively represented about 70% of the sample. By far the most prevalent of these profiles, making up nearly 50% of the sample, was a comorbid group characterized by high levels of both externalizing and internalizing symptoms. An additional 20% of the sample fit an externalizing profile with moderate externalizing symptoms and lower internalizing symptoms. Although participants were oversampled for elevated externalizing symptoms, no criterion regarding internalizing symptoms was applied. Thus, the predominance of internalizing symptom comorbidity among children exhibiting early externalizing symptoms suggests that this type of comorbidity is the norm rather than the exception, consistent with prior research (Bird et al., 1993; Epkins, 2000). Additionally, the higher severity of externalizing symptoms in the comorbid profile relative to the externalizing profile is consistent with prior research showing that groups of children with internalizing-externalizing comorbidity tend to have the most severe symptoms (Basten et al., 2013; Frankel et al., 1992; Kamphaus et al., 1999, 1997; Polier, Vloet, Herpertz-Dahlmann, Laurens, & Hodgins, 2011).

Although no screening procedure was used to select for internalizing symptoms, a profile emerged characterized by elevated levels of anxiety and social withdrawal in the absence of externalizing symptoms, representing approximately 20% of the sample. Surprisingly, the well-adjusted profile,
characterized by the absence of any internalizing or externalizing symptoms, captured only about 10% of the sample. It is possible that the sampling strategy of selecting comparison children who were low on externalizing symptoms inadvertently oversampled for children whose anxious withdrawal served to inhibit any oppositional or aggressive behavior.

A latent transition analysis (LTA) was conducted to model the probability of transitioning between each set of profiles across adjacent years. The findings revealed high levels of continuity across years for the externalizing, internalizing, and comorbid symptom profiles. This high degree of continuity is particularly notable given that a different teacher completed the symptom checklists in each year. The LTA also revealed that the externalizing profile, but not the internalizing profile, was associated with a moderately increased risk for emergent internalizing-externalizing comorbidity. Additionally, children with an internalizing profile were much more likely to show full symptom remission than were children who exhibited externalizing symptoms.

**Does the developmental course of comorbidity fit a common vulnerability, accumulation, or differentiation model?**

The comorbid profile comprised nearly half of the study sample in kindergarten, and this proportion did not change substantially over the years. Continuity in this profile was very high, ranging from 82% to 89% depending on the time interval. Additionally, the emergence of new comorbid cases was relatively rare; 81% of the children exhibiting a comorbid profile in 2nd grade had already exhibited a comorbid profile in kindergarten. The high prevalence and stability of the comorbid profile is consistent with the common vulnerability model. According to this model, internalizing-externalizing comorbidity would likely be present early in childhood as a result of a common vulnerability that predisposes toward the expression of symptoms in both domains. This model would likewise predict high continuity of the comorbid profile and low rates of developmentally emergent comorbidity, since the underlying vulnerability is not likely to change over time.

Although the present study does not provide insight into the nature of this common vulnerability factor, strong candidates for intermediate phenotypes include negative affectivity (Mikolajewski et al.,
2013; Rhee et al., 2015; Tackett et al., 2013) or emotion dysregulation (Beauchaine, 2015), and in some cases reward insensitivity (Andrews et al., 2011; Brenner & Beauchaine, 2011; Forbes & Dahl, 2005). At the neural level, negative affectivity is associated with exaggerated reactivity of threat-response circuitry (Whittle et al., 2006), which has been linked to genetic variation in central serotonergic functioning (Canli & Lesch, 2007; Murphy et al., 2013). Indeed, genetic markers of serotonergic function have been implicated in risk for anxiety, depression, and reactive aggressive (Beitchman et al., 2006; Karg, Burmeister, Shedden, & Sen, 2011; Lesch et al., 1996; Lesch & Merschdorf, 2000). Additionally, disruptions in prefrontal-limbic connectivity are associated with emotion dysregulation and risk for both internalizing and externalizing psychopathology (Beauchaine, 2015). Finally, reward insensitivity is linked to underactivation of the mesolimbic dopamine system (Brenner & Beauchaine, 2011; Neuhaus & Beauchaine, 2013) and has been implicated in sensation-seeking behaviors in externalizing disorders (Neuhaus & Beauchaine, 2013) and in anhedonic symptoms in depression (Treadway & Zald, 2014). One or more of these underlying factors could predispose toward stable expression of both internalizing and externalizing symptoms when combined with adverse environmental circumstances (Beauchaine & McNulty, 2013; Sroufe, 1997), which are likely experienced by many children in the present study given the high-risk sample demographics.

The findings of the present study do not provide strong support for the differentiation model of comorbidity, which suggests that comorbidity early in childhood may reflect nonspecific emotional-behavioral dysregulation that differentiates over the course of development into more “pure” internalizing or externalizing symptom presentations based on the child’s experiences. Year-to-year transitions from the *comorbid* profile to the *internalizing* profile were very rare (1.1%), and transitions to the *externalizing* profile were only slightly more common (9.8%). It is worth noting that these transitions to the *externalizing* profile are likely to reflect a decrease in symptom severity across all 4 symptom factors, with an especially pronounced decrease in internalizing symptoms. This could reflect a delayed adjustment to the transition to school that may have exacerbated symptom expression during kindergarten for some children. Although these results suggest that comorbidity present in childhood is already highly
stable, with very little evidence of differentiating toward single-domain profiles, participants were only followed through 2\textsuperscript{nd} grade. Whether children with comorbid symptom profiles differentiate toward single-domain symptom profiles in later childhood or adolescence requires further study.

Although the findings generally support the common vulnerability model, some evidence for the accumulation hypothesis was evident specifically for the pathway whereby externalizing symptoms increase the risk for the additional acquisition of internalizing symptoms. Research has proposed that internalizing symptoms develop as the social consequences of externalizing problems, such as peer rejection, begin to take an emotional toll (Gooren, van Lier, Stegge, Terwogt, & Koot, 2011; Ladd & Troop-Gordon, 2003; van Lier & Koot, 2010), and thus this model does not necessarily imply a common mechanism underlying symptoms in both domains. In the present study, having a profile of moderate externalizing symptoms was associated with a 25\% probability of transitioning to a comorbid internalizing-externalizing profile in the following year, and a 40\% probability of developing comorbid symptoms within 2 years. Conversely, consistent with prior literature (Gilliom & Shaw, 2004; Keiley, Bates, Dodge, & Pettit, 2000), having an internalizing symptom profile was associated with extremely low risk of later developing comorbid symptoms. Although there was clear evidence of transitions from externalizing to comorbid profiles, it is important to note that this pathway only accounts for a small percentage of comorbid symptom presentations in the present sample, with fewer than 20\% of the children classified as comorbid in 2\textsuperscript{nd} grade having exhibited an externalizing profile in kindergarten.

Since 60\% of kindergarten externalizing children did not develop comorbid internalizing symptoms by 2\textsuperscript{nd} grade, future research should investigate the factors that predict which externalizing children are likely to develop emergent internalizing-externalizing comorbidity. It is possible that the children who do not develop comorbid internalizing symptoms may experience fewer negative consequences of their externalizing behaviors, such as peer-rejection. For instance, some children may appear hyperactive, inattentive, and oppositional from the teacher’s perspective but still manage to succeed socially with peers. It is also possible that some externalizing children are less capable of internalizing the consequences of their actions, and may not experience rejection from peers in the same
way that individuals prone to anxiety do. Research has identified cognitive biases among children with externalizing problems such that their estimation of their own social standing can be highly discrepant from actual peer perceptions and social relationships (Gresham, MacMillan, Bocian, Ward, & Forness, 1998). These types of unrealistic attributional tendencies may be explained by neurobiological theories of hyperactivity/impulsivity. Dopaminergic deficiencies observed in both rodent models and human studies indicate a deficiency in the ability to identify contingent associations between behavior and adverse consequences (Gatzke-Kopp et al., 2009; Sagvolden, Johansen, Aase, & Russell, 2005). Externalizing children with such underlying deficiencies in recognizing the consequences of their behaviors may be more likely to see rejection from peers as arbitrary and unfair, and therefore be more likely to react with anger than sadness. Thus, it is possible that among children with elevated externalizing symptoms in kindergarten, different neural vulnerabilities predispose children toward or away from the likelihood of developing comorbidity.

**Continuities and discontinuities in symptom profiles**

The strikingly high continuity of the comorbid symptom profile across the first three years of school is consistent with prior studies suggesting that comorbidity of internalizing and externalizing symptoms is associated with particularly high risk for pervasive and persistent adjustment problems (Ialongo et al., 1996; Sourander et al., 2007). The presence of comorbidity has been associated with more severe consequences than either internalizing or externalizing symptom profiles alone. Children with internalizing-externalizing comorbidity are more likely to experience academic struggles (Yoo, Brown, & Luthar, 2009) and to be rejected and victimized by peers (Harrist, Zaia, Bates, Dodge, & Pettit, 1997; Ladd & Burgess, 1999). These adverse experiences create a positive feedback loop, reinforcing both internalizing and externalizing symptoms over time (Hymel, Rubin, Rowden, & LeMare, 1990; Ladd, 2006; Moilanen, Shaw, & Maxwell, 2010; van Lier & Koot, 2010). The developmental persistence of comorbid symptoms underscores the importance of identifying interventions that are effective for the sizable proportion of children who show mixed emotional and behavioral problems at school entry.
In the present study, moderately high continuity was also observed for the *externalizing* symptom profile, with 53% of *externalizing* kindergarteners continuing to show this same profile of symptoms in the spring of 2nd grade. Importantly, another 40% of *externalizing* kindergarteners transitioned into the *comorbid* symptom profile, which was characterized by even higher mean externalizing symptom severity along with high internalizing symptom severity. Thus, 93% of children with an *externalizing* profile in kindergarten continued to show externalizing symptoms, with or without comorbid internalizing symptoms, in 2nd grade. This continuity rate is higher than that typically found in studies utilizing threshold-based approaches to classify children as disordered versus non-disordered, which tend to yield externalizing disorder persistence estimates of 40 to 50% over similar time periods (Lavigne et al., 1998; McConaughy, Stanger, & Achenbach, 1992; Verhulst & Althaus, 1988). The high continuity of externalizing symptoms observed in the present study may reflect a strength of the latent transition analysis technique, which takes advantage of the richness of information available from continuous symptom scales collected over multiple occasions. Indeed, studies have shown that continuous symptom scales show higher stability over time than do threshold-based classifications of psychopathology (McConaughy et al., 1992). In the present study, the *externalizing* profile likely included many children who would fall below conventional cutoffs for “clinically-significant” externalizing psychopathology, yet this profile of symptoms was highly persistent over time and was associated with substantial risk for developing more severe comorbid symptoms. Had a threshold-based classification approach been used, the marked persistence of relatively moderate externalizing behaviors and the associated risk for worsening symptoms would likely have been missed.

In interpreting the low externalizing symptom remission rate in the present study, however, it is important to note that the *well-adjusted* profile was characterized by extremely low symptom levels, rather than by the absence of high symptom levels. Thus, children showing modest decreases in externalizing symptoms over time may still have been classified in the *externalizing* profile because their symptoms did not decrease to the level of the *well-adjusted* profile. From this perspective, the low remission rate for externalizing symptoms in the present study is consistent with prior studies that
distinguish between symptom improvement and full remission of symptoms. For example, in a large-scale study of children’s emotional-behavioral symptoms over the course of two years, Verhulst and Althaus (1988) observed that 46% of children who were initially above the 90th percentile on the Child Behavior Checklist were below this cutoff two years later, indicating a substantial rate of symptom improvement, however only 5% of those initially above the cutoff were within the “normal” range (below the 50th percentile) two years later, indicating a very low rate of full symptom remission.

Finally, the continuity of externalizing symptoms in the present sample must be interpreted in light of social-contextual factors. The sample was drawn from a low-income, urban school district with high levels of neighborhood crime, low average parental education levels, and a high proportion of single-parent households. These sample characteristics are associated with heightened risk for externalizing problems (McLoyd, 1998) and are therefore likely to contribute to particularly high continuity of these problems. Research on samples from diverse socioeconomic backgrounds will be required to ascertain the generalizability of the symptom continuity rates observed in the present study.

In contrast to the extremely low rates of symptom remission observed for the externalizing and comorbid profiles, kindergarteners exhibiting an internalizing profile had a moderate (29%) probability of remitting by 2nd grade. It is possible that these remitting internalizing children had only temporarily displayed noticeable anxiety and social withdrawal as a response to the transition to school, which can be particularly stressful for children with a predisposition toward social anxiety (Coplan & Arbeau, 2008), and that these symptoms subsided as they adjusted to the social demands of school. Despite the moderate probability of remitting by 2nd grade, the continuity of internalizing symptoms observed in the present study is still substantially higher than that frequently observed in studies using “clinically-significant” threshold-based classifications (McConaughy et al., 1992; Verhulst & Althaus, 1988). This provides further evidence in support of the power of the latent transition analysis technique to detect developmentally stable symptom profiles. Interestingly, the probability of transitioning from the comorbid profile to a profile characterized by low internalizing symptoms (either externalizing or well-adjusted) was roughly half of the probability of transitioning from the internalizing profile to a profile
with low internalizing symptoms, suggesting that internalizing symptoms may be more persistent when
paired with co-occurring externalizing symptoms. This observation is consistent with the research cited
above on the particularly high persistence of comorbid internalizing-externalizing disorders, as well as the
tendency for externalizing psychopathology to be associated with increased risk for subsequent
internalizing psychopathology.

It is important to note that, despite the high prevalence of the comorbid profile in all years, the
chance that a child exhibiting either an internalizing or an externalizing symptom profile would transition
to the other profile in a later year was exceedingly low. Thus, in addition to the hypothesized common
vulnerability factor predisposing toward both internalizing and externalizing symptoms, there must also
be differential risk factors that increase the risk for one domain of symptoms over the other, thereby
maintaining distinct developmental trajectories among children who are either high or low on these
factors. The traits of behavioral inhibition and impulsivity are clear candidates for such differential risk
factors (Beauchaine, 2015). Excessive behavioral inhibition has been robustly demonstrated to be a risk
factor for internalizing psychopathology (Rosenbaum, Biederman, Bolduc-Murphy, Faraone, Chaloff,
Hirshfeld, & Kagan, 1993), whereas trait impulsivity is a well-established precursor to all forms of
externalizing psychopathology (Beauchaine & McNulty, 2013; Clark, 2005). Comorbidity may be most
likely to emerge in individuals who are high on a common vulnerability factor, such as negative
affectivity or emotion dysregulation, and who exhibit moderate levels on differentiating risk factors such
as behavioral inhibition versus impulsivity.

Is there an “externalizing only” profile?

Several previous studies using exploratory latent profile or cluster analysis of symptom scales
have failed to identify a group of children characterized by high externalizing symptoms in the absence of
internalizing symptoms (Basten et al., 2013; Bulotsky-Shear et al., 2010; Frankel et al., 1992;
Kamphaus et al., 1999, 1997). In the present study, two profiles were identified with elevated scores on
externalizing factors, and notably neither of them had internalizing scores as low as those in the well-
adjusted profile. The highest externalizing scores were observed within the comorbid profile, which was
also characterized by high anxiety and the highest levels of social withdrawal of any profile. The majority of children with externalizing symptoms in the present sample fit this profile, suggesting that severe externalizing symptoms are most often accompanied by high levels of internalizing symptoms as well. The \textit{externalizing} profile was characterized on average by more moderate levels of externalizing symptoms and lower levels of internalizing symptoms, however the mean anxiety and withdrawal scores for this profile were still significantly higher than those for the \textit{well-adjusted} profile. Thus, this profile also does not appear to represent a true “externalizing-only” profile. The lack of a true externalizing-only profile may indicate that such a profile is rare, and reflective of psychopathic tendencies that occur with extremely low frequency.

It is important to note that frequent failure of studies using exploratory latent profile or cluster analysis techniques to identify an externalizing-only profile is in contrast to studies that employ threshold-classification approaches, and highlights the descriptive value of these exploratory techniques, which maximize symptom information along a full continuum. Indeed, since the mean externalizing factor scores in the \textit{externalizing} profile were not significantly higher than the sample mean for these factors in the present study, if a threshold/diagnostic classification approach had been used this group may have been classified as typically developing or excluded due to the subthreshold elevations in externalizing symptoms. Such an approach would have missed important distinctions between this moderately-externalizing group and truly well-functioning children, such as their heightened risk for developing comorbid internalizing-externalizing symptoms.

\textbf{Syndrome-level patterns of co-occurrence}

In the present study, the internalizing domain was represented by anxiety and social withdrawal factors, and the externalizing domain was represented by aggression/oppositionality and hyperactivity/inattention factors. These factors reflect well-recognized emotional-behavioral syndromes that are often examined independently. By measuring multiple syndromes within the broader internalizing and externalizing domains, it is possible to address the question of whether certain syndromes are particularly likely to exhibit cross-domain comorbidity (Vaidyanathan, Patrick, & Iacono, 2011).
The profiles that emerged in the present study were generally characterized by similar levels on the two factors within each domain, consistent with a view of these syndromes as reflecting underlying, perhaps genetically mediated, internalizing and externalizing factors (Carragher et al., 2015). The comorbid profile in this sample was equally elevated on aggression/oppositionality, hyperactivity/inattention, anxiety and social withdrawal, indicating that none of these syndromes was differentially likely to exhibit cross-domain comorbidity. The only potential case of within-domain syndrome differentiation was observed for the internalizing profile, which exhibited slightly higher elevations in anxiety than in social withdrawal. In fact, this profile had significantly lower social withdrawal scores than did the comorbid profile, despite the two sharing very similar elevations on the anxiety factor. This finding is consistent with prior research showing that children with internalizing-externalizing comorbidity are particularly likely to experience peer rejection and victimization (Harrist et al., 1997; Ladd & Burgess, 1999), which may increase their inclination to withdraw from social interactions as a defensive strategy. Peer rejection of children exhibiting comorbid symptoms is likely to be a consequence of these children’s inappropriate social behaviors. In contrast, it is possible that elevated anxiety symptoms in the absence of comorbid externalizing symptoms could motivate a desire to engage in appropriate social behavior, thereby partially counteracting the fear of social interaction experienced by many anxious children. Anxiety has been associated with increased sensitivity to negative social feedback (Cremers, Veer, Spinhoven, Rombouts, & Roelofs, 2014), which could enhance the rate at which anxious children learn through experience how to adjust their behaviors to improve their social interactions and gain acceptance by their peers. In contrast, anxious children with comorbid externalizing symptoms may lack this social awareness and motivation.

**Limitations**

The high demographic risk of the population from which the participants were selected likely had a significant effect on the prevalence of the different profiles, as well as rates of continuity in symptom profiles over time. This raises important issues related to generalization and representation. If study results can only be interpreted to represent the very specific sample from which the data were drawn, the
proliferation of descriptive studies may not suffice to propel the field forward. However, if findings cannot be assumed to generalize, it is imperative that the literature represent a diverse range of populations, with guidance as to whom specific studies can be considered to represent (Gatzke-Kopp, 2016). It is very likely, however, that core classifications are largely consistent across populations, with sample-specific factors directly influencing the prevalence of profile membership rather than the structure of the latent profiles themselves. For instance, epidemiological research with an adult sample found the structure of a dimensional and multivariate model of comorbidity fit equally well for both males and females, with sex affecting only the prevalence of specific dimensions (Eaton et al., 2012). Similarly, the structure of psychiatric comorbidity has been shown to be invariant across ethnic categories, with ethnicity affecting only the prevalence of symptoms (Eaton et al., 2013). It is also likely that the general pattern of transitions between profiles over time is generalizable across samples, even if the specific transition probabilities may vary.

Additionally, when comparing the present results to other studies, the age range and sampling interval of the present study must be considered. This study examined continuity and discontinuity in symptom profiles over the first few years of formal schooling. Studies over longer time intervals are likely to find lower continuity rates than those observed here. Additionally, the developmental patterns observed in the present study cannot be assumed to generalize across different age ranges. In particular, key periods of developmental change, such as puberty, may be expected to alter these developmental processes. The developmental dynamics of children’s latent symptom profiles over longer time intervals or across different developmental periods require further investigation.

2.5. Summary

This study is one of the first to employ LTA to characterize latent profiles of continuous externalizing and internalizing symptom factors and quantify the dynamics in internalizing-externalizing symptom profile membership across the early school years. This sample was assessed at the start of formal schooling, thus capturing early developmental manifestations of symptom expression. These results indicate a strong degree of continuity for psychopathology, and do not clearly support the
hypothesis that symptom presentation is in flux among younger children. In contrast, comorbid internalizing-externalizing symptoms at this age appear to be highly stable and prevalent as early as kindergarten, providing support for a common vulnerability model of comorbidity. However, moderate externalizing symptoms do appear to increase the risk for the development of comorbidity in a subset of participants, providing some support for a symptom accumulation model of comorbidity by which externalizing symptoms indirectly increase the risk of developing internalizing symptoms.


Table 2.1. Characteristics of the analysis sample in all years.

<table>
<thead>
<tr>
<th></th>
<th>Kindergarten</th>
<th></th>
<th>1&lt;sup&gt;st&lt;/sup&gt; Grade</th>
<th></th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; Grade</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
<td>Mean (SD)</td>
<td>Range</td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td>Age</td>
<td>6.1 (0.4)</td>
<td>5.4 – 7.5</td>
<td>7.2 (0.4)</td>
<td>6.6 – 8.6</td>
<td>8.2 (0.3)</td>
<td>7.5 – 9.3</td>
</tr>
<tr>
<td>SDQ Subscale Scores</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emotional Symptoms</td>
<td>1.9 (2.3)</td>
<td>0 – 10</td>
<td>1.4 (1.9)</td>
<td>0 – 10</td>
<td>1.5 (2.0)</td>
<td>0 – 9</td>
</tr>
<tr>
<td>Conduct Problems</td>
<td>2.5 (2.8)</td>
<td>0 – 10</td>
<td>2.7 (2.9)</td>
<td>0 – 10</td>
<td>2.7 (2.8)</td>
<td>0 – 10</td>
</tr>
<tr>
<td>Hyperactivity/Inattention</td>
<td>4.6 (3.3)</td>
<td>0 – 10</td>
<td>4.4 (3.5)</td>
<td>0 – 10</td>
<td>4.2 (3.3)</td>
<td>0 – 10</td>
</tr>
<tr>
<td>Peer Problems</td>
<td>1.8 (1.9)</td>
<td>0 – 9</td>
<td>1.7 (1.8)</td>
<td>0 – 9</td>
<td>2.0 (2.0)</td>
<td>0 – 9</td>
</tr>
<tr>
<td>CBQ Subscale Scores</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggressive/Oppositional</td>
<td>2.4 (1.2)</td>
<td>1 – 5.7</td>
<td>2.2 (1.2)</td>
<td>1 – 5.7</td>
<td>2.3 (1.2)</td>
<td>1 – 6.0</td>
</tr>
<tr>
<td>Internalizing</td>
<td>2.3 (0.9)</td>
<td>1 – 5.5</td>
<td>2.2 (0.8)</td>
<td>1 – 4.8</td>
<td>2.3 (0.9)</td>
<td>1 – 5.2</td>
</tr>
</tbody>
</table>

Note. SDQ = Strengths and Difficulties Questionnaire. CBQ = Child Behavior Questionnaire (items compiled for the present study). The SDQ subscales have possible score range of 0 – 10. The CBQ subscales have a possible score range of 1 – 6.
Table 2.2. Fit statistics for the baseline and measurement-invariant exploratory structural equation models for the factor structure across all three years.

<table>
<thead>
<tr>
<th></th>
<th># Free Parameters</th>
<th>$\chi^2$</th>
<th>$df$</th>
<th>$p$</th>
<th>$p$-diff</th>
<th>RMSEA (95% CI)</th>
<th>CFI</th>
<th>TLI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline model</td>
<td>624</td>
<td>3205.4</td>
<td>2886</td>
<td>0.00</td>
<td>0.00</td>
<td>.018 (.014, .022)</td>
<td>.992</td>
<td>.991</td>
</tr>
<tr>
<td>Measurement-invariant model</td>
<td>260</td>
<td>3698.4</td>
<td>3250</td>
<td>0.00</td>
<td>0.00</td>
<td>.020 (.017, .023)</td>
<td>.988</td>
<td>.988</td>
</tr>
</tbody>
</table>

Notes. In the baseline model, all factor loadings and item thresholds were freely estimated, and factor variances were fixed to 1 for model identification purposes. In the measurement-invariant model, all factor loadings and item thresholds were constrained to be equal over time, and the factor variances were fixed to 1 in kindergarten and freely estimated in 1$^{\text{st}}$ and 2$^{\text{nd}}$ grade. $\chi^2$ = model chi-squared test statistic for goodness of fit; $df$ = error degrees of freedom; $p$ = probability value of the $\chi^2$ test statistic; $p$-diff = $p$-value of the $\chi^2$ difference between the baseline and measurement-invariant models; RMSEA = Root Mean Square Error of Approximation; CFI = Comparative Fit Index; TLI = Tucker-Lewis Fit Index.
Table 2.3. Factor loadings.

<table>
<thead>
<tr>
<th>Item</th>
<th>AGG</th>
<th>HYP</th>
<th>ANX</th>
<th>WITH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loses temper</td>
<td>0.805</td>
<td>0.098</td>
<td>0.057</td>
<td>0.099</td>
</tr>
<tr>
<td>Fights or bullies other children</td>
<td>0.927</td>
<td>0.039</td>
<td>0.127</td>
<td>-0.083</td>
</tr>
<tr>
<td>Lies or cheats</td>
<td>0.638</td>
<td>0.294</td>
<td>0.208</td>
<td>-0.080</td>
</tr>
<tr>
<td>Steals</td>
<td>0.575</td>
<td>0.163</td>
<td>0.291</td>
<td>-0.232</td>
</tr>
<tr>
<td>Breaks things on purpose</td>
<td>0.537</td>
<td>0.358</td>
<td>-0.065</td>
<td>0.168</td>
</tr>
<tr>
<td>Stubborn</td>
<td>0.668</td>
<td>0.178</td>
<td>-0.054</td>
<td>0.241</td>
</tr>
<tr>
<td>Yells at others</td>
<td>0.778</td>
<td>0.126</td>
<td>-0.027</td>
<td>0.069</td>
</tr>
<tr>
<td>Breaks rules</td>
<td>0.636</td>
<td>0.356</td>
<td>0.022</td>
<td>0.112</td>
</tr>
<tr>
<td>Fights with other children</td>
<td>0.829</td>
<td>0.082</td>
<td>0.115</td>
<td>0.038</td>
</tr>
<tr>
<td>Disobeys adults</td>
<td>0.651</td>
<td>0.277</td>
<td>-0.026</td>
<td>0.243</td>
</tr>
<tr>
<td>Hits, pushes</td>
<td>0.701</td>
<td>0.226</td>
<td>0.011</td>
<td>0.074</td>
</tr>
<tr>
<td>Restless/overactive</td>
<td>0.094</td>
<td>0.941</td>
<td>0.096</td>
<td>-0.174</td>
</tr>
<tr>
<td>Fidgets</td>
<td>0.061</td>
<td>0.916</td>
<td>0.197</td>
<td>-0.218</td>
</tr>
<tr>
<td>Easily distracted</td>
<td>-0.056</td>
<td>0.884</td>
<td>0.011</td>
<td>0.245</td>
</tr>
<tr>
<td>Thinks before acting</td>
<td>-0.308</td>
<td>-0.515</td>
<td>0.049</td>
<td>-0.267</td>
</tr>
<tr>
<td>Good attention span</td>
<td>0.003</td>
<td>-0.748</td>
<td>0.127</td>
<td>-0.419</td>
</tr>
<tr>
<td>Acts young</td>
<td>0.081</td>
<td>0.538</td>
<td>0.051</td>
<td>0.334</td>
</tr>
<tr>
<td>Somatic complaints</td>
<td>0.225</td>
<td>0.013</td>
<td>0.464</td>
<td>0.034</td>
</tr>
<tr>
<td>Worries</td>
<td>0.077</td>
<td>-0.099</td>
<td>0.810</td>
<td>0.098</td>
</tr>
<tr>
<td>Unhappy, tearful</td>
<td>0.355</td>
<td>0.005</td>
<td>0.490</td>
<td>0.345</td>
</tr>
<tr>
<td>Nervous, clingy</td>
<td>-0.166</td>
<td>0.230</td>
<td>0.714</td>
<td>0.158</td>
</tr>
<tr>
<td>Fearful</td>
<td>-0.095</td>
<td>0.059</td>
<td>0.893</td>
<td>0.088</td>
</tr>
<tr>
<td>Prefers to play alone</td>
<td>-0.110</td>
<td>-0.011</td>
<td>0.276</td>
<td>0.737</td>
</tr>
<tr>
<td>Invites others to play</td>
<td>-0.207</td>
<td>-0.090</td>
<td>-0.073</td>
<td>-0.638</td>
</tr>
<tr>
<td>Low energy</td>
<td>-0.104</td>
<td>-0.033</td>
<td>0.218</td>
<td>0.677</td>
</tr>
<tr>
<td>Keeps to self, withdraws</td>
<td>-0.070</td>
<td>-0.109</td>
<td>0.366</td>
<td>0.724</td>
</tr>
<tr>
<td>Avoids playing with others</td>
<td>0.216</td>
<td>-0.046</td>
<td>0.298</td>
<td>0.481</td>
</tr>
</tbody>
</table>

Notes. Item-factor loadings > 0.400 are in bold text. AGG = aggression/oppositionality; HYP = hyperactivity/inattention; ANX = anxiety; WITH = withdrawal.
Table 2.4. Univariate statistics for factor scores.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kindergarten</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AGG</td>
<td>300</td>
<td>-0.017</td>
<td>0.905</td>
<td>-1.80</td>
<td>2.02</td>
<td>0.15</td>
<td>-0.60</td>
</tr>
<tr>
<td>HYP</td>
<td>299</td>
<td>0.062</td>
<td>0.834</td>
<td>-1.84</td>
<td>1.96</td>
<td>-0.07</td>
<td>-0.63</td>
</tr>
<tr>
<td>ANX</td>
<td>299</td>
<td>0.210</td>
<td>0.820</td>
<td>-1.48</td>
<td>2.59</td>
<td>0.38</td>
<td>-0.29</td>
</tr>
<tr>
<td>WITH</td>
<td>300</td>
<td>0.058</td>
<td>0.832</td>
<td>-1.80</td>
<td>2.65</td>
<td>0.12</td>
<td>-0.12</td>
</tr>
<tr>
<td>1st Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AGG</td>
<td>271</td>
<td>-0.009</td>
<td>0.960</td>
<td>-2.02</td>
<td>2.32</td>
<td>0.07</td>
<td>-0.66</td>
</tr>
<tr>
<td>HYP</td>
<td>271</td>
<td>-0.007</td>
<td>0.865</td>
<td>-2.16</td>
<td>1.80</td>
<td>0.03</td>
<td>-0.70</td>
</tr>
<tr>
<td>ANX</td>
<td>270</td>
<td>-0.026</td>
<td>0.789</td>
<td>-1.84</td>
<td>2.19</td>
<td>0.38</td>
<td>-0.57</td>
</tr>
<tr>
<td>WITH</td>
<td>271</td>
<td>-0.084</td>
<td>0.726</td>
<td>-1.60</td>
<td>2.75</td>
<td>0.32</td>
<td>0.10</td>
</tr>
<tr>
<td>2nd Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AGG</td>
<td>238</td>
<td>0.004</td>
<td>0.995</td>
<td>-1.98</td>
<td>2.63</td>
<td>0.12</td>
<td>-0.55</td>
</tr>
<tr>
<td>HYP</td>
<td>239</td>
<td>-0.032</td>
<td>0.869</td>
<td>-1.93</td>
<td>2.18</td>
<td>0.09</td>
<td>-0.51</td>
</tr>
<tr>
<td>ANX</td>
<td>239</td>
<td>0.022</td>
<td>0.750</td>
<td>-1.68</td>
<td>2.09</td>
<td>0.31</td>
<td>-0.17</td>
</tr>
<tr>
<td>WITH</td>
<td>237</td>
<td>0.048</td>
<td>0.854</td>
<td>-1.91</td>
<td>2.76</td>
<td>0.16</td>
<td>-0.20</td>
</tr>
</tbody>
</table>

Notes. AGG = aggression/oppositionality; HYP = hyperactivity/inattention; ANX = anxiety; WITH = withdrawal.
Table 2.5. Correlations among factor scores.

<table>
<thead>
<tr>
<th>Kindergarten</th>
<th>1st Grade</th>
<th>2nd Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AGG</td>
<td>HYP</td>
</tr>
<tr>
<td>AGG</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>HYP</td>
<td>0.60</td>
<td>---</td>
</tr>
<tr>
<td>ANX</td>
<td>0.22</td>
<td>0.23</td>
</tr>
<tr>
<td>WITH</td>
<td>0.25</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Notes. Pearson correlation coefficients with pairwise deletion of missing cases are reported. Pairwise sample sizes across years are between 236 and 238 for kindergarten with 1st grade; between 215 and 219 for 1st grade with 2nd grade; and between 205 and 208 for kindergarten with 2nd grade. All correlation coefficients with an absolute value greater than 0.12 are significant at $p < .05$. AGG = aggression/oppositionality; HYP = hyperactivity/inattention; ANX = anxiety; WITH = withdrawal.
Table 2.6. LTA model fit statistics for 2- through 6-profile solutions.

<table>
<thead>
<tr>
<th># Profiles</th>
<th>#Free Parameters</th>
<th>LL</th>
<th>AIC</th>
<th>BIC</th>
<th>aBIC</th>
<th>Entropy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>21</td>
<td>-3669.009</td>
<td>7380.0</td>
<td>7460.2</td>
<td>7393.6</td>
<td>0.870</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
<td>-3553.189</td>
<td>7182.4</td>
<td>7327.4</td>
<td>7206.9</td>
<td>0.828</td>
</tr>
<tr>
<td>4</td>
<td>59</td>
<td>-3434.080</td>
<td>6986.2</td>
<td>7211.4</td>
<td>7024.2</td>
<td>0.831</td>
</tr>
<tr>
<td>5</td>
<td>84</td>
<td>-3358.711</td>
<td>6885.4</td>
<td>7206.1</td>
<td>6939.6</td>
<td>0.820</td>
</tr>
<tr>
<td>6</td>
<td>113</td>
<td>-3309.219</td>
<td>6844.4</td>
<td>7275.8</td>
<td>6917.3</td>
<td>0.840</td>
</tr>
</tbody>
</table>

Notes. Four factor scores were used as indicators of the latent profiles: aggression/oppositionality, hyperactivity/inattention, anxiety, and withdrawal. In all models, factor score means and variances were freely estimated across profiles within years, and the within-profile means and variances were constrained to be equal across years. LL = log-likelihood value; AIC = Akaike’s Information Criterion, BIC = Bayesian Information Criterion; aBIC = sample-size adjusted Bayesian Information Criterion.
Table 2.7. LTA 4-profile solution.

<table>
<thead>
<tr>
<th>Prevalence, n (%)</th>
<th>Comorbid</th>
<th>Internalizing</th>
<th>Externalizing</th>
<th>Well-Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kindergarten</td>
<td>160.7 (47.8%)</td>
<td>78.4 (23.3%)</td>
<td>74.6 (22.2%)</td>
<td>22.3 (6.6%)</td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; grade</td>
<td>161.7 (48.1%)</td>
<td>69.3 (20.6%)</td>
<td>71.6 (21.3%)</td>
<td>33.3 (9.9%)</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; grade</td>
<td>162.0 (48.2%)</td>
<td>64.5 (19.2%)</td>
<td>71.2 (21.2%)</td>
<td>38.4 (11.4%)</td>
</tr>
</tbody>
</table>

Factor Score Means

<table>
<thead>
<tr>
<th></th>
<th>AGG</th>
<th>HYP</th>
<th>ANX</th>
<th>WITH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.628</td>
<td>-0.886</td>
<td>-0.041</td>
<td>-1.194</td>
</tr>
<tr>
<td>HYP</td>
<td>0.561</td>
<td>-0.716</td>
<td>0.000</td>
<td>-1.123</td>
</tr>
<tr>
<td>ANX</td>
<td>0.404</td>
<td>0.395</td>
<td>-0.552</td>
<td>-0.837</td>
</tr>
<tr>
<td>WITH</td>
<td>0.423</td>
<td>0.048</td>
<td>-0.465</td>
<td>-1.098</td>
</tr>
</tbody>
</table>

Factor Score Variances

<table>
<thead>
<tr>
<th></th>
<th>AGG</th>
<th>HYP</th>
<th>ANX</th>
<th>WITH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance</td>
<td>0.545</td>
<td>0.327</td>
<td>0.333</td>
<td>0.142</td>
</tr>
<tr>
<td>HYP</td>
<td>0.429</td>
<td>0.341</td>
<td>0.308</td>
<td>0.111</td>
</tr>
<tr>
<td>ANX</td>
<td>0.532</td>
<td>0.400</td>
<td>0.230</td>
<td>0.073</td>
</tr>
<tr>
<td>WITH</td>
<td>0.435</td>
<td>0.593</td>
<td>0.280</td>
<td>0.110</td>
</tr>
</tbody>
</table>

Notes. All pairs of profiles differ significantly in their mean values on all factor scores, except for the comorbid and internalizing profiles which do not differ in mean anxiety scores. AGG = aggression/oppositionality; HYP = hyperactivity/inattention; ANX = anxiety; WITH = withdrawal.
Table 2.8. Profile transition probabilities across adjacent years and cumulatively from kindergarten to 2nd grade.

<table>
<thead>
<tr>
<th></th>
<th>Comorbid</th>
<th>Internalizing</th>
<th>Externalizing</th>
<th>Well-Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1-Year Transition Probabilities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comorbid</td>
<td>0.892</td>
<td>0.011</td>
<td>0.098</td>
<td>0.000</td>
</tr>
<tr>
<td>Internalizing</td>
<td>0.000</td>
<td>0.801</td>
<td>0.000</td>
<td>0.199</td>
</tr>
<tr>
<td>Externalizing</td>
<td>0.248</td>
<td>0.000</td>
<td>0.705</td>
<td>0.047</td>
</tr>
<tr>
<td>Well-Adjusted</td>
<td>0.000</td>
<td>0.217</td>
<td>0.147</td>
<td>0.636</td>
</tr>
<tr>
<td><strong>Cumulative 2-Year Transition Probabilities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comorbid</td>
<td>0.819</td>
<td>0.018</td>
<td>0.156</td>
<td>0.007</td>
</tr>
<tr>
<td>Internalizing</td>
<td>0.000</td>
<td>0.684</td>
<td>0.029</td>
<td>0.286</td>
</tr>
<tr>
<td>Externalizing</td>
<td>0.395</td>
<td>0.013</td>
<td>0.529</td>
<td>0.063</td>
</tr>
<tr>
<td>Well-Adjusted</td>
<td>0.036</td>
<td>0.311</td>
<td>0.197</td>
<td>0.455</td>
</tr>
</tbody>
</table>

Notes. The value in each cell represents the probability of being in the column profile conditional on previous membership in the row profile. Profile stability rates are in bold font on the diagonal. Transition probabilities are constrained to be equal across adjacent years.
Figure 2.1. LTA model relative information criteria for 2- through 6-profile solutions

Notes. BIC = Bayesian Information Criterion; aBIC = sample-size adjusted Bayesian Information Criterion; AIC = Akaike’s Information Criterion.
Figure 2.2. Factor score means within profiles for the LTA 4-profile solution.

Notes. AGG = aggression/oppositionality; HYP = hyperactivity/inattention; ANX = anxiety; WITH = withdrawal.
Figure 2.3. Schematic diagram of transition pathways between latent profiles.

Notes. The size of each circle approximates the prevalence of the profile, and the position of each circle approximates the severity of internalizing and externalizing symptoms within the profile. Transitions between profiles having probabilities greater than 10% are represented with thick arrows and transitions having probabilities between 5% and 10% are represented with thin arrows. AGG = aggression/oppositionality, HYP = hyperactivity/inattention, ANX = anxiety, WITH = withdrawal.
CHAPTER 3:

Neural Indices of Social Threat Processing Biases:

Associations with Children’s Internalizing and Externalizing Symptoms
3.1. Introduction

Both internalizing symptoms, including anxiety and social withdrawal, and externalizing symptoms, including aggression and hyperactivity/inattention, have been associated with biases in the perceptual and attentional processing of social threat cues (Dodge & Crick, 1990; Mogg & Bradley, 1998; Uekermann et al., 2010; Wilkowski & Robinson, 2010). Biases in the earliest stages of social information processing, namely the detection and allocation of attention to potentially threatening cues, have been proposed to play an important role in the etiology of both aggression and anxiety (Dodge & Crick, 1990; Mogg & Bradley, 1998). These early perceptual-attentional biases may contribute to the development and maintenance of emotional and behavioral problems by decreasing the threshold for detecting potential threats, amplifying negative emotional reactions to perceived threats, and/or increasing negative biases in subsequent cognitive processing of these threats. Individuals who attend excessively to mild social threats are more likely to exhibit inappropriate defensive responses to these threats. These may take the form of either aggressive or avoidant behaviors, depending on individual differences in approach or withdrawal motivational tendencies.

However, many details about the nature of early social threat processing biases associated with internalizing and externalizing symptoms remain to be clarified. One important detail is the timing of the bias – i.e., whether it occurs at very early, automatic information-processing stages versus later, controlled information-processing stages. Understanding the timing of the bias may have important implications for the kinds of interventions that would be expected to be effective in ameliorating this bias. For example, biases at early, automatic information-processing stages may be more susceptible to implicit attention bias modification training whereas biases at later, controlled information-processing stages may be more responsive to explicit cognitive-behavioral therapy. Furthermore, very little is known about how early social threat processing biases may be associated with patterns of internalizing and externalizing symptom co-occurrence within individuals. This is an important oversight given the high prevalence of internalizing-externalizing comorbidity, as described in Chapter 2 of this dissertation.
In the remainder of this introduction, I will discuss the neural mechanisms that are proposed to underlie biases in the perceptual-attentional processing of potentially threatening information, including electrophysiological measures of these biases at the millisecond time scale. Second, I will review the literature on early perceptual-attentional social threat processing biases in internalizing and externalizing psychopathology, including both behavioral and neurophysiological studies, and incorporating research on children where available. The review of threat processing biases and internalizing symptoms will focus on anxiety, since depression rarely manifests in young children and often emerges developmentally from pre-existing anxiety. Finally, I will discuss the limited research that has been conducted to date on associations between perceptual-attentional biases to threat and patterns of both internalizing and externalizing symptoms within individuals.

**The neural basis of emotional attention biases**

The “top-down” allocation of visual attention on the basis of internal goals, plans, or expectations is mediated by a network of dorsal frontal and posterior parietal cortical regions, termed the dorsal frontoparietal attention network (Corbetta & Shulman, 2002). Top-down selective attention directly biases perceptual information-processing by enhancing the responsivity of relevant neurons in primary and secondary visual cortical areas to stimuli that match the selected criteria, such as a particular spatial location, color, or shape (Kastner & Ungerleider, 2000). As a result, these stimuli receive more perceptual processing and are more likely to rise to the level of conscious awareness and thereby to receive further cognitive encoding and elaboration.

Attention allocation is also strongly influenced by the affective salience of a stimulus, which is evaluated by a network of emotional brain regions centered on the amygdala. The amygdala receives perceptual information from both subcortical and cortical sensory regions and sends feedback on the affective salience of this information to sensory processing cortices (among other areas), thereby directly enhancing the perceptual processing of affectively salient information (Pourtois, Schettino, & Vuilleumier, 2013). In addition, amygdala activation modulates dorsal frontoparietal attention network activity to bias selective attention toward affective stimuli (Pourtois et al., 2013). Thus, when an
emotional stimulus is presented, inputs from both emotion and selective attention networks combine to
direct the allocation of perceptual and attentional resources to processing the stimulus. Depending on the
situation, inputs from these emotional and selective attention networks may be in competition or may
function additively or even interactively.

Perceptual information is transmitted to the amygdala in multiple stages. Coarse perceptual
information, such as low spatial-frequency visual information or movement in peripheral visual areas, is
transmitted at a very early information-processing stage, prior to the completion of more refined stimulus
evaluation, via “quick and dirty” subcortical (LeDoux & Phelps, 2008) and possibly also fast “feed-
forward” cortical (Pourtois et al., 2013) routes. The amygdala evaluates this coarse perceptual information
for potential threats, such as an object in the rough shape of a snake. When a potential threat is detected at
this very early, preattentive information-processing stage, feedback projections from the amygdala to
primary and secondary sensory cortices automatically enhance perceptual processing of the potentially
threatening stimulus in order to more fully evaluate the nature of the threat (LeDoux & Phelps, 2008;
Pourtois et al., 2013). The amygdala subsequently receives the output of this more refined, higher-level
stimulus evaluation process and integrates this information with the previously-received coarse perceptual
information to re-evaluate the threat level of the stimulus (LeDoux & Phelps, 2008). For example, an
object in the rough shape of a snake may be detected as a potential threat at the preattentive information-
processing stage, resulting in enhanced perceptual processing which reveals that this object is in fact only
a coiled rope; this information would then be transmitted back to the amygdala and other affective brain
regions, which should re-evaluate the stimulus as non-threatening, resulting in a reduction in perceptual-
attentional processing of the stimulus and in the emotional response to the stimulus (Bar-Haim, Lamy,
Lee, Bakermans-Kranenburg, & van IJzendoorn, 2007). Thus, attention biases toward threat at very early,
automatic information-processing stages are presumed to primarily reflect reactivity of the amygdala to
potentially threatening information. In contrast, attention biases at later, controlled information-
processing stages may arise from individual differences in a variety of cognitive-affective processes,
including tendencies to appraise certain stimuli as threatening, motivational direction in response to a
threat (i.e., whether to approach or avoid the threat), or deficient down-regulation of the initial cognitive-emotional response after a stimulus has been recognized as non-threatening (Pine, 2007).

The amygdala is particularly responsive to fearful faces (Whalen, 1998), which are hypothesized to act as a diffuse threat cue signaling the presence of danger in the environment. Indeed, humans appear to be ‘pre-wired’ to attend preferentially to fearful faces from infancy (Leppänen & Nelson, 2009), and the amygdala is particularly responsive to low-spatial-frequency fearful face stimuli, suggesting that this response is mediated by very early coarse visual information-processing routes (Pourtois et al., 2013; Vuilleumier & Pourtois, 2007). Angry faces also generate a response in the amygdala, although this response may be less robust than that for fearful faces (Öhman, 2002). Unlike fearful faces, angry faces signal direct social hostility and the immediate potential for aggression. Thus, controlled attention biases toward or away from angry faces may reflect individual differences in motivational direction; more approach-motivated individuals may allocate controlled attention toward angry faces in preparation for aggressive action, whereas more withdrawal-motivated individuals may allocate controlled attention away from angry faces to avoid social confrontations (Putman, Hermans, & van Honk, 2004).

Neurophysiological studies of the time course of emotional face processing

A number of studies have utilized electroencephalographic (EEG) event-related potentials to elucidate the time course of neural activity in the human brain that is responsive to facial expressions of emotion. Event-related potentials (ERPs) measure voltage changes across the scalp that are time-locked to a particular event, such as the presentation of a visual stimulus. These event-related scalp voltage changes reflect the summed, volume-conducted synchronous activity of large groups of cortical pyramidal neurons (Buzsáki, Anastassiou, & Koch, 2012). ERPs are ideally suited to studying the time course of neural activity since they provide excellent temporal resolution, essentially measuring neural activity as it occurs. ERP studies have provided evidence that emotional versus neutral faces can elicit differentiated neural activity at various stages of visual information-processing (Vuilleumier & Pourtois, 2007).

At the early perceptual-attentional stage, facial emotion-related modulations have been observed in the amplitude of the P1 ERP, a positive peak in the waveform at occipital electrodes that is consistently
elicited around 100-130 ms following the onset of a visual stimulus in adults. This early visual component shows a similar post-stimulus latency and scalp distribution in children as in adults, although its amplitude decreases substantially across childhood (Batty & Taylor, 2006; Doucet, Gosselin, Lassonde, Guillemot, & Lepore, 2005; Kuefner et al., 2010; MacNamara et al., 2016; Meaux et al., 2014). The P1 appears to reflect neural activity in both dorsal and ventral extrastriate visual cortex involved in early visual processing of basic stimulus features (Di Russo, Martínez, Sereno, Pitzalis, & Hillyard, 2002) and is the earliest ERP component that has been shown to be modulated by selective attention to a spatial location, with P1 amplitudes being enhanced to spatially attended versus unattended stimuli (Luck, Woodman, & Vogel, 2000). Interestingly, some studies have found the P1 to show a specific sensitivity for face stimuli in both children and adults (Herrmann, Ehlis, Muehlberger, & Fallgatter, 2005; Taylor, Batty, & Itier, 2004), which may reflect facilitated holistic processing of faces based on their high motivational salience (Taylor et al., 2004). It has been hypothesized that the P1 reflects the initial attentional selection of a stimulus for further processing and may be a necessary precursor to conscious awareness (Railo, Koivisto, & Revonsuo, 2011). Thus, enhanced P1 amplitudes to emotional versus neutral stimuli are expected to reflect automatic facilitation of the perceptual processing of motivationally salient content, presumably reflecting excitatory inputs from the amygdala in response to preliminary perceptual information conveyed prior to conscious visual awareness (Pourtois et al., 2013).

Studies in healthy adults have observed enhancements in P1 amplitudes to emotional, particularly fearful, versus neutral facial expressions (Luo, Feng, He, Wang, & Luo, 2010; E. Smith, Weinberg, Moran, & Hajcak, 2013), although this effect has not been universally observed (Frühholz, Jellinghaus, & Herrmann, 2011; Jiang et al., 2009), and at least one study actually observed lower P1 amplitudes to fearful faces versus other facial expressions, including neutral and angry (Bar-Haim, Lamy, & Glickman, 2005). In typically-developing children, several studies have failed to find evidence for P1 amplitude sensitivity to emotional facial expressions (Batty & Taylor, 2006; Dennis, Malone, & Chen, 2009; MacNamara et al., 2016; Meaux et al., 2014; Thai, Taber-Thomas, & Pérez-Edgar, 2016; Todd, Lewis, Meusel, & Zelazo, 2008), although one study has revealed enhanced P1 amplitudes to high-spatial-
frequency images of fearful versus neutral faces in children aged 3 to 8 years (Vlamings, Jonkman, & Kemner, 2010).

Immediately following the P1, a negative peak is observed at posterior temporal sites occurring roughly 170 ms following the onset of a face stimulus in adults, termed the N170. This ERP has been argued to be reflect face detection processes, as its amplitude is heightened to faces or eyes alone versus other kinds of stimuli (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Itier & Taylor, 2004) and it is sensitive to heavily degraded face cues that are detected as faces based solely on configural or holistic properties of the stimulus (Eimer, Gosling, Nicholas, & Kiss, 2011). This component appears to reflect multiple neural sources in bilateral inferior occipital and temporal cortices including the face-sensitive fusiform gyrus (Herrmann et al., 2005; Itier & Taylor, 2004). The N170 occurs at a longer post-stimulus latency and has a higher amplitude in childhood than in adulthood (Batty & Taylor, 2006; Meaux et al., 2014; Vlamings et al., 2010), but the face-sensitive properties of this component remain stable from 4 years of age through adulthood (Kuefner et al., 2010).

Recent studies in healthy adults have provided substantial evidenced for enhanced amplitudes of the N170 to emotional versus neutral faces, particularly for fearful faces (Almeida et al., 2016; Batty & Taylor, 2003; Frühholz et al., 2011; Jiang et al., 2009; Pegna, Landis, & Khateb, 2008), but also for a wide variety of emotions including anger, disgust, and happiness (Kolassa et al., 2009; Luo et al., 2010; Mühlberger et al., 2009; M. L. Smith, 2012). However, a modulatory effect of emotion on N170 amplitude in adults is not universally observed (E. Smith et al., 2013). In typically-developing children, findings on modulation of N170 amplitude by facial emotion are mixed, with several studies failing to find any emotional modulation in childhood (Batty & Taylor, 2006; Dennis et al., 2009; Meaux et al., 2014; Thai et al., 2016), although one of these studies observed that higher N170 amplitudes to negative facial expressions emerged in mid-adolescence (Batty & Taylor, 2006). In contrast, one study found lower N170 amplitudes to high-spatial-frequency fearful versus neutral faces in children (Vlamings et al., 2010).
The posterior P2 is a positive peak at parieto-occipital sites occurring immediately following the negative deflection of the N170. This posterior P2 should be distinguished from a positive peak at fronto-central sites occurring simultaneously with the N170, which has been variously referred to as a P2 or ‘vertex positive potential’ (VPP), and which has been suggested to reflect the same neural generator as the N170 (Joyce & Rossion, 2005). The posterior P2 has been less thoroughly investigated and is therefore less well understood than the earlier P1 and N170 peaks. One study that examined the developmental course of posterior P2 amplitudes to face stimuli found decreases in both the amplitude and latency of this peak across childhood, suggesting that it follows a similar developmental course as the earlier visual-perceptual peaks (Meaux et al., 2014). The posterior P2 peak has been hypothesized to reflect re-entrant activity in primary and secondary visual cortices involved in the formation of a conscious visual percept (Kotsoni, Csibra, Mareschal, & Johnson, 2007). Consistent with a link between the P2 and conscious visual-perceptual processing, the timing of this component coincides with the timing of neural activity indexing conscious awareness of facial identity (Genetti, Khateb, Heinzer, Michel, & Pegna, 2009). It has been suggested that higher amplitude of the P2 peak is associated with greater allocation of neural resources to conscious perceptual analysis of the stimulus (Latinus & Taylor, 2005).

Studies in healthy adults have revealed enhancements in the amplitudes of posterior P2 peaks to negatively valenced emotional images, which the authors interpreted as reflecting a negativity bias in attention allocation (Carretié, Martín-Loeches, Hinojosa, & Mercado, 2001; Carretié, Mercado, Tapia, & Hinojosa, 2001). However, there is less evidence for modulation of the posterior P2 amplitude specifically to emotional face expressions among healthy adults, with some studies observing lower posterior P2 amplitudes to angry versus neutral faces (Kolassa et al., 2009; Schutter, de Haan, & van Honk, 2004) and others failing to observe any modulation of posterior P2 amplitude by emotional expression (Peschard, Philippot, Joassin, & Rossignol, 2013). Interestingly, however, Peschard and colleagues (2013) did observe that P2 amplitudes were higher on average when participants were asked to explicitly attend to the emotional expression versus the color of face stimuli, suggesting that the amplitude of this component reflects the deeper perceptual processing required to identify emotional
expressions versus simpler stimulus features such as color. Few studies have been conducted on the posterior P2 to emotional faces in typically-developing children, but one recent exception (Meaux et al., 2014) found no evidence for posterior P2 amplitude modulation by emotional expression in 4- to 10-year-olds.

Finally, the P3 is a relatively broad late positive peak is observed at centro-parietal electrodes with an onset in adults around 300 to 400 ms following the onset of an attended visual stimulus (Duncan et al., 2009; Linden, 2005; Polich, 2007). The topographical scalp distribution of this peak has been shown to be similar in children as in adults, although in children the peak occurs later and is larger (Pfueller et al., 2011). The amplitude of this peak reflects higher-order cognitive processing of the stimulus, including stimulus categorization (Kok, 2001) and working memory updating (Polich, 2007). This peak has been linked to neural generators in both temporo-parietal and dorsal parietal regions of the fronto-parietal attention network (Linden, 2005). Thus, P3 amplitude enhancements to emotional stimuli would be expected to reflect greater higher-order cognitive processing of these stimuli. In healthy adults, enhanced P3 amplitudes have been observed to angry (Schupp et al., 2004) and fearful (Frühholz et al., 2011; Luo et al., 2010) versus neutral faces, and in typically-developing children, enhanced P3 amplitudes have been observed to angry versus neutral faces (Lewis, Todd, & Honsberger, 2007).

**Threat processing biases and anxiety**

*Behavioral studies of early attention biases to threat and anxiety.* An extensive body of empirical research using behavioral paradigms, including dot-probe, emotional Stroop, and visual search tasks, provides evidence for enhanced attention biases toward threatening (angry or fearful) faces and words in anxious adults (Bar-Haim et al., 2007; Cisler & Koster, 2010) as well as in anxious children (Bar-Haim et al., 2007; Field, Hadwin, & Lester, 2011; Muris & Field, 2008; Roy et al., 2008; Shechner et al., 2013; Waters, Henry, Mogg, Bradley, & Pine, 2010; Waters, Kokkoris, Mogg, Bradley, & Pine, 2010), relative to non-anxious controls. In adults, anxiety-related attention biases have been observed even to subliminally presented stimuli (Bar-Haim et al., 2007), suggesting they reflect automatic facilitation of perceptual-attentional processing of potentially threatening environmental cues (Mogg &
Bradley, 1998). On the other hand, some studies suggest that anxiety is associated with greater attentional avoidance of threat, particularly at longer latencies, yielding a “vigilance-avoidance” pattern of attention biases (Cisler & Koster, 2010). There is also some evidence that children with fear-related disorders (e.g., phobias) exhibit attentional avoidance of threat, while children with distress-related disorders (including generalized anxiety disorder) exhibit attention biases toward threat (Salum et al., 2013). Thus, the evidence for attention biases toward threat in anxiety is not universal, but nonetheless this effect has been observed in many studies.

There is also some evidence to suggest that attention biases to threat play a role in the development and maintenance of anxiety disorders. For example, implicitly training anxious individuals to direct their attention away from threatening stimuli (i.e., attention bias modification training) has shown promise for reducing anxiety symptoms, at least in the short term, in both adults (Browning, Holmes, & Harmer, 2010) and children (Waters, Pittaway, Mogg, Bradley, & Pine, 2013). Some evidence has also come from longitudinal studies. For example, attention biases toward angry versus neutral faces have been shown to be associated with the development of posttraumatic stress disorder among children exposed to intimate partner violence (Swartz, Graham-Bermann, Mogg, Bradley, & Monk, 2011), and attention biases to threat have been shown to mediate the association between temperamental behavioral inhibition and social anxiety in childhood (Pérez-Edgar et al., 2011) and adolescence (Pérez-Edgar et al., 2010).

However, behavioral studies of emotional attention biases have several important limitations. Most of these studies measure attention biases based on differences in response times, which capture attention biases at a discrete time-point but do not reveal the continuous time course of attention allocation. Additionally, each behavioral paradigm measures a particular behavioral consequence of attention allocation – for example, faster response times to targets presented at the same spatial location as the attended cue in the dot-probe task, or slower response times due to cognitive interference in the emotional Stroop task. Each of these behavioral measures also reflects processes other than attention allocation during visual processing of the threat cues, such as motor speed or cognitive control while
executing the response, which are also sensitive to emotional influences. Moreover, multiple studies have recently provided evidence for very poor psychometric reliability of attention biases measured using response times differences on various commonly-used tasks including the dot-probe and emotional Stroop (Brown et al., 2014; Roy, Dennis, & Warner, 2015; Waechter & Stolz, 2015). There is some preliminary evidence that ERP measures of attention biases may be more reliable (Kappenman, Farrens, Luck, & Proudfit, 2014).

**ERP studies of perceptual-attentional biases to threatening faces and anxiety.** A number of studies have been conducted using ERP techniques to provide insight into the time course and nature of neural activity underlying the processing of socially threatening faces in anxious individuals. While many of these studies have identified some component of the evoked scalp potential that is differentially modulated by facial emotion between high- and low-anxious individuals, the details of which components are modulated, and how they are modulated, are inconsistent across studies (Bar-Haim et al., 2005; Eldar, Yankelevitch, Lamy, & Bar-Haim, 2010; Frenkel & Bar-Haim, 2011; Holmes, Nielsen, & Green, 2008; Mueller et al., 2009; Taddei, Bertoletti, Zanoni, & Battaglia, 2010).

Some studies have provided evidence that anxious individuals exhibit greater P1 amplitudes to threatening versus neutral facial expressions, including fearful (Holmes et al., 2008) and angry faces (Mueller et al., 2009), although other studies have failed to observe a significant association between anxiety and modulation of P1 amplitude to emotional expressions (Bar-Haim et al., 2005; Eldar et al., 2010; Frenkel & Bar-Haim, 2011). A variety of studies have observed that anxious or inhibited individuals exhibit higher P1 amplitudes to face stimuli regardless of the emotional expression (Dennis & Chen, 2007; Frenkel & Bar-Haim, 2011; Kolassa et al., 2009; Kolassa, Kolassa, Musial, & Miltner, 2007; Mühlerberger et al., 2009; Rossignol, Campanella, Bissot, & Philippot, 2013; Rossignol, Philippot, Bissot, Rigoulot, & Campanella, 2012). This finding may reflect heightened vigilance to exogenous stimuli in general, rather than face stimuli specifically. In support of this hypothesis, a recent study (Peschard et al., 2013) revealed enhanced P1 amplitudes in socially anxious individuals across both face and non-face (shape) stimuli. Few ERP studies have been conducted of facial expression processing in anxious
children. In line with the adult studies reported above, one study of 8- to 12-year-old children found that those diagnosed with an anxiety disorder exhibited higher P1 amplitudes to face stimuli regardless of the emotional expression (Hum, Manassis, & Lewis, 2013). Another study found that P1 amplitudes to emotional face displays were not correlated with children’s social anxiety symptoms or levels of behavioral inhibition (Thai et al., 2016).

A variety of studies have been conducted exploring associations between social anxiety and amplitude of the face-sensitive N170 peak in adults. These studies have mostly found no evidence for associations between social anxiety and N170 amplitudes to face stimuli, either on average or as modulated by different emotional expressions (Kolassa et al., 2009, 2007; Mühlberger et al., 2009; Peschar et al., 2013; Rossignol, Campanella, et al., 2012; Rossignol et al., 2013). In contrast, one study (Kolassa & Miltner, 2006) observed that adults with social anxiety disorder exhibited heightened N170 amplitudes when identifying the emotion, but not the gender, of angry faces. In children, one study has observed no correlation between children’s social anxiety symptoms or levels of behavioral inhibition and N170 amplitudes to emotional face displays (Thai et al., 2016). Thus, there is very little evidence for an association between anxiety and N170 amplitudes to emotional faces.

Mixed findings have been reported for associations between anxiety symptoms and amplitude of the posterior P2 peak to emotional faces, indexing resource allocation during early conscious perceptual processing. Some studies in adults have observed associations between anxiety and higher posterior P2 amplitudes specifically to angry versus neutral faces (Bar-Haim et al., 2005; Rossignol et al., 2013). Other studies have revealed elevated posterior P2 amplitudes to face stimuli in anxious adults regardless of the emotional expression (Dennis & Chen, 2007; Eldar et al., 2010; Felmingham, Stewart, Kemp, & Carr, 2016; Rossignol, Philippot, et al., 2012). Conversely, one study observed lower posterior P2 amplitudes to face stimuli, regardless of neutral or fearful expression, in anxious adults (Frenkel & Bar-Haim, 2011). Finally, several other studies with adults have failed to find evidence for an association between social anxiety and posterior P2 amplitudes to emotional faces (Kolassa et al., 2009; Kolassa & Miltner, 2006; Peschar et al., 2013). To my knowledge, no studies have been conducted on the association between
posterior P2 amplitudes to emotional faces and anxiety in children. Although one study (Thai et al., 2016) found that social anxiety in children aged 9 to 12 years was associated with lower amplitudes of a frontal P2 peak to emotional face displays, the scalp topography of this peak suggests that it more closely matches the VPP than the posterior P2.

Evidence has also been mixed for an association between anxiety and amplitude of the parietal P3 peak to threatening face stimuli, presumed to reflect higher-order cognitive processing of the stimulus. Some studies have found evidence for a blunting of the normal enhancement of a parietal positivity in the P3 time window to threatening versus neutral facial expressions in anxious adults (Frenkel & Bar-Haim, 2011; Mühlberger et al., 2009). In contrast, other studies have found no evidence for an association between social anxiety and parietal P3 amplitudes to threatening or neutral facial expressions (Kolassa et al., 2007; Rossignol, Campanella, et al., 2012), and at least one study has observed an association between social anxiety and higher amplitudes of the parietal P3 peak to threatening versus non-threatening faces (Moser, Huppert, Duval, & Simons, 2008). Finally, some studies have observed general enhancements in parietal P3 amplitudes to face stimuli in socially anxious individuals, regardless of the emotional expression (Felmingham et al., 2016; Sewell, Palermo, Atkinson, & McArthur, 2008). To my knowledge, no studies have yet been conducted on the association between anxiety and the parietal P3 amplitude to emotional face stimuli in children.

**Threat processing biases and externalizing symptoms**

*Behavioral studies of early attention biases to social threat and externalizing symptoms.* In contrast to the substantial literature available on attention biases in anxiety, a relatively small number of studies using behavioral paradigms provide evidence supporting threat-related attention biases in individuals with externalizing behavior problems, including aggression and attention-deficit/hyperactivity symptoms. Some studies have shown that adults higher in trait anger exhibit greater Stroop task color-naming interference from supraliminally-presented angry/hostile versus neutral word or face stimuli (P. Smith & Waterman, 2003; van Honk, Tuiten, de Haan, van den Hout, & Stam, 2001) and enhanced attention biases toward aggressive words presented for 500 ms in a dot-probe task (P. Smith & Waterman,
Several studies have also suggested that higher trait-angry individuals may exhibit a preattentive threat bias as revealed by greater threat-related response interference effects on the emotional Stroop with subliminally-presented (masked) threatening (Putman et al., 2004; van Honk et al., 2001) or emotional (Bertsch, 2009) face distracters. Other studies have found that young adults higher in trait anger only showed increased attentional distraction by hostile words on a visual search or emotional Stroop task when they completed the task following an anger-provoking manipulation (Cohen, Eckhardt, & Schagat, 1998; Eckhardt & Cohen, 1997), and one study found that individuals higher in trait anger who had just completed an anger-provoking manipulation showed increased interference effects of various masked emotional expressions (angry, fearful, and happy) versus masked neutral faces on the emotional Stroop task (Bertsch, 2009). Thus, there is suggestive evidence for attention biases toward threat in aggressive adults at both preattentive and controlled information-processing stages, at least when they are experiencing state anger. However, the vast majority of these studies used the emotional Stroop paradigm, which assesses attentional control capabilities in addition to emotional influences on attention allocation; replication with a wider variety of paradigms, such as dot-probe or visual search tasks, could clarify the interpretation of this attention bias effect. Additionally, the majority of the studies used angry or hostile stimuli, leaving the question of whether aggressive individuals show behavioral attention biases toward or away from fearful faces largely unaddressed.

Very few behavioral studies have been conducted on attention biases to threat in aggressive children. A couple studies have provided evidence that aggressive children have greater difficulty disengaging their attention from angry facial expressions and aggressive scenes (Gouze, 1987; Wilson, 2003). On the other hand, two other studies observed that, when anxiety symptoms were controlled, the association between children’s aggressive behaviors and attention biases to threatening words on a variation of the dot-probe task was either null (Reid, Salmon, & Lovibond, 2006) or, at least for reactive aggression, reversed (i.e., associated with attentional avoidance of threat words; Schippell, Vasey, Cravens-Brown, & Bretveld, 2003). Finally, one study of a large community sample of children found that attention biases to angry faces on the dot-probe task did not vary according to whether children met
diagnostic criteria for a behavioral disorder (including ADHD and ODD), a distress- or fear-related internalizing disorder, or no disorder. Thus, the literature on early attention biases in children with externalizing problems is currently sparse and inconsistent.

**ERP studies of perceptual-attentional biases to threatening faces and externalizing symptoms.** Studies examining the association between externalizing symptoms and ERP responses to threatening faces have the potential to provide insight into neural correlates of threat-processing biases in individuals with externalizing behavior problems. Unfortunately, few studies of this nature have been published. One study examined variation in maternally reported emotion dysregulation, which is associated with risk for reactive aggression, in a sample of typically-developing children aged 5 to 9 years (Dennis et al., 2009). This study revealed that lower P1 amplitudes to fearful and sad face distracter stimuli were associated with higher maternal reports of emotion dysregulation. In adults, a study of trait aggression found no association between self-reported trait aggression and modulation of P2 or P3 peak amplitudes by masked emotional face stimuli in a Stroop task (Bertsch, 2009). However, these authors did observe a main effect of an anger-provoking manipulation on threat-related ERP amplitudes regardless of self-reported trait aggression; provoked individuals exhibited greater enhancements in centro-parietal P2 amplitudes to masked angry and fearful versus neutral or happy faces, potentially reflecting enhancements in early conscious perceptual processing of threat-related information.

A small number of studies have also examined ERP correlates of emotional face processing in individuals with ADHD, with mixed results. With regard to the early perceptual-attentional P1 peak, one study (Raz & Dan, 2015) observed that adults with ADHD exhibited enhanced P1 amplitudes to angry and happy faces, but not neutral faces, relative to non-ADHD controls, suggestive of an early perceptual-attentional bias toward emotional faces. However, another study found that children with ADHD exhibited lower P1 amplitudes to face stimuli in general, regardless of the emotional expression, and within the ADHD group lower P1 amplitudes to face stimuli were associated with greater emotional lability (Williams et al., 2008).
Mixed findings have also been reported for the face-sensitive N170 peak. Two studies in adults have suggested that individuals with ADHD show relatively blunted N170 amplitudes to positive versus negative emotional expressions; i.e., larger amplitudes to negative expressions (Raz & Dan, 2015) or no modulation by emotional expression (Ibáñez et al., 2011), whereas non-ADHD controls showed higher N170 amplitudes to positive vs. negative expressions. However, one study with children (Tye et al., 2014) found that N170 amplitudes to emotional expressions did not differ between children with ADHD and non-ADHD controls, and another study (Williams et al., 2008) found that children with ADHD exhibited greater N170 amplitudes to face stimuli across angry, fearful, and neutral expressions.

With regard to the late P3 peak, studies have found that the amplitude of this peak was not differentially modulated by emotional expression in adults with ADHD versus non-ADHD controls (Raz & Dan, 2015), that the amplitude of this peak was lower across various emotional expressions in children with ADHD versus non-ADHD controls (Williams et al., 2008), and that the amplitude of this peak was blunted specifically to angry faces in children with ADHD (Köchel, Leutgeb, & Schienle, 2014). Given the sparseness of the literature and the inconsistency of results to date, further studies examining associations between emotional face-processing ERP abnormalities and children’s externalizing behaviors are clearly justified.

**Threat processing biases and co-occurring internalizing and externalizing symptoms**

Very little research has explored associations between early social threat processing biases, measured at either the behavioral or neural level, and patterns of internalizing and externalizing symptom co-occurrence within individuals. In one partial exception, Salum and colleagues (2013) explored associations between threat biases, as measured by response times on a dot-probe task with emotional faces, and symptom presentations within a large community sample of children aged 6 to 12 years. As reported above, they found that when children were grouped according to diagnostic category (no disorder, or behavioral, distress-related, or fear-related disorder), these groups did not differ significantly in their threat biases. However, among children either not meeting criteria for any psychiatric diagnosis or meeting criteria for a distress-related disorder (GAD or depression), greater internalizing symptom
severity was associated with a greater attention bias toward angry faces. In contrast, this association between internalizing symptom severity and attention biases toward angry faces was not observed among children meeting criteria for a behavioral disorder such as ADHD or oppositional defiant disorder. This pattern of results is consistent with an attention bias to angry faces operating as a specific risk factor for internalizing symptoms only among children who are low on externalizing symptoms. However, this study was not intended to test hypotheses about internalizing-externalizing comorbidity, and its ability to address such questions was limited by the decision to exclude children with comorbid psychiatric diagnoses (thus implying a limited range of internalizing symptom severity within the behavior disorder group) and to only examine dimensionally-scored internalizing, but not externalizing, symptoms.

To the degree that the association between social threat processing biases and either internalizing or externalizing symptoms is moderated by symptom levels on the other dimension, this would be expected to contribute to mixed findings in the literature on behaviorally- and neurophysiologically-assessed social threat processing biases. Moreover, given the high prevalence of internalizing-externalizing comorbidity, it is important to explore the possibility that threat processing biases may play a different role in comorbid versus “pure” symptom presentations.

**The present study**

As reviewed above, research on the neurophysiological basis of perceptual-attentional social threat processing biases in anxious children is currently sparse and inconsistent, and with regard to childhood externalizing symptoms (other than ADHD) and internalizing-externalizing comorbidity such research is essentially nonexistent. The present study addresses these substantial research gaps by exploring associations between children’s internalizing, externalizing, and comorbid symptoms and their ERP indices of social threat processing biases, operationalized as ERP amplitude differences to threatening (angry or fearful) versus neutral facial expressions.
3.2. Methods

Participants

The sample for the present study was a subset of the full PATHS to Success study sample which was used for the first paper of this dissertation. Details regarding the full study sample of 339 children can be found in the first paper. The present analyses are limited to the 272 children whose teachers responded to the 1st-grade teacher survey. For the primary analyses utilizing ERP data, the sample was further restricted to the 202 children who had valid data for at least one ERP peak of interest.

Sixty-two percent of children in the analysis sample had been recruited into the study based on high teacher ratings of aggressive and oppositional behaviors at the beginning of their kindergarten year, while the other 38% had low teacher ratings of aggression and oppositionality (see Chapter 2 for details on the aggression/oppositionality screening procedures). Sixty-seven percent of the children in the analysis sample were male. Seventy-seven percent were African American, 21% Hispanic/Latino, 7% Caucasian, and 1% Asian. At the time of the 1st-grade EEG data collection, children were an average of 7.2 years old (SD = 0.38, range = 6.5 – 8.7).

Children in the analysis sample did not differ significantly from those who were excluded from the sample with regard to their membership in the high- vs. low-aggression recruitment group ($\chi^2 = 0.1$, df = 1, $p = .707$), gender ($\chi^2 = 2.0$, df = 1, $p = .159$), or race/ethnicity (African-American, Hispanic, or White/Asian: $\chi^2 = 1.5$, df = 2, $p = .482$). However, there was a trend for children in the analysis sample to be slightly older (average age at kindergarten entry = 5.6 vs. 5.5 years, $t_{337} = 1.8$, $p = .07$). Importantly, inclusion in the analysis sample was not significantly correlated with any of the symptom factor scores that were used as indicators in the latent profile analysis (aggression/oppositionality, hyperactivity/inattention, anxiety, and social withdrawal) either in kindergarten ($p$’s = .15 to .88) or in 1st grade ($p$’s = .39 to .70). Thus, it was expected that the same latent symptom profiles that had been identified using the full sample of 339 children would also be observed in the present analysis sample.
Measures

Symptom factor scores. As described in Chapter 2 of this dissertation, teachers responded to questionnaires about participating children’s emotional and behavioral symptoms. These survey responses were submitted to an exploratory structural equation model (ESEM; Asparouhov & Muthén, 2009; H. W. Marsh, Morin, Parker, & Kaur, 2014) which yielded four symptom factors – aggression/oppositionality, hyperactivity/inattention, anxiety, and social withdrawal – that were measurement-invariant across kindergarten, 1st, and 2nd grade. The present analyses utilized the 1st-grade factor scores from this model. Item loadings on each factor and univariate and bivariate statistics for the factor scores are reported in Tables 2.3, 2.4 and 2.5 of Chapter 2.

Psychophysiological assessment. In the fall of participating children’s kindergarten, 1st- and 2nd-grade school years, psychophysiological assessments were conducted by trained research assistants in a mobile research laboratory. Psychophysiological equipment was installed into a recreational vehicle (RV) and driven to each school to conduct the assessments. This maximized consistency of the testing environment across the school sites while minimizing burden on parents. The psychophysiological assessments took place during the school day and lasted approximately 45 minutes. During the assessment, electroencephalographic (EEG), electrocardiographic (ECG), and electrodermal data were collected during an emotional go/no-go task followed by a passive emotion induction task. In kindergarten, the emotional go/no-go task used non-human cartoon character stimuli in order to appeal to young children; in 1st and 2nd grade, this task was modified to use adult human face stimuli expressing the four primary emotions of anger, sadness, fear, and happiness, as well as emotionally neutral and ambiguous faces. Only EEG event-related potential data to angry, fearful, and neutral faces in the 1st-grade go/no-go task were used in the present analyses. A total of 273 children participated in a psychophysiological assessment in 1st grade; however, 23 of these children lacked 1st-grade teacher survey data (similarly, 22 children with 1st-grade teacher survey data did not participate in a psychophysiological assessment in 1st grade). Thus, 250 children had teacher survey data and had participated in a psychophysiological assessment in 1st grade. However, as will be described below, 48 of
these children were not included in the analyses due to insufficient valid EEG data from the go/no-go task.

*Emotional face go/no-go task.* Children completed a go/no-go task in which they were asked to press a response button as quickly as possible to frequently-presented target (go) stimuli and to refrain from pressing the response button to non-target (no-go) stimuli. Both go and no-go stimuli consisted of computer-generated images of human faces displaying either a neutral or an emotional expression, counter-balanced across gender and race (African American or Caucasian). The face stimuli were generated using FaceGen Modeller version 3.1 (Singular Inversions Inc.; www.facegen.com). This program uses a data-driven statistical model based on 3D laser scans of faces (Blanz & Vetter, 1999) and allows for the generation of novel faces. Expressions of emotions were controlled for intensity and based on Facial Action Coding (Ekman & Freisen, 1978) using the muscular contractions composing standard emotions. The images generated in FaceGen Modeller were then manipulated using Adobe Photoshop to control for stimulus features such as luminosity and contrast that may affect sensory processing. Each face was centered within a black oval template that conceals peripheral features and allows for increased focus on emotional information. Representative examples of the neutral, angry, and fearful face stimuli are provided in Appendix A.

The no-go condition was signaled by the repetition of the same stimulus (i.e., the same face with the same emotional expression) on immediately adjacent trials. The task instructions were made into a game in order to capture children’s interest. Children were told to pretend that they were “Mission Control Captain for a team of astronauts” and that their task was to “energize” astronauts before they head into space to fight aliens by pressing a button as quickly as possible when the astronaut’s face appeared on the screen, but that they could not “re-energize” the same astronaut twice in a row because they “had not left the station yet.” Children were also told that the astronauts would have different expressions on their faces depending on whether they see “friendly” or “not-so-friendly” spaceships. They were then told that if the same astronaut re-appeared with a different expression, they should still hit the button; they should only *not* hit the button if the same astronaut with the same expression appeared twice in a row. For
this reason, children were explicitly instructed to “pay close attention to the look on their face” so they would know whether or not they should hit the button. Thus, the emotional expressions were both intrinsically salient and relevant for the task; however, the task did not require that children identify or label the emotional expressions.

Children were informed that during the game they would be earning points for correct answers and losing points for mistakes, which were signaled by a large red box appearing around the stimulus. Children were also told that they would win a prize if they were able to earn enough points. No specific criterion of point value was associated with earning a prize so children would be motivated to maximize points. Prizes were shown to the child ahead of time and consisted of goody bags filled with small toys, stickers, and other items. During the task, children were provided with visual feedback approximately every 10 trials informing them of their progress in earning points.

After the task was explained, children engaged in a practice session and the program calculated the child’s error rate on no-go trials during that session. In order to assess error-related negativity (data not presented here), error rates were targeted to be between 40-60% on no-go trials. Participants whose no-go error rate exceeded this window were administered the practice session again with a longer inter-stimulus interval and additional coaching as needed. Participants who did not meet the minimum no-go error level were administered the practice session again with a shorter inter-stimulus interval to increase the challenge. Initial stimulus presentation rates for the testing phase matched those used for the last practice session, and throughout the testing phase a dynamic algorithm adjusted the inter-stimulus intervals in order to attempt to keep no-go error rates in the targeted window. If no-go error rates exceeded 60%, trial presentation rate was automatically slowed, whereas if error rates fell below 40% trial presentation rate was speeded.

The task was administered in three equal-sized blocks, with the algorithm for awarding points differing across blocks in order to experimentally manipulate the reward context. This manipulation was patterned after an affective go/no-go paradigm first reported by Lewis, Lamm, Segalowitz, Stieben, and Zelazo (2006) and Stieben et al. (2007). In the first block, the algorithm awarding points strongly favored
correct responses and weakly punished incorrect responses, thus resulting in a rapid accumulation of points. In the second block, this algorithm was reversed, resulting in a loss of points regardless of equivalent performance, thus representing a frustrative non-reward condition. The final block employed the same high-reward algorithm as the first block and all participants ended the game with enough points to win the prize. In the present study, because the research question of interest was not related to the effects of the manipulation of reward context and in order to maximize the number of trials available for each emotional face condition, data were collapsed across all three task blocks.

EEG data acquisition. EEG was recorded using an extended 10-20 montage with a 32-channel elastic stretch BioSemi headcap with the Active Two BioSemi system (BioSemi, Amsterdam, Netherlands). Two additional electrodes were placed on the left and right mastoids, and four additional facial electrodes were used to measure eye movement. Vertical eye movements were measured from electrodes placed on the infra-orbital ridges centered under the pupils of both eyes and corresponding supra-orbital electrodes embedded within the cap. Horizontal eye movements were measured from electrodes placed approximately 1 cm outside the participants’ right and left outer canthi. Data were recorded at 512 Hz with Actiview Software, v8.0.

EEG data post-processing. EEG data were post-processed using Brain Vision Analyzer 2.0. Voltages were re-referenced to the average of all electrode sites. EEG data were strongly affected by very low frequency power in the delta band, considered typical of young children and conceptualized as a marker of developmental immaturity (Somssen, van’t Klooster, van der Molen, van Leeuwen, & Licht, 1997; Yordanova & Kolev, 2008). In order to reduce the impact of sub- and very low delta frequency noise, a 1 to 30 Hz Butterworth Zero Phase filter was employed (see, e.g., Lewis et al., 2006), as has been done in previously published studies of ERPs in the present sample (DuPuis et al., 2015; Gatzke-Kopp et al., 2015; Willner, Gatzke-Kopp, Bierman, Greenberg, & Segalowitz, 2015). The high-pass filter at 1 Hz also served to remove very slow wave drift that was present in the data.

Event-related potentials to angry, fearful, and neutral face go-trial stimuli were used for the present analyses. Each facial expression was presented on 48 go trials across the full task. Trials were
segmented from -200 to 1000 ms relative to stimulus onset, separately for each emotional face condition, and voltages were baseline-corrected to the mean voltage during the 200 ms pre-stimulus period. Corrections were made for eye blink artifacts using the Gratton and Coles algorithm, as implemented by Brain Vision Analyzer 2.0 (Gratton, Coles, & Donchin, 1983). After this correction, trials with a voltage step of more than 100 µV between sampling points or a voltage reading outside the range of -75 µV to 75 µV were marked as artifactual and were excluded from the calculation of average voltages across trials. Average waveforms were calculated across all valid segments for each emotional face condition. Children with fewer than 10 segments remaining after artifact rejection for angry, fearful, or neutral face stimuli were not included in the analyses. Following these procedures, there were an average of 37.9 segments (SD = 8.3, range = [12, 48]) contributing to the average waveform for angry faces, 38.4 segments (SD = 8.3, range = [12, 48]) contributing to the average waveform for fearful faces, and 38.2 segments (SD = 8.0, range = [12, 48]) contributing to the average waveform for neutral faces.

**ERP amplitude measures.** Amplitudes were calculated for the occipital P1, temporo-parietal N170, parieto-occipital P2, and centro-parietal P3 ERPs. The grand-average waveform to angry, fearful, and neutral face go-trial stimuli at central, parietal, and occipital electrodes is presented in Figure 3.1. ERP peaks were identified based on visual inspection of the waveform, guided by previously-reported scalp locations and latencies for these peaks in children (e.g., Meaux et al., 2014; Pfueller et al., 2011; Thomas & Nelson, 1996; Tye et al., 2014).

The P1, N170 and P2 peaks were scored based on each child’s average waveform for each emotional face condition by trained research assistants using a computer-assisted hand-scoring peak analysis program (Segalowitz, 1999). P1 amplitude was measured at the peak of the first positive deflection at the occipital electrodes O1, Oz, and O2, occurring between 80 and 156 ms after stimulus onset, with a mean latency of about 125 ms. Correlations between the P1 amplitude values measured at these three electrodes were very high (collapsed across emotional face conditions, O1 with Oz: $r = .87$; O2 with Oz: $r = .93$; O1 with O2: $r = .81$). N170 amplitude was measured at the peak of the first major negative deflection at the temporo-parietal electrodes P7 and P8, occurring between 130 and 340 ms after
stimulus onset, with a mean latency of about 207 ms. The N170 amplitude values measured at these two electrodes were moderately highly correlated \((r = .47, \text{collapsed across emotional face conditions})\). P2 amplitude was measured at the peak of the second positive deflection at the parieto-occipital electrodes PO3 and PO4, occurring between 216 and 453 ms after stimulus onset, with a mean latency of about 305 ms. The P2 amplitude values measured at these two electrodes were highly correlated \((r = .76, \text{collapsed across emotional face conditions})\).

The mean P3 amplitude was calculated using the area amplitude export feature in Brain Vision Analyzer 2.0, using a consistent time window across all emotional face conditions and children. P3 amplitude was measured as the mean voltage at the centro-parietal electrodes CP1, Pz, and CP2 in the time window between 430 and 630 ms. The P3 amplitudes measured at these three electrodes were highly correlated (collapsed across emotional face conditions, CP1 with Pz: \(r = .69\); CP2 with Pz: \(r = .67\); CP1 with CP2: \(r = .68\)).

Of the 250 children who had participated in a 1st-grade physiological assessment and who had 1st-grade teacher survey data, 202 also had valid amplitude data for the angry, fearful, and neutral face conditions for at least one of the ERPs of interest. Children were missing ERP data for the following reasons: technical difficulties during data collection \((n = 35)\); noisy data that resulted in 10 or fewer segments remaining for the angry, fearful, and/or neutral face condition after artifact rejection \((n = 9)\); the go/no-go task was not completed during the assessment \((n = 2)\); the EEG cap could not be used due to the child’s hair style preventing proper electrode contact with the scalp \((n = 1)\); and human error during data collection \((n = 1)\). Cases that were missing data at any relevant electrode for the angry, fearful, or neutral emotional face condition were excluded from analyses for that ERP. Data were missing differentially for individual ERPs due to data quality problems specifically at electrodes relevant to that ERP; additionally, for the ERPs that were scored using a single-point measure of the peak (i.e., the P1, N170, and P2), the ERP was not scored if a clearly discernible peak was not visible for that ERP, e.g., due to noise in the signal. Analyses were conducted using the maximum available sample size for each ERP \((P1: n = 167; \text{N170: } n = 170; \text{P2: } n = 168; \text{P3: } n = 199)\).
Average amplitudes across all relevant electrodes were calculated for the P1, N170, P2, and P3 ERPs for each emotional face condition. Average ERP amplitudes to the neutral face condition were subtracted from the amplitudes to the angry and fearful face conditions, forming difference scores representing biases toward processing social cues of anger and fear, respectively. As reported in the Results section, no significant differences were observed between children’s average ERP amplitudes to angry and fearful faces, and moderately high positive correlations were observed between the angry-neutral and fearful-neutral difference scores for each ERP. Given these observations and the lack of firm empirically-supported hypotheses regarding differences in symptom correlates of angry versus fearful face processing biases, the primary analyses were conducted using an average ERP threat bias score collapsing across the angry-neutral and fearful-neutral contrasts. Multivariate analyses were conducted to assess whether effects differed significantly between the angry-neutral and fearful-neutral threat biases and, where indicated, additional exploratory analyses were conducted in which the angry-neutral and fearful-neutral contrasts were examined independently. Correlations between the ERP threat biases and children’s gender were examined, and gender was included as a covariate only if it was significantly correlated with the threat bias score.

**Analytic approach**

The associations between children’s ERP indices of social threat processing biases and their internalizing and externalizing symptoms were examined using two complementary analytic strategies. First, building on the latent profile analysis reported in Chapter 2, differences in children’s ERP threat biases across internalizing-externalizing symptom profiles were explored. Second, a more traditional variable-oriented analysis was conducted in which children’s ERP threat biases were regressed on continuous measures of internalizing and externalizing symptom severity.

**Strategy 1: Latent symptom profiles.** A latent profile analysis (LPA) of children’s 1st-grade aggression/oppositionality, hyperactivity/inattention, anxiety, and social withdrawal factor scores was conducted, with the expectation that the same 4 profiles that had been identified for the full sample across all three school years in Chapter 2 would also emerge using only the 1st-grade data \( (n = 272) \). After
selecting the optimal latent profile model for children’s 1st-grade symptom factors, omnibus tests of mean differences across profiles in children’s ERP threat biases were examined, and pairwise contrasts between profile means were only examined in the case of a significant omnibus test of profile differences. These analyses were conducted using an adjusted classify-analyze approach in which children are assigned to the profile for which they have the highest probability of membership and cases are weighted to adjust for error in profile assignment using a method originally proposed by Bolck, Croon, & Hagenaars (2004) and refined by Vermunt (2010) and Bakk and Vermunt (2016), referred to as the BCH method. The BCH-adjusted analyses were conducted using the implementation of this method in Mplus v.7.4 (Asparouhov & Muthén, 2015).

**Strategy 2: Dimensional symptom severity.** A secondary set of analyses was performed examining the associations between children’s ERP threat biases and their dimensional symptom factor scores. For these analyses, children’s aggression/oppositionality and hyperactivity/inattention factor scores were averaged to form an externalizing dimension score, and children’s anxiety and social withdrawal factor scores were averaged to form an internalizing dimension score. This averaging was justified because (1) the two symptom factors within each domain were moderately highly correlated (aggression/oppositionality with hyperactivity/inattention: \( r = .55 \); anxiety with social withdrawal: \( r = .58 \)); (2) the latent profile solution in Chapter 2 did not identify any profiles with discordant levels on the within-domain symptom factors; and (3) the two factors within each symptom domain exhibited a similar pattern of correlations with each ERP threat bias score (results not reported). Children’s internalizing and externalizing symptom severity were entered as predictors in a multiple regression analysis in order to assess the unique associations of each symptom dimension, controlling for the other symptom dimension, with children’s ERP threat biases. Furthermore, the interaction between these symptom dimensions was examined to test for comorbidity effects.

Since the focus of the present study is on ERP indices of social threat processing biases, the ERP threat biases are the primary outcomes of interest. For completeness, associations between symptom
profiles or dimensions and average ERP amplitudes are also reported, but these are not the focus of the present study.

3.3. Results

**ERP amplitudes by emotional face condition, across the full sample**

Prior to conducting analyses on ERP threat bias scores, repeated-measures analyses of variance (ANOVAs) were conducted to examine the average variation in ERP amplitudes between angry, fearful, and neutral faces across the full analysis sample. These models were run using the GLM procedure in SAS 9.3. In all models, the Greenhouse-Geisser and Huynh-Feldt ε estimates of sphericity were close to 1 (range = [.968, 1.00]), indicating that the assumption of sphericity was appropriate for the data; therefore, unadjusted univariate hypothesis tests of the omnibus emotion effect are reported.

Average P1 amplitudes to angry, fearful, and neutral faces were 29.7 μV (SD = 8.0), 29.7 μV (SD = 8.1), and 30.4 μV (SD = 8.1), respectively. The omnibus test for the emotional face condition was significant (F_{2,332} = 5.89, p = .003). Tests of linear contrasts revealed that P1 amplitudes were significantly lower to angry vs. neutral faces (t_{166} = 3.09, p = .002) and to fearful vs. neutral faces (t_{166} = 2.85, p = .005), whereas P1 amplitudes to angry and fearful faces did not differ (t_{166} = 0.00, p = .982).

Average N170 amplitudes to angry, fearful, and neutral faces were -7.55 μV (SD = 4.7), -7.62 μV (SD = 4.4), and -7.27 μV (SD = 4.5), respectively. The omnibus test for the emotional face condition was significant at the trend level (F_{2,338} = 2.32, p = .099). Tests of linear contrasts revealed that N170 amplitudes were significantly more negative to fearful vs. neutral faces (t_{169} = 2.19, p = .030), whereas N170 amplitudes did not differ significantly for angry vs. neutral (t_{169} = 1.49, p = .138) or angry vs. fearful (t_{169} = 0.44, p = .664) faces. In order to facilitate interpretation, throughout the remainder of the paper N170 amplitude values are multiplied by -1 so that, consistent with the P1, P2, and P3, a positive value reflects greater amplitude of the ERP.

Average P2 amplitudes to angry, fearful, and neutral faces were 12.4 μV (SD = 5.8), 12.4 μV (SD = 6.3), and 11.9 μV (SD = 5.8), respectively. The omnibus test for the emotional face condition was significant at the trend level (F_{2,334} = 2.61, p = .075). Tests of linear contrasts revealed that P2 amplitudes
were significantly higher to angry vs. neutral faces ($t_{167} = 2.14, p = .034$) and to fearful vs. neutral faces at the trend level ($t_{167} = 1.87, p = .063$), whereas P2 amplitudes to angry and fearful faces did not differ ($t_{167} = 0.00, p = .967$).

Average P3 amplitudes to angry, fearful, and neutral faces were 2.0 μV (SD = 2.3), 2.1 μV (SD = 2.1), and 2.3 μV (SD = 2.1), respectively. The omnibus test for the emotional face condition was significant ($F_{2,396} = 3.27, p = .039$). Tests of linear contrasts revealed that P3 amplitudes were significantly lower to angry vs. neutral faces ($t_{198} = 2.33, p = .021$) and to fearful vs. neutral faces ($t_{198} = 1.95, p = .052$), whereas P3 amplitudes to angry and fearful faces did not differ ($t_{198} = 0.39, p = .704$).

The primary analyses were conducted on children’s ERP threat biases, calculated as the ERP amplitude differences to angry and fearful vs. neutral faces. Means, standard deviations, and intercorrelations of these ERP threat biases collapsed across the angry-neutral and fearful-neutral contrasts are reported in Table 3.1, and these statistics are reported separately for the angry-neutral and fearful-neutral ERP amplitude differences in Table 3.2. Consistent with the ANOVA results reported above, the mean P1 and P3 ERP threat biases were significantly less than 0, reflecting lower amplitudes to threatening vs. neutral faces, whereas the mean N170 and P2 ERP threat biases were significantly greater than 0, reflecting higher amplitudes to threatening vs. neutral faces. As reported in Table 3.2, the angry-neutral and fearful-neutral ERP amplitude differences were moderately highly correlated within each ERP, with Pearson’s correlation coefficients ranging between .48 and .57, thereby supporting the validity of examining average ERP threat biases collapsed across the angry-neutral and fearful-neutral contrasts. In contrast, correlations between threat biases measured at different ERPs were generally small, with most Pearson’s correlation coefficients being between -0.09 and 0.19, although there was a slightly larger correlation between the P1 and P2 threat biases ($r = 0.36, p < .001$). This pattern of correlations suggests that the threat biases measured at different ERPs do indeed reflect distinct processes, thereby supporting the validity of examining them independently of one another.

None of the ERP threat biases differed between boys and girls at $p < .05$, and therefore gender was not included as a covariate in the primary analyses. However, girls exhibited a higher average P3
amplitude across all emotional face conditions (girls = 2.6 μV, boys = 1.9 μV; \( t_{199} = 2.17, p = .03 \)). Therefore, exploratory analyses on average P3 amplitude were conducted both with and without adjustment for gender.

**Strategy 1: Latent symptom profiles**

*Selecting the latent profile model.* To replicate the 4 latent symptom profiles that had been identified using all three years of data in Chapter 2, a 4-profile LPA model was fit to children’s 1\(^{st}\)-grade aggression/oppositionality, hyperactivity/inattention, anxiety, and social withdrawal factor scores (\( n = 272 \)) in Mplus 7.3. As before, the factor score means and variances were allowed to vary freely across profiles and the correlations between factor scores within each profile were fixed to 0. A model was also tested in which factor score variances were constrained to be equal across profiles, but this model provided significantly worse fit to the data (\( \Delta \text{-}2LL = 68.0, df = 12, p < .001 \)).

Models with 3 and 5 latent profiles were also estimated and their relative fit criteria were compared to those of the 4-profile model in order to verify that this model was the optimal solution for the 1\(^{st}\)-grade data. The 5-profile model did not converge on a well-identified solution (the 5\(^{th}\) profile was estimated to have a membership of just 3 individuals). This is likely an indication that the data could not support the extraction of 5 profiles and this model was not considered further. To compare the fit of the 3- and 4-profile models, a bootstrapped likelihood ratio test (BLRT; McLachlan, 1987) was conducted in Mplus following the procedures outlined in Asparouhov & Muthén (2012), using 100 randomly permuted bootstrap draws. This test indicated that the 4-profile model provided a significantly better fit to the data (\( \Delta \text{-}2LL = 69.6, df = 9, p < .001 \)). Additionally, the 4-profile model provided a more optimal balance of fit and parsimony as evidenced by the relative model information criteria (\( \Delta \text{AIC} = -51.6, \Delta \text{BIC} = -19.2, \Delta \text{aBIC} = -47.6 \)).

The factor score means and variances for each profile in the 1\(^{st}\)-grade 4-profile solution are reported in Table 3.3, and the profile-specific factor score means are plotted in Figure 3.2. The profiles closely matched those identified across the full three years of data in Chapter 2. The *comorbid* profile, characterized by elevated scores across all four symptom factors, constituted roughly 44% of the sample.
The *externalizing* profile, characterized by moderate levels of aggression/oppositionality and hyperactivity/inattention and lower levels of anxiety and withdrawal, accounted for 32% of the sample. The *internalizing* profile, characterized by high levels of anxiety and moderately high withdrawal combined with low levels of aggression/oppositionality and hyperactivity/inattention, constituted 16% of the sample. Finally, the *well-adjusted* profile, characterized by very low scores on all four symptom factors, constituted 9% of the sample. As was observed in Chapter 2, there was also markedly low variance in each factor score within the *well-adjusted* profile, indicating high within-profile homogeneity.

The analyses of ERP amplitude differences across profiles were conducted on the subset of children having valid data for each ERP. The estimated number of children in each symptom profile across the four ERP analysis samples were: 12 – 16 children in the *well-adjusted* profile, 23 – 31 in the *internalizing* profile, 49 – 62 in the *externalizing* profile, and 77 – 90 in the *comorbid* profile. For these analyses, children were assigned to their most-likely symptom profile and mean ERP measures were compared across symptom profiles using the BCH adjustment for classification error (Asparouhov & Muthén, 2015).

**Associations with average ERP amplitudes.** Prior to exploring profile differences in children’s ERP threat bias scores, profile differences in children’s average ERP amplitudes across angry, fearful, and neutral faces were assessed. Omnibus Wald tests did not provide evidence for differences across the four profiles in the mean amplitude of any ERP (P1: Wald $\chi^2 = 1.17$, df = 3, $p = .760$; N170: Wald $\chi^2 = 4.27$, df = 3, $p = .234$; P2: Wald $\chi^2 = 0.02$, df = 3, $p = .999$; P3: Wald $\chi^2 = 5.61$, df = 3, $p = .132$), and symptom profile differences in average P3 amplitude remained non-significant when controlling for gender (Wald $\chi^2 = 3.67$, df = 3, $p = .299$).

**Associations with ERP threat biases.** Omnibus Wald tests did not provide evidence for significant mean differences across the four profiles in any of the ERP threat biases, collapsed across the angry-neutral and fearful-neutral contrasts (P1 threat bias: Wald $\chi^2 = 3.00$, df = 3, $p = .392$; N170 threat bias: Wald $\chi^2 = 3.67$, df = 3, $p = .299$; P2 threat bias: Wald $\chi^2 = 4.78$, df = 3, $p = .189$; P3 threat bias: Wald $\chi^2 = 1.82$, df = 3, $p = .611$). Additionally, omnibus tests of differences in effects between the angry-
neutral and fearful-neutral contrasts were not significant for any ERP (P1 angry vs. fearful threat bias: Wald $\chi^2 = 5.27$, df = 3, $p = .153$; N170 angry vs. fearful threat bias: Wald $\chi^2 = 0.83$, df = 3, $p = .842$; P2 angry vs. fearful threat bias: Wald $\chi^2 = 4.21$, df = 3, $p = .240$; P3 angry vs. fearful threat bias: Wald $\chi^2 = 5.01$, df = 3, $p = .171$) (see Appendix B for an example of the Mplus syntax that was used to conduct this omnibus test). Since these omnibus tests were not significant, there was insufficient justification to examine the pairwise contrasts between profiles in average ERP threat biases or in ERP amplitude biases specifically to angry or fearful faces. However, in order to facilitate comparison of the results of the latent symptom profile analysis strategy with those obtained from the dimensional symptom severity analysis strategy, the full results from all 48 pairwise contrasts between profiles on angry-neutral and fearful-neutral ERP amplitudes are reported in Appendix C.

**Strategy 2: Dimensional symptom severity**

As described above, for this set of analyses children’s symptom factor scores were condensed into an internalizing score (averaged across the anxiety and withdrawal factor scores) and an externalizing score (averaged across the aggression/oppositionality and hyperactivity/inattention factor scores).

**Associations with average ERP amplitudes.** Zero-order correlations were examined between children’s internalizing and externalizing symptom severity scores and their average ERP amplitudes across angry, fearful, and neutral faces. Neither symptom dimension was significantly correlated with average amplitudes for the P1 (externalizing: $r = -.09$, $p = .223$; internalizing: $r = .11$, $p = .167$), the N170 (externalizing: $r = -.07$, $p = .397$; internalizing: $r = -.08$, $p = .275$), or the P2 (externalizing: $r = .06$, $p = .452$; internalizing: $r = .03$, $p = .676$). However, average P3 amplitudes were negatively correlated with children’s internalizing symptom severity ($r = -.15$, $p = .030$) and, at the trend level, their externalizing symptom severity ($r = -.13$, $p = .072$). With gender partialled out, the correlation between average P3 amplitudes and internalizing symptoms remained significant ($r = -.14$, $p = .043$), but the correlation with externalizing symptoms did not ($r = -.09$, $p = .196$).

**Associations with ERP threat biases.** Zero-order correlations between children’s ERP threat biases and their internalizing and externalizing symptom severity are presented in Table 3.4. These
unadjusted correlations provided evidence for a negative association between externalizing symptom severity and children’s P2 threat bias ($r = -.21, p = .008$). Linear multiple regression analyses were then conducted in which children’s ERP threat biases were predicted by their internalizing symptom severity, externalizing symptom severity, and the interaction between internalizing and externalizing symptom severity. The results of these analyses are reported in Table 3.5 and are discussed below separately for each ERP. These analyses were conducted in two steps; In step 1, children’s internalizing and externalizing symptoms were entered as predictors, and in step 2, the interaction between the internalizing and externalizing symptom dimensions was added to the model. Although the main effects of both symptom dimensions were included in the step 2 model, results from this model are only reported for the interaction term.

**P1 threat biases.** Neither children’s externalizing nor internalizing symptoms, nor the interaction between these symptom dimensions, significantly predicted their P1 threat biases averaged across the angry-neutral and fearful-neutral face contrasts (externalizing: $\beta = -0.092, p = .269$; internalizing: $\beta = 0.088, p = .250$; externalizing x internalizing: $\beta = 0.020, p = .809$). However, a multivariate ANOVA indicated that the associations of both externalizing and internalizing symptoms with the P1 threat bias varied as a function of the type of threatening face (externalizing: $t_{163} = 2.40, p = .018$; internalizing: $t_{163} = 1.91, p = .058$), although this was not true for the externalizing x internalizing interaction term ($t_{162} = 0.10, p = .905$). Table 3.6 reports the results of regression analyses conducted separately for the angry-neutral and fearful-neutral P1 amplitude differences. Children’s externalizing and internalizing symptoms were not associated with their angry-neutral P1 amplitude. In contrast, higher externalizing symptoms (controlling for internalizing symptoms) were associated with a more negative fearful-neutral P1 amplitude ($\beta = -0.165, p = .037$), whereas higher internalizing symptoms (controlling for externalizing symptoms) were associated at the trend level with a more positive fearful-neutral P1 amplitude ($\beta = 0.144, p = .069$). Figure 3.3 plots the estimated associations of children’s fearful-neutral P1 amplitudes with their externalizing symptoms (Panel A) and internalizing symptoms (Panel B), with the other symptom domain fixed to the sample mean. As is apparent from the confidence intervals around the
predicted values, a significant P1 amplitude bias away from fearful faces (i.e., a value significantly less than 0) was present among children with high externalizing symptoms, or among children with low internalizing symptoms, with average levels on the other symptom domain. In contrast, the fearful-neutral P1 amplitude bias was not significantly different from 0 among children with low externalizing symptoms or high internalizing symptoms.

To gain further insight into the nature of the association between symptoms and children’s early face processing biases, follow-up analyses were conducted in which mean P1 amplitudes to fearful and neutral faces were separately regressed on children’s internalizing and externalizing symptoms. Higher externalizing symptoms were significantly associated with lower P1 amplitudes to fearful faces ($\beta = -0.16, p = .038$) but were not significantly associated with P1 amplitudes to neutral faces ($\beta = -0.10, p = .211$). Conversely, higher internalizing symptoms were significantly associated with higher P1 amplitudes to fearful faces ($\beta = 0.17, p = .034$) but were not significantly associated with P1 amplitudes to neutral faces ($\beta = 0.11, p = .162$). Thus, these fearful face bias effects cannot be accounted for by differential processing of the neutral faces.

**N170 threat biases.** There was a trend for higher internalizing symptoms (controlling for externalizing symptoms) to be associated with a lower N170 amplitude bias to threatening vs. neutral faces ($\beta = -0.139, p = .083$). Externalizing symptoms were not associated with the N170 threat bias ($\beta = 0.048, p = .550$), nor was the interaction between externalizing and internalizing symptoms ($\beta = 0.048, p = .542$). The multivariate ANOVA tests of differences in effects between the N170 angry-neutral and fearful-neutral contrasts were not significant for any predictor (externalizing: $t_{166} = 0.49, p = .625$; internalizing: $t_{166} = 0.20, p = .832$; externalizing x internalizing: $t_{165} = 0.14, p = .902$).

**P2 threat biases.** Greater externalizing symptoms (controlling for internalizing symptoms) were associated with a lower P2 amplitude to threatening vs. neutral faces ($\beta = -0.245, p = .002$), whereas greater internalizing symptoms (controlling for externalizing symptoms) were associated with a higher P2 amplitude to threatening vs. neutral faces ($\beta = 0.174, p = .026$). However, these associations were qualified by a significant interaction between externalizing and internalizing symptoms ($\beta = 0.160, p = .
This interaction is graphed in Figure 3.4. Simple-slope region of significance analyses (Preacher, Curran, & Bauer, 2006) revealed that the association between higher externalizing symptoms and lower P2 amplitude to threatening vs. neutral faces was only significant among children whose internalizing symptoms were at most 0.5 SD above the mean. Conversely, the association between higher internalizing symptoms and a greater P2 amplitude bias toward threat was only significant among children whose externalizing symptoms were 0.3 SD below the mean or higher. Thus, increasing externalizing symptom severity was associated with a lower P2 amplitude bias toward threat only among children with moderate or low levels of internalizing symptoms, and greater internalizing symptom severity was associated with a higher P2 amplitude bias toward threat only among children with moderate or high levels of externalizing symptoms. Children with very low internalizing symptoms (-1 SD) and very high externalizing symptoms (+1 SD) were predicted to show a significant P2 amplitude bias away from threatening vs. neutral faces (estimated P2 threat bias = -1.2 μV, which was less than 0 at \( p = .010 \)). In contrast, children with internalizing symptoms at 1 SD above the mean were predicted to show a significant P2 amplitude bias toward threatening vs. neutral faces regardless of their level of externalizing symptoms (e.g., for children with both externalizing and internalizing symptoms at 1 SD above the mean, the estimated P2 threat bias was 0.68 μV, which was greater than 0 at \( p = .057 \)). Finally, children with low levels of externalizing symptoms were predicted to show a P2 amplitude bias toward threat regardless of their level of internalizing symptoms.

To gain further insight into the nature of the association between symptoms and the P2 threat processing bias, separate regression analyses were conducted for mean P2 amplitudes to neutral faces and for mean P2 amplitudes averaged across the two threatening faces (fearful and angry). There was no association between children’s externalizing symptoms (controlling for internalizing symptoms) and their average P2 amplitudes to the threatening faces (\( \beta = 0.02, p = .829 \)); on the other hand, there was a non-significant trend for higher externalizing symptoms to be associated with higher P2 amplitudes to neutral faces (\( \beta = 0.13, p = .118 \)). Internalizing symptoms (controlling for externalizing symptoms) were not significantly associated with P2 amplitudes to the threatening faces (\( \beta = 0.04, p = .580 \)) or to neutral faces.
(β = -0.03, p = .697), and the interaction between internalizing and externalizing symptoms was also not significant for threatening (β = 0.00, p = .985) or neutral (β = -0.07, p = .365) faces. However, in order to follow up on the significant interaction effect reported above for the P2 amplitude threat bias, the simple slopes for externalizing symptoms predicting P2 amplitudes to neutral faces among children with low or high internalizing symptoms were examined. Among children with low (-1 SD) internalizing symptoms, externalizing symptoms were associated with a trend for greater P2 amplitudes to neutral faces (β = 0.20, p = .083); in contrast, among children with high (+1 SD) internalizing symptoms, externalizing symptoms were not associated with P2 amplitudes to neutral faces (β = 0.05, p = .638). Thus, these follow-up analyses suggest that the lower P2 threat biases observed for children with high externalizing symptoms and low internalizing symptoms may in fact be driven by a tendency for these children to exhibit higher P2 amplitudes to neutral faces, as opposed to lower P2 amplitudes to threatening faces.

The multivariate ANOVA tests of differences in effects between the P2 angry-neutral and fearful-neutral contrasts were not significant for any predictor (externalizing: $t_{164} = 0.63, p = .527$; internalizing: $t_{164} = 0.98, p = .327$; externalizing x internalizing: $t_{163} = 1.14, p = .255$). Thus, there was no evidence that the associations reported above varied according to the type of threatening face (angry vs. fearful).

P3 threat biases. Neither children’s externalizing nor internalizing symptoms, nor the interaction between these symptom dimensions, significantly predicted their P3 threat biases averaged across the angry-neutral and fearful-neutral face contrasts (externalizing: $β = 0.053, p = .479$; internalizing: $β = -0.029, p = .693$; externalizing x internalizing: $β = 0.029, p = .697$). Additionally, the multivariate ANOVA tests of differences in effects between the P3 angry-neutral and fearful-neutral contrasts were not significant for any predictor (externalizing: $t_{195} = 1.20, p = .229$; internalizing: $t_{195} = 0.60, p = .549$; externalizing x internalizing: $t_{194} = 0.87, p = .388$).

3.4 Discussion

The present study explored associations between at-risk 1st-grade children’s social threat processing biases, as indexed by the amplitudes of perceptual-attentional ERPs to threatening versus neutral faces, and their internalizing and externalizing symptoms as measured by teacher report. Two
analytic approaches were employed: first, mean ERP threat biases were compared across groups of children classified as exhibiting a well-adjusted, internalizing, externalizing, or comorbid symptom profile; second, linear associations were examined between ERP threat biases and children’s dimensional internalizing and externalizing symptom severity, including the interaction between these two dimensions. The symptom profile approach did not provide evidence for significant differences across profiles for any of the ERP threat bias measures; therefore, the results of these analyses are not discussed. In contrast, the dimensional symptom severity analyses provided evidence for associations between children’s symptoms and biases in both early attentional selection and deeper perceptual processing of social cues. These results are discussed below.

**P1 amplitude to fearful faces was differentially associated with externalizing versus internalizing symptoms.**

The amplitude of the P1 peak reflects early attentional selection of a stimulus for visual processing (Railo et al., 2011). In the present study, P1 amplitudes were higher on average to neutral faces than to angry or fearful faces, a pattern that was unexpected and will be discussed in more detail below. With regard to associations with children’s symptoms, higher externalizing symptom severity was associated with a more negative fearful-neutral P1 amplitude difference, whereas higher internalizing symptom severity was associated with a less negative fearful-neutral P1 amplitude difference. Importantly, these associations appeared to be driven by variation in the P1 amplitude specifically to fearful faces; externalizing symptoms were negatively associated and internalizing symptoms were positively associated with P1 amplitudes to fearful faces, and neither symptom dimension was significantly correlated with P1 amplitudes to neutral faces. Furthermore, the interaction between internalizing and externalizing symptoms was not significantly associated with the fearful-neutral P1 amplitude difference. Thus, children exhibiting comorbid internalizing and externalizing symptoms would be expected to show fearful-neutral P1 amplitude differences that are intermediate between those of children exhibiting more “pure” internalizing or externalizing symptoms. Finally, no significant associations were observed between children’s symptoms and their angry-neutral P1 amplitude
difference. Thus, these results suggest that P1 amplitude specifically to fearful faces may be a differential risk factor for externalizing versus internalizing symptoms.

This finding contributes substantially to the extremely limited literature base on associations between children’s externalizing symptoms and ERP indices of perceptual-attentional biases in social threat processing. Prior findings regarding P1 amplitude to emotional faces in children with externalizing problems are sparse and inconclusive, but the present result is generally consistent with one prior study that revealed an association between lower P1 amplitudes to fearful faces and greater emotion dysregulation among children aged 5 to 9 years (Dennis et al., 2009). Although not equivalent to externalizing symptoms, emotion dysregulation is generally more closely associated with externalizing than internalizing problems in children (Eisenberg et al., 2001). Similarly, within a sample of children diagnosed with ADHD, lower P1 amplitudes to face stimuli have been associated with greater emotional lability, although this association was not modulated by the emotional expression of the face (Williams et al., 2008).

Theoretically, lower P1 amplitudes to fearful faces may reflect reduced automatic recruitment of perceptual-attentional resources to processing these faces, potentially due to deficient activation of the amygdala to preconsciously-transmitted visual information conveying the threat content of the fearful face (Pourtois et al., 2013). Indeed, functional neuroimaging studies have observed that children and adolescents with high levels of callous-unemotional traits show lower amygdala activation to fearful faces, but not to angry or neutral faces (Jones, Laurens, Herba, Barker, & Viding, 2009; A. A. Marsh et al., 2008; White et al., 2012). Similarly, antisocial individuals have been shown to exhibit a particularly strong deficit in recognizing fearful facial expressions (A. A. Marsh & Blair, 2008). Given that fearful expressions are a signal of distress, individuals who are less responsive to others’ fearful expressions are thought to be more likely to engage in antisocial behaviors because they do not perceive others’ distress as personally aversive (Blair, 2003). It is tempting to speculate that deficient automatic attentional capture by fearful faces, as indexed in the present study by blunted P1 amplitudes to fearful faces, may contribute to a deficit in recognizing fearful expressions. Evidence that emotional modulation of P1 amplitudes may
be important for downstream emotional face recognition processes was provided by Williams et al. (2008), who observed that, in their sample of children with ADHD, lower P1 amplitudes to emotional faces (particularly angry and fearful faces) were associated with poorer performance on a facial emotion recognition task.

In contrast to the negative association with externalizing symptoms, higher internalizing symptoms in the present sample were associated with larger P1 amplitudes specifically to fearful faces. This result is similar to that of a prior study in which adults with high versus low trait anxiety levels exhibited a greater P1 amplitude enhancement to fearful faces (Holmes et al., 2008). This result diverges, however, from a number of studies that have observed anxiety-related enhancements to P1 amplitude to faces regardless of the emotional expression (Dennis & Chen, 2007; Frenkel & Bar-Haim, 2011; Kolassa et al., 2009, 2007; Mühlberger et al., 2009; Rossignol et al., 2013; Rossignol, Philippot, et al., 2012). The results of the present study suggest that internalizing symptoms may be associated with enhanced early perceptual-attentional processing of fear-relevant stimuli, and that this early perceptual-attentional bias is present by middle childhood. This is consistent with results from behavioral studies in which enhanced attention biases to threatening information were observed in anxious individuals even when this information was presented subliminally (Bar-Haim et al., 2007), suggesting that these biases reflect enhanced preconscious threat detection processes presumably reflecting amygdala hypersensitivity to early visual cues of potential threat (Mogg & Bradley, 1998). Indeed, functional neuroimaging studies have provided evidence that greater trait anxiety is associated with greater amygdala activation to fearful faces in adults (Calder, Ewbank, & Passamonti, 2011) as well as in children (Thomas, Drevets, Dahl, et al., 2001). In support of the hypothesis that anxious individuals show particularly strong sensitivity to preconsciously-transmitted visual information about fearful faces, Etkin et al. (2004) observed that greater trait anxiety in adults was associated with greater activations in the amygdala as well as in ventral visual cortex (including the fusiform gyrus) specifically when fearful faces were presented subliminally, but not when they were presented supraliminally. Thus, a greater P1 amplitude to fearful faces in anxious individuals may index amygdala-mediated enhancement of the preconscious feedforward sweep of
perceptual information to higher-order visual information-processing regions (Lamme & Roelfsema, 2000).

The interpretation of the results for P1 amplitude in the present study are complicated by the observation that, across the full sample, average P1 amplitudes were lower to both angry and fearful faces relative to neutral faces. Due to the unexpectedly enhanced P1 amplitudes to neutral faces across the full sample, even children with severe levels of internalizing symptoms were not estimated to show a significantly greater P1 amplitude to fearful versus neutral faces. This was also observed in the results from the latent profile approach (see Appendix C); although the fearful-neutral P1 amplitude difference was estimated to be larger in children with an internalizing versus well-adjusted profile (despite a non-significant omnibus test across all four profiles), the mean amplitude bias in the internalizing profile was not significantly different from 0.

It is not clear why children in the present study exhibited enhanced P1 amplitudes specifically to neutral faces. Prior studies in typically-developing children have generally not found evidence for P1 amplitude differences between neutral and emotional expressions (Batty & Taylor, 2006; Dennis et al., 2009; Meaux et al., 2014; Thai et al., 2016; Todd et al., 2008). It is possible that the divergence from these prior studies can be attributed to differences in sample characteristics, since 62% of the present sample was selected for elevated aggression/oppositionality in kindergarten and the entire sample was drawn from a low-income urban community. Thus, to the extent that emotional expression processing differs according to these characteristics, average biases in the present sample would be expected to differ from those observed in lower-risk samples. Indeed, since a negative association was observed between externalizing symptoms and P1 amplitude to fearful faces, the elevated levels of externalizing symptoms in the sample as a whole can account for the lower average P1 amplitudes to fearful versus neutral faces; this does not, however, account for the lower P1 amplitudes observed to angry versus neutral faces, which were not associated with symptom severity. It is also possible that the divergence from prior studies is due to differences in the experimental tasks used. Notably, in each of the aforementioned studies the children were not explicitly instructed to attend to the emotional expressions of the faces. In the present
study, the face stimuli were presented as the target and non-target stimuli in a go/no-go task in which the no-go condition was signaled by the immediate repetition of the same face stimulus, matched for both identity and emotional expression. Therefore, children were explicitly instructed to attend to both the identities and the expressions of the faces. It is possible that the P1 amplitude enhancement to neutral versus fearful and angry faces observed in the present study may only emerge when children are explicitly instructed to attend to the emotional expression of the face.

However, this still does not explain why higher P1 amplitudes would be observed to neutral versus threatening faces, as this finding appears to contradict the hypothesis that P1 amplitude enhancement to emotional faces reflects amygdala sensitivity to coarse pre-conscious perceptual information conveying potential threat (e.g., widened eyes in fearful faces). This finding is, however, consistent with a neuroimaging study of emotional face processing in children, which found that typically-developing 11-year-old children exhibited a higher amygdala response to neutral than fearful faces, whereas adults showed the reverse pattern (Thomas, Drevets, Whalen, et al., 2001). The authors hypothesized that the greater amygdala activation to neutral faces in children may reflect developmental immaturities in recognizing these faces as neutral and non-threatening; if these faces are instead seen as ambiguous with regard to their threat value, this would be expected to activate the amygdala and increase perceptual vigilance in order to resolve this motivational ambiguity (Whalen, 1998). Indeed, prior research has shown that children have particular difficulty identifying neutral faces (Gross & Ballif, 1991), and that accuracy in identifying neutral faces is still developing through middle childhood (Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007). Thus, the P1 amplitude enhancement to neutral faces observed in the present study may reflect children’s need to allocate greater perceptual-attentional resources to processing these faces in order to discriminate their emotional expression.

In support of the hypothesis that P1 amplitude may be sensitive to the need to resolve facial expression ambiguity, a couple recent ERP studies of facial emotion processing in adults have provided suggestive evidence for P1 amplitude enhancements to face stimuli that present a greater emotion-identification challenge. For example, using a task in which adults were asked to identify either the
emotional expression or the color of an inverted or upright face stimulus, Peschard et al. (2013) observed enhanced P1 amplitudes to inverted versus upright face stimuli only in the emotion-identification condition, presumably reflecting the greater difficulty of identifying the emotion of an inverted versus upright face. In another study (Frenkel & Bar-Haim, 2011) in which adults were asked to identify the first face that they perceived as fearful in a sequentially-presented series of faces with emotional expressions morphing from neutral to fearful, P1 amplitudes were observed to increase markedly to the face that immediately preceded the first face that the participant overtly identified as fearful, followed by a relative decrease in amplitude to the overtly-identified fearful face. The morphed face just below the threshold for overt detection of fear presumably presents the most emotionally ambiguous stimulus, thus suggesting that the P1 amplitude enhancement to this face indexes increased automatic perceptual-attentional processing triggered by the need to identify the emotion expressed by this ambiguous face. It is possible that a similar process was operating for the present sample of children in response to neutral faces due to developmental immaturities in the automatic identification of neutral, non-threatening facial expressions.

**N170 threat biases were not significantly associated with externalizing or internalizing symptoms.**

The amplitude of the N170 peak is particularly sensitive to face cues and is presumed to reflect processes involved in face detection (Bentin et al., 1996; Eimer et al., 2011). In the present study, N170 amplitudes were greater on average to fearful versus neutral face stimuli, but did not differ significantly between angry and neutral faces. This is consistent with findings in adult samples of particularly heightened N170 amplitudes to fearful faces (Almeida et al., 2016; Batty & Taylor, 2003; Frühholz et al., 2011; Jiang et al., 2009; Pegna et al., 2008), potentially reflecting the particularly strong sensitivity of this component to eyes (Bentin et al., 1996), which are generally larger and more salient in fearful faces. However, this finding stands in contrast to several studies in typically-developing children that have failed to find significant differences in N170 amplitudes between fearful and neutral expressions (Batty & Taylor, 2006; Dennis et al., 2009; Meaux et al., 2014).

In the present study, there was a non-significant trend for higher internalizing symptoms to be associated with a lower N170 amplitude bias to threatening faces, and this effect did not differ between
the fearful and angry threat faces. No significant associations were observed between N170 amplitude threat biases and children’s externalizing symptoms, or the interaction between internalizing and externalizing symptoms. Since the correlation with internalizing symptoms was only trend-level, and since most studies with adults (Kolassa et al., 2009, 2007; Mühlberger et al., 2009; Peschard et al., 2013; Rossignol, Campanella, et al., 2012; Rossignol et al., 2013) and children (Thai et al., 2016) have failed to find associations between anxiety and N170 amplitudes to emotional expressions, this association will not be discussed further.

**A blunted P2 threat bias was associated with a pattern of high externalizing and low internalizing symptoms.**

The amplitude of the posterior P2 peak is presumed to reflect the allocation of neural resources to early conscious perceptual processing of a visual stimulus (Kotsoni et al., 2007; Latinus & Taylor, 2005). In the present study, posterior P2 amplitudes were higher on average to both angry and fearful versus neutral faces, suggesting that children generally allocated greater resources to conscious perceptual processing of threatening versus neutral faces. This is not consistent with a prior study that found no evidence for posterior P2 amplitude modulation across emotional and neutral expressions in children (Meaux et al., 2014), however that study excluded children with emotional or behavioral problems and it did not explicitly instruct the children to attend to the emotional expressions of the faces. The heightened P2 amplitudes to threatening versus neutral faces observed in the present study are also noticeably a reversal of the pattern that was observed for the P1 amplitude. This shift in the average perceptual-attentional bias between about 100 and 300 ms (which is when the P2 peaked in the present sample of children) may arise following a re-evaluation of the threat content of the stimulus based on more refined visual information, resulting in an appropriate down-regulation of resource allocation to processing neutral faces and/or an up-regulation of resource allocation to processing threatening faces. Interestingly, Durand et al. (2007) observed that typically-developing children most often mistook neutral faces for sad or happy expressions, rather than threatening expressions such as fearful or angry. Thus, although neutral expressions may have been more difficult for the children in this study to identify and would therefore
have required a greater initial allocation of perceptual processing resources (as discussed above with regard to the P1 amplitude enhancement to neutral faces), following the first feedforward sweep of visual information-processing the majority of children may have correctly determined that the neutral faces were not threatening, whereas the angry and fearful faces were threatening and therefore warranted greater attention allocation.

Importantly, the posterior P2 amplitude enhancement to threatening versus neutral faces differed according to children’s patterns of externalizing and internalizing symptoms. Among children with low to moderate levels of internalizing symptoms, greater externalizing symptom severity was associated with a blunting of the P2 amplitude bias to threatening (angry and fearful) versus neutral faces. Follow-up analyses suggested that this association may have been driven primarily by greater P2 amplitudes to neutral faces (at the trend level), as opposed to lower P2 amplitudes to threatening faces, in children with high externalizing symptoms and low or moderate internalizing symptoms. In contrast, children with high internalizing symptom severity were predicted to exhibit a significant P2 bias toward threatening faces regardless of their level of co-occurring externalizing symptoms (e.g., children exhibiting high levels of both internalizing and externalizing symptoms were predicted to show a significant P2 bias toward threat). Among children with low levels of externalizing symptoms, however, internalizing symptom severity was not associated with the magnitude of the P2 threat bias (i.e., children with low levels of externalizing symptoms showed a significant P2 threat bias regardless of their level of co-occurring internalizing symptoms). Thus, a blunted P2 threat bias, driven primarily by enhanced P2 amplitudes to neutral faces, was associated specifically with a pattern of high externalizing symptoms and moderate or low internalizing symptoms.

The lack of an association between the P2 threat bias and internalizing symptoms among individuals with low levels of externalizing symptoms may not be surprising, given that most studies in adults have failed to find evidence for anxiety-related differences in modulation of posterior P2 amplitudes across facial emotions (Dennis & Chen, 2007; Eldar et al., 2010; Felmingham et al., 2016; Frenkel & Bar-Haim, 2011; Kolassa et al., 2009; Kolassa & Miltner, 2006; Peschard et al., 2013;
Rossignol, Philippot, et al., 2012). Although two studies did find evidence for enhanced P2 amplitudes to angry versus neutral faces in adults (Bar-Haim et al., 2005; Rossignol et al., 2013), these studies did not measure participants’ levels of co-occurring externalizing symptoms and thus it cannot be known to what extent these findings may be limited to anxious individuals with at least moderate levels of co-occurring externalizing symptoms. No prior studies appear to have been conducted on modulation of the posterior P2 component by emotional expression in anxious children. One prior study using behaviorally-assessed attention biases on the dot-probe task (Salum et al., 2013) found that greater internalizing symptoms were not associated with a significant threat bias among children meeting criteria for externalizing disorders, whereas internalizing symptoms were associated with a bias toward threat among children without any psychiatric diagnosis or with a distress-related disorder. To the extent that the P2 threat bias may be expected to relate to attention biases measured on the dot-probe task, the present study would appear to find the reverse pattern – i.e., higher associations between internalizing symptoms and threat biases among children with higher levels of externalizing symptoms. However, the study by Salem et al. excluded children with comorbid psychiatric diagnoses, thus there was probably a limited range of internalizing symptom severity among children with externalizing disorders, which may account for the null relationship that they observed between internalizing symptoms and threat biases within this group.

To my knowledge, no prior studies have examined associations between the posterior P2 amplitude to emotional faces and externalizing symptoms in children. One study in adults failed to find an association between trait aggression and P2 amplitudes to emotional faces (Bertsch, 2009). However, consistent with the present findings, a neuroimaging study by Passamonti et al. (2010) revealed that, relative to healthy controls, adolescents and young adults diagnosed with early- or adolescent-onset conduct disorder showed lower activation in the amygdala and in face-sensitive regions of the temporal lobe to angry versus neutral faces, and this effect was driven by heightened activation to neutral faces rather than reduced activation to angry faces. Interestingly, this study did not observe associations with callous-unemotional or psychopathic personality traits, suggesting that enhanced reactivity to neutral
faces may be more closely linked to reactive aggression or impulsivity than to proactive or instrumental aggression.

There are two theoretical explanations that may account for the trend for enhanced P2 amplitudes to neutral but not threatening faces in children with high externalizing and low internalizing symptoms. One possibility is that high-externalizing/low-internalizing children allocate more conscious attentional resources to processing neutral faces due to a tendency to perceive these faces as threatening, and as a result they do not show as great a difference in P2 amplitudes between the objectively neutral and threatening faces. Hostile biases in the interpretation of ambiguous social situations are well documented in aggressive children and are hypothesized to be a key social information-processing mechanism contributing to aggressive behavior (De Castro, Veerman, Koops, Bosch, & Monshouwer, 2002; Dodge & Crick, 1990). Little is known, however, about children’s hostile interpretations of emotional faces specifically (as opposed to situational vignettes), or the role such interpretation biases may play in comorbid internalizing-externalizing symptom presentations. If heightened P2 amplitudes to neutral faces do indeed reflect biases towards hostile interpretations of ambiguous facial expressions, the present results suggest that children with comorbid internalizing-externalizing symptoms may be less likely to show such interpretation biases than are children with more “pure” externalizing symptoms.

Another possibility is that high-externalizing/low-internalizing children exhibit deficits in emotion recognition processes and they therefore engage in more sustained (less efficient) perceptual processing of the neutral faces in order to resolve their emotional ambiguity. Indeed, both adolescents with early-onset conduct disorder (Fairchild, Van Goozen, Calder, Stollery, & Goodyer, 2009) and children with ADHD (Bora & Pantelis, 2016) have been shown to exhibit facial emotion recognition deficits across a variety of discrete emotions. Moreover, reduced discrimination of positive versus negative emotional faces by N170 peak amplitudes has been observed in adults with ADHD, and this lower neural discrimination of emotional expressions was found to predict worse performance on an emotion recognition task (Ibáñez et al., 2011). Although no associations with externalizing symptoms were observed for the N170 in the present study, it is possible that the reduced P2 amplitude
discrimination between threatening and neutral faces may similarly relate to poorer emotion recognition skills. In support of this hypothesis, Meaux et al. (2014) observed that children who spent more time fixated on the eyes of emotional faces within the first 300 ms of stimulus onset, a strategy which is associated with stronger emotion recognition skills, also exhibited lower P2 amplitudes to emotional face stimuli. The authors interpreted this association as suggesting that lower P2 amplitudes reflected greater emotion processing efficiency; thus, higher P2 amplitudes may be linked to greater resource allocation to compensate for processing inefficiencies. Since children with comorbid internalizing and externalizing symptoms did not exhibit enhanced P2 amplitudes to neutral faces in the present study, this may suggest that, unlike children with relatively “pure” externalizing symptoms, those with comorbid symptoms do not show a particular deficit in conscious perceptual processing of ambiguous emotional expressions.

**P3 threat biases were not significantly associated with externalizing or internalizing symptoms.**

The amplitude of the relatively late P3 peak is presumed to reflect higher-order cognitive processing of the stimulus, in particular stimulus evaluation and categorization (Kok, 2001; Polich, 2007). In the present study, P3 amplitudes were observed to be lower on average to threatening versus neutral faces. This could reflect a general tendency for children to avoid prolonged processing of threatening content. Alternatively, since it is well known that P3 amplitude is enhanced to categories of stimuli that are relatively rare within the task context (Polich, 2007), it is possible that P3 amplitudes were enhanced to neutral faces simply because they were embedded within a larger stream of emotional faces. If children implicitly categorized the neutral faces as being different from the emotional faces and were therefore relatively surprised when a neutral face occurred, this would be expected to elicit a larger P3 amplitude.

The present study is the first to my knowledge to examine associations between P3 amplitudes to emotional face stimuli and children’s internalizing and externalizing symptoms. Results revealed no associations between children’s symptoms and the P3 amplitude bias to threatening versus neutral faces. This is generally unsurprising given mixed results for P3 amplitude biases to threatening faces in both anxiety and externalizing disorders. With regard to the association between anxiety and P3 amplitudes to emotional faces in adults, studies have observed lower amplitudes (Frenkel & Bar-Haim, 2011;
Mühlberger et al., 2009), higher amplitudes (Moser et al., 2008), and no differences in amplitudes (Felmingham et al., 2016; Sewell et al., 2008) to threatening versus neutral faces in anxious versus non-anxious adults. Additionally, ERP studies of emotional face processing in children with ADHD have observed either no differences in emotional modulation of the P3 amplitude (Williams et al., 2008) or blunted P3 amplitudes specifically to angry faces (Köchel et al., 2014) in ADHD versus non-ADHD control children. I am not aware of any studies of P3 amplitudes to emotional faces in children with aggressive or oppositional behavior problems. The results of the present study suggest that children’s internalizing and externalizing symptoms may not be associated with differential allocation of resources to cognitive-elaborative processing of threatening versus neutral faces. However, to the extent that neutral faces in the present study may have been perceived as a less expected category of stimulus, individual differences in P3 sensitivity to stimulus frequency effects may be confounding any symptom correlates of the P3 amplitude bias to threatening versus neutral faces.

Limitations

The design of the present study has several limitations that should be considered when interpreting the results. First, the cross-sectional analyses do not allow for the determination of causality. Thus, it is not clear whether the observed associations between children’s symptoms and their perceptual-attentional biases to threatening faces may reflect a causal role of these biases in symptom manifestation (as is implied by the “risk factor” framework), or if these biases may be epiphenomenal to children’s symptoms. Children’s symptoms may also indirectly cause changes in their social threat processing biases, for example externalizing or internalizing symptom expression may result in peer rejection, which may in turn potentiate social threat processing biases (Lansford, Malone, Dodge, Pettit, & Bates, 2010).

Second, the study sample is different from most samples used in psychophysiological research, in that it was recruited from a low-income urban community with high levels of neighborhood violence. Thus, it is not clear whether the findings can be generalized to more socially advantaged samples, particularly since severely adverse childhood experiences have been shown to increase children’s sensitivity to social threat cues (Pollak, Klorman, Thatcher, & Cicchetti, 2001; Pollak, Messner, Kistler, 113
& Cohn, 2009). However, the unique sample is also a strength of this paper, as it contributes to the diversity of representation within psychophysiological research (Gatzke-Kopp, 2016).

Third, the recruitment strategy for the study sample was intended to maximize variance in externalizing symptoms. Although remarkable variance was also observed in internalizing symptoms, there was greater representation of severe externalizing than severe internalizing symptoms. It is possible that stronger associations between social threat processing biases and children’s internalizing symptoms may have been observed had the sampling strategy involved over-selection for severe internalizing as well as externalizing symptoms.

Finally, the psychometric properties of the ERP threat biases examined in the present study have not been established. This is unfortunately a very common situation in psychophysiological research, and only relatively recently have psychophysiological scientists begun to systematically document the psychometric properties of ERP measures. Encouragingly, a recent investigation (Kappenman et al., 2014) has revealed at least moderate internal reliability for an ERP component called the N2pc elicited during a dot-probe task in young adults, whereas no internal reliability was observed for the behavioral measure of threat biases on this task, suggesting that ERP measures of threat biases may at least be more reliable than the commonly-used dot-probe behavioral measures. However, far more research needs to be conducted to establish the reliability of ERP measures of social threat processing biases, particularly in children.

3.5. Summary

The present study contributes substantially to the limited research base on neurophysiological indices of social threat processing biases and children’s externalizing, internalizing, and combined internalizing-externalizing symptom patterns. The results suggest that children with a pattern of high externalizing and low internalizing symptoms exhibit deficient automatic attentional capture by fearful faces and blunted differences in sustained perceptual processing of threatening versus neutral faces. This blunted differential processing was driven by heightened resource allocation to neutral faces, potentially reflecting hostile interpretation biases or inefficient processing of neutral expressions. In contrast,
children with a pattern of high internalizing and low externalizing symptoms exhibited greater automatic attentional capture by fearful faces and normative sustained perceptual processing of threatening versus neutral faces. Finally, children with comorbid internalizing and externalizing symptoms were found to exhibit more normative levels of automatic attentional capture by fearful faces relative to both “pure” symptom patterns, and more normative sustained perceptual processing of threatening versus neutral faces relative to children with “pure” externalizing symptoms.
3.6. References


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Table 3.1. Means, standard deviations, and intercorrelations of ERP threat biases.

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<th>N170a</th>
<th>P2</th>
<th>P3</th>
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<tr>
<td>Mean (SD)</td>
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<td>0.32 (1.99) *</td>
<td>0.46 (2.55) *</td>
<td>-0.24 (1.42) *</td>
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Correlations

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<th>P3</th>
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<tr>
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<td>-0.14 †</td>
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<td>0.08</td>
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Note. ERP threat biases are averaged across the angry-neutral and fearful-neutral contrasts. Significance tests on means reflect the difference of the mean from 0 (i.e., no threat bias). Unadjusted Pearson correlation coefficients are reported in the correlation table. All correlations are conducted using pairwise deletion of missing data. Sample sizes for the correlation coefficients range from 151 to 199. N170 amplitude values are multiplied by -1 so that greater threat bias scores reflect a larger N170 amplitude to the threatening vs. neutral face. † p < .10; * p < .05; ** p < .01
Table 3.2. Means, standard deviations, and intercorrelations of ERP angry-neutral and fearful-neutral amplitudes.

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<tr>
<td>Mean (SD)</td>
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<td>-0.69 (3.1) **</td>
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Correlations

P1

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<th>Fearful - Neutral</th>
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<tr>
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N170⁹

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<tr>
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P2

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P3

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<td>Fearful - Neutral</td>
<td>0.02</td>
<td>0.13 *</td>
</tr>
</tbody>
</table>

Note. Significance tests on means reflect the difference of the mean from 0 (i.e., no threat bias). Unadjusted Pearson correlation coefficients are reported in the correlation table. All correlations are conducted using pairwise deletion of missing data. Sample sizes for the correlation coefficients range from 151 to 199.

⁹N170 amplitude values are multiplied by -1 so that greater threat bias scores reflect a larger N170 amplitude to the threatening vs. neutral face.

† p < .10; * p < .05; ** p < .01
Table 3.3. 1st-grade LPA 4-profile solution \((n = 272)\).

<table>
<thead>
<tr>
<th>Prevalence, (n) (%)</th>
<th>Comorbid</th>
<th>Internalizing</th>
<th>Externalizing</th>
<th>Well-Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>119.2 (43.8%)</td>
<td>42.7 (15.7%)</td>
<td>86.2 (31.7%)</td>
<td>23.9 (8.8%)</td>
<td></td>
</tr>
</tbody>
</table>

Factor Score Means

<table>
<thead>
<tr>
<th></th>
<th>AGG</th>
<th>HYP</th>
<th>ANX</th>
<th>WITH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.585</td>
<td>-1.053</td>
<td>0.047</td>
<td>-1.300</td>
</tr>
<tr>
<td>HYP</td>
<td>0.439</td>
<td>-0.851</td>
<td>0.096</td>
<td>-1.093</td>
</tr>
<tr>
<td>ANX</td>
<td>0.440</td>
<td>0.384</td>
<td>-0.639</td>
<td>-0.894</td>
</tr>
<tr>
<td>WITH</td>
<td>0.431</td>
<td>-0.046</td>
<td>-0.513</td>
<td>-1.171</td>
</tr>
</tbody>
</table>

Factor Score Variances

<table>
<thead>
<tr>
<th></th>
<th>AGG</th>
<th>HYP</th>
<th>ANX</th>
<th>WITH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Var.</td>
<td>0.576</td>
<td>0.213</td>
<td>0.483</td>
<td>0.062</td>
</tr>
<tr>
<td>HYP</td>
<td>0.501</td>
<td>0.320</td>
<td>0.498</td>
<td>0.114</td>
</tr>
<tr>
<td>ANX</td>
<td>0.450</td>
<td>0.344</td>
<td>0.186</td>
<td>0.037</td>
</tr>
<tr>
<td>WITH</td>
<td>0.335</td>
<td>0.290</td>
<td>0.156</td>
<td>0.055</td>
</tr>
</tbody>
</table>

Notes. AGG = aggression/oppositionality; HYP = hyperactivity/inattention; ANX = anxiety; WITH = withdrawal.
Table 3.4. ERP threat bias correlations with internalizing & externalizing symptom dimensions.

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>N170*</th>
<th>P2</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Externalizing</td>
<td>-0.07</td>
<td>0.01</td>
<td>-0.21 **</td>
<td>0.04</td>
</tr>
<tr>
<td>Internalizing</td>
<td>0.07</td>
<td>-0.13</td>
<td>0.12</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

Note. Unadjusted Pearson correlation coefficients are reported. ERP threat biases are averaged across the angry-neutral and fearful-neutral contrasts.

*N170 amplitude values are multiplied by -1 so that greater threat bias scores reflect a larger N170 amplitude to the threatening vs. neutral face.

† p < .10; * p < .05; ** p < .01
Table 3.5. Regression of ERP threat biases on children's internalizing and externalizing symptom dimensions.

<table>
<thead>
<tr>
<th>ERP Threat Bias</th>
<th>P1</th>
<th>N170&lt;sup&gt;a&lt;/sup&gt;</th>
<th>P2</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Externalizing</td>
<td>-0.092</td>
<td>0.048</td>
<td>-0.245 **</td>
<td>0.053</td>
</tr>
<tr>
<td>Internalizing</td>
<td>0.088</td>
<td>-0.139 †</td>
<td>0.174  *</td>
<td>-0.029</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ext x Int</td>
<td>0.020</td>
<td>0.048</td>
<td>0.160  *</td>
<td>0.029</td>
</tr>
<tr>
<td>N</td>
<td>166</td>
<td>169</td>
<td>167</td>
<td>198</td>
</tr>
</tbody>
</table>

Note. Standardized regression coefficients are reported. ERP threat biases are averaged across the angry-neutral and fearful-neutral contrasts. <sup>a</sup>N170 amplitude values are multiplied by -1 so that greater threat bias scores reflect a larger N170 amplitude to the threatening vs. neutral face. † p < .10; * p < .05; ** p < .01
Table 3.6. Regression of P1 angry-neutral and fearful-neutral amplitudes on children's internalizing and externalizing symptom dimensions.

<table>
<thead>
<tr>
<th>P1</th>
<th>Angry - Neutral</th>
<th>Fearful - Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Externalizing</td>
<td>0.014</td>
<td>-0.165 *</td>
</tr>
<tr>
<td>Internalizing</td>
<td>0.003</td>
<td>0.144 †</td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ext x Int</td>
<td>0.013</td>
<td>0.021</td>
</tr>
</tbody>
</table>

\( N \) 166 166

Note. Standardized regression coefficients are reported.

† \( p < .10 \); * \( p < .05 \); ** \( p < .01 \)
Figure 3.1. Grand-averaged waveform at parieto-occipital electrodes, averaged across angry, fearful, and neutral faces.

Note. The electrode sites at which each ERP peak amplitude was measured are color-coded as follows. P1: red; N170: green; P2: purple; P3: blue.
Figure 3.2. Factor score means within profiles for the 1st-grade LPA 4-profile solution.

Notes. AGG = aggression/oppositionality; HYP = hyperactivity/inattention; ANX = anxiety; WITH = withdrawal.
Figure 3.3. Associations between P1 fearful-neutral amplitudes and children’s internalizing and externalizing symptoms

Note. Estimated mean P1 fearful-neutral amplitude values are plotted for each symptom dimension where the other symptom dimension is at the sample mean. Dotted curves mark the lower and upper bounds of the 95% confidence interval around the estimated mean values. (A) Estimated mean P1 fearful-neutral amplitude by externalizing symptoms, where internalizing symptoms are at the sample mean ($\beta = -0.165, p = .037$). (B) Estimated mean P1 fearful-neutral amplitude by internalizing symptoms, where externalizing symptoms are at the sample mean ($\beta = 0.144, p = .069$).
Figure 3.4. Association between the P2 threat bias and externalizing symptoms, by level of internalizing symptoms.

Note. The P2 threat bias is averaged across the angry-neutral and fearful-neutral contrasts. The slope for children with internalizing symptoms at 1 SD below the mean is significant at $p < .001$; the slope for children with mean levels of internalizing symptoms is significant at $p < .01$; the slope for children with internalizing symptoms at 1 SD above the mean is not significant ($p = .435$).
CHAPTER 4:

Discussion
The two studies in this dissertation explored the developmental course and social information-processing correlates of internalizing, externalizing and comorbid internalizing-externalizing symptom manifestations in young school-aged children from an urban, low-income school district.

Study 1 explored latent transitions in children’s profiles of aggression/oppositionality, hyperactivity/inattention, anxiety, and social withdrawal between kindergarten and 2nd grade. Four latent symptom profiles best accounted for the observed symptom co-occurrences. The largest profile was a *comorbid* profile, constituting nearly half of the sample in each year, and characterized by elevated levels on all four symptom factors. The high prevalence of this comorbid profile reveals that comorbidity is the norm rather than the exception, underlining the importance of investigating internalizing and externalizing symptom co-occurrence patterns rather than examining each dimension independent of the other. An *externalizing* profile, constituting about 20% of the sample in each year, was characterized by moderate levels of aggression/oppositionality and hyperactivity/inattention, and relatively low levels of anxiety and withdrawal (notably, aggression/oppositionality and hyperactivity/inattention factor scores in this profile were lower than those in the *comorbid* profile). An *internalizing* profile comprised another 20% of the sample in each year and was characterized by high levels of anxiety (equal to those of the *comorbid* profile), moderately high social withdrawal, and low levels of both aggression/oppositionality and hyperactivity/inattention. Finally, roughly 10% of the sample in each year fit a *well-adjusted* profile, with low mean levels and low variance on all four symptom factors.

The latent transition analysis revealed high levels of continuity in symptom profiles across years, particularly for the comorbid profile. Additionally, children with an externalizing profile had a very low probability of symptom remission and were at some risk of developing comorbid internalizing symptoms over time, whereas children with internalizing symptoms had a 20% chance of remitting in the next year and were at no risk of developing comorbid externalizing symptoms. These results reveal that internalizing-externalizing comorbidity may emerge in some individuals as a developmental consequence of early externalizing symptoms, but not as a consequence of early internalizing symptoms. However, the high prevalence of comorbidity at school entry and the relatively low prevalence of emergent comorbidity
suggests that the majority of comorbid cases result from common underlying risk factors as opposed to reflecting a symptom accumulation model.

Study 2 explored associations between ERP amplitude biases to social threat cues and children’s externalizing, internalizing, and comorbid symptom patterns. Omnibus tests of differences in mean ERP threat biases between the latent symptom profiles that had been identified in study 1 did not reveal any significant differences across the four profiles in any of the ERP threat bias measures (although a couple of the pairwise contrasts between profiles were significant at $p < .05$, correction for multiple hypothesis-testing renders all pairwise contrasts insignificant). However, a subsequent set of analyses in which children’s ERP threat biases were regressed on dimensional measures of internalizing and externalizing symptom severity, and the interaction between these two dimensions, did reveal an intriguing pattern of findings. The results suggested that individual differences in automatic perceptual-attentional capture by fearful faces, as indexed by amplitude of the P1 peak, differentially predicted internalizing versus externalizing symptoms. Higher internalizing symptoms, independent of co-occurring externalizing symptoms, were related to a larger P1 amplitude to fearful faces; conversely, higher externalizing symptoms, independent of co-occurring internalizing symptoms, were related to a smaller P1 amplitude to fearful faces. Additionally, effects were found for the P2 threat bias to both angry and fearful faces, which is presumed to index resource allocation to conscious perceptual processing of the visual stimulus. A marked blunting of this bias was observed specifically for children with high externalizing symptoms and low to moderate internalizing symptoms. All other children, including those with comorbid internalizing and externalizing symptoms, were estimated to show a greater P2 amplitude to threatening versus neutral faces. Since this blunting of the P2 threat bias appeared to be driven primarily by enhanced P2 amplitudes to neutral faces, this suggests that it may reflect either hostile interpretation biases or emotion-recognition deficits among children with “pure” externalizing symptoms.

Together, these studies highlight the importance of considering the co-occurrence between internalizing and externalizing symptom dimensions. In study 1, it was revealed that internalizing-externalizing comorbidity is highly prevalent and stable as early as kindergarten within a sample of high-
risk children, and it was hypothesized that this high early prevalence and stability were suggestive of a strong role for common underlying risk factors. Study 2 was able to test whether neural indices of social threat processing biases may be a common risk factor contributing to internalizing-externalizing comorbidity. However, no support was found for this hypothesis. In contrast, the finding that variation in early attentional capture by fearful faces was differentially related to internalizing versus externalizing symptoms suggests that either high or low levels on this factor would serve to reduce the probability of comorbid internalizing-externalizing symptoms. Additionally, blunted P2 threat biases appeared to function as a risk factor for externalizing symptoms only among children who did not exhibit comorbid internalizing symptoms. Thus, children exhibiting a comorbid profile were actually more similar on both of these threat bias measures to typically-developing children than they were to children exhibiting either “pure” symptom pattern. From a developmental psychopathology perspective, it is expected that some risk factors will increase the probability of “pure” versus comorbid symptom presentations, and individuals exhibiting comorbid symptoms would be expected to show intermediate levels on such differential risk factors.

Factor-analytic investigations of internalizing-externalizing comorbidity have provided substantial evidence for trait negative affectivity as a common underlying risk factor (Mikolajewski, Allan, Hart, Lonigan, & Taylor, 2013; Rhee, Lahey, & Waldman, 2015; Tackett et al., 2013). Although it was expected that the neural threat processing biases assessed in study 2 might tap some aspects of negative affectivity, this is a complex trait with many different facets in addition to negative biases in attention and interpretation (Watson & Clark, 1984). It is possible that the association between negative affectivity and internalizing-externalizing comorbidity is due to general emotion dysregulation, perhaps reflecting deficient prefrontal regulation of limbic system reactivity. Such deficient prefrontal control would be expected to yield a proclivity toward more intense and/or sustained emotional reactions to mildly threatening or frustrating events, which may or may not be potentiated by negativity biases in automatic perceptual processing of these events.
Although study 2 did not yield insight into common risk factors for internalizing-externalizing comorbidity, it is interesting to speculate that individual differences in the P1 amplitude to fearful faces (indexing automatic attentional capture by fear cues), may contribute to the extremely low probability of transitions between the internalizing and externalizing latent symptom profiles observed in study 1. Indeed, the probability that a child would transition from either “pure” symptom profile to the other “pure” symptom profile in the following year was estimated as 0. For such a low probability to be estimated, it stands to reason that there would need to be deeply-embedded differential risk factors that actively decrease the probability that an individual exhibiting one profile of symptoms would switch to the other. Similarly, the blunted P2 threat bias that was associated specifically with a pattern of high externalizing and low internalizing symptoms may contribute to the continuity of the “pure” externalizing symptom profile. Future research is warranted to investigate the role that such ERP threat biases may play in shaping developmental continuities in internalizing and externalizing symptoms.
4.1. References


Appendix A: Emotional face stimulus examples

Provided below are examples of angry, fearful, and neutral emotional face stimuli presented to participants during the Emotional Face Go-/No-Go Task. For each emotion, examples of female and male faces of African American and Caucasian race/ethnicity are provided.

*Neutral*

*Angry*

*Fearful*
Appendix B. Mplus model syntax for the omnibus test of differences between profiles in ERP angry-neutral and fearful-neutral amplitudes.

! P1AN = P1 angry – neutral
! P1FN = P1 fearful – neutral

Model:
%OVERALL%

! Estimate the means of the ERP threat bias scores within latent classes
%c#1%
[P1AN] (A1) ;
[P1FN] (F1) ;

%c#2%
[P1AN] (A2) ;
[P1FN] (F2) ;

%c#3%
[P1AN] (A3) ;
[P1FN] (F3) ;

%c#4%
[P1AN] (A4) ;
[P1FN] (F4) ;

! Create new variables equal to the profile differences in the means
Model Constraint:
New (A12 F12 A23 F23 A34 F34) ;

! Differences between profile means for the angry-neutral threat bias
! 3 contrasts for the 3 DF in the omnibus test (4 profiles - 1)
A12 = A1 - A2 ; ! angry-neutral: class 1 – class 2
A23 = A2 - A3 ; ! angry-neutral: class 2 – class 3
A34 = A3 - A4 ; ! angry-neutral: class 3 – class 4

! Differences between profile means for fearful-neutral
! 3 contrasts for the 3 DF in the omnibus test (4 profiles - 1)
F12 = F1 - F2 ; ! fearful-neutral: class 1 – class 2
F23 = F2 - F3 ; ! fearful-neutral: class 2 – class 3
F34 = F3 - F4 ; ! fearful-neutral: class 3 – class 4

Model Test:
! Omnibus test of Emotion (angry-neutral v. fearful-neutral) x Profile interaction
! DF = (4 Profiles - 1) * (2 emotions - 1) = 3
A12 = F12 ;
A23 = F23 ;
A34 = F34 ;
### Appendix C. Symptom profile differences in mean ERP amplitude biases to angry and fearful versus neutral faces.

<table>
<thead>
<tr>
<th>Symptom Profile</th>
<th>Well-Adjusted</th>
<th>Internalizing</th>
<th>Externalizing</th>
<th>Comorbid</th>
<th>Omnibus p</th>
<th>Significant Pairwise Contrasts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angry - Neutral</td>
<td>-1.81 [-3.8, 0.2]</td>
<td>-0.64 [-2.1, 0.8]</td>
<td>-0.43 [-1.5, 0.6]</td>
<td>-0.68 [-1.3, -0.1]</td>
<td>0.694</td>
<td></td>
</tr>
<tr>
<td>Fearful - Neutral</td>
<td>-1.50 [-2.6, -0.4]</td>
<td>0.75 [-0.8, 2.3]</td>
<td>-0.98 [-2.2, 0.2]</td>
<td>-0.81 [-1.5, -0.1]</td>
<td>0.134</td>
<td>Internalizing &gt; Well-Adjusted**, Externalizing†, Comorbid†</td>
</tr>
<tr>
<td><strong>N170\textsuperscript{a}</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angry - Neutral</td>
<td>1.31 [0.1, 2.5]</td>
<td>0.32 [-1.0, 1.7]</td>
<td>-0.05 [-0.7, 0.6]</td>
<td>0.30 [-0.3, 0.9]</td>
<td>0.298</td>
<td>Well-Adjusted &gt; Externalizing‡</td>
</tr>
<tr>
<td>Fearful - Neutral</td>
<td>1.06 [0.0, 2.2]</td>
<td>0.17 [-0.8, 1.2]</td>
<td>0.25 [-0.4, 0.9]</td>
<td>0.36 [-0.1, 0.8]</td>
<td>0.618</td>
<td></td>
</tr>
<tr>
<td><strong>P2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angry - Neutral</td>
<td>1.53 [0.5, 2.6]</td>
<td>1.25 [0.4, 2.1]</td>
<td>-0.16 [-1.2, 0.9]</td>
<td>0.41 [-0.3, 1.1]</td>
<td>0.066</td>
<td>Well-Adjusted &gt; Externalizing*, Comorbid‡; Internalizing &gt; Externalizing*</td>
</tr>
<tr>
<td>Fearful - Neutral</td>
<td>0.60 [-0.9, 2.1]</td>
<td>1.20 [0.3, 2.2]</td>
<td>0.67 [-0.3, 1.7]</td>
<td>0.03 [-0.9, 0.9]</td>
<td>0.399</td>
<td>Internalizing &gt; Comorbid‡</td>
</tr>
<tr>
<td><strong>P3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angry - Neutral</td>
<td>-0.45 [-1.2, 0.3]</td>
<td>-0.51 [-1.4, 0.3]</td>
<td>-0.16 [-0.7, 0.3]</td>
<td>-0.22 [-0.5, 0.1]</td>
<td>0.865</td>
<td></td>
</tr>
<tr>
<td>Fearful - Neutral</td>
<td>-0.43 [-1.2, 0.3]</td>
<td>-0.14 [-1.0, 0.7]</td>
<td>0.13 [-0.4, 0.6]</td>
<td>-0.46 [-0.8, -0.1]</td>
<td>0.282</td>
<td>Externalizing &gt; Comorbid‡</td>
</tr>
</tbody>
</table>

Note. Within-profile means and 95% confidence intervals are provided. All pairwise profile contrasts with \( p \)-values < .10, uncorrected, are reported.\textsuperscript{a} N170 amplitude values are multiplied by -1 so that greater threat bias scores reflect a larger N170 amplitude to the threatening vs. neutral face. † \( p < .10 \); * \( p < .05 \); ** \( p < .01 \)
Curriculum Vitae

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