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EXAMINING THE RELATIONSHIPS BETWEEN PRENATAL TOBACCO EXPOSURE, TEMPERAMENT, AND COGNITIVE ABILITY IN EARLY CHILDHOOD

by

Sam Pérez-González

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EXAMINING THE RELATIONSHIPS BETWEEN PRENATAL TOBACCO EXPOSURE, TEMPERAMENT, AND COGNITIVE ABILITY IN EARLY CHILDHOOD

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University of Nebraska, 2017

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Prenatal tobacco exposure (PTE) has been extensively researched and consistently associated with outcomes indicative of self-regulation deficits (e.g., ADHD, behavioral problems, and impaired cognitive function). Self-regulation is a multifaceted construct critical to children's successful behavioral, emotional, and academic adjustment and involves the integration of a cognitive component (executive function) and a temperamental component (effortful control). Previous research suggests temperament may be a pathway through which PTE affects children's future behavior and cognitive outcomes, but such studies have been limited to infancy and have not included measures of executive function. Thus, the current study had three aims: a) to examine clusters of temperament in a sample of PTE and unexposed children, b) to test whether PTE predicted these profiles, and c) to compare cluster performance across measures of cognitive ability and working memory. Participants were 250 (*M* age = 60.90 months) who completed the follow-up phase of a longitudinal study. Results from hierarchical and K-means clustering analyses of parent temperament ratings identified three distinct clusters with different self-regulation patterns: unregulated, average, and regulated. A

univariate nominal regression analysis showed that children with PTE were over 2 times more likely to be classified in average or unregulated clusters than the regulated clusters and males were over 3 times more likely to be classified as such. Lastly, an ANOVA with multiple group comparisons showed all three clusters differed significantly from each other in cognitive ability and working memory. Performance followed the same pattern as cluster self-regulation scores: children in the unregulated cluster showed the lowest performance followed by those in the average cluster. Children in the regulated cluster showed the highest levels of cognitive performance. These findings suggest children with PTE, particularly boys, are at risk for poorer self-regulation at this critical age of transition to schooling, which could have implications for their school functioning and social adjustment.

DEDICATION

To my mother and her mother before her, for their everlasting magic and unwavering belief in me.

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CHAPTER I

Introduction

The quality of the prenatal environment can have long-term implications for an individual's behavior patterns in both adaptive and maladaptive ways (e.g., Schuetze, Eiden, Colder, Gray, & Huestis, 2011). Prenatal tobacco exposure (PTE) is one environmental factor affecting the downstream development particularly well known for its associations with externalizing (Wakschlag, Leventhal, Pine, Pickett, & Carter, 2006) and disruptive behavior (Cornelius, Goldschmidt, DeGenna, & Day, 2007) and attention deficit hyperactivity disorder (ADHD) (e.g., Cornelius et al., 2007; Nomura, Marks, & Halperin, 2010). Some evidence suggests that impaired self-regulation is the common thread among these outcomes (see Wiebe et al., 2015). Self-regulation is typically examined from the standpoints of cognition (executive function) and temperament (effortful control). The literature suggests PTE negatively impacts children's ability to self-regulate by impairing neurocognitive function and exacerbating traits that may result in more difficult temperamental configurations. The purpose of the current study is to examine how PTE may influence the emergence of temperamental profiles in a sample of preschool-aged children, and to determine how these profiles compare to each other at the trait level and across measures of cognitive performance.

Self-Regulation

Self-regulation refers to the internal processes individuals use, across the lifespan and in multiple contexts, to guide and execute the necessary steps to achieve their goals (Karoly, 1993). Essentially, self-regulation is the modulation of one's thoughts, emotions, and behavior to comply with the demands of a given context. The development and workings of this construct, encompassing the periods of infancy, early childhood, and adolescence, are conceptualized through the scope of two frameworks: executive functioning (EF) and effortful control (EC). EF refers to the cognitive aspects of self-regulation, while EC, offered by the field of temperament, encompasses the behavioral and emotional predispositions of the individual and the ability to control them (Zhou, Chen, & Main, 2012).

Executive Function. Executive functions are broadly defined as the higher-order cognitive components and processes necessary to solve a problem through the representation of the problem and the planning, evaluation, and execution of a solution (Zelazo, Müller, Frye, & Marcovitch, 2003). Arguably, the most widely recognized model for EF is that of Miyake and colleagues (2000), where EF consists of a single construct consisting of three principal components: attention shifting, inhibition, and working memory. Each component of EF is crucial to cognitive function and regulation for different reasons. Inhibition, for instance, refers to the ability to resist the urge to respond in an inappropriate way or initiate an unwanted behavior. Inhibition is also crucial in the control of one's attention and emotions. Poor inhibitory capacities are typically manifested through higher impulsivity, lower attentional regulation, and lower persistence (Diamond, 2013). Working memory is often defined as a workspace where information relevant to a task at hand can be temporarily stored and accessed (Baddeley, 1983). The usage of this workspace is necessary for the construction of relationships between pieces of information; as such, it is crucial for understanding and producing language, establishing cause and effect, and organizing items (Diamond, 2013). Finally, shifting (also referred to as cognitive flexibility) is responsible for allowing the sustaining or re-focusing of attention as well as for applying rules and problem-solving strategies while taking into account different situational demands (Diamond, 2013).

Effortful Control. Effortful control (EC) is the temperamental dimension of self-regulation. Temperament refers to an individual's constitutionally-based reactivity to different types of stimuli, and the modulation of this reactivity (Rothbart & Bates, 2006). Individuals show different tendencies in terms of how they react to their environment and how they regulate their responses to environmental stimuli (Rothbart & Derryberry, 1981). Rothbart and Bates (2006) defined EC as "the efficiency of executive attention, including the ability to inhibit a dominant response, activate a subdominant response, plan, and detect errors" (p.129). EC is exerted through the effective use of attention to monitor one's thoughts, emotions, and behaviors to complete a task (Rothbart & Posner, 2006). This construct, much like EF, begins its development around the first year of life (Posner & Rothbart, 1998) and its different components also undergo rapid changes (although also on different timetables) across toddlerhood (e.g., Jones, Rothbart, & Posner, 2003; Zhou et al., 2007; Rueda, Posner, & Rothbart, 2005) and continue to develop into adulthood (Murphy, Eisenberg, Fabes, Shepard, & Guthrie, 1999).

Recently, Zhou and colleagues (2012) reviewed the overlap between the EF and EC frameworks. These constructs share components and, due to this, measures purporting to measure EF are frequently used to measure EC and vice versa. Indeed, it could be argued that EF and EC are measuring the same construct through the context of different interests. EF may be more concerned with the purely cognitive aspects of self-regulation while EC (and the temperament field) may be more focused on the behavioral and emotional expressions of it, but these are, arguably, inextricably linked. Based on the literature and the recommendations made by Zhou and colleagues (2012), here, we will refer to self-regulation as an umbrella term encompassing both traditions and consider the influence of both EF and EC.

PTE and Self-Regulation

Tobacco is the most commonly consumed teratogenic substance (i.e., substances that are toxic to the developing fetus) (Office of Applied Studies National Survey on Drug Use and Health [NSDUH], 2005, Merriam-Webster, 2017). Although rates of maternal smoking have decreased during the past two decades, it is estimated that around 8.4% women in the United States smoke at some point during the gestational period (Reitan & Callinan, 2017; Curtin & Matthews, 2016). However, these rates may be higher for women who are White or Native American, teenaged, who have less than 12 years of education, or are economically disadvantaged (Wiebe, Clark, de Jong, Chevalier, Espy, & Wakschlag, 2015; Curtin & Matthews, 2016). Tobacco contains multiple chemical components, the most notable being nicotine. During PTE, nicotine can cross the placenta and lodge in the fetal tissue (Cornelius & Day, 2009). Animal studies have demonstrated nicotine's detrimental effects on the fetus at the physiological and chemical levels, resulting in growth deficits, and negative, long-lasting impacts in cognition, behavior, and brain function (Cornelius & Day, 2009; Lambers & Clark, 1996; Espy et al., 2011a).

Much of the attention received by PTE has been because of its strong associations with maladaptive behavioral outcomes, all of which appear to hold self-regulation as a common component (e.g., externalizing behaviors; Batstra, Neeleman & Haddars-Algra, 2003; Brook, Brook & Whiteman, 2000; Orlebeke, Knol & Verhulst, 1997; ADHD;

conduct disorders; Wakschlag et al., 1997; Weissman, Warner, Wickramaratne, & Kanderl, 1999; delinquency; Räsänen et al., 1999). Diminished self-regulation during early childhood predicts substance dependence, criminal activity, externalizing behaviors, and antisocial behavior (Moffitt et al, 2011). Indeed, children with PTE are more likely to display higher levels of aggression, impulsivity, and hyperactivity across childhood and into adolescence as compared to non-exposed peers (e.g., Martin et al., 2006; Cornelius et al., 2012). They are also more likely to be diagnosed with oppositional defiance disorder (ODD) or other conduct disorders during childhood and, as adults, they are more likely to display severe antisocial behaviors and engage in substance use (Waskchlag, Leventhal, Pickett, Pine, & Carter, 2006a; Waskchlag, Pickett, Kasza, & Loeber, 2006b; Ellis, Widmayer, & Das, 2012; Munshouwer et al., 2011; Gatzke-Kopp & Beauchaine, 2007). Taken together, these findings point to salient self-regulation impairments in this population. However, while most studies so far have shown associations between PTE and individual factors that may be detrimental to the development of self-regulation (e.g., higher levels of activity, poorer attention skills, distractibility, and impulsivity), few appear to target self-regulation as a whole (e.g., Cornelius, Goldschmidt, DeGenna, & Day, 2007; Cornelius & Day, 2009; Day, Richardson, & Goldschmidt, 2000; Johnson, Vicary, Heist, & Corneal, 2001).

EF and PTE. The link between PTE and executive function remains poorly understood. There is some evidence for diminished EF in the PTE population, but the underlying mechanism is not yet clear or well documented. Among the extant literature, a study by Wiebe and colleagues (2009) showed evidence for a gene-environment interaction whereby PTE was linked to impairments in cognitive self-regulation in preschool children when paired with the A1+ genotype of the DRD2 gene. Other sources support this, indicating that PTE is associated with specific EF impairments such as poorer executive control performance, sustained attention, working memory, and response inhibition (e.g., Mezzacappa, Buckner, & Earls, 2011; Noland et al., 2005; Fried & Watkinson, 2001; Cornelius, Goldschmidt, De Genna, & Larkby, 2012). Thus far, research suggests that there are several biological paths through which PTE may impair neurocognitive development. Some argue that this relationship is due to the role of nicotine in hindering intrauterine growth, and consequently, brain development (Herrmann, King, & Weitzman, 2008). Others cite animal research showing that nicotine can interact with acetylcholine receptors and negatively impact the development of brain regions like the frontal cortex and the hippocampus (which are heavily implicated in EF and cognitive function) where these receptors can be found in large quantities during gestation (Dwyer, McQuown, & Leslie, 2009).

Temperament and PTE. The literature offers some evidence that PTE impacts temperament such that children who experience PTE may present temperamental configurations resulting in cognitive, behavioral, or emotional regulation difficulties. For example, Pickett and colleagues (2008) examined temperament at 9 months in a large sample and found that children of heavy smokers had more difficult temperament (as reported by mothers) than those of mothers who quit smoking during pregnancy. Difficult temperament refers to instances when a child's temperament leads to behavioral patterns that are hard for caregivers to manage (Curby, Rudasill, Edwards, & Pérez-Edgar, 2011). The definition of difficult temperament may vary across the literature, but it typically involves frequent displays of negative moods, high levels of activity, low adaptability, and difficulty in regulating behaviors and emotions (Rudasill et al., 2013: Prior 1992; Thompson, Winer, & Goodvin, 2011). Adding to this evidence, two other studies (Lester et al., 2009; Clark et al., 2015) have found that, for children who experienced prenatal substance exposure (cocaine on the first, tobacco in the latter), difficult temperament may act as a pathway to behavioral disinhibition and later externalizing behaviors. Out of the two studies referenced here, the one dealing specifically with PTE (Clark et al., 2015) focused only on infants. To our knowledge, no other studies have examined the temperamental profiles of children with PTE past infancy or the potential implications of their temperamental self-regulation.

Links to Cognitive Outcomes

Cognitive ability, also labeled intelligence, is another variable closely tied to neurodevelopment and self-regulation (Blair, 2002; Diamond et al., 2007). Cognitive ability refers to an individual's capacity to perform high-order mental processes necessary for learning and problem solving (National Council on Measurement in Education, [NCME], 2017) and is typically assessed through measures of intelligence (IQ). Research suggests that IQ scores tend to remain stable after middle childhood (Mackintosh, 2011) and are associated with several outcomes such as risk of mortality (e.g., Osler & Batty, 2004; Batty & Deary, 2004), academic achievement (e.g., Bartels, Rietveld, Van Vaal, & Boomsma, 2002b; Neisser et al., 1996; Sternberg, Grigorenko, & Bundy, 2001; Jencks et al., 1979), workplace performance (Campbell, 1990; Gottfredson, 2004), socioeconomic status (Jencks et al., 1979; Murray, 1998), and delinquency (e.g., Rushton & Templer, 2009; Templer & Rushton, 2011). Research shows that individuals with higher scores typically present better outcomes.

There is a long-standing, relatively consistent association between PTE and lower IQ scores during childhood (e.g., Hermann, King, & Weitzman, 2008; Olds, Henderson, & Tatelbaum, 1994; Cornelius et al., 2009; Fried, Watkinson, & Gray, 2003). As for most outcomes related to PTE, existing research has yet to provide an explanation for what drives this association (Yolton et al., 2005). One possibility that has not been examined is that self-regulation could also be the common factor at play between these variables. Cognitive ability and EF are separate constructs, but the former relies on the latter for more efficient use of resources (e.g., Arffa, 2007). Most notably, PTE has been linked to lower working memory performance, an EF component considered nearly equivalent to cognitive ability (or ‘g’) due to its role in problem solving and a variety of intellectual skills (Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004). Furthermore, in the temperament literature, negative emotionality has been associated with poorer working memory under demanding conditions (Ng & Lee, 2015; Visu-Petra, Cheie, Benga, & Packiam Alloway, 2011) and the effortful control (regulatory) dimension of temperament has been associated with verbal and nonverbal cognitive performance (Valiente, Lemery-Chalfant, & Swanson, 2010; Dobbs, Doctoroff, Fisher, & Arnold, 2006). Interestingly, as previously discussed, research has found PTE and difficult temperament to be a pathway for externalizing behaviors, which some have suggested are a mediator between IQ scores and later outcomes (Fergusson, Horwood, & Ridder, 2005). Taken together these findings suggest PTE may have a negative impact on cognitive ability which, by itself, has extensive implications for developmental outcomes. In order to examine the functional significance of the relationship between PTE and self-regulation, the present study includes an examination of the participants' cognitive performance and their working memory capacity.

Covariates

One important consideration when examining PTE is that there are several risk factors associated with it, many of which can affect the development of self-regulation. In the United States, for example, PTE is more common among women who are younger, less educated, unmarried, and of lower socioeconomic status (e.g., Pickett, Wilkinson, & Wakschlag, 2009; Wiebe et al., 2015). To minimize potential confounding, we account for two such factors: SES and maternal education.

In summary, this study extends on literature linking PTE to patterns of externalizing behavior and poor cognitive outcomes by examining patterns of temperament in a sample from a longitudinal cohort of young children with PTE. The relevance of these temperament patterns for cognitive outcomes was also considered, after accounting for relevant sociodemographic factors that may confound relations between PTE and developmental outcomes.

CHAPTER II

Methods

Participants

Participants for the initial phase of this study were recruited through the distribution of fliers at the local obstetric clinics in 5 rural counties located in Southern Illinois and a small city located in Nebraska. All women were screened via telephone interviews to rule out those who used illegal substances or engaged in binge drinking (i.e., more than 4 drinks on a single occasion) during pregnancy. Smokers were oversampled and matched to non-smokers on the basis of poverty status and ethnicity to reduce confounding between the PTE and SES variables. The initial sample consisted of 422 women. A total of 380 women were deemed eligible and enrolled, with eight later excluded upon disclosure of illegal drug use or alcohol abuse. Moreover, eight participants gave birth before 35 weeks of gestation and were excluded due to the possible effects of pre-term birth on infant brain development. Therefore, a total n = 369 infants (including 5 sets of twins) and their mothers participated in the infant waves of the study.

There was a follow-up study comprising a home- and a lab-based assessment when the children were approximately five years old (*M* = 60.9 months). To maintain consistency across analyses, only those participants who completed all phases of the follow-up study (in-home as well as lab-based assessments) were included. This ensured all cases had most, if not all, data available for the measures of interest. On the basis of this criterion, the available *n* = 369 was reduced to *n* = 250 **(see Table 2.1)**. A chi-square analysis between the full sample and this subset was conducted across the demographic variables in use. The groups differed significantly only in the level of maternal education, as reported at the prenatal $\chi2(5, N = 422) = 91.60$, $p = < .01$ and 5 year follow-up stages $\chi2(5, N = 422) = 255.79$, $p = < .01$ and proportion of PTE children $\chi2(1, N = 421) = 4.20$, $p < .05$. The full sample consisted of 48.9% (215) PTE children and 51.1% (206) non-PTE children, whereas the chosen subset represented proportions of 55.2 % (138) and 44.8% (112) respectively. Since smokers were already over-represented in the original sample for the study, the groups in question were considered comparable.

All procedures were approved by university ethics boards, and all mothers provided written, informed consent prior to participation. The procedures carried out for the neonatal and prenatal phases of this sample's data collection were previously described by Espy and colleagues (2011a). Later, within 6 months of their children's fifth birthdays, mothers were contacted once again and invited to participate in a home-based interview and a laboratory-based assessment. The home interview consisted of socio-demographic background and family environment measures, as well as the child general cognitive assessment. During the lab proceedings, mothers were asked to complete additional questionnaires assessing their stress and their children's externalizing behaviors. Children remained in a separate room accompanied by a trained examiner and completed various computerized neuropsychological assessments. Children were offered regular breaks and snacks during the procedure. Parents received financial compensation for their participation and children received a small toy.

Measures

Child temperament. The Children's Behavior Questionnaire (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001) is a caregiver report measure of temperament in children aged 3-7 years old. Its intended purpose is to provide an assessment sensitive to individual differences across 15 primary temperamental dimensions encompassed by three broad factors: extraversion/surgency, negative affectivity, and effortful control **(see table 2.2)**. The CBQ is available as a full 195-item form as well as alternative 94-item short (CBQ-SF) and 36-item very short (CBQ-VSF) forms (Putnam & Rothbart, 2006). Seven scales (49 items) from the CBQ-SF were collected in the 5-year-follow-up phase of the study: activity level (7 items, $\alpha = .70$), anger/frustration (6 items, $\alpha = .84$), attentional focusing (6 items, $\alpha = .73$), falling reactivity/soothability (6 items, $\alpha = .79$), high intensity pleasure (6 items, $\alpha = .73$), impulsivity (6 items, $\alpha = .58$), and inhibitory control (6 items, $\alpha = .55$).

Cognitive assessment. The Woodcock-Johnson III (WJ III) (Woodcock, McGrew, & Mather, 2001a) was designed with the purpose of measuring general intellectual ability as conceptualized by the Cattell-Horn-Carroll (CHC) theory of cognitive ability. It consists of two batteries intended to measure specific cognitive abilities, achievement, and oral language in order to provide a comprehensive measurement of general intellectual ability (*g*) across these domains. Following the CHC model, the WJ-III measures broad cognitive abilities across 9 factors: Comprehension-Knowledge (*Gc*), Fluid reasoning (*Gf*), Quantitative knowledge (*Gq*), Reading and Writing Ability (*Grw*), Short-Term Memory (*Gsm*), Long-Term Storage and Retrieval (*Glr*), Visual Processing (*Gv*), Auditory Processing (*Ga*), and Processing Speed (*Gs*).

The test can be used to obtain a composite score for General or Brief Intellectual Ability. The latter is less time consuming, as it can be administered in 15 minutes or less, and is typically used for screening purposes or when in need of a short, less comprehensive intellectual assessment. This was the method used to assess participants for the current sample. The BIA is obtained by combining the scores from three cognitive tests: Concept Formation, Verbal Comprehension, and Visual Matching. These tests measure Fluid Reasoning (*Gf*), Comprehension Knowledge (*Gc*, and Processing Speed (*Gs*) respectively. The Concept Formation test requires the taker to identify a rule that divides a set of symbols into groups; the Verbal Comprehension test includes naming pictures, providing synonyms or antonyms for spoken words and completing analogies; the visual matching task requires circling pairs of identical numbers within rows of 6 numbers each.

The BIA has a reliability coefficient of .95 (Schrank, McGrew, & Woodcock, 2001) and validity correlations with other intelligence measures ranging from .60 to .70 (Newton, McIntosh, Dixon, Williams, & Youman, 2008). The reliability coefficients for the cognitive tests included are as follows: .92 for Verbal Comprehension, .91 for Visual Matching, and .94 for Concept Formation. The dataset available for this study contained the composite BIA scores as well as the individual scores from all three cognitive tests for each case.

Working memory assessment. Participants were also administered a working memory assessment. The instrument used for this purpose was the Nebraska Barnyard task, based on the Noisy Book task introduced by Hughes and colleagues (1998). The Nebraska Barnyard task requires children to remember a sequence of animal names and reproduce that sequence by pressing the corresponding buttons on a touch screen. First, there is a training phase in which children are introduced to nine pictures of animals in a 3 x 3 grid layout on the computer screen (Wiebe, Sheffield, Nelson, Clark, Chevalier, &

Espy, 2011). These animal pictures are located within boxes of a color associated with the identity of the depicted animal. Upon pressing each animal box, the computer reproduces the noise corresponding to it. The children must then complete nine practice trials, during which the experimenter names each individual animal and the child must press the corresponding box correctly. Subsequently, the pictures are removed but the colored boxes remain. After this, the actual test trials proceed: sequences of animals are presented starting with two at a time and increasing, with up to three trials per span length. If the first two trials are correct, the task automatically proceeds to the next span length. If all three trials are incorrect, the task is discontinued.

Tobacco exposure classification. Prenatal tobacco exposure (PTE) was assigned via a multi-step approach. If maternal reports of smoking remained consistent across the initial screening, the prenatal and postnatal interviews, the PTE status was retained. If initial reports indicated the mother was a non-smoker but the mother reported smoking during dates following the last menstrual period, the child was re-classified into the PTE group. Aside from interview methods of screening, another common form of assessing this is by measuring cotinine, a biomarker for exposure to tobacco. The levels of cotinine present in bodily fluids such as blood, saliva, or urine, is a proportionate indicator of the amount of tobacco exposure (Florescu, Ferrence, Einarson, Selby, Soldin, & Koren, 2009). The same procedure can also be performed by analyzing the meconium, the first stool passed by a newborn, as it contains materials ingested in-utero (Ostrea, Knapp, Romero, Montes, & Ostrea, 1994). In order to inform classification in this sample, samples of maternal urine and infant meconium were collected. Cotinine values on the 11 ng/mL - 30 ng/mL range are typically associated with light smoking, while active smokers may reach levels up to 500 ng/mL or above. (Jarvis, Fidler, Mindell, Fayerabend, & West, 2008). In two cases, mothers in the study reported no exposure during interviews but further analyses revealed cotinine levels above 100 ng/mL, so their children were reclassified as PTE.

Covariates

Maternal education. Mothers reported their highest level of education during the background interview conducted as part of the home visit phase of the 5-year-old follow-up. This variable was originally continuous in the form of total number of years of education. For the purposes of this study, it was recoded as a categorical variable comprised by 5 possible levels of education: less than high school (11 < years), high school (12 years), some postsecondary education or college (14 years), college degree (16 years), and graduate education (17 > years).

Household income. Mothers reported on their household income at the five-year follow-up home visit using a scale of 0-20,000$, 20-40,000$, 40-60,000$, 60-80,000$, 80-100,000$, 100,000$ >.

Statistical Analyses

Analyses were conducted using SPSS V. 24 in three phases, in accordance with the aims of the study.

Phase 1: temperamental clusters. The first aim of the study was to examine the temperamental profiles of the sample. In a recent study by Prokasky and colleagues (2017), children were classified into clusters on the basis of temperament. The authors followed the approaches of previous studies (e.g., Caspi & Silva, 1995; Sanson et al., 2009), employing two clustering methods: hierarchical clustering and k-means clustering.

Consistent with this precedent, we applied the same procedure here. Essentially, the first of these methods, hierarchical clustering, was used as an exploratory step to inform the use of the latter one. Hierarchical clustering is appropriate when the number of clusters to be found in the data has not been previously defined. The type of hierarchical clustering performed here, known as agglomerative clustering, treats each case as its own cluster, then links the cases with the smallest distance between them, creating slightly larger clusters (Ward's linkage), all of which will be placed under a larger one, and so forth. As a result, a dendogram graph is produced. The dendogram presents all the clusters formed at each level, allowing the researcher to visually gauge the relative distance between them. Ultimately, the goal is to determine the number of clusters effectively showing differentiated groups while keeping the least possible distance between individual cases (Hair, Anderson, Tatham, & Black, 1995). There is no defined protocol to interpret a dendogram; as such, the current interpretation is based on theoretical interpretability and consistency with previous studies (Hair et al., 1995).

The second clustering method is known as a K-means cluster analysis. In order to perform a K-means analysis, a defined number of clusters must be known. Due to the lack of a standard procedure to identify the number of clusters within a dataset, and following recommendations by Hair and colleagues (1995), multiple k-means cluster analyses were conducted based on the output obtained in the hierarchical cluster analysis. Once the number of clusters to be found has been specified, an initial mean center is established for each cluster. Generally speaking, the algorithm will create centers with the maximum possible distance between them. Each case is then assigned to the cluster with the most similar center. Once this process has concluded, the centers will be recalculated based on the means of the individual cases, and the cases will be redistributed according to the new closest mean. The same procedure is performed until the group means cease to change, thus indicating the final cluster centers (Eshghi, Haughton, Legrand, Skaletsky, & Woolford, 2011). Ultimately, the goal is to minimize the distance between the individual cases and the cluster center (Mooi & Sarstedt, 2011).

The K-means method is regarded as superior to hierarchical clustering due to its lower sensitivity to outliers and more refined results. The approach has been shown to succeed at delineating clusters that are superior in terms of within-cluster homogeneity and between-cluster heterogeneity (Eshghi et al., 2011; Mooi & Sarstedt, 2011). However, as mentioned previously, there is value to an exploratory analysis of the data when the number of possible groupings is unknown. In accordance with Prokasky et al. (2017) and the guidelines provided by Hair and colleagues (1995), both methods were performed in order to better inform the process of cluster identification.

Phase 2: multinomial regression. The second aim of the study was to determine the relation between PTE and temperament profiles identified through the cluster analysis. For this, we conducted a multinomial regression to determine whether PTE predicted cluster membership after accounting for maternal education and household income.

Phase 3: ANOVA with multiple group comparisons. The third and final aim of the study was to examine whether the self-regulatory tendencies of the profiles identified in the sample showed any overlap with cognitive ability and/or working memory capacity. For this, we conducted one-way ANOVAs comparing children’s scores on the

Brief Intelligence Assessment of the Woodcock-Johnson III and the Nebraska Barnyard working memory task with cluster membership as the independent variable.

CHAPTER III

Results

Cluster Analyses of Temperament Scales

Hierarchical clustering. Figure 3.1 shows the dendogram produced from the hierarchical clustering analysis of the CBQ scales. Upon examination of this dendogram procedure, three to five possible clusters could be identified.

K-means clustering. Findings in previous research indicate between two and seven cluster solutions are typically found for child temperament (e.g., Thomas & Chess, 1977; Caspi & Silva, 1995, Sanson et al., 2009). Following this precedent, along with the information provided by the dendogram, 2 through 5 cluster solutions were tested. The analyses revealed that the 3- and 4-cluster solutions were both theoretically interpretable; as such, graphs of the mean centers by scale were produced to compare them. Both solutions were similar in that they both revealed the emergence of two seemingly opposite clusters. The main difference was that the 3-cluster solution showed one cluster falling between these opposing clusters while the 4-cluster solution showed two clusters in similar positions. The opposing clusters were consistent with conceptual definitions of individuals on opposite ends of the spectrum of temperamental regulation; thus, it seemed likely that the categories found between them both depicted average types of temperament. For the purposes of the present study, collapsing these types of temperament into a single category improved the ease of theoretical interpretation. Therefore, we used the 3-cluster solution throughout the remainder of the analyses.

Figure 3.2 shows the graph of the mean centers by cluster for each of the selected CBQ scales. Cluster 1 was labeled as "Unregulated", while clusters 2 and 3 were labeled as "Average" and "Regulated" respectively. One-way ANOVAs with Bonferroni correction of post-hoc comparisons were performed for each temperament scale to characterize the differences between clusters. Results showed the clusters were significantly different across the following scales: impulsivity $F(2, 247) = 73.02$, $p < .001$, high intensity pleasure $F(2, 247) = 88.65$, $p < .001$, activity level $F(2, 247) = 158.91$, $p < .001$, attention focusing $F(2, 247) = 86.36$, $p < .001$, inhibitory control $F(2, 247) = 86. 35$, p < .001, anger $F(2, 247) = 58.99$, $p < .001$, and fear $F(2, 247) = 65.17$, $p < .001$. **Figures 3.3, 3.4, and 3.5** show these results by examining each possible Bonferroni-corrected comparison between individual clusters. In summary, children in the *regulated* cluster showed the highest means across the regulatory scales (attentional focusing and inhibitory control) and low reactivity. Children in the *unregulated* cluster followed the opposite pattern. Children in the *average* cluster showed regulatory levels that fell between those of the *regulated* and *unregulated* clusters and moderate reactivity levels.

Relation of PTE to Temperament Clusters

The second aim of the current study was to examine the relation of PTE to cluster membership, accounting for covariates of interest. For this purpose, a multinomial logistic regression was conducted. Maternal education and household income at 5 years of age, child's age in months, child's sex, and PTE status were all included in the model as potential predictors of the dependent variable – temperament cluster. The full model significantly improved the prediction relative to the intercept alone, $X^2(10, 249) = 30.08$, $p < .01$. Further, the likelihood ratio tests showed that only two predictors were significant: child's PTE status $X^2(2, 249) = 12.60$, $p < .01$, and sex $X^2(2, 249) = 12.70$, *p*

< .01. More specifically, children with PTE (*b* = -1.09, Wald $X^2(1)$ = -1.09, *p* < .01) and boys (*b* = -96, Wald $X^2(1)$ = 8.26, *p* < .01) were at significantly higher relative risk of being classified as *unregulated* or *average* relative to non PTE children or girls (*b* = -91, Wald $X^2(1)$ = 7.81, *p* < .01 and *b* = -1.08, Wald $X^2(1)$ = 10.05, *p* < .01, respectively) **(see table 3.1)**. Tests for interactions between these two predictors were not significant.

Relation of Temperament Clusters to Cognitive Performance

The final aim of the study was to examine the overlap between the temperamental clusters and children's cognitive and working memory performance. Table 4 describes the mean performance of each cluster on the BIA subtests and the working memory assessment. The differences in performance across cognitive tasks between clusters were examined using one-way ANOVAs with Bonferroni correction of post-hoc comparisons. After controlling for age, univariate analyses of variance revealed significant differences among clusters for working memory performance (*F* (2, 244) = 7.60, *p* = <.01), WJBIA (*F* (2, 246) = 7.43, *p* =<.01), WJVC (*F* (2, 246) = 3.80, *p* = <.05), WJCF (*F* (2, 246) = 3.50, *p* = <.05), and WJVM (*F* (2, 246) = 6.82, *p* = <.01). Further, post-hoc comparisons revealed all significant differences were confined to clusters 1 and 3 **(see table 3.2)**. Children in the *regulated* cluster scored significantly higher on all the individual subtests of the BIA and on the Nebraska Barnyard task. Moreover, scores appeared to follow a similar linear trend as that depicted by the cluster solution graph, such that the scores within the *average* cluster consistently fell between those of the *unregulated* and *regulated* clusters.

CHAPTER IV

Discussion

This study addressed a gap in the PTE literature by considering its relation to different patterns of temperament during early childhood and describing the overlap between these patterns and measures of cognitive ability and working memory capacity. Analyzing a cohort consisting of PTE as well as unexposed children of approximately 5 years of age, we found that PTE children were more likely to show patterns of unregulated or average temperament and that these profiles were associated with poorer cognitive and working memory performance. Self-regulatory skills are crucial to school-readiness and functioning and undergo critical development during early childhood (Blair, 2002; Blair & Razza, 2007); as such, difficulties in this domain are likely to have long-term implications for children's outcomes.

The first aim of the study was to determine whether there were distinct profiles of temperament in this sample. Although the focus of this work was the self-regulatory dimension of children's temperament, Rothbart and Derryberry (1981) note that the reactive and regulatory components of temperament are not independent from each other, but rather each hold aspects of the other and work synergistically. Taking this into account, all the scales available from the surgency/extraversion and negative affectivity dimensions were included to obtain a more detailed picture of children's behavior. The clustering methods performed in the present study yielded three distinct temperamental profiles following an ascending pattern in terms of effortful control scores. The clusters were denominated: *unregulated*, *average*, and *regulated*. These labels correspond to the mean of each cluster (relative to each other) on the EC dimension scales: inhibitory control and attentional focusing.

Children in the *regulated* cluster showed the highest EC, as reflected by their inhibitory control and attentional focusing. In terms of negative affectivity, they showed the lowest levels of anger, and a moderate degree of falling reactivity/soothability. In terms of surgency/extraversion, these children showed low levels of impulsivity, high intensity pleasure, and activity level. This temperamental configuration suggests these children are more physically restrained (e.g., they have little trouble sitting still and are less likely to frequently be "on the go") and do not typically react rapidly without forethought. They do not have a strong preference for high-intensity situations (i.e., not thrill-seekers), are not quick to anger when plans change or activities are disrupted, and are able to move on from negative emotions with moderate ease. Moreover, their EC tendencies suggest they will be the ones who find it least challenging to suppress inappropriate urges or responses (such as touching a forbidden toy or eating a snack before time) or redirect their attention as needed/desired.

Children classified within the average cluster showed moderate-to-low EC, with scores on inhibitory control and attention focusing following this pattern. They showed low anger and, although their level of falling reactivity/soothability was significantly higher than that of other profiles, it was still moderate. Their scores for impulsivity, high-intensity pleasure, and activity level were all in the moderate range as well. Overall, this configuration suggests these are children who do not typically engage in behavioral extremes. Thus, they may occasionally seek exciting or intense activities, respond without much regard for the consequences, or have periods of high physical excitability, but it is unlikely their behavior will become disruptive. The EC scores of this cluster suggest it will not be as easy for children in this group to self-regulate their attentional resources or stop themselves from doing something gratifying before it is appropriate or permitted. Despite this, the moderate nature of most of their reactive tendencies indicate they may not have the need to self-regulate beyond their capabilities.

The children classified as *unregulated* showed the poorest EC levels, with significantly lower scores of inhibitory control and attentional focusing relative to other profiles. These children showed the highest levels of anger and the lowest levels of falling reactivity/soothability. Additionally, they showed the highest levels of activity and high intensity pleasure. Overall, the children in the *unregulated* cluster had moderate impulsivity scores, slightly below those in the *average* cluster, though decidedly higher than those children classified as *regulated*. This profile suggests children who enjoy high sensory stimulation and, thus, frequently seek out exciting situations. They have a high drive for physical activity and are likely to act on their desires without much forethought. Furthermore, they are highly prone to anger when their activities are interrupted and have a hard time moving on from high excitability or negative emotions. This configuration suggests these children are highly reactive and have very limited resources to appropriately modulate these tendencies on their own. Taken together, our results indicate that it is possible to identify three distinct, theoretically interpretable, profiles of temperament that reflect different patterns of reactivity and self-regulation.

Previous studies point to temperament as a potential pathway through which young children who are prenatally exposed to tobacco and stress may develop externalizing behaviors and poorer executive function (Clark et al., 2015). The temperament data from our sample suggests there is at least one group of children in our sample who are well regulated. Children in the *regulated* cluster do not appear to be at risk for behavioral problems or disruptive behavior patterns. Moreover, children in the *average* cluster may not necessarily show significant difficulties in modulating their behaviors despite exhibiting only “moderate” self-regulatory capacities. Moderate levels of surgency/extraversion often come across as adaptive as children who display them approach their environment in an outgoing and curious way (Berdan, Keane, & Calkins, 2008). The same is not the case for children classified as *unregulated*. The patterns of reactivity and regulation of *unregulated* children may lead to maladaptive adjustment in various ways. For example, children who are prone to anger and who experience difficulty in are very likely easily upset by daily occurrences, and this could result in aggressive responses (Berdan et al., 2008). Moreover, this may, in turn, interact reciprocally with a disposition inclined toward impulsivity, eagerness to experience strong stimulation, and high activity levels. Indeed, the literature has consistently shown these patterns of negative affectivity and surgency/extraversion to be associated with externalizing behaviors and ADHD across development (e.g., Oldehinkel, Hartman, de Winter, & Ormel, 2004; Sanson, Hemphill, & Smart, 2004), outcomes with which PTE has been consistently linked. Moreover, research shows these links between temperament and maladjustment can be buffered by high self-regulatory capacities (i.e., high EC) which the available literature suggests are not a reality for this group (Olson et al., 2005; Blair, Denham, Kochanoff, & Whipple, 2004).

The second aim of the study was to test whether PTE predicted/was associated with the clusters identified when accounting for other potential confounders: household income and maternal education. For this, a univariate multinomial regression was conducted to examine if any such variables were predictive of cluster membership. Only PTE status and male sex were significant predictors. Prenatally exposed children were almost three times more likely to be classified as unregulated and over twice as likely to be classified as average rather than their non-exposed peers. Boys also showed almost a three-fold greater likelihood of falling into the less regulated clusters relative to girls. These findings are in line with previous research in the PTE and temperament areas. Previous studies point to temperament as a potential pathway through which young children who are prenatally exposed to tobacco and stress may develop externalizing behaviors and poorer executive function (Clark et al., 2015). The case for gender differences on such a mechanism has not yet been explored, but there is some compelling evidence for it. For example, externalizing behaviors and ADHD are both more common among boys (e.g., Wilcutt, 2012; Mulraney et al, 2016; Liu, 2004) and some studies have suggested that boys may be more vulnerable to the potential detrimental effects of PTE (e.g., Schuetze, Lopez, Granger, & Eiden, 2008; Willoughby, Greenberg, Blair, & Stifter, 2007; Elsmén, Steen, & Hellström-Westas, 2004). Moreover, the literature on gender differences across temperament shows that, during childhood, girls tend to have a significant advantage over boys in terms of effortful control, while boys tend to score significantly higher than girls in terms of surgency/extraversion (Else-Quest, Hyde, Hill Goldsmith, & Van Hulle, 2006; Else-Quest, 2012). Findings from the current study offer further support for these differences. Our results suggest PTE children are at higher risk of being classified as *average* or *unregulated* in temperament and this risk is greater for boys. Taking this into consideration, it is a possibility that PTE status may exacerbate the temperamental differences typically observed in boys, who are already susceptible to lower levels of regulation and higher levels of reactivity. Well done!

The third and final aim of the study was to examine whether the self-regulatory patterns found in the identified clusters overlapped with children's cognitive performance and their working memory capacity. One of the gaps we sought to address was the lack of research on both temperament and EF components of self-regulation as related to PTE. While EF is multifaceted, and all components contribute to an individual's cognitive regulation in different ways, we focused solely on the working memory component due to its unique relationship to cognitive ability (Colom et al., 2004). More specifically, working memory seems to play a critical role in problem-solving and learning in situations where no previous knowledge is available (Gathercole, Pickering, Knight, & Stegmann, 2004). As such, this aim involved examining children's working memory capacity as well as their cognitive performance as a means to characterize the implications of their self-regulatory patterns for their functioning.

Children's scores on the Brief Intelligence Assessment of the Woodcock-Johnson III and the Nebraska Barnyard working memory task were compared with cluster membership as the independent variable. There were significant differences between all three clusters across each individual subtest of the BIA, the full battery, and the Nebraska Barnyard working memory task. Moreover, the observed differences followed the trend of the self-regulatory patterns found in the temperamental profiles. Across all measures, children in the regulated cluster performed best, followed by those in the average cluster, while those in the unregulated cluster performed the worst. This suggests that the same children who show poor temperamental self-regulation are also show poorer working memory capacity and lower cognitive performance even prior to entering the formal academic environment.

Previous research has shown that cognitive ability is influenced by personality. In fact, studies have identified instances where specific personality traits (e.g., self-discipline) have proven to be better predictors of academic performance than measures of IQ (Duckworth & Seligman, 2005). The idea behind this seems to be that there are complex mechanisms behind performance where raw ability must be supported by effective goal-directed behavior. Our results indicate that certain temperamental configurations are associated with less effective performance. This suggests a similar mechanism to the one described above may also be present in early childhood; thus, it is possible that PTE children are not necessarily at significant intellectual disadvantage, but their temperamental tendencies make it difficult to successfully manage their cognitive resources. A tendency to very high levels of activity, impulsivity, and difficulties in inhibiting undesirable responses or refocusing attention would likely make it very difficult for a child to participate of the academic environment in effective ways (Blair, 2002; Rudasill et al., 2011, Sanson, Hemphill, & Smart, 2004). Combined with difficulties in modulating critical components such as working memory, this may result in persisting detrimental patterns. Indeed, there is precedent for such a relationship where working memory capacity in the context of problem-solving and temperamental difficulties similar to those described in the unregulated cluster, accounted for up to 60% of the variance in young adolescents' academic performance (Colom, Escorial, Shuh, & Privado, 2007). Thus, PTE may place children at higher risk for less effective regulation and, subsequently, lower cognitive performance and academic achievement.

Limitations and Future Directions

Arguably, one of the main reasons why it is difficult to determine causality in the impact of PTE on self-regulation outcomes is the large array of factors that may explain or intensify this relationship. Here, we accounted for two such factors, SES and maternal education; however, there are many other potential confounders or moderators. For example, the extent of the PTE exposure and whether the mother ceased to smoke after the pregnancy are also important variables (e.g., Olds, Henderson, & Tatelbaum, 1994; Yolton et al., 2009; Linnet et al., 2003). Importantly, smoking during pregnancy often coincides with various conditions such as maternal depression (e.g., Schuetze & Eiden, 2006; Fergusson, Goodwin, & Horwood, 2003), anxiety (Patton et al., 1998), and ADHD (Goodwin, Keyes, & Simuro, 2007; Kodl & Wakschlag, 2004), which may also impact parenting quality and children's outcomes. These stressors may interact in such a way that leads the mother to engage in other behaviors that are detrimental for the pregnancy or may negatively affect the postnatal environment. Additionally, genetic influence may also be an important factor in the current findings. Executive function and intelligence are often considered highly heritable (Friedman et al., 2008; Benyamin et al., 2014) and this is an important factor to account for. As such, the first limitation of this study is that it is a correlational one and lacks measures of important covariates such as parenting quality and mothers' stress, EF, and IQ.

Other important limitations are the cross-sectional nature of the study and the lack of comprehensive measures of temperament and executive function. Although the current data were collected as part of a longitudinal study, our main goal was to address the lack of studies such as this one past infancy, as such, we focused only on the last time point.

The addition of further time points would provide much needed insight into the developmental implications of PTE for self-regulatory abilities, which undergo rapid changes during early childhood. As for measurements, the full form of the CBQ was not collected. Rather, only seven out of ten scales were available. Moreover, analyses revealed that two scales (inhibitory control and impulsivity) did not reach acceptable reliability. Additionally, we only included one executive function measure and a brief form of intellectual assessment. Taken together, these limitations suggest that findings from the current study make an important contribution but could be further refined by the addition of measures, more comprehensive versions of the current ones, and a longitudinal design.

Conclusions

Findings from the current study further support the argument for a connection between PTE and children's temperament during toddlerhood. Further, this connection may have implications for children's self-regulation patterns at the temperamental and cognitive level, and may, in turn, influence important outcomes such as cognitive performance. Temperament, EF, and cognitive ability are all biologically rooted to some extent; as such, one possibility is that PTE disrupts early neural development. However, genetic factors and parenting quality, although unexamined in this work, may also account for important variability in these relationships.

Temperament can affect adjustment as an intrinsic set of tendencies influencing the nature of a child's interactions with their environment, but it is also strongly tied to the dynamics of the parent-child relationship. Further knowledge regarding how environmental factors can affect children's predispositions from as early as the prenatal environment can aid in the efforts to ameliorate the occurrence of such factors. Providing further evidence regarding the various ways in which children may be affected by maternal smoking may help to further reduce the percentage of women who engage in this behavior.

The abilities to exert self-control and regulate attention and behavior are critical for positive adjustment (Blair & Diamond, 2008). Considering the associations between self-regulation and a myriad of outcomes such as delinquency, SES, health, and substance dependence, it becomes clear that the promotion of these abilities is crucial at a societal level (Moffitt et al., 2010). Moreover, this is especially important for PTE children, who may already have a high likelihood of being exposed to other developmental risk factors such as poverty and lower quality relationships with caregivers. The current study further underscores the notion that these children may be at risk for self-regulatory deficits. Self-regulation skills can be improved, and early awareness of who is at risk may help parents, teachers, and practitioners in implementing interventions and better practices during critical periods of high plasticity (Blair & Diamond, 2008; Diamond, 2012).

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Table 2.1

Demographics

		Original full sample (n = 422)	Analytic subset sample (n = 250)
Child age (in months)	Mean (SD)	61.35 (3.77)	60.89 (3.12)
	Range	55-83	55-72
Child sex	Males (N) %	(213) 50.5	(124) 50.4
	Females (N) %	(209) 49.5	(126) 49.6
Child race	White (N) %	(215) 58.0	(138) 55.2
	African American (N) %	(95) 25.6	(69) 27.6
	Native American (N) %	(6) 1.6	(3) 1.2
	Hispanic/Latino (N) %	(48) 12.9	(35) 14.0
	Asian (N) %	(3) .8	(1) .4
	Other (N) %	(4) 1.1	(4) 1.6
Prenatally exposed to tobacco	Yes (N) %	(215) 51.1	(138) 55.2
	No (N) %	(206) 48.9	(112) 44.8
Maternal education (prenatal)	Less than high school (N) %	(43) 10.2	(28) 11.2
	High school (N) %	(111) 26.3	(82) 32.8
	Some postsecondary education (N) %	(158) 37.4	(106) 42.4
	College degree N (%)	(48) 11.4	(29) 11.6
	Graduate education (N) %	(9) 2.1	(5) 2.0
Household income (prenatal)	0-20 K (N) %	(193) 53.3	(125) 51.2
	20-40 K (N) %	(105) 29.0	(67) 27.5
	40-60 K (N) %	(38) 10.5	(32) 13.1
	60-80 K (N) %	(16) 4.4	(13) 5.3
	80-100 K (N) %	(9) 2.5	(6) 2.5
	100 K > (N) %	(1) .3	(1) .4
Maternal education (at child's 5 years of age)	Less than high school (N) %	(24) 5.7	(21) 8.4
	High school (N) %	(35) 8.3	(30) 12.0
	Some postsecondary education (N) %	(165) 39.1	(143) 57.2
	College degree (N) %	(54) 12.8	(41) 16.4
	Graduate education (N) %	(21) 5.0	(15) 6.0
Household income (at child's 5 years of age)	0-20 K (N) %	(76) 25.8	(68) 27.4
	20-40 K (N) %	(113) 38.3	(91) 36.7
	40-60 K (N) %	(68) 23.1	(56) 22.6
	60-80 K (N) %	(18) 6.1	(16) 6.5
	80-100 K (N) %	(11) 3.7	(10) 4.0
	100 K > (N) %	(9) 3.1	(7) 2.8

Table 2.2

CBQ-SF scales

Broad dimension/Temperament scales	Scale definition
Effortful control	
Attentional focusing	The ability to focus/shift attention when desired.
Inhibitory Control	The abilities to plan and initiate appropriate responses and suppress inappropriate ones.
Low-Intensity Pleasure	Enjoyment or pleasure derived from stimuli that is low in intensity, complexity, novelty, or rate.
Perceptual Sensitivity	The degree to which low-intensity stimuli is perceived.
Extraversion/surgency	
Activity Level	Child's level of gross motor activity.
High-Intensity Pleasure	Enjoyment or pleasure derived from stimuli that is high in intensity.
Impulsivity	Child's speed of response initiation.
Positive Anticipation	Positive excitement in anticipation of pleasurable activities.
Smiling & Laughter	Increase in positive affect as a response to changes in stimuli's intensity, complexity, novelty, or rate.
Negative affectivity	
Discomfort	Negative affect in response to the qualities of stimuli, physical or otherwise.
Fear	Negative affect due to the anticipation of distress.
Frustration	Negative affect due to the interruption of present tasks or blocking of goal attainment.
Sadness	Negative affect, decreased energy, and lowered mood in response to suffering, disappointment, or object loss.
Falling Reactivity/Soothability	Child's rate of recovery from peak distress, excitement, or general arousal.

As seen on Temperament, Development, and Personality by Rothbart, 2007 and the CBQ Short Form User's Guide.

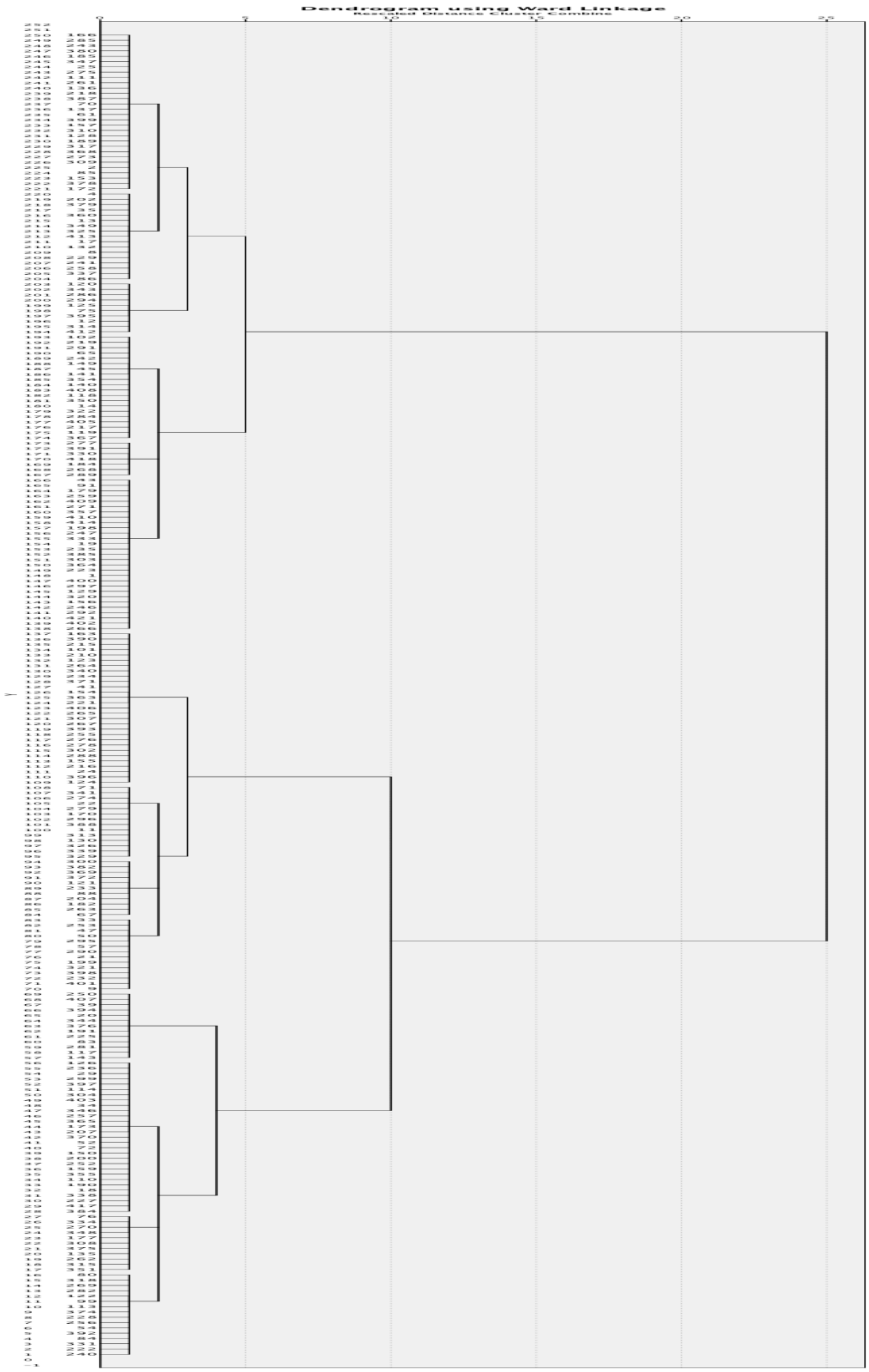

Figure 3.1 Dendogram of hierarchical cluster analysis

Figure 3.2. 3-Cluster Solution and mean centers for the unregulated, average, and regulated clusters by temperament dimension: impulsivity (IM), high intensity pleasure (HP), activity level (AL), attention focusing (AT), inhibitory control (IC), anger (ANG), and fear (FR).

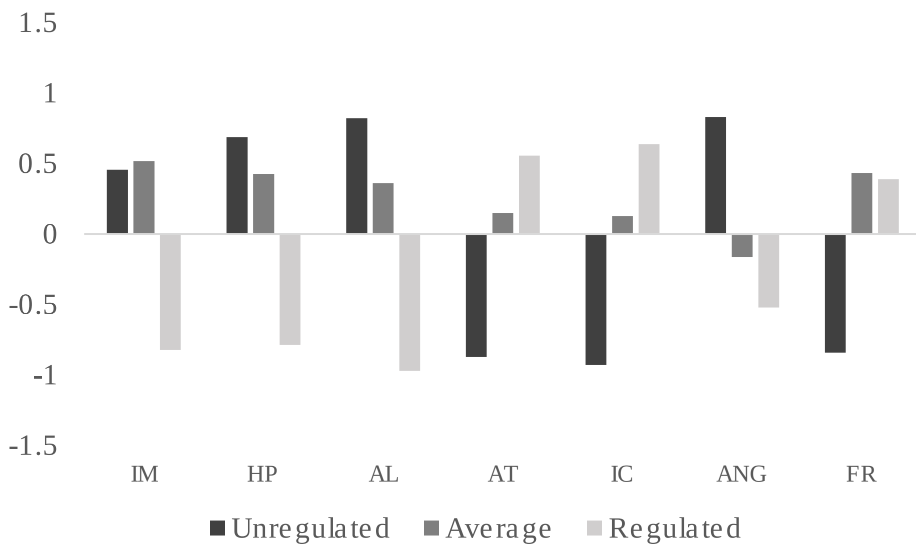

Figure 3.3 Unregulated vs. regulated cluster comparison. The *unregulated* cluster was significantly higher in impulsivity, high intensity pleasure, activity level, and anger, and significantly lower in fear, inhibitory control, and attention focusing.

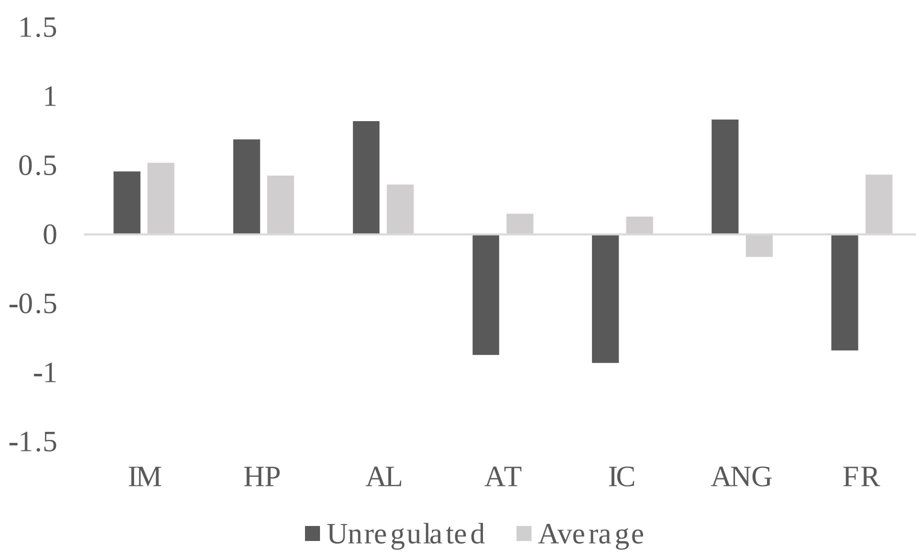

Figure 3.4 Unregulated vs. regulated cluster comparison. The *unregulated* cluster was significantly in impulsivity, high intensity pleasure, activity level, and anger, and significantly lower in fear, inhibitory control, and attention focusing.

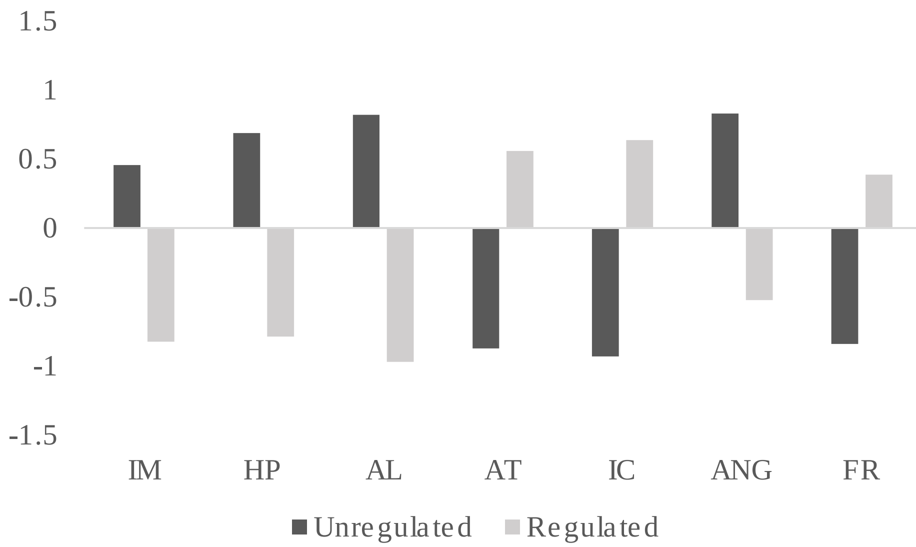

Figure 3.5 Regulated vs. average cluster comparison. The *regulated* cluster was significantly higher in attention focusing and inhibitory control, and significantly lower in impulsivity, high intensity pleasure, activity level, and anger. The difference between cluster on the fear dimension was non-significant with the *regulated* cluster being slightly lower.

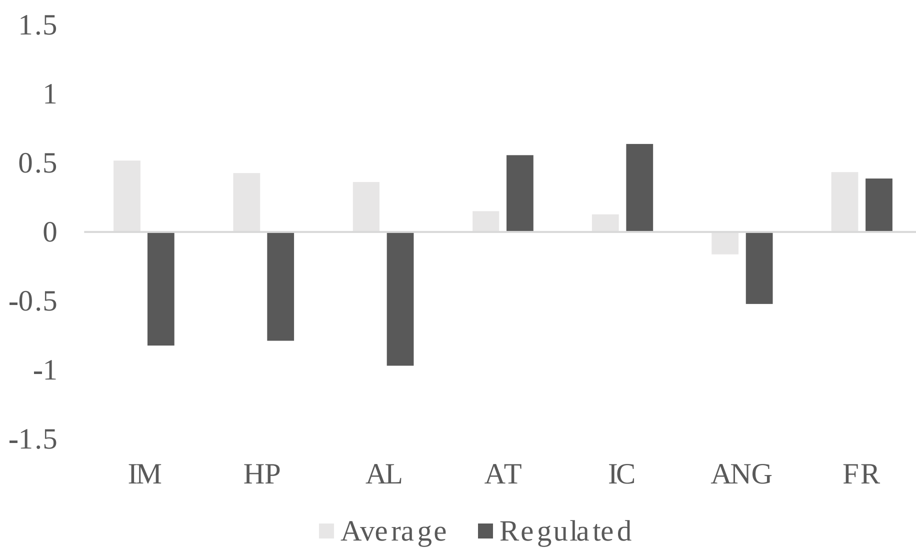

Table 3.1

Multinomial regression

Cluster	Predictor	B(SE)	OR/Exp(B)(95% CI)
1 (Unregulated)	Intercept	-1.55(3.62)	
	Maternal education at 5 years	-.07(.09)	.93(.78 – 1.11)
	House income at 5 years	.00(.00)	1.00(1.00 – 1.00)
	Child age in months	.03(.05)	1.03(.92 – 1.14)
	Child sex		
	Male	**-.96(.34)****	2.62(1.36 – 5.06)
	Female	–	–
	PTE		
	Yes	**-1.09(.34)****	2.97(1.52 – 5.79)
	No	–	–
2 (Average)	Intercept	.31(3.35)	
	Maternal education at 5 years	-.10(.08)	.90(.77 – 1.10)
	House income at 5 years	.00(.00)	1.00(1.00 – 1.00)
	Child age in months	.03(.05)	1.03(.93 – 1.14)
	Child sex		
	Male	**-1.02(.33)****	2.77(1.47 – 5.19)
	Female	–	–
	PTE		
	Yes	**-.91(.33)****	2.48(1.31 – 4.68)
	No	–	–

The reference is cluster number 3 (Regulated)
**p < .05*
*** p < .01*

Table 3.2

Mean differences in performance across clusters

Measure	Cluster	N	Mean	SD	Range
WJBIA	Unregulated	74	93.58[a]	14.10	62 – 120
	Average	86	98.40[ab]	13.23	67 – 125
	Regulated	90	101.89[b]	13.84	63 – 134
	Total	250	98.23	14.06	62 – 134
WJVC	Unregulated	74	97.81[a]	13.59	63 – 129
	Average	86	100.19[ab]	12.58	67 – 125
	Regulated	90	103.74[b]	15.28	69 – 140
	Total	250	100.76	14.05	63 – 140
WJCF	Unregulated	74	96.11[a]	12.36	70 – 126
	Average	86	100.07[ab]	11.61	71 – 122
	Regulated	90	101.08[b]	13.32	71 – 125
	Total	250	99.26	12.60	70 – 126
WJVM	Unregulated	74	92.61[a]	14.02	60 – 130
	Average	86	97.42[ab]	15.26	64 – 131
	Regulated	90	100.94[b]	13.70	70 – 132
	Total	250	97.26	14.68	60 – 132
NB	Unregulated	73	6.25[a]	2.49	2.25 – 13.00
	Average	68	7.27[ab]	2.69	1.00 – 14.00
	Regulated	89	7.82[b]	2.74	2.50 – 14.00
	Total	248	7.16	2.72	1.00 – 14.00

Note: Means with matching superscripts are not significantly different from each other at the $p < .05$
WJBIA – Woodcock-Johnson Brief Intellectual Ability
WJVC – Woodcock-Johnson Verbal Comprehension subtest
WJCF – Woodcock-Johnson Concept Formation subtest
WJVM – Woodcock-Johnson Visual Matching subtest
NB – Nebraska Barnyard task