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A Behavior Genetic Study of Activity Levels and Internalizing Problems Across Childhood

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A BEHAVIOR GENETIC STUDY OF ACTIVITY LEVELS AND INTERNALIZING PROBLEMS ACROSS CHILDHOOD

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This study used a twin and triplet sample to investigate the influence of preschoolers' physical activity levels and internalizing problems on subsequent health outcomes (body-mass index, internalizing behavior problems, household health behaviors) in middle childhood. The potential influence of stressors salient in childhood (household chaos, socioeconomic status, stressful life events) on the hypothesized relationship between physical activity and internalizing on health was also explored. A specific focus was placed on examining the underlying genetic and environmental influences of children's physical activity levels, as assessed by both temperamental (parent-reported) activity levels and observed (in-lab) motor behavior, using a behavioral genetic approach. By measuring physical activity in these two ways, this project also investigated the validity of the observational coding scheme developed for the current study to assess preschoolers' overt motor behavior during laboratory testing. Data from 65 families (*n* = 134 children) included in the Southern Illinois Twins/Triplets and Siblings Study (SITSS) were examined from age 5 (physical activity levels, internalizing problems, and household chaos) to follow-up (body-mass index, internalizing problems, household health behavior, socioeconomic status, and stressful life events) when children were age 7-13 years old. Findings indicated that observed motor behavior and temperamental activity were not significantly correlated, suggesting that these measures assess different aspects of preschoolers' physical activity levels. Additionally, results supported the reliability and validity of the newly developed observational coding scheme, which underscores the utility of this measure; employing this methodological tool in future studies focused on investigating motor behavior in childhood may be particularly fruitful. Genetic analyses demonstrated that approximately 66% and 34% of the variance in observed motor behavior was accounted for by additive genetic and non-shared environmental influences, respectively, whereas the variance in temperamental activity was attributable to dominant genetic effects (72%) and non-shared environmental influences (28%). These results suggest that differences in age 5 physical activity levels are largely due to genetic differences. Finally, longitudinal analyses showed that health outcomes at follow-up were significantly influenced by 5-year-old temperamental activity and internalizing problems, as well as follow-up socioeconomic status and stressful life events: 1) children who were older, were boys, and lived in a low socioeconomic status household had a higher body-mass index at follow-up; 2) children with higher age 5 internalizing problems and concurrent stressful life events had greater internalizing problems at follow-up; 3) boys and children with higher age 5 temperamental activity had lower scores for household health behaviors. The present project provides greater insight into childhood health (body-mass index, internalizing, household health behaviors) by examining factors relevant to health (physical activity levels, internalizing problems, stress) across development (i.e., from age 5 to ages 7-13 years).

ACKNOWLEDGMENTS

With the completion of this project, I end one chapter of my story and look toward the start of another. This transitory period brings a sense of reflection for the many experiences that occurred along this path. Words cannot describe how extremely grateful I am for them. *I am because I am at this very moment*. My ramblings below attempt to capture my feelings and give recognition to all who took part in my story. However, more simply, one word sums it up - Love.

The chapter I close, my graduate studies and completion of my doctorate, has been a challenging but unbelievably rewarding process. Embarking on this path in my early twenties, I had little idea what an exciting journey would unfold. My studies have taught me so much and, as a result, I have grown in so many ways, both professionally and, perhaps most importantly, as an individual. The lessons, experiences, and memories of this chapter will always be cherished.

Over the past 18 months, I worked on my dissertation project through the uncertainties posed by the COVID-19 pandemic which, quite literally, turned humanity upside down. This was the context in which my final year of graduate school took place. This event had a profound impact on me; however, not as one might expect. Truth be told, I would have never imagined the adventure that would become my 2020. With chaos comes order. It has truly been a blessing.

The completion of this project, as well as the journey through my doctoral studies, would not have been possible without many individuals - not only the 'known' helpers, but also all those individuals not known. I greatly appreciate all these people for their assistance along this path I have walked. This includes my family and friends, my peers and colleagues in the department, professors whose classes I took, many collaborators from various projects, and all others I have associated with over the years. To everyone who has stood beside me on this journey, you all know who you are – from the bottom of my heart, I deeply thank you.

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Next, I would like to thank the three matriarchal figures in my life whose guidance and wisdom has shaped who I am today: my mother, my grandmother, and my great-grandmother. To my mother, Sue – I am blessed to have a parent as loving as her. She is there for me, always, with no conditions. I love you, Mom! To my grandmother, Gerda – her enthusiasm and zest for life will forever inspire the adventures of my own story. Yodelayheehoo, Grandma! Finally, to my great-grandmother, Omi, who is no longer with us but whose presence remains everlasting in spirit. I am eternally grateful for the guiding light that the love of my lineage provides for me.

Last, I must also thank my two brothers, Eric and Andrew. It is a privilege to be their older brother and lead by example. As I watch the adventures of their own stories unfold, I am proud of the humans they strive to be. No matter what, until the end, I am with you two.

In closing, I reflect on a statement that my advisor, Liz, oft reminded me of throughout my studies - “Science is to be shared,” she would say. It is through this sharing that we inform our collective knowledge and understanding. And so, with that, I share this project with you.

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CHAPTER 1

INTRODUCTION

As Virgil (~25 BC / 1910) suggested and Emerson (1860/2003) echoed, health is the greatest wealth. Invest early and throughout life, and the return may be invaluable. Health is a necessary component of day-to-day life, yet it is oft overlooked until the occurrence of poor health arises (e.g., disease, chronic illness). On the contrary, when people experience good physical and mental health, they also report greater wellbeing (Hampson & Vollrath, 2012). So, what exactly is health? Definitions of health range from the more subjective to objective. According to the Institute of Medicine, health is the developmental capacity that allows an individual to interact successfully within biological, psychological, and social environments (National Research Council, 2004).

Today, however, unprecedented global forces are shaping the health of the largest generation of young people (10- to 24-year-olds) in human history, such as the promotion of unhealthy lifestyles (Patton et al., 2016). Humans now consume increasingly obesogenic diets, as well as engage in less physical activity (i.e., skeletal movements requiring energy) and greater sedentary behavior (i.e., waking actions which expend little energy) than ever before (Farhud, 2015; Ferretti, 2015). These maladaptive behaviors all pose major threats to an individual's physical and mental health (e.g., Collings et al., 2017; Patton et al., 2016). People also report living an increasingly stressful lifestyle (Gallup, 2019), characterized by events or experiences producing severe strain, which is also associated with higher risk for all-cause mortality (Chau et al., 2013). Estimates even suggest nearly 1 in 4 total global deaths are attributable to unhealthy environments (World Health Organization [WHO], 2014). If left unaddressed, these pose substantial health challenges across the lifespan (Bremer & Cairney, 2018). In fact, for the first time ever, young people today face a shorter average life expectancy than that of their parents' generation (Centers for Disease Control and Prevention [CDC], 2018). Recent work demonstrates that, compared to individuals from older generations, younger individuals experience worse outcomes for both physical and mental health (Zheng & Echave, 2021).

Furthermore, WHO states that physical inactivity is the fourth leading cause of death worldwide (WHO, 2010). Current estimates indicate approximately 80% of adolescents and adults do not accumulate sufficient guideline-recommended levels of physical activity on a weekly basis (Thompson & Eijsvogels, 2018). Further, studies investigating children's physical activity suggest only about 14% of preschoolers, 7% of 5- to 11-year-olds, and 3.5% of 12- to 17-year-olds meet guidelines for daily activity levels (Colley et al., 2013; Piercy et al., 2018). Other estimates even suggest upwards of 90+% of school-aged children do not engage in sufficient movement behaviors (Timmons, LeBlanc, et al., 2012). This is especially troubling, given that early development sets the stage for health trajectories across the lifespan (Gluckman et al., 2010; Halfon, et al., 2018; Halfon & Forrest, 2018; Halfon, Larson, et al., 2014; Halfon, Wise, et al., 2014). It is therefore vital to encourage movement!

Physical activity, or movement, is any bodily movement produced by the skeletal muscles that uses energy (WHO, 2010); therefore, physical inactivity means not engaging in bodily movements that expend energy (i.e., meet recommended physical activity guidelines). A vast literature clearly indicates (lack of) time spent in physical activity is a key driver of obesity (Dunton et al., 2012; Saldanha-Gomes et al., 2016; Telama et al., 2014), over and beyond the health risks posed by sedentary behavior alone (Katzmarzyk et al., 2015; Pate et al., 2013; Pate, Lau, et al., 2015). Sedentary behaviors are those waking actions involving very little energy expenditure, such as sitting, reclining, or lying down for prolonged periods (U.S. Department of

Health and Human Services [HHS], 2018a). Increased sedentary behavior is related to poorer health, even when controlling for engagement in regular physical activity (Biswas et al., 2015; Panahi & Tremblay, 2018). (An interesting, comprehensive breakdown of these behaviors and their terminologies is provided by Trembley and colleagues, 2017).

Physical activity (and movement) has positive implications for the overall health of children, adolescents, and adults (HHS, 2018b), and is one way to counteract negative health outcomes associated with living an unhealthy lifestyle (American Heart Association [AHA], 2014). Individuals who are not sufficiently active are at an elevated risk for physical and mental health problems, such as obesity, depression, and anxiety (Johns Hopkins Medicine, 2014). This comorbidity among health problems (Adams et al., 2017) is alarming because these problems often increase an individual's susceptibility for additional health complications, as highlighted by the current COVID-19 pandemic (Richardson et al., 2020). As of August 2020, across 5,700 patients, COVID-19 hospitalizations coincided with hypertension (56.6%), diabetes (33.8%), and obesity (41.7%); all three of which, in their own regard, increase mortality risk (Livingston & Ko, 2005).

Apart from physical inactivity, there is also a rising prevalence in both physical and mental health problems today (Anxiety and Depression Association of America [ADAA], 2015; CDC, 2015; HHS, 2017). Approximately half of the population of individuals over age 20 are affected by mental health problems (ADAA, 2015), over 15% are affected by cardio-metabolic diseases (Gluckman et al., 2010), and over a third are overweight or obese (Hruby et al., 2016). Similarly, among children, increases in physical and mental health problems (e.g., obesity and internalizing problems) are also seen. For example, the National Alliance on Mental Health (2014) reports that children and adolescents experience greater mental health difficulties (e.g., anxiety and depression) today than in previous decades. Furthermore, with nearly 1 in 5 children affected, the childhood obesity epidemic poses a serious public health challenge (Sahoo et al., 2015) and is even considered a national health priority by several different institutions (e.g., WHO, 2016).

Obesity has both immediate consequences for health in childhood, as well as implications for health later in life (WHO, 2016). Over time, the negative health ramifications of obesity are further exacerbated. Children who are obese at age 6 have a greater than 50% chance of remaining obese in adulthood, and 80% of children who are overweight between ages 10-15 will become obese by age 25 (Frieden et al., 2010). Put simply, childhood obesity can lay a foundation for a lifetime of health consequences (e.g., Kain et al., 2019). Better understanding health behaviors in young children (e.g., preschoolers) is crucial for improving health outcomes later in life (Carson et al., 2017; Kuzik et al., 2017; Saunders et al., 2016; Timmons, Proudfoot, et al., 2012). Thus, specifically focusing on health in early childhood is a particularly important endeavor.

Taking action and enacting change is not easy, but if we do not, the epidemic of childhood obesity will become increasingly difficult to address (Frieden et al., 2010). Continued investigation into predictors and outcomes related to obesity is necessary to help further elucidate possible mechanisms for intervention efforts. Indeed, research indicates that obesity may be both preventable and treatable through healthy lifestyle modifications (Wadden et al., 2012). Interventions focused on modifying lifestyle behaviors, such as decreasing unhealthy behaviors (e.g., sedentary behavior) and encouraging engagement in healthy behaviors (e.g., movement), have shown great promise for improving health outcomes over time (Pate et al., 2013; Roychowdhury, 2019; Thompson & Eijsvogels, 2018).

A robust literature supporting the health promoting effects of physical activity (and movement, in general) exists (Roychowdhury, 2019). Studies examining physical activity interventions have shown great promise for decreasing obesity and increasing both physical and mental health outcomes (Pate, Lau, et al., 2015). In this way, physical activity levels may be one modifiable risk factor to prevent or mitigate health problems (Bremer & Cairney, 2018). This sentiment is echoed by Thompson and Eijsvogels (2018) who discuss how movement can help lower health risks and, therefore, encourage a call for physical activity. Other health initiatives also endorse movement for improving health outcomes, such as “Get Up, Get Moving” (Oncology Nursing Society, 2014) and Michelle Obama’s “Let’s Move” campaign (Wojcicki & Heynab, 2010). These examples highlight the role of physical activity for promoting health, and thereby underscore the importance of further examining associations between physical activity levels and related health outcomes (both physical and mental), especially early in life (e.g., preschoolers).

As the Life Course Health Development (LCHD) framework suggests, health emerges as the result of coactions, transactions, and interactions among genetic, biological (e.g., temperament), psychological (e.g., mental health), and environmental factors (Halfon & Forrest, 2018; Halfon, Larson, et al., 2014). This approach parallels other developmental perspectives that discuss the bidirectional interplay across various levels of influence, such as those by Piaget (1954, 1972) and Bronfenbrenner (1978), as well as behavioral genetic work examining genetic and environmental influences (e.g., Sameroff, 2010). Sameroff (2010) discusses how genes and the environment may both influence behaviors uniquely, as well as in combination (i.e., gene-environment interplay), that is, via gene-environment interaction (GxE; Plomin et al., 1977) and gene-environment correlation (rGE; Scarr & McCartney, 1983). In sum, these various perspectives suggest behavior emerges as the result of complex and dynamic interrelations among genetic and environmental factors across development. Therefore, a thorough investigation of health should broadly consider these relevant influences.

A behavioral genetic (BG) approach provides one useful methodology to examine health from this more nuanced perspective. Using various family-based designs, BG studies allow for the relative influence of genes and the environment to be disentangled. The two most common designs are adoption and twin studies (Knopik et al., 2016). The twin method was focused on here, given that the current project used this design to examine underlying influences of preschoolers' physical activity levels. The logic of the twin method relies on the differing genetic similarity between monozygotic (MZ) and dizygotic (DZ) twins (Roysamb & Tambs, 2016). Because MZ twins share 100% of their genes, differences between them are primarily due to non-shared environmental factors; whereas, because DZ twins only share about 50% of their genes, both genetic and environmental influences may contribute to their dissimilarities (and similarities). Because of this underlying difference in genetic similarity, the within-pair correlations among MZ and DZ twins can be: 1) used to tease apart the respective effects of genes and environment (shared and nonshared) using advanced statistical analyses (e.g., structural equation modeling) and 2) compared to broadly estimate genetic effects via the influence of heredity (i.e., the amount of variability in a population for a given trait that is attributable to individual genetic differences). In these ways, studying twins is a useful way to better understand the etiology of the behavior of interest.

The current project used a longitudinal and genetically informed design to provide insight into various aspects of middle childhood health (body-mass index, internalizing problems, household health behaviors). A specific focus was placed on 5-year-old physical activity levels, in addition to considering the underlying role of genetic and biological predispositions (e.g., temperament), psychological factors (internalizing problems), and salient environmental circumstances most proximal to children of this age (household chaos, socioeconomic status, life stressors). Broadly, it was hypothesized that preschoolers' physical activity levels and internalizing problems would both predict subsequent health outcomes in middle childhood, albeit in opposite directions. That is, physical activity levels would predict more positive health outcomes whereas internalizing problems would predict poorer health outcomes. Additionally, it was expected those previously mentioned stressful environmental factors would negatively impact health outcomes in middle childhood. Finally, the amount of variance in physical activity levels accounted for by genetic and environmental factors was examined to further understand the development of these behaviors in early childhood.

To these ends, the current project had three main objectives. The primary objective was the development of an observational coding scheme to assess preschoolers' engagement in motor behavior during laboratory testing. These observed ratings were compared to parent-reported temperamental activity levels as a way of assessing this newly developed coding scheme, which will be a useful tool for future studies. A secondary main objective was to further inform our understanding of preschoolers' movement by utilizing a twin sample to determine the amount of variance in physical activity levels attributable to genetic and environmental influences. Better understanding the underlying influences of physical activity levels was important, given that, only relatively recently, a drastic reduction in movement is seen worldwide (Thompson & Eijvogels, 2018). This rapid decrease in physical activity in recent decades is somewhat paradoxical, considering that these behaviors are a fundamental component of biologically based temperament (Shiner et al., 2012) and, therefore, are essential to being human (albeit to varying degrees across individuals). Hence, further elucidating the underpinnings of physical activity levels was a timely, and necessary, endeavor. The third and final objective was to investigate the influence of preschoolers' physical activity levels, internalizing problems, and stressful experiences on subsequent physical and mental health outcomes (body-mass index, internalizing problems, and household health behaviors) reported later in middle childhood. Together, this project provides greater insight into the underlying genetic and environmental factors contributing to preschoolers' movement, as well as sheds light on the etiology of childhood health by having examined relevant factors (physical activity levels, internalizing, stress) across development (i.e., from preschool-aged to middle childhood).

CHAPTER 2

LITERATURE REVIEW

The following literature review discusses our current understanding of health and related behaviors across childhood. To best understand childhood health, the current project explored the bidirectional relationship between physical and mental health (physical activity levels and internalizing problems, respectively). Furthermore, the impact of stress on health was also examined. This review discusses physical activity levels, internalizing problems, and subsequent health outcomes (e.g., obesity). An emphasis was placed on the influence of movement (i.e., physical activity and motor behavior) for overall health and, therefore, a specific focus was given to the etiology of children's physical activity levels. To disentangle genetic and environmental influences of movement, a twin-based design was used and a brief introduction into this methodology is provided. A comprehensive overview of childhood health is put forth before discussing the current project: a behavioral genetic investigation of physical activity levels and internalizing problems across childhood.

Health and Wellbeing

"Life requires movement" – Aristotle (c. 350 BC / 1907)

Movement is a fundamental principle of the universe; all things are in constant motion, including humans (Tyson, 2017). Physical activity (movement) helps facilitate good physical and mental health (Pate, Lau, et al., 2015) which, in turn, predicts greater reported wellbeing (Hampson & Vollrath, 2012). It is a necessity for life, like health. But what exactly is health? Definitions of health range from the more subjective to objective. According to the Institute of Medicine, health is the developmental capacity that allows an individual to interact successfully within biological, psychological, and social environments (National Research Council, 2004).

Today, unprecedented global forces are shaping the health of the largest generation of young people (10- to 24-year-olds) in human history, including the promotion of unhealthy lifestyles (Patton et al., 2016). Humans now consume increasingly obesogenic diets, engage in less physical activity and greater sedentary behavior than ever before (Farhud, 2015; Ferretti, 2015), and report living an increasingly stressful lifestyle characterized by demands, pressures, and/or burdens that are significantly overwhelming (Gallup, 2019). These unhealthy lifestyle behaviors all pose major threats to our physical and mental health (e.g., Collings et al., 2017; Patton et al., 2016). Indeed, a rising prevalence in both physical and mental health problems, as well as the growing comorbidity among these health issues (Adams et al., 2017), is currently seen (Anxiety and Depression Association of America [ADAA], 2015; Centers for Disease Control and Prevention [CDC], 2015; National Alliance on Mental Illness [NAMI], 2014; U.S. Department of Health and Human Services [HHS], 2017). Furthermore, if left unaddressed, these maladaptive behaviors cause substantial health challenges across the lifespan (Bremer & Cairney, 2018). Therefore, specifically focusing on health early in life was a particularly important endeavor.

Physical activity, or movement, is any bodily movement produced by the skeletal muscles that uses energy (World Health Organization [WHO], 2010), whereas sedentary behaviors are those waking actions (e.g., sitting, reclining, lying down) involving very little energy expenditure (HHS, 2018a). Research clearly indicates that (lack of) engagement in physical activity is a key driver of obesity (Dunton et al., 2012; Saldanha-Gomes et al., 2016; Telama et al., 2014), beyond the health risks posed by sedentary behavior alone (Katzmarzyk et al., 2015; Pate et al., 2013; Pate, Lau, et al., 2015). Similarly, even when controlling for regular physical activity, increased sedentary behavior is also related to poorer health outcomes (Biswas et al., 2015; Panahi & Tremblay, 2018). Hence, the need for encouraging movement (i.e., both increased physical activity and decreased sedentary behavior) is of utmost importance!

The current project used a longitudinal approach to explore the relationship between various aspects of preschoolers' physical and mental health (physical activity levels and internalizing problems, respectively), experiences of stress (household chaos, socioeconomic status, life stressors), and subsequent health outcomes (body-mass index, internalizing problems, and household health behaviors) during middle childhood. A specific focus was placed on broadly examining the etiology of preschoolers' physical activity levels, in attempt to advance our understanding of how these healthy behaviors develop early in life. To this end, a genetically informed design (twin study) was used to disentangle the relative impact of genes (additive genetics) and environment (both shared and nonshared) on preschoolers' physical activity levels. The current study provides insight into mechanisms related to preschoolers' movement and sheds light on children's overall health (physical and mental) by investigating related factors (physical activity levels, internalizing, and stress) that affect health outcomes at a later period.

Theories of Health

Health investigations span a wide array of disciplines and provide several different theoretical perspectives of health, such as the biomedical model (see Engel, 1977), biopsychosocial theory (Borrell-Carrió, Suchman, & Epstein, 2004), and life course health development (Halfon & Forrest, 2018; Halfon, Larson, et al., 2014; Halfon, Wise, et al., 2014). Early 20th century models of health were shaped by the dominant scientific perspective (i.e., Cartesian-Newtonian) of the time and took a reductionist approach, dividing the world up into separate categories (e.g., nature vs. nurture, mind-body). However, worldviews change and science advances (Kuhn, 1962; Aldwin, 2014). Over time, a fundamental paradigm shift occurred (Kuhn, 1962) and increased attention, both empirically and theoretically, was given to the mind-body connection (Acolin, 2016). Theoretical advances expanded 20th century models of health into the more complex systems-oriented perspectives of the 21st century. Contemporary models posit that health is not a fixed process, but rather unfolds dynamically across time as the result of unique person-environment interrelations (Halfon & Forrest, 2018).

Historically, the prevailing theoretical approach (i.e., biomedical model) suggested health was simply the absence of disease or risk factors. The body was viewed as a machine and disease was a breakdown in organ structure and function (Engel, 1977). This 20th century perspective presupposed a mind-body split (a vestige of Cartesian dualism) and reified the distinction between physical and mental health (Borrell-Carrió et al., 2004). As a result, this oversimplified mechanical model of health could not account for the effect of the mind on the body (e.g., psychosomatic illnesses). This model placed a focus on acute illness or injury treatment across an immediate short-term (days, weeks) timeframe (Halfon, Larson, et al., 2014). Therefore, it also failed to successfully explain how health impacts the lives of individuals and how health develops throughout the lifespan (Halfon, Wise, et al., 2014).

These shortcomings were addressed by the biopsychosocial model of health (Engel, 1977). This systems-based approach shed the mind-body distinction and added in non-biological influences (psychological and socio-environmental) that were previously overlooked (Bolton & Gillett, 2019). It transformed the mechanistic biomedical model into a hierarchical, dynamic, and multiply determined model of health (Adler, 2009; Lehman, et al., 2017). This shifted the medical focus away from only acute short-term problems and towards also including management of chronic illness across an intermediate (months, years) timeframe (Halfon, Larson, et al., 2014). However, like its predecessor, it did not sufficiently address how human health and patterns of disease develop over time (e.g., Gluckman et al., 2010). This developmental perspective is crucial, given that a vast literature demonstrates that early life events and experiences significantly impact adult health conditions (Halfon, Larson, et al., 2014). An individual's past health history is reflected by their current health which, in turn, affects their future health status (Hampson & Vollrath, 2012).

Over the next several decades, the biopsychosocial model of health was further refined and transformed (Bolton & Gillett, 2019; Farre & Rapley, 2017). A comprehensive theory of health emerged which incorporated various theoretical breakthroughs from various disciplines, such as developmental psychology (e.g., Sameroff, 2010), behavior genetics (e.g., Plomin et al., 2016; Plomin, 2019), epigenetics (e.g., Bohacek et al., 2018; Petronis, 2010), and evolutionary development (e.g., Bjorklund & Ellis, 2014; Bjorklund et al., 2015; Ellis & Del Guidice, 2019). The focus expanded beyond simply treating acute (immediate) and chronic (intermediate) health problems to also examining ways of optimizing health across a lifelong and multi-generational timeframe. This new approach, called Life Course Health Development (LCHD), views health as an emergent, developmental process that provides the individual with the functional and adaptive capacities necessary to survive (Halfon et al., 2018). This 21st century model of health states health develops as the result of dynamic coactions and interactions between biological, genetic, psychological, and environmental factors throughout the lifespan (Halfon & Forrest, 2018).

Life Course Health Development

The Life Course Health Development (LCHD) framework posits several core tenets related to health development (Halfon & Forrest, 2018; Halfon, Larson, et al., 2014). First, health is an emergent set of developmental capacities, comprised of both our body (physical) and mind (mental), that enable humans to adapt to unknown challenges and unexpected environments.

These capacities allow people to pursue life's goals. For children, they promote development by affording the ability to interact successfully within the biological, physical, and social environment. Second, health development occurs in specific phases but also unfolds continuously. This occurs as a non-linear process across varying levels and multiple dimensions (i.e., physical, biochemical, psychological, social, and cultural) throughout the lifespan. It is therefore sensitive to the timing and synchronization of molecular, physiological, and behavioral functions, as well as environmental (e.g., social, cultural) exposures and experiences. Finally, these processes evolve in the face of changing and often constraining environmental contexts. Optimal health is promoted by a 'match' between internal and external systems, whereas a 'mismatch' contributes to negative health consequences (Halfon & Forrest, 2018). In sum, the LCHD model states that health develops across the lifespan as the result of transactions between the individual and their internal and external environments. Therefore, in line with this perspective, investigations of health should consider the various influences affecting these processes over time, namely, genetic and environmental factors. A behavioral genetic approach provides an informative way to study and tease these factors apart.

Behavior Genetics

Behavior genetics (BG) is a discipline wholly concerned with studying the nature and nurture of observed behavior (Knopik et al., 2016). The notion of either-or (nature versus nurture) has long since been abandoned for a more contemporary understanding of both nature and nurture (along with their dynamic coactions, transactions, and interactions across the lifespan; see Sameroff, 2010). By utilizing various family-based designs, BG theory and methods provide a unique naturalistic approach for disentangling genetic and environmental influences (Plomin et al., 2016). The logic of these elegant designs allows for measurement of nature and nurture (i.e., genetic and environmental effects), which cannot be directly studied (Roysamb & Tambs, 2016). In this way, BG studies are helpful for better understanding the etiology of behaviors (e.g., physical activity).

Establishing evidence of causality is one basic challenge for scientific endeavors, especially within psychology, medicine, and epidemiology. This is because it is not always ethical or feasible to conduct studies designed to do so (Stewart-Brown et al., 2011). That is, the gold standard for investigating causality is to use a randomized, double-blinded, controlled experimental study (Rutter, 2007; Simon, 2001). Thus, cross-sectional data are often used instead; however, correlation does not equal causation. To circumvent this dilemma, BG methodologies offer a technique that allows for causal factors, such as genetic and environmental influences, to be estimated using cross-sectional data and path analysis (Roysamb & Tambs, 2016).

The two most common behavioral genetic methodologies are adoption and twin studies (Knopik et al., 2016). In adoption studies, adopted children are compared to their biological and adoptive parents to disentangle respective genetic and environmental influences (Harold et al., 2017). Greater similarities between children and birth parents emphasize underlying genetic influences, whereas greater similarities between children and adoptive parents indicate the role of environmental factors. On the other hand, twin studies allow for genetic and environmental influences to be disentangled by examining similarities and differences between monozygotic (MZ) and dizygotic (DZ) twins (Plomin et al., 2016). A twin-based design was used in the current project and, therefore, is described in greater detail below.

Twin Method

The classic twin design offers a beneficial methodology for investigating the unique contributions of genetic and environmental influences of behavior (Blokland et al., 2013; Boomsma, Busjahn, & Peltonen, 2002). The basic premise of twin studies relies on the 'natural experiment' of twinning (Segal, 2000). That is, twins share much of their environment but differ in terms of genetic similarity (i.e., MZ and DZ twins share 100% and approximately 50% of their genes, respectively). Therefore, differences among MZ twins (MZs) must be attributable to the environment, whereas genetic or environmental factors may contribute to dissimilarities (and similarities) between DZ twins (DZs). In this way, twin studies afford the ability to hold genetic effects constant and, in turn, investigate salient environmental influences. Furthermore, twin studies may also indicate genetic effects when a greater intraclass correlation (i.e., within-pair similarity) among MZs compared to DZs is seen (Kendler, 1993; Nivard et al., 2017).

In twin-based designs, the degree of within-pair similarity (i.e., correlations between co-twins) is examined and compared among MZ versus DZ twin pairs (Rijsdijk & Sham, 2002; Roysamb & Tambs, 2016). The underlying logic of the twin design (i.e., comparing MZ and DZ twins) relies on the varying genetic similarity among MZ and DZ twins. From these observed within-pair correlations, genetic and environmental effects can be estimated. By use of structural equation modeling (SEM) and path analysis, the variance attributable to genes and environment can be disentangled in a twin design (Kendler, 1993; Roysamb & Tambs, 2016). These influences can also be broadly examined via an estimate of heritability (i.e., extent to which genetic differences account for individual differences in observed behavior). In sum, twin analyses allow for the relative contribution of genetic and environmental influences on a certain trait or behavior to be teased apart. In this way, the twin design provided a useful tool for better understanding the etiology of behaviors, such as physical activity levels.

Heritability. Genetic influences for an outcome of interest may be investigated by examining MZs and DZs concurrently. Heritability provides an estimate for the amount of variation in a phenotype (i.e., set of observable characteristics) that can be attributed to individual genetic differences for a certain population (of study). To estimate heritability (h^2) for a given construct, the within-pair similarities of MZs and DZs for the behavior of interest are examined and compared. Estimates of heritability range from 0 to 1.0, which illustrates how both genetic and environmental influences contribute to observed behavior (i.e., zero indicates solely environmental effects, whereas 1.0 indicates solely genetic influences). Although useful for broadly investigating these underlying influences, it is important to keep in mind that this estimate informs us about differences in observed behavior for a specific measure, at a specific time, using a specific population (DiLalla & DiLalla, 1995). Therefore, as with any study, caution should be used when interpreting and generalizing results to other populations. To further examine the data more rigorously, it is beneficial to employ a more sophisticated analysis, such as biometric modeling, to investigate these underlying factors (genes and environment).

Biometric (ACE/ADE) modeling. In a twin design, structural equation modeling (SEM) is a technique for investigating the relative effects of genetic and environmental influences for a trait or behavior of interest (Knopik et al., 2016; Nivard et al., 2017). Although briefly introducing this analytic procedure is helpful here, a greater discussion of the specific details of this modeling technique is presented in a later section (Results, Chapter 4). Theoretically, human traits are influenced by four types of factors: additive (A) and non-additive (D) genetics, and shared (C) and nonshared (E) environments (Roysamb & Tambs 2016). The rules of path analysis and empirical model testing can be used to disentangle these factors (ADCE; see Figure 1 for a sample theoretical model), given that they naturally vary in association within MZ versus

DZ twins (i.e., due to varying genetic similarity).

Additive genetic (A) influences refer to genetic effects that represent the combined summative effect of individual alleles across all loci that influence the phenotype under investigation (i.e., the effect of those salient genes ‘add up’). Non-additive genetic (D) influences refer to those genetic effects that represent an interaction between alleles at 1) the same loci (known as dominance) or 2) different loci (known as epistasis). In other words, the main difference between each of these genetic effects is that genes salient for the trait of interest will ‘add up’ (for additive genetic effects) or interact (for non-additive genetic effects). On the other hand, shared environment (C) effects are those external influences that contribute to similarity among siblings (e.g., MZ-pairs and DZ-pairs), whereas nonshared environment (E) effects are those components of experience that contribute to dissimilarity within twin pairs. The nonshared environmental (E) effects also account for measurement error and any unreliability of measures, given these may potentially influence differences in correlations among twin pairs.

With certain restrictions applied, each of these paths (i.e., A, D, C, and E) can be estimated by employing structural equation modeling (SEM) and using a twin sample (Blokland et al., 2013; Rijsdijk & Sham, 2002). In accordance with path analysis, to allow the other paths to be estimated and avoid model over-parameterization, one unknown parameter (i.e., A, D, C, or E) must be fixed to zero. That is, the model tested must have sufficient degrees of freedom for parameter estimation to be permitted (Kline, 2016). This model reduction process is informed by the observed correlation structure across twinship and, again, relies on the varying within-pair genetic similarity among MZ and DZ twins (Roysamb & Tambs, 2016). A greater discussion of the procedure used for ACE/ADE modeling is provided in Chapter 4 (see Results).

Assumptions. It is necessary to keep several assumptions in mind when employing a twin-based design. The two main assumptions of twin studies include the equal environments assumption (EEA) and the overall generalizability of twins to the general population. The first (and main) assumption (EEA) assumes that twinship type (i.e., MZ versus DZ twins) does not affect, in a way that is relevant to the measures being investigated, the treatment twins receive or the environment they are presumed to share. That is, both types of twins are assumed to have the same degree of exposure to common environmental factors. If MZs and DZs differ in environmental similarity and this affects the phenotype under investigation, the EEA may be violated. For example, as young children, MZ twin pairs may share a bedroom and be dressed alike more often than DZ twin pairs. However, so long as the phenotype of interest is unaffected, the EEA is not violated. Therefore, greater environmental similarity is only an issue if it contributes to greater phenotypic similarity. In other words, it is assumed the resemblance of MZ and DZ twin pairs is equally influenced by those trait-relevant environmental factors (Blokland et al., 2013). Several studies have provided evidence in support of the EEA by demonstrating any of the differences (as groups) between MZs and DZs were uncorrelated with the measured outcome of interest (i.e., the trait under investigation was unaffected by twinship type), using both twins reared together (Kendler, 1993; Scarr & Carter-Saltzman, 1979) and twins reared apart (Tellegen et al., 1988).

Secondly, twin studies are assumed to generalize to non-twin populations. This is not unlike the generalizability assumption made in other research designs; that is, do the results extend to other populations outside those currently under investigation? It is assumed having a twin does not affect experiences in a way that would differ from singletons (i.e., those born without a twin). Studies comparing twins and singletons provide evidence in support of this assumption; for example, research has indicated twins and singletons do not significantly differ in experiences of internalizing and externalizing problems (Robbers et al., 2010). Overall, the field has come to a consensus that these assumptions typically hold (Knopik et al., 2016). However, this may not be true depending on the trait or behavior under investigation, especially for those studies that examine novel constructs for which these assumptions have not yet been tested. Therefore, it is important to keep these assumptions in mind, and test and investigate them when possible.

Genetic and Environmental Influences

The etiology of any trait is attributable to the complex interrelations among genetic and environmental factors throughout the lifespan (Knopik et al., 2016). This is supported by the unified theory of development, which suggests development occurs in a biologically informed way (i.e., because of genes) as the result of coactions, transactions, and interactions across and within levels (i.e., the environment) of child functioning (Sameroff, 2010). In other words, genetic and environmental factors may both individually impact behavior, as well as co-act with one another to cause a different unique effect (Plomin et al., 1977; Scarr & McCartney, 1983). When the latter occurs, these combined influences are typically conceptualized as either a gene-environment interaction (GxE) or a gene-environment correlation (rGE). These gene-environment interplay concepts are briefly introduced and defined below, although they were not examined in the present study.

Gene-environment interplay (GxE and rGE) indicate the ways in which genes and the environment may cause a differential effect together, compared to the main effect from either factor alone (Knopik et al., 2016). However, GxE and rGE concepts differ in describing the interplay between these two factors. A GxE suggests an interaction between one’s genes and the surrounding environment; that is, the impact of the environment is moderated by genetics (Reiss et al., 2013). In other words, exposure to certain environments will result in differing outcomes depending on an individual's genotype (Plomin et al., 1977). For example, exposure to a stressful event may cause significant impairment for an individual with an underlying genetic vulnerability to stress, whereas someone without this biological predisposition may be less affected (or unaffected) by the very same experience. On the other hand, an rGE indicates an association between a genetic propensity and the corresponding environment. That is, exposure to certain environments may be influenced by, or correlated with, an individual's genotype (Knafo & Jaffee, 2013; Scarr & McCartney, 1983). For example, consider a child whose parents are professional athletes. This child will not only inherit a genetic predisposition for athleticism but may also be exposed to an environment characterized by greater opportunities for athletic experiences and, thereby, a correlation between genetic and environmental influences for athleticism would be seen. These associations are complex and, a behavior genetic methodology to tease them apart, is essential for investigating gene-environment correlations (rGE).

In summary, the complexities of gene-environment interplay suggest the environment may have a differential effect depending on genes, but genetic differences may also correspond with environmental exposure differences (Johnson, 2007). Via these two mechanisms (GxE and rGE), genetic and environmental factors may co-act to cause unique influences beyond the individual impact of either alone (Knafo & Jaffee, 2013; Reiss et al., 2013). Various models of GxE have been proposed, such as diathesis-stress and differential susceptibility (Reiss et al., 2013), and several types of rGE exist, including passive, evocative (reactive), and active processes (Scarr & McCartney, 1983). It is important to keep these complexities in mind while investigating the underlying etiology for a trait of interest; however, the current project was unable to examine these and therefore it is beyond the scope of this review to address these dynamic processes further.

To investigate the genetic and environmental influences of preschoolers' movement, the current study used a twin design. Specifically, a focus was given to the question: to what extent do genes and the environment contribute to physical activity levels? Examining this question by employing a BG approach (twin study) is beneficial for gaining deeper insight into the emergence of movement behaviors early in life. This was accomplished by using path analysis and SEM to tease apart the relative variance that genetic and environmental influences account for in 5-year-old physical activity levels. As others have suggested, naturalistic studies (such as the twin design employed here) are necessary for investigating the underlying factors which contribute to poorer outcomes in some, but not all, individuals (Rutter, 2015). This is especially relevant for health and related behaviors, given the wide disparities seen across populations (e.g., the socioeconomic-health gradient; Adler et al., 1994; Adler, 2009; Johnson & Krueger, 2005). To this end, the current project helps to elucidate the underlying genetic and environmental mechanisms of early childhood physical activity levels by having examined preschool-aged twins. Further investigating the emergence of these behaviors is beneficial for better informing our understanding of the salient influences underlying movement early in life.

Childhood Physical Activity

Traditionally, because of the common assumption that children engage in lots of movement and are highly active (Pate et al., 2010, 2013), society views childhood as a time of life when people are 'active enough' (Timmons et al., 2007). Despite this, a growing body of evidence demonstrates children and adolescents do not engage in sufficient amounts of physical activity (Chaput et al., 2017; Frieden et al., 2010; Lee et al., 2017; Pate, O'Neill, et al., 2015). Given children today engage in less physical activity than ever before, and most studies highlight the necessity of physical activity for optimal health, it can also be assumed physical inactivity (i.e., sedentary behavior) during the early years puts children at greater risks for health 'deficits' (Timmons, LeBlanc, et al., 2012). In other words, early life can lay the foundation for subsequent health outcomes across the lifespan (Halfon et al., 2018). This is supported by research on obesity, which indicates chronic disease risks are present at very young ages and adult-onset chronic diseases (e.g., hypertension) have origins early in life (WHO, 2010).

Although the optimal way to promote a healthy life from conception to late adulthood is not yet known, and likely varies per individual and context, a developmental perspective is beneficial for better understanding health and related behaviors (Gluckman et al., 2010). The health benefits of movement for school-aged children and adolescents are well-established (e.g., Roychowdhury, 2019; Thompson & Eijsvogels, 2017). However, very little research has investigated physical activity in early life (e.g., ages 2 to 5 years) and, therefore, much less is known about preschoolers' physical activity levels (Cliff et al., 2017; Schmutz et al., 2017; Timmons, LeBlanc, et al., 2012; Timmons, Proudfoot, et al., 2012). As Womack (2017) suggests, the scarcity of studies assessing early childhood physical activity may be partly explained by the longstanding assumption mentioned above (i.e., humans are naturally active early in life); for example, preschoolers are perceived to be more active than they really are (Reilly, 2010). Thus, examining physical activity in childhood and the influence these behaviors have on subsequent physical and mental health outcomes is greatly important.

Physical activity encompasses those energy expending behaviors involving bodily movements (WHO, 2010). This is often traditionally conceptualized as 'exercise.' However, more broadly, physical activity simply refers to those overt actions involving motor behavior. Physical activity levels, therefore, refer to the overall amount of movement engaged in. Some common examples of these behaviors include walking, jumping, running, and climbing. Children attain these motor behaviors and movement abilities throughout early development (i.e., ages 0 to 5) as the result of genetic, maturational, experiential, and environmental influences (Levine & Munsch, 2018). This project conceptualized physical activity as both overt motor behavior, as well as more biologically based characteristics that influence the tendency to engage in movement, such as temperament or personality. Additional research is needed on these various dimensions of physical activity in young children (Saudino, 2009), in addition to examining how these may potentially impact health outcomes later in development (Cliff et al., 2017; Schmutz et al., 2018). This consideration is important because, although research clearly indicates physical activity is good for weight-related outcomes (Moore et al., 2003), it could also be that too much physical activity (e.g., hyperactivity) may be indicative of other underlying difficulties (e.g., attention deficit hyperactivity disorder). Therefore, when studying physical activity, it is important to be conscientious of potential outliers because they may in fact reflect *hyper*activity rather than high physical activity.

Over the last three decades, much of our understanding of physical activity in childhood has come from research conducted by the interdisciplinary team at the Children's Physical Activity Research Group (CPARG; Pate, Lau, et al., 2015). This group has completed dozens of studies examining various aspects of physical activity in childhood (e.g., predictors of, outcomes related to) and the different methods used to study them. Early studies typically relied on questionnaire measures to examine physical activity levels (e.g., self- and parent-report), whereas now, contemporary research also employs objective measurements (e.g., heart-rate monitors, accelerometers) and observational techniques, too (Pate et al., 2010; Worobey, 2014). Regardless of the method used, in typically developing populations, findings have generally demonstrated an inverse relationship between levels of physical activity and indicators of health problems (e.g., markers of body fat, risk for all-cause mortality) and underscore the health consequences of engaging in sedentary behavior (Pate, Lau, et al., 2015). In sum, the CPARG offers information and insight into various tools and techniques (direct observation, objective assessment, and questionnaire report) used to assess physical activity in children and youth. However, like other studies, this research has often focused on youth older than preschool age and, therefore, further studying physical activity in young children is needed.

Regarding test and measurement development, the CPARG developed a widely used observational assessment measure for studying physical activity in children called the Observational System for Recording Physical Activity in Children (OSRAC; Brown et al., 2006; McIver et al., 2009). This measure offers a useful technique for studying physical activity in children and the contexts in which these behaviors occur. The OSRAC has been shown to be a reliable and valid tool for measuring physical activity (Larsen et al., 2011; McIver et al., 2016) and, compared to other objective measures (e.g., accelerometer), provides similar results (Hands et al., 2006; Howie et al., 2012). However, the utility of this technique is limited by the extensive training it requires for use. For this reason, the current project developed a new coding scheme for assessing preschooler’s physical activity using the OSRAC as an example. Before discussing the literature on activity in early childhood, it is useful to briefly introduce two underlying components of physical activity, motor behavior (and motor development, generally) and childhood personality (i.e., temperament).

Motor Development

One important component of physical activity includes the ‘active’ behavior itself, which involves motor behavior and motor development. Motor development refers to those age-related changes in movement abilities that occur continually throughout the lifespan as a result of the dynamic interplay between the individual, environment, and task at hand (Adolph & Berger, 2006). These movement abilities, known as motor behavior, involve the coordination, synchronization, and organization of various parts of the body to create gross and fine motor movements (Adolph & Franchak, 2017). Gross motor skills involve large muscle groups and are often typically whole-body movements, like crawling, standing up, walking, and running. Fine motor skills involve small muscles and movements, such as handling/manipulating objects and writing, and even include blinking and chewing. Working together, these two types of motor movements provide the coordination necessary to be an active human (Santrock, 2019) which, in turn, provides the ability to flexibly maneuver the specific constraints of the immediate environment in an infinite number of ways (Adolph & Robinson, 2015). Put simply, motor behavior encompasses all that people do.

The early work of Gesell (1925) and McGraw (1935; 1945) greatly influenced our understanding of motor development and the emergence of movement abilities. The importance of both genes and maturation for motor development was emphasized by Gesell (1925) who observed specific age-related norms (sequence and timing) for the acquisition of motor skills. However, this strict biological interpretation was challenged by findings from McGraw (Thelen & Adolph, 1994). By differentially exposing one twin in a pair and not the other, McGraw (1935) demonstrated that exposure to environmental experiences for movement abilities (e.g., walking, swimming) corresponded with greater motor skill development (i.e., both greater skill acquisition and performance ability). Together, this early work demonstrated both genes and the environment play an influential role in motor behavior (Levine & Munsch, 2018). As Thelen (1989) suggested, the nature of physical development is not absolute or fixed, but flexible.

Behaviors emerge as the result of complex and dynamic processes throughout development (Sameroff, 2010; Thelen, 1989).

Motor behavior allows humans to see the world, manipulate the environment, and even communicate with others (Adolph et al., 2015). For children, these behaviors provide the means to walk, talk, look around, and interact with people and objects in the environment. As infants grow into toddlers and toddlers into preschoolers, basic motor skills and movement abilities improve alongside children's developing bodies and ever-changing environments (Adolph & Berger, 2011). A typically developed 5-year-old can complete basic motor skills with ease, including locomotor (i.e., moving the body), manipulative (e.g., moving an object), and stability (i.e., balance and weight transfer) behaviors, in addition to fine motor skills like using buttons/zippers and holding a pencil. These skills and abilities develop gradually throughout the early years (ages 0 to 5) and are typically mastered between the ages of 6 to 12 years old (Adolph & Franchak, 2017). In this way, the foundation for movement capabilities across development is laid by these basic motor skills; thus, preschool-age represents the end point of a critical moment in the lifespan for physical activity behaviors.

For most babies around the world, motor milestones occur in a similar sequence. They typically begin with sitting up and crawling (about 8 to 9 months), proceed to standing and walking (around 12 to 14 months), and by about 18 months (1.5 years old) toddlers have attained the abilities necessary to master basic motor skills (Levine & Munsch, 2018). Given this specific sequence of expected events, motor development is therefore described as being strongly influenced by our genes (Gottlieb, 1991). However, the timing of these milestones varies across individuals. Despite 12 to 14 months being the 'typical' age, some children walk at 9 months and others at 18 months. In this way, motor development is not necessarily age dependent but age-related (Rosenbaum et al., 2004). These differences in ‘timing’ highlight both the importance of individual differences (e.g., temperament, body size) and environmental experience for motor behavior. Nevertheless, in general, a typically developing 5-year-old will have attained the basic motor skills necessary for exploring and interacting with the surrounding environment, including postural control and vertical mobility.

Motor Impairment. Motor development is crucial for the physical and mental growth of the developing child. In fact, a measure of motor behavior is typically included in most developmental screen tests used to assess problematic development; for example, the Denver II screening test features domains for both gross and fine motor skills (Frankenburg et al., 1990). Those who fail to reach major motor milestones and/or demonstrate motor skill deficits may have a condition known as Developmental Coordination Disorder (DCD), which places children at risk for impairment in other areas like social and academic functioning (Zwicker et al., 2012). However, due to the wide range of ages at which children normally develop these skills, a DCD diagnosis is not usually made before age 5 (Levine & Munsch, 2018). Therefore, focusing on 5-year-old physical activity levels is beneficial because, by this age, the typically developed child will have attained the basic motor skills (e.g., standing, walking, and hand-/foot-eye coordination) necessary to be an active little human (Adolph & Franchak, 2017). These abilities allow children to gain information and learn about their surrounding environment which, in turn, fosters cognitive development (Piaget, 1954). This is echoed by the Montessori preschool educational approach, which suggests the best learning is active (Byun et al., 2013). Hence, overall development depends on movement behaviors and these basic motor abilities.

Temperament

The other important component of physical activity to consider includes the propensity or tendency for engaging in those ‘active’ behaviors, such as temperament and personality. Although motor behavior is something all humans engage in (Adolph & Berger, 2011), individuals vary in the amount and degree of physical activity they display. Some individuals gravitate towards high physical activity, whereas others desire a more slow-going pace. These individual differences in patterns of behavior arise as the result of external environmental influences, as well as underlying variation in genetic and biological factors, such as innate characteristics and predispositions, like temperament (Santrock, 2019).

Temperament refers to the general way the individual responds to experiences in the world (Levine & Munsch, 2018). The psychological investigation of temperament has a longstanding history, which is described in two seminal roundtable discussions (Goldsmith et al., 1987; Shiner et al., 2012). The first discussion presented commonalities and differences among several different theoretical conceptualizations of temperament (Goldsmith et al., 1987). These varying theories proposed considerations for genetic factors (e.g., Buss & Plomin, 1975; Rowe & Plomin, 1977), self-regulatory and reactivity abilities (e.g., Rothbart et al., 2000), differences in affective responses (e.g., Goldsmith and Campos, 1986), and the importance of ‘goodness of fit’ between the individual and their environment (e.g., Thomas et al., 1968; Thomas & Chess, 1977). After 25 years of empirical work, Shiner and colleagues (2012) revisited these four perspectives to provide an updated overall definition of temperament. These authors concluded temperament refers to individual differences in affect, activity, attention, and self-regulation that occur as the result of complex interactions between genetics, biology, and the environment (Shiner et al., 2012).

Important for the current discussion, this contemporary definition of temperament includes consideration for individual differences in physical activity. This is supported by two other influential approaches for studying temperament, which also suggest an 'activity' component to temperament (Thomas et al., 1968; Thomas & Chess, 1977; Rothbart et al., 2000). The approach originally described by Thomas and colleagues (1968) suggests three distinct temperamental profiles (easy, slow-to-warm, and difficult), which are made up of nine distinct dimensions of temperament (Thomas & Chess, 1977). Of these nine dimensions, one is called 'activity level' and refers to the child's physical energy and "level, tempo, and frequency of motor behavior present in the child's functioning" (Thomas et al., 1968; Thomas & Chess, 1977). On the other hand, Rothbart and colleagues (2000) suggest that temperament consists of three higher order factors (extraversion/surgency, negative emotionality/affect, and self-regulation, or effortful control). Although this latter approach does not explicitly assess physical activity like the former, it does capture physical activity within the extraversion/surgency factor (i.e., greater extraversion/surgency corresponds with increased physical activity levels). Together, these alternative approaches both provide additional evidence indicating people have a 'tendency' for engaging in physical activity to varying degrees. Thus, physical activity not only encompasses those overt behaviors (e.g., movement) but also includes underlying behavioral tendencies and predispositions, such as temperament.

Temperament and Diet/Nutrition

Research examining the association between early childhood temperament and diet/nutrition displays differing results. Some studies provide evidence suggesting that the extraversion/surgency higher-order factor (of which activity levels are a subcomponent) is related to more favorable dietary/nutrition behaviors, such as increased daily vegetable consumption (Kaukokin et al., 2019) at ages 3 to 6 years old and, over time (from age 18 months to ages 1.5 and 7 years old), a greater likelihood of consuming fruits/vegetables (Vollrath et al., 2012). Other studies report results that are in the opposite direction, suggesting that early childhood temperamental extraversion/surgency is related to negative dietary-/nutrition-related outcomes, such as a greater preference for candy over grapes during 5-year-old laboratory testing (Zhou et al., 2019) and, in girls but not boys, greater body-mass index and waist circumference at ages 14 and 15 (Sutin et al., 2017). Overall, it appears early temperamental extraversion/surgency relates to diet/nutrition, but the direction of these associations is less clear. It may be that children with greater extraversion/surgency (again, of which activity levels are a subcomponent) tend to generally consume more food, whether healthy or unhealthy. Although this is an interesting and important research question to explore, the current measures do not assess diet or nutrition directly and, therefore, the association between temperamental activity levels and diet/nutrition was not investigated in the current project.

Behavior Genetic Studies of Physical Activity Levels

To better understand the etiology of physical activity in childhood, it is beneficial to broadly investigate the genetic and environmental basis of preschoolers' physical activity levels. As previously mentioned, one technique to disentangle these underlying factors includes the use of a BG approach (e.g., twin design). Given that relatively few studies have specifically examined physical activity using both a temperamental and motor behavioral conceptualization, it is less clear how these factors may differentially affect the innate drive for movement (temperamental activity levels) versus the observable action (motor behavior) itself. A considerable body of work supports the genetic basis of temperament, including activity levels (e.g., Shiner et al., 2012; Strelau & Zawadzki, 2012). However, behaviors are also affected by contextual and situational factors (i.e., the environment). In other words, varying environments place differential demands on the individual and, in turn, may elicit variations in motor behavior

(Fisher et al., 2010; Frazier-Wood & Saudino, 2017; Saudino, 2012; Saudino & Cherny, 2001). This is important to keep in mind, given young children often have limited control over daily routines or autonomy in the environment (Pate et al., 2013). Thus, this project provides a useful contribution to advance the current literature by having employed a twin design to further investigate the etiology of these varying dimensions of physical activity in young children.

Genetic and Environmental Influences

A recent review of twin studies that examined physical activity levels in early life (ages 0-18 years) provides evidence indicating that these behaviors are influenced by both genes and the environment, albeit to differing degrees depending on the conceptualization of physical activity investigated (Fisher et al., 2015). Overall, across those BG studies identified, Fisher and colleagues (2015) found children's day-to-day physical activity levels were largely influenced by shared environment (weighted mean 60%) and, to a lesser extent, genetic factors (weighted mean 21%). However, compared to these day-to-day physical activity levels, results also demonstrated that momentary self-directed physical activity (i.e., motor behavior displayed during laboratory free play) had a larger genetic estimate (weighted mean 45%) and a smaller environmental effect (weighted mean 25%). Regarding these differing findings, these authors concluded that the base tendency for physical activity in any given moment (i.e., temperamental activity) is predominantly influenced by genetic factors, but daily physical activity (i.e., observable motor behavior), overall, is predominantly determined by the environment in which children live (Fisher et al., 2015). These results are in line with a previous study by Fisher and colleagues (2010) who found objectively assessed day-to-day physical activity levels in twins (ages 9-12) were predominantly influenced by the shared environment (73%), whereas reported preferences for children's physical activity engagement were primarily attributable to genetic factors (parent-report: 85%; child-report: 60%).

Using a longitudinal twin design, another BG study investigated parent-reported temperamental activity levels across development (ages 14 - 36 months) and found similar results indicating differences in stability and change (Saudino & Cherny, 2001). This study found genetic factors affected stability in parent-reported temperamental activity levels from infancy to toddlerhood, whereas change in temperamental activity was primarily due to environmental influences (Saudino & Cherny, 2001). A later study by Saudino (2012) reported similar results for objective measurements of physical activity from ages 2 to 3. That is, genetic factors primarily influenced phenotypic continuity in physical activity and (nonshared) environmental influences accounted for change in those behaviors (Saudino, 2012). Thus, it may be that genes provide the basic tendency for physical activity levels but, over time, the environment further influences and refines these behaviors. This interpretation seems plausible, given that one's level of physical activity encompasses not only an inherent genetic component (temperament) but also a more malleable aspect (the actual motor behavior itself). Considered alongside the conclusion provided by Fisher and colleagues (2015), these results suggest the genetic and environmental underpinnings of physical activity levels may vary depending on 1) the developmental timing (i.e., age), 2) short-term (in the moment) versus long-term (day-to-day) assessment, and/or 3) the specific conceptual dimension being measured (temperament or motor behavior).

Similarly, Horimoto and colleagues (2011) found the underlying etiology of physical activity varied depending on the temporal context assessed (i.e., daily versus weekly). Using a family-based design (rather than a twin study), these authors compared family members of differing genetic relatedness (first-degree relatives: parents, siblings, offspring; second-degree relatives: grandparents; third-degree relatives: first-cousins) to estimate the heritability of self-reported daily physical activity (i.e., amount of physical effort during work and free-time activities) and weekly physical activity (i.e., average time spent in physical activity engagement). Results indicated a moderate influence of genetics on weekly physical activity (heritability = 35%), whereas a lower heritability estimate (12%) was found for daily physical activity (Horimoto et al., 2011). These findings are in line with those results found in the other BG studies described above (e.g., Fisher et al., 2010; 2015; Saudino, 2012; Saudino & Cherny, 2001), which, overall, suggest momentary physical activity is primarily environmentally influenced and engagement in physical activity, generally, is more genetically based. This conclusion provides evidence in support of the distinction made in the current project between observed motor behavior (i.e., that may occur more 'in-the-moment') and temperamental activity (i.e., an individual's tendency to engage in those behaviors).

The biological basis of temperament (Shiner et al., 2012), including activity levels, is supported by a considerable body of evidence (e.g., Strelau & Zawadzki, 2012). Beyond the general support inherently offered by the temperamental aspect of physical activity, additional evidence for the genetic basis of these behaviors has been found in several other studies. For example, Smith and colleagues (2017) found significant evidence of genetic effects for parent-reported temperamental activity levels in 3-month-old twins, as well as the age at which the child first exhibited several basic motor abilities (i.e., sat unsupported, crawled, and walked unaided). Specifically, results indicated genetic and shared environmental factors influenced temperamental activity, as well as the age the child first sat and crawled, to about the same degree (45-48% and 45-54%, respectively). However, interestingly, 84% of the variance in the age the child first walked was accounted for by genetic influences (Smith et al., 2017). These results are in line with the motor development literature, which suggests the timing and sequence of motor behavior development is genetically determined but may also vary due to experience.

Specific to motor behavior, Missitzi and colleagues (2013) used a behavioral genetic approach to elucidate the relative influence of genetic and environmental factors underlying individual differences in motor control (i.e., initial proficiency) and motor learning (i.e., acquisition of improved proficiency) in a sample of 44 college-aged MZ and DZ twins. Interestingly, results indicated a large portion of the individual differences in both motor control and motor learning were accounted for by genetic factors (68% and 70%, respectively), which highlights the role of heredity for basic motor behavior, such as fine motor skills, in young adulthood (Missiziti et al., 2013). This conclusion is in line with research suggesting environmental factors have a larger influence on physical activity early in life (Fisher et al., 2010) and genetic influences become more salient in adulthood (Hoed et al., 2013), which also supports the larger theoretical discussion regarding waning environmental effects and waxing genetic effects throughout the lifespan (Plomin et al., 2016).

The increased salience of genetic factors for physical activity later in life (e.g., adulthood) is supported by two other BG studies, one examining adult twins (Hoed et al., 2013) and another examining college-aged twins (Gielen et al., 2014). In a manner similar to the design used here, both studies used structural equation modeling (SEM) to tease apart the phenotypic variance in physical activity engagement into additive genetic (A) effects, and shared (C) and nonshared (E) environmental effects (i.e., ACE modeling). Over a 14-day period, Gielen and colleagues (2014) used accelerometers to objectively measure college-aged twins' habitual physical activity (i.e., the amount of total movement from waking time to bedtime). Analyses indicated that the AE model was most parsimonious, which suggested a significant role of additive genetic effects (and nonshared, or unique, environmental effects) and a heritability of 57% for engagement in physical activity (Gielen et al., 2014). Another study found similar results using accelerometers and heart-rate monitors to measure adult twins' (ages 45 to 67) overall amount of sedentary behavior (SB) and moderate-to-vigorous intensity physical activity (MVPA) across a 7-day period (Hoed et al., 2013). Results suggested additive genetics accounted for 47% of the variance in MVPA (and nonshared environmental effects explained 53% of differences) and 31% of the variance in SB (with 14% and 55% of the variance attributed to shared and nonshared environmental effects, respectively). Hoed and colleagues (2013) discuss that these findings suggest innate biological processes play an influential role in between-individual differences in daily physical activity (i.e., because genetic factors explained up to one-half of the variance), but so too do environmental influences (especially for sedentary behavior).

Furthermore, the importance of genetic and environmental factors for both subjective and objective assessments of physical activity levels are underscored by the following two studies. In a longitudinal twin study, Huppertz and colleagues (2016) found that (self-reported) engagement in exercise behaviors was significantly heritable over time. These authors demonstrated genetic effects increased from age 7 (14% for males; 12% for females) to age 18 (79% in males; 49% in females) and, although initially quite substantial, shared environmental influences decreased across development for both males (from 80% to 4%) and females (from 80% to 19%). Similarly, Schutte and colleagues (2020) provide evidence indicating substantial genetic influence for individual differences in objectively assessed movement behaviors (both sedentary behavior and physical activity). Using accelerometer data, this study found genetic factors accounted for 56% and 46% of the variance in sedentary behavior and physical activity, respectively (Shutte et al., 2020). However, interestingly, genetic factors accounted for 45% of the shared variance across sedentary behavior and physical activity. This indicates unique genetic effects may increase sedentary behavior and decrease physical activity (and vice-versa), which provides support for the assertion that sedentary behavior is not simply the inverse of physical activity (Panahi & Tremblay, 2018).

Etiological Differences. As Saudino and Cherny (2001) demonstrated, it is also possible for the influence of underlying genetic and environmental factors to vary over time. These etiological differences may occur as the result of various factors, such as age (e.g., developmental timing), method of assessment (i.e., subjective report versus objective measurement), and even situational/contextual differences. Regarding age of development, research emphasizes the salience of environmental influences early on but also indicates genetic factors become increasingly influential later in life. For example, consider the heritability of intelligence, which is about 41% in childhood (age 9) but steadily increases throughout the lifespan to upwards of 80% in late adulthood (Plomin et al., 2016). This research demonstrates how etiological differences may arise due to the age of measurement (i.e., environmental influences may wane, whereas genetic influences increase, throughout the lifespan).

Regarding methodological differences, other work has specifically investigated whether underlying genetic and environmental influences on childhood physical activity levels differ per the specific assessment method employed. These studies suggest the relative impact of genetic and environmental influences may uniquely differ depending on objective (actigraph, accelerometer) versus rater-based (parent, observer) measures of physical activity. For example, in a sample of 2-year-old twins, Saudino (2009) examined the underlying genetic etiology of varying measures of physical activity levels (actigraph, parent-reported temperament, and observer-rated) and found genetic associations were substantially shared across measurement techniques (r_g = .95 for actigraph and observer-rated), but also differed across physical activity conceptualization (e.g., r_g = .38 across objective actigraph and parent-reported temperament). Similarly, Fisher and colleagues (2010) found that shared environmental effects explained the majority (73%) of variance in objectively-measured physical activity (i.e., actigraph) whereas additive genetics accounted for 60% and 85% of differences in self-report and parent's report of children's preferences for physical activity, respectively. These findings provide evidence suggesting assessment methods and conceptualizations (e.g., parent-reported temperamental activity versus measured motor behavior) may etiologically differ in a way that is not interchangeable (Saudino, 2009).

Finally, research also suggests differing situational or contextual differences (e.g., at home or in the lab) may affect the underlying etiology of children's physical activity levels. For example, Saudino and Zapfe (2008) found varying results across three different situations (at home, during laboratory testing, and during a laboratory play situation) for the underlying genetic and environmental influence of objective assessments of 2-year-old physical activity levels. Across situations, similarity in physical activity levels was attributable entirely to genetics, whereas cross-situational differences arose as the result of both genetic (accounted for approximately 33% of variance) and environmental (shared and nonshared) influences (Saudino & Zapfe, 2008). Building upon this study, Frazier-Wood & Saudino (2017) partitioned the shared variance across lab-based and home-based assessments of physical activity levels to further investigate these cross-situational differences. Results demonstrated nearly half (43%) of the shared genetic variance was unique to lab-based physical activity levels and differed from home-based assessments (i.e., 57% of genetic influences were shared between each), which indicates engagement in physical activity engagement may vary based on different environmental situations (Frazier-Wood & Saudino, 2017). Overall, the collective work from studies by Saudino and others emphasizes the role of genes for continuity and environmental influences for change in physical activity levels, which is in line with findings from other labs and research groups (e.g., Fisher et al., 2010).

In sum, these studies provide support for the conceptual distinction made in the current project for those various dimensions of physical activity (i.e., temperament versus motor behavior). This research also underscores the need to further examine potential etiological differences that are the result of the varying methodologies used (e.g., parent-report versus observer-rated); it may be that heritability estimates vary depending on the report and/or the type of measurement employed. Hence, to thoroughly investigate children's physical activity, it is beneficial for the current study to employ a multimethodological approach and individually investigate these various methods. The utility of this approach for behavioral research is highlighted by a previous study that found, across varying methods (observational coding, as well as parent-/child-report), differences in outcomes related to preschoolers' aggression (Jamnik & DiLalla, 2018).

Taken together, the BG studies reviewed here illustrate the relatively limited research conducted on physical activity levels in children, especially preschool-age or younger (e.g., Fisher et al., 2015), and also emphasizes the benefit of a twin design for elucidating the underlying etiology of physical activity levels. Thus, using a BG methodology to further investigate the physical activity levels of preschool-aged twins is beneficial for better understanding how these behaviors emerge early in life. As Cliff and colleagues (2017) point out, we know the least about how physical activity in the early years (ages 0 to 5) affects health and development (also echoed by Schmutz et al., 2018). Although additional research is needed, these authors suggest promoting physical activity in young children may be one avenue to provide the best start for health in life (Cliff et al., 2017). Therefore, exploring salient outcomes that may be related to these behaviors (such as indices of health) was a beneficial endeavor to further clarify the influence movement has for overall physical and mental wellbeing across time (e.g., physical health: body-mass index; mental health: internalizing problems).

Childhood Health

With nearly 1 in 5 children now affected, childhood obesity poses a serious public health challenge (Sahoo et al., 2015). Obesity has both immediate consequences for health in childhood, as well as implications for health later in life (WHO, 2016). Over time, these negative health challenges become further exacerbated. An obese child at age 6 has a greater than 50% chance of remaining obese in adulthood, and 80% of children who are overweight between ages 10-15 will become obese by age 25 (Frieden et al., 2010). Put simply, childhood obesity places the individual at risk for a lifetime of health challenges (e.g., Kain et al., 2019). If we do not act now, the epidemic of childhood obesity will become increasingly difficult to address (Frieden et al., 2010).

However, approaches to undertake this challenge do exist. Research demonstrates obesity may be both preventable and treatable through healthy lifestyle modifications (Wadden et al., 2012). Continued investigation into predictors and outcomes related to obesity is necessary to help further elucidate possible mechanisms for prevention and intervention efforts. Studies focused on modifying lifestyle behaviors, such as decreasing unhealthy behaviors (e.g., sedentariness, poor diets) and encouraging engagement in healthy behaviors (e.g., physical activity, healthier diets), have shown great promise for improving health outcomes over time (Pate et al., 2013; Roychowdhury, 2019; Thompson & Eijsvogels, 2018). In this way, one modifiable option to promote healthy living and address this public health challenge may include encouraging movement.

Physical activity has positive implications for overall health across the lifespan (HHS, 2018b), and is one way to counteract negative health outcomes associated with living an unhealthy lifestyle (American Heart Association [AHA], 2014). Individuals who are not sufficiently active are at an elevated risk for physical and mental health problems, such as obesity, depression, and anxiety (Johns Hopkins Medicine, 2014). In general, current estimates indicate approximately 80% of adults do not accumulate sufficient levels of physical activity to meet guideline recommendations (Thompson & Eijsvogels, 2018). Worse yet, studies investigating physical activity levels in childhood suggest nearly 85% of preschoolers, 90% of 5- to 11-year-olds, and 95% of 12- to 17-year-olds fail to meet recommended guidelines (Colley et al., 2013). This is especially concerning, considering the World Health Organization states physical inactivity is the fourth leading cause of death worldwide (WHO, 2010).

On one hand, several literature reviews indicate measurements of physical activity are related to favorable health indicators (e.g., weight status, cardiometabolic markers) in children from ages 5 to 17 (Saunders et al., 2017), as well as those under age 5 (Carson et al., 2017). On the other hand, a different review concluded that very little evidence exists for the association between health outcomes (e.g., adiposity) and physical activity levels in children ages 2-5 (Kuzik et al., 2017). These null findings paralleled those discussed in a review conducted a decade earlier, which also suggested inconclusive evidence existed for the association of physical activity and health in 2- to 5-year-old children (Timmons et al., 2007). However, because very little research had been done at that time, these authors concluded the scientific evidence was weak and in need of additional investigation (Timmons, Proudfoot, et al., 2012). Together, these reviews highlight the mixed findings and relatively few studies conducted over the last decade examining physical activity levels in young children. Therefore, it is necessary to further examine physical activity in early childhood, like preschool-age, and outcomes related to these behaviors.

Motor Behavior and Health

Interestingly, Kuzik and colleagues (2017) did find that increased physical activity was related to greater motor development during early childhood (ages 2-5 years). Despite not supporting the association between physical activity and health found by other reviews (e.g., Carson et al., 2017; Saunders et al., 2017), these results are important to keep in mind. For one, intervention work involving fundamental motor ability training, including locomotor (e.g., run, hop), object control (e.g., throw, kick and strike), and stability (i.e., single-leg balance) skills, emphasize the importance of both physical activity and motor behavior for subsequent health outcomes. Furthermore, research indicates that greater motor skill proficiency is related to developmental improvements extending beyond mere bodily movements, such as changes in perceptual, cognitive, and social abilities (Adolph & Robinson, 2015). Thus, motor behavior not only affects physical health but is crucial for children's overall development (Adolph & Franchak, 2017).

This intervention work is summarized in two recent literature reviews, which highlight the necessity of motor behaviors for mitigating potential negative health issues (Bremer & Cairney, 2018; Tompsett et al., 2017). Across 29 studies, Tompsett and colleagues (2017) found motor skill training positively affected physiological (e.g., cardiovascular fitness, body composition), psychological (e.g., self-worth, attention/inhibition control), and behavioral (e.g., physical activity and sedentary behavior) outcomes in children ages 5 to 12 (27 studies) and 13 to 15 years old (two studies). This review also demonstrated that weight status was predicted by both motor abilities and physical activity levels (Tompsett et al., 2017). Similarly, the narrative review by Bremer and Cairney (2018) found movement (and movement-related skills) broadly influenced optimal development, including aspects of both physical (body composition) and mental (depression/anxiety) health. Focusing on studies using either an experimental or observational longitudinal design, this review examined the association between movement skills and various aspects of physical and mental health (physical activity and fitness, body composition, self-beliefs, executive functioning) in both children (ranging in age from 3 to 5 or 6 to 10 years old) and adolescents (ranging in age from 10 to 16 years old), as well as into young adulthood (age 16 to 26 years old). From this literature review, these authors concluded motor engagement (e.g., movement) at an early age may be a proactive (and modifiable) way to minimize future negative health consequences, such as obesity or depression (Bremer & Cairney, 2018). Together, across both literature reviews, the association between motor behavior, in general, and health is highlighted. However, importantly, do studies focused explicitly on young children, including preschoolers, find similar results that emphasize movement for optimal health?

Physical Activity and Health

As two recent book chapters exemplify, a robust literature supports the functional benefits of physical activity, via both behavioral and temperamental assessments, for health (Hampson & Vollrath, 2012; Strelau & Zawadzki, 2012). Overall, this literature indicates that increased physical activity promotes better physical health outcomes, such as cardiovascular risk factors (Roychowdhury, 2019) and decreased body-mass index (Carson et al., 2017; Saunders et al., 2017), as well as decreased mental health difficulties, such as anxiety and depression (Brown et al., 2013; Spruit et al., 2016). Physical activity has also been demonstrated to be an effective mechanism for mitigating the negative repercussions that stress poses for an individual's physical and mental health (Cohen et al., 1998; Holmes & Rahe, 1967; McEwen, 2000). (However, it is important to note that, although physical activity itself may be a stressor, this form of stress is most similar to 'eustress,' or positive stress, as opposed to 'distress,' or negative stress, which is the form most often implied when discussing general stress; Seyle, 1976). Several authors emphasize the importance of recognizing the importance of physical activity for preventing excess weight gain (Worobey, 2014) and for improving cognitive, emotional, and social development, especially in young children (Roychowdhury, 2019). Thus, taken together, the overwhelming evidence supports the role of physical activity for alleviating negative influences (e.g., stress) and promoting positive effects for overall health and wellbeing. Some even argue that physical activity may be one of the best indicators for overall physical and mental health (Strelau & Zawadzki, 2012).

Additionally, other research highlights the close relationship between behavioral and temperamental assessments of physical activity (e.g., Buss et al., 1977; Schmutz et al., 2017, 2018). However, it is not entirely apparent which approach may be best (Worobey, 2014). For example, objective measurements are preferable because they allow for the collection of quantifiable data but are often difficult to use and quite expensive to employ (Palou et al., 2019). Additionally, although temperamental activity is a useful and well-supported metric, it is not a quantifiable indicator of physical activity, per say. Finally, observational techniques are touted as the gold standard for behavioral assessment (Sirard & Pate, 2001), but often require extensive training for validity and reliability (e.g., Brown et al., 2006; McIver et al., 2009). Therefore, further investigation into the various methods used to assess physical activity is clearly warranted (Worobey, 2014). Regardless, irrespective of how physical activity is conceptualized or assessed (i.e., behaviorally or temperamentally), the association between physical activity and health is well-supported by the empirical literature.

Physical Activity: Observational/Objective and Temperamental

Seminal research on young children's physical activity levels is provided by Buss and colleagues (1977) who examined the relationship between individual temperamental differences and different methods of assessing physical activity levels, including objective and subjective measurements (actometer and teacher-report, respectively) during early childhood (i.e., at ages 3, 4, and 7 years old). Findings indicated actometer- and teacher-based ratings of physical activity levels at all three ages, both within-ages and across-ages, were all strongly correlated. This study also demonstrated that actometer measurements at ages 3 and 4 were predictive of 7-year-old temperamental activity characteristics, as well as a similar association between 7-year-old temperamental activity and concurrent physical activity (via actometer). Together, Buss and colleagues (1977) provided initial evidence for the validity of, and interrelations among, varying methods used to assess physical activity levels in young children and the strong relationship among these varying methods.

Since then, many other studies provide evidence in support of the close association between overt motor behavior and an individual's underlying tendency or predisposition (i.e., temperament) for physical activity (Strelau & Zawadzki, 2012). For example, in a series of studies, Schmutz and colleagues (2017, 2018) examined the relationship between temperamental activity and other objective measurements of movement behaviors (physical activity and sedentary behavior) in young children (ages 2 to 6 years). Using a 1-year longitudinal design, these authors were able to investigate salient factors that were related to preschoolers' physical activity and sedentary behaviors both concurrently (Study 1), as well as over time (Study 2).

At Time 1, Schmutz and colleagues (2017) found a positive relationship between the total amount of physical activity children engaged in (as measured by accelerometry) and children's temperamental activity, in addition to age and sex (older children and boys were most active). Interestingly, results indicated children's physical activity did not relate to BMI, parental health behaviors (physical activity and dietary), parenting stress, or household SES (Schmutz et al., 2017). One year later, at Time 2, Schmutz and colleagues (2018) found similar results suggesting a strong positive relationship between children's total physical activity and temperamental activity. Furthermore, for children's engagement in sedentary behavior, the strongest (negative) predictor was temperamental activity, which accounted for 20% of the differences in sedentariness (Schmutz et al., 2018). This provides additional evidence, albeit in the inverse direction, for the close relationship between temperament and physical activity engagement.

However, when temperament is examined using the three higher-order factors (surgency, effortful control, and negative emotionality), the relationship between temperamental and objective physical activity is less clear. Korczak and colleagues (2018) examined the longitudinal relationship between temperament and physical activity in very young children (from approximately 2 to 4 years old) and found that, although negative emotionality predicted future physical activity level (negatively for girls, positively for boys), surgency and effortful control did not (Korczak et al., 2018). These results are somewhat surprising, given that temperamental activity is a component of the larger surgency factor and, therefore, underscoring the importance of examining specific components of temperament (e.g., activity levels) and not just temperament more broadly (i.e., higher-order factors). As Korczak et al. (2018) discuss, it is important for future studies to use varying assessments and/or multiple informants when examining children's behavior. This is paralleled by Worobey (2014) who states the best way to monitor childhood physical activity is not yet clear. In line with these suggestions, the current study used both observer-ratings and parent-report to assess preschoolers' physical activity in two different ways (i.e., behaviorally and temperamentally, respectively).

Observed/Objective Physical Activity and Health

The positive influence of movement for health outcomes is supported by studies examining physical activity using observational or objective measurements (e.g., accelerometer or actigraph). For example, Moore and colleagues (2003) used motion sensor tracking and anthropometric body fat measures (i.e., body-mass index, five-skinfold thickness) to investigate the effect of physical activity on body fat change over 8 years from childhood (age 4) to early adolescence (age 11). Results indicated that children in the highest tertile (compared to the lowest and middle tertiles) for average daily physical activity consistently had the lowest increase in body fat (i.e., smaller gains in BMI and average five-skinfold thickness) and also had the latest adiposity rebound. Examining the adiposity rebound (i.e., the second rise in BMI that occurs during preschool-age) is particularly important because research indicates that an earlier age of rebound (i.e., before approximately 5 to 7 years old) is associated with an increased risk for later obesity and, therefore, Moore and colleagues (2003) discuss how these findings further highlights the protective effect of physical activity on body fat change.

More recently, additional support for the positive effect that physical activity has for preventing excess adiposity comes from a study of 7-year-old children conducted by Collings and colleagues (2017). Unlike Moore et al. (2003), these authors used both heart-rate monitors and wearable movement sensors to assess children's movement and, therefore, were able to quantify physical activity levels into low-intensity, moderate-intensity, and high-intensity.

Interestingly, regardless of the intensity of the movement, lower adiposity was associated with increased physical activity and, inversely, increased sedentary behavior was related to a higher fat mass index (Collings et al., 2017). These findings highlight an important point related to engagement in movement and sedentariness; that is, when accounting for physical activity level, engagement in increased sedentary behavior is still related to poorer health outcomes (Pate et al., 2013). Furthermore, the significant effect across physical activity intensities highlights another important point – movement, in any amount, is beneficial for health.

Finally, in a group of 3- to 5-year-old children, Palou and colleagues (2019) examined the efficacy of a single-item parent-report measure of physical activity compared to other objective measurements of physical fitness (e.g., hand grip, 20-meter sprint, long jump), as well as investigated the relationship between these measures of physical activity and children's body composition. Results indicated that parent-reported physical activity was positively associated with objective measures of physical fitness, which provided support for the utility of parent-report as a metric for studying physical activity in preschoolers (Palou et al., 2019). Furthermore, these measures of preschoolers' physical activity were negatively associated with body composition markers, including body-mass index, waist circumference, and waist-to-height ratio. Specifically, children rated by parents as very low in physical activity had the lowest physical fitness and highest body composition scores, whereas the children rated as very high in physical activity had the highest physical fitness and lowest body composition scores (Palou et al., 2019).

Temperamental Activity and Health.

Studies investigating physical activity from a temperamental perspective also demonstrate the positive influence that physical activity has for health. For example, Vollrath and colleagues (2018) examined the influence of early childhood temperament (ages 1.5, 3, and

5 years old) on the timing of children's adiposity rebound (i.e., steep BMI increase), Results demonstrated a significant association between young children's temperamental activity and adiposity rebound, albeit in the opposite direction than expected. Findings indicated that an earlier adiposity rebound (i.e., indicating obesity risk) was associated with greater temperamental activity at age 1.5 (18 months), but not at age 3 or 5. This stands in contrast with other research that has found an inverse relationship between physical activity and adiposity (e.g., Collings et al., 2017); however, as other authors suggest, very early childhood (i.e., infancy) may be too early to detect excess adiposity (e.g., Chaput et al., 2017).

As Vollrath and colleagues (2018) discuss, very young children do not have the same autonomy and control as older children to act upon the environment in a way that corresponds with their tendency for high physical activity. Compared to a preschooler, an 18-month-old has not yet fully developed the basic motor abilities (e.g., jumping and running). However, by age 3 to 5, children can locomote in a way more akin to their predisposition for high physical activity. In other words, at older ages, children have attained motor behaviors that translate into greater caloric output and, in turn, better weight regulation and a lowered risk for obesity. This is supported by the work of Anderson and colleagues (2004) who, in a sample of 8- to 12-year-old children, found that temperamental activity predicted increased non-resting energy expenditure (i.e., energy expended during physical activity) and decreased overall body fat. Importantly, this study measured body fat using a water displacement technique, which allowed for the weight of fat-free mass to be accounted for and, thus, provided an accurate measure of fat mass, specifically.

Similarly, several other studies have also found that temperamental activity significantly affects later weight status. For example, in a 3-year longitudinal study examining the temperamental activity of 6- to 15-year-old children, Ravaja and Keltikangas-Jarvinen (1995) found that greater physical activity was associated with a lower body-mass index over time. Similar results were found by Slining and colleagues (2009) who examined infants' (ages 3 to 18 months) temperamental activity and various anthropomorphic indicators (skin fold and weight-to-length *z*-scores). High temperamental activity at age 3 months was associated with decreased fatness (i.e., skin fold thickness) and lower weight-for-length scores when infants were 18 months old, which highlights the role of infant temperament as an important predictor of early weight status (Slining et al., 2009). Over a longer developmental period (4 to 11 years later), Song and colleagues (2017) found that temperamental activity at age 4.5 was a key predictor of overall energy expenditure at ages 9, 12, and 15 years. Specifically, results indicated that, compared to less active 4.5-year-olds, highly active children had higher rates of energy expenditure across late middle childhood and early adolescence (ages 9 to 15).

Physical Activity and Internalizing

Not only does increased physical activity coincide with better physical health, but movement has also been shown to positively affect mental health (Thompson & Eijvogels, 2018). This is supported by several different meta-analyses that demonstrate increased physical activity is related to better mental health outcomes (e.g., Ahn & Fedewa, 2011; Brown et al., 2013; Spruit et al., 2016) and that, inversely, a lack of physical activity (i.e., physical inactivity or sedentary behavior) is related to increased experiences of anxiety and depression (Biddle & Asare, 2011; Biddle et al., 2019). Considering that other research indicates early childhood internalizing can lead to continued internalizing over time (Wlodarczyk et al., 2017) and that internalizing (both at preschool-age and in adolescence) is associated with other health problems during adolescence (Jamnik & DiLalla, 2019), it is important to investigate potential mechanisms salient to mental health, such as physical activity. As Bremer and Cairney (2018) suggest, promoting physical activity in childhood may be one modifiable behavior for health intervention efforts to target.

Evidence supporting this endeavor is highlighted by a series of meta-analyses indicating that physical activity interventions in adolescence had a significant moderate effect (d = .32) on subsequent psychosocial outcomes, like decreased internalizing problems (Spruit et al., 2016). Reviewing physical activity intervention programs using randomized controlled trials, Brown and colleagues (2013) found a small, but significant, effect of physical activity on depressive symptoms in children and adolescents (Brown et al., 2013). However, more research is needed because very little is known about movement early in life, like preschool-age (Schmutz et al., 2018). Some authors even suggest that the evidence for the relationship between physical activity and mental health is not yet conclusive and needs additional, better controlled, studies (e.g., Hinkley et al., 2014). (Although it is important to note that Hinkley and colleagues (2014) did find evidence indicating that increased physical activity and decreased sedentariness had a benefit for psychosocial wellbeing, albeit small).

Recent studies from the latest body of work offer additional evidence demonstrating the positive effect that physical activity has for mental health. For example, in line with a previous review that demonstrated physical inactivity was related to poorer psychosocial outcomes (Biddle & Asare, 2011), Mannikko and colleagues (2020) found a strong association between increased internalizing problems and greater physical inactivity in 15- and 16-year-olds. Conducting an updated review of reviews, Biddle and colleagues (2019) found that, across 42 studies, greater physical activity and improved physical fitness were associated with, and (partially) casually related to, better mental health outcomes. Another review found similar results indicating a significant impact of physical activity for internalizing, but only found this effect during adolescence and not childhood (Rodriguez-Ayllon et al., 2019). Finally, another study found that adolescents' self-reported moderate-to-vigorous physical activity, but not objectively measured physical activity, negatively predicted concurrent anxiety and depression symptomology experienced at age 15 (Hrafnkelsdottir et al., 2018). These results highlight the importance of measuring physical activity using varying methods of assessment and, additionally, because most studies focus on older ages, the need to further study these relationships in early childhood.

Internalizing and Health

Like physical activity, a large body of evidence exists that emphasizes the relationship between internalizing behaviors and subsequent health outcomes, which underscores the alarming public health issue these problems pose (Patton et al., 2016; van Geelen & Hagquist, 2016). For example, Jamnik and DiLalla (2019) found that preschoolers' internalizing problems predicted greater body-mass index and increased physical health problems (e.g., somatic complaints, days spent ill) during adolescence. Furthermore, results also indicated adolescents' internalizing was negatively related to concurrent physical activity engagement (Jamnik & DiLalla, 2019). These findings provide support for both the association between physical activity and internalizing association, in addition to evidence for the relationship between internalizing and various measures of health. As Johnson (2017) suggests, it is crucial to acknowledge the close association between psychosocial difficulties (e.g., internalizing) and physical health, especially in children, because mounting scientific evidence indicates that emotional factors can, and do, contribute to impairing physical symptoms (and vice-versa). This is supported by work from van Eck van der Sujis and colleagues (2017) who demonstrated that mental (and physical) health functioning is predictive of the persistence of medically unexplained symptoms (i.e., bodily complaints with no known medical cause).

Given that research highlights the negative influence that internalizing symptoms in childhood pose for mental health later in life (e.g., Essex et al., 2009; Herrenkohl et al., 2010), it is particularly important to study the extent to which mental health problems affect later health and wellbeing. For example, Essex and colleagues (2009) found that 5-year-old internalizing problems were predictive of increased impairment (academic and social functioning) and greater physical health problems (e.g., days spent sick) when children were 10 to 11 years old. Building upon these findings, another study demonstrated that internalizing problems during middle childhood (ages 10 to 12) were significantly predictive of poorer physical and mental health outcomes in middle adulthood at ages 27 and 30 (Herrenkohl et al., 2010). However, limited research has focused on internalizing symptoms in young children, like preschoolers, and further investigation into these problems in early childhood is needed (Caserta et al., 2011).

Additional support for the detrimental effect that internalizing problems have for overall health outcomes is provided by research examining biological factors associated with mental health difficulties. For example, one study found that preschool-aged children who report greater depressive symptoms displayed significant differences in immunological functioning (e.g., increased cytokine response and rate of total illnesses), compared to children with lower scores for depression (Caserta et al., 2011). Relatedly, another study found that 8-year-old internalizing problems predicted upregulated inflammatory responses at age 10 (Slopen et al., 2013); however, support for the inverse relationship was not found (i.e., 10-year-old inflammatory responses did not predict age 12 internalizing). Moreover, other work demonstrates that greater internalizing problems are associated with both chronic illness in adolescence (Woods et al., 2012) and an increased risk for physical health symptoms, such as infectious diseases and respiratory illnesses (Aarons et al., 2008; Nelson et al., 2013). By highlighting the role of internalizing problems for immune functioning, overall, these studies emphasize the consequences that mental health difficulties present for overall health (both physical and mental), as well as provide support for other theories of stress and health (Cohen et al., 1998; McEwen, 2000).

Stress and Health

An overarching framework supporting the deleterious effects of stress on health outcomes is provided by two prominent theories of stress, including the chronic stress paradigm (Cohen et al., 1998) and the allostatic stress model (McEwen, 2000). Broadly, both theories support the hypothesis that chronic stress is a potential risk factor for poorer health, both physically and mentally. The chronic stress paradigm suggests that stressors weaken the immune system and, therefore, increase vulnerability to illnesses, which, in turn, causes greater susceptibility for developing health problems (Cohen et al., 1998). Alternatively, the allostatic stress model (McEwen, 2000) suggests chronic stressors cause ‘wear and tear on the body’ (i.e., allostatic load) that accumulates over time and, subsequently, is then related to the development of health problems.

Related to chronic stress, socioeconomic-related adversity poses one particularly insidious risk for overall health throughout the lifespan (Kim et al., 2017). Studies consistently indicate a significant association between socioeconomic status and health outcomes (Adler et al., 1994) and disparities across income do exist. For example, a behavioral genetic study by Johnson and Kruger (2005) found a significant gene-environment interaction for the income-health gradient, which indicated lower genetic effects for health in higher versus lower income households (i.e., high SES households had greater environmental influences on health). In other words, an individual who is genetically at-risk for health problems is at an even greater risk in a low SES household compared to a high SES household. In children, lower SES has been associated with increased body-mass index (Jang et al., 2019), poorer physical health ratings (Larkin & Otis, 2019), heightened mental health problems (Wlodarczyk et al., 2017), and greater risk for metabolic diseases (Razzoli & Bartolomucci, 2016).

Aside from SES, other salient stressors in childhood include more proximal influences, like parental and household characteristics. For example, Larkin and Otis (2019) found that higher levels of parenting stress predicted poorer physical health ratings when children were 15 months old; specifically, for every one-point increase in parenting stress, children had a 67% greater chance of receiving a poor health rating (in comparison to children with an excellent rating). Similarly, Jang and colleagues (2019) found that, across 27 studies, parents' general stress and parental-role stress both predicted increased risk for child obesity. Findings also indicated that household characteristics, such as family structure and stressful life events, predicted child obesity (Jang et al., 2019), which highlights the importance of investigating a multitude of potential environmental stressors. Regarding mental health, one study found that increased exposure to adverse life events between ages 1 to 9 predicted increased risk for internalizing problems at ages 9 to 12 (Flouri et al., 2019). Interestingly, results also indicated this relationship was partially mediated by an inflammatory marker (interleukin-6) at follow-up. In other words, findings indicated that early chronic stressors (partially) contributed to a greater inflammatory response at follow-up and, in turn, heightened concurrent internalizing (Flouri et al., 2019), which is in line with the two theories of stress mentioned above. Finally, Klemfuss and colleagues (2018) examined the influence of household chaos on physical and mental health outcomes in children ages 4.5 to 6 years old and found increased household chaos was related to greater internalizing, general health problems, and overnight hospitalizations (Klemfuss et al., 2018). These results were in line with previous research that found household chaos negatively related to children's health, even when accounting for socioeconomic status (Coley et al., 2015; Kamp Dush et al., 2013). Overall, these studies demonstrate that a variety of stressors, especially SES-related, are related to poorer health outcomes, both physically and mentally.

Conclusion

The current literature review makes evident several key takeaways regarding childhood physical activity (e.g., the longitudinal benefit early-life movement offers for the entire lifespan) and important directions for future research, including further investigating these behaviors in young children (e.g., preschool-age). As Schmutz and colleagues (2018) point out, very few studies have focused on physical activity levels in preschoolers (or younger) and, for those that have, mixed evidence for the health benefits of physical activity in early life have been found (e.g., Carson et al., 2017; Kuzik et al., 2017). However, across other ages (e.g., adolescence and adulthood), the benefits of physical activity for optimal health are well-supported (Thompson & Eijsvogels, 2018; Roychowdrury, 2019). As several authors suggest, these inconsistent results and inconclusive findings are likely explained by the limited research examining young children (Schmutz et al., 2017; Timmons, Proudfoot, et al., 2012). Furthermore, BG studies have also primarily focused on older children, adolescents, and adults when examining the genetic and environmental underpinnings of physical activity and little research has specifically examined the underlying etiology of physical activity in early childhood. This shortage of research is underscored by a recent literature review (Fisher et al., 2015), which identified only six twin studies investigating childhood physical activity (i.e., ages 2 to 13). Of those six studies, only three examined young children age 5 or below. To these ends, the current project helps fill this gap by having used a longitudinal and genetically informed design to investigate 5-year-old physical activity levels and various aspects of health (body-mass index, internalizing problems, household health behaviors) in middle childhood, in addition to examining the influence of psychological factors (internalizing problems) and salient environmental circumstances most proximal to young children (household chaos, socioeconomic status, life stressors). Examining the negative effect these other stressful experiences may have on health outcomes was important, given the pervasive threat chronic stress poses for physical and mental health throughout the lifespan (NIHM, 2019).

Most commonly, studies investigate engagement in physical activity by proxy. In other words, research often employs questionnaires to collect subjective accounts (reports, ratings) of these behaviors or uses objective measures, like a heart-rate monitor, to assess an aspect of physical activity (i.e., heart rate). Research indicates that these alternative methods provide comparable results to those collected via observational assessments (Hands et al., 2006; Howie et al., 2012; McIver et al., 2016; Saudino, 2009). However, often, these studies do not account for the influence of underlying individual differences for these behaviors, like temperament. Given the gold standard for behavioral assessment is direct observation (Palou et al., 2019; Sirard & Pate, 2001), this project placed specific emphasis on observationally assessing preschoolers' motor behavior (i.e., physical activity levels). However, the underlying role of biological predispositions (e.g., temperament) for physical activity in early life was also investigated. The current study provides an important and novel contribution to the literature by having developed an observational coding scheme to assess young children's motor behavior and examined individual differences in proclivities for these behaviors (i.e., temperament), in addition to having compared preschoolers' observed motor behavior to those parent-reported temperamental activity levels collected at age 5.

Present Study

The current project aimed to advance our understanding of childhood health by investigating preschoolers' physical activity levels and subsequent health outcomes that are theoretically related but have been previously understudied. Specifically, the present study had two main objectives. The first objective was the development and use of an observational coding scheme to assess 5-year-old motor behavior (i.e., physical activity levels). These observed ratings were used alongside parent-reported temperamental activity levels to assess both observable in-the-moment motor behaviors and, more generally, the basic tendency to engage in those behaviors (i.e., temperament). To better understand the development of these behaviors, a secondary aim of this project was to use a twin design and behavioral genetic approach to broadly examine the genetic and environmental influences underlying physical activity in early childhood. Further investigating the etiology of physical activity is important because 1) limited research has focused on preschoolers (Schmutz et al., 2018) and 2) although these behaviors are a fundamental component of biologically based temperament, which is fairly stable over time (Shiner et al., 2012), levels of physical activity engagement have drastically decreased in recent decades (Thompson & Eijvogels, 2018). The other main objective was to investigate the influence of preschoolers' physical activity and internalizing problems on subsequent physical and mental health outcomes reported later in middle childhood, as well as examine the (hypothesized) negative effect that stressful experiences were predicted to have on health outcomes. The present study provides greater insight into childhood health by having further examined relevant factors (physical activity, internalizing, stress) across development (i.e., from preschool-aged to middle childhood). By using a behavioral genetic approach, it also sheds light on the underlying contributors (i.e., genetic and environmental influences) of physical activity in 5-year-old children. With these objectives in mind, the current project investigated the following research questions and hypotheses.

Research Questions

The current study examined the influence of 5-year-old physical activity levels, via both behavioral (observation) and temperamental (parent-rated) assessments, and internalizing problems on subsequent measures of health (internalizing, body-mass index, household health behavior) during middle childhood. A measure of household health behavior was used, which captured the amount of health promoting behaviors the child engages in (or is exposed to), such as child physical activity behaviors, child eating habits, household mealtime routines, and parental health behavior (i.e., diet and exercise). The possible influence of proximal environmental stressors salient to children (household chaos, SES, stressful life events) on health outcomes in middle childhood was also examined.

First, as a way of assessing the efficacy of the coding scheme developed for this project, observed motor behavior ratings were compared to children's parent-reported temperamental activity levels (Research Question 1). It was proposed that, if these two measurements of physical activity were highly correlated ($r > 0.70$), then they would be combined into one larger 'physical activity' factor for subsequent analyses (Research Questions 2 and 3). If these factors were not highly correlated and could not be combined, it was proposed that analyses for Research Questions 2 and 3 would be run separately for observed motor behavior and temperamental activity levels. Next, a behavioral genetic approach (twin study) with biometric analyses was employed. This analytic plan was used to investigate the amount of variance in preschoolers' physical activity that is attributable to genetic and environmental factors (Research

Question 2). Finally, in regard to the overall purpose of this project, Research Question 3 investigated the impact of 5-year-old physical activity and internalizing problems, as well as the influence of environmental stressors, on health measures at follow-up (ages 7-13) by use of mixed multilevel modeling (MLM).

Research Question 1

Research Question 1 examined the validity of a newly developed observational coding scheme for children's physical activity levels by comparing observed motor behavior ratings to parent-reported temperamental activity levels collected at age 5.

Hypothesis 1. Age 5 observed motor behavior would be significantly positively correlated with 5-year-old parent-reported temperamental activity levels.

Research Question 2

The aim of Research Question 2 was to investigate the amount of variance in age 5 physical activity (observed motor behavior and temperamental activity levels) that is accounted for by underlying genetic and environmental factors.

Hypothesis 2. Both genetic and environmental influences would significantly contribute to preschoolers' observed motor behavior and temperamental activity, and environmental influences would account for a greater amount of variance in observed motor behavior and temperamental activity than genetic factors at age 5.

Research Question 3

Research Question 3 focused on the influence that 5-year-old physical activity (observed motor behavior and temperamental activity levels) and internalizing problems have on subsequent health outcomes in middle childhood. This research question was split into three parts to allow for three different dependent variables (i.e., health outcomes) to be examined: 3a) body-mass index, 3b) internalizing problems, and 3c) household health behaviors.

Furthermore, Research Question 3 also examined the impact that salient environmental stressors (i.e., household chaos, SES, and stressful life events) have on health outcomes at follow-up. If highly correlated ($r > 0.70$), it was proposed that these stressors would be combined. This would be beneficial in terms of power by increasing the odds of correctly rejecting the null hypothesis (i.e., lowering the chance of making a Type II error). However, if these variables were not highly correlated, each stress variable would be separately included in the analyses.

Hypothesis 3a. Body-mass index in middle childhood would increase as age 5 physical activity decreased, age 5 internalizing problems increased, and stressors increased.

Hypothesis 3b. Follow-up internalizing problems would increase as 5-year-old physical activity decreased, 5-year-old internalizing problems increased, and stressors increased.

Hypothesis 3c. Hypothesis 3c predicted that household health behaviors in middle childhood would decrease as age 5 physical activity decreased, age 5 internalizing problems increased, and stressors increased.

CHAPTER 3

METHODS

Participants

The current study included a twin and triplet sample who were originally recruited as part of the longitudinal Southern Illinois Twins/Triplets and Siblings Study (SITSS; DiLalla, 2002; DiLalla et al., 2013; DiLalla & Jamnik, 2019), which is an ongoing longitudinal investigation of social and cognitive development in young children using a behavioral genetic approach. Families who express interest in participating bring their children to the lab annually from age 1 to age 5. Families are recruited from a primarily rural population located within a 2-hour radius of Southern Illinois and the surrounding vicinity. To recruit twins and triplets, SITSS uses a variety of methods to contact potential families, including flyers posted around campus and at local businesses in Carbondale, IL, and surrounding cities, the SITSS Facebook page, referrals from participating families, and letters mailed to families of multiples who are listed in the birth announcement section of local newspapers. Since SITSS testing began in 1993, 388 families of multiples (375 twin pairs, 12 sets of triplets, and 1 set of quadruplets) have participated and a variety of follow-up projects (15 total) have been completed over the last 27 years. All data collection for the larger SITSS project has been approved by the SIU Carbondale Human Subjects Committee (HSC) or the SIU School of Medicine Institutional Review Board (IRB).

One recently completed follow-up project that was of specific interest to the current project, titled THAnx (the Twins, Health, and Anxiety study), examined health and anxiety in twin and triplet children during middle childhood (ages 7 to 13 years old). During Fall 2017 and Spring/Summer of 2018, the THAnx follow-up recruited families whose children were previously tested at age 5 (170 potential children) and brought them back to the laboratory for testing in middle childhood. At the completion of testing, 45 twin/triplet families (93 children; 34 boys and 59 girls) participated in the THAnx follow-up. I helped with that project by providing ideas and assistance during the study design phase, in addition to helping test families brought to the lab.

The current project augmented the THAnx subsample by recruiting additional families whose children were currently 7 to 13 years old, and were tested at age 5, but did not previously participate in THAnx (40 potential families). These potential families included those who did not participate in THAnx testing (*n* = 23), as well others who were not yet 7 years old at the time of THAnx (*n* = 17). In sum, the current project used archival data (ages 5 and 7-13) collected between the years of 2010 - 2016 (as part of SITSS) and 2017 - 2018 (as part of THAnx), as well as newly collected data from those additional families that were recruited for the present study.

The Current Sample

The current project employed two samples of participants for analyses, given the differing developmental timing across hypotheses. Because Hypotheses 1 and 2 focus on age 5 only, a complete age 5 sample was employed to investigate Research Questions 1 and 2. Because Research Question 3 features a longitudinal component (i.e., from age 5 to middle childhood), a subsample of that age 5 dataset that had follow-up data (collected as part of THAnx and/or the current follow-up) was used to test Hypothesis 3. Throughout this project, these two samples are respectively referred to as the Full Age 5 sample and the follow-up subsample, respectively.

Important to note, 2 children (from different families) were reported to have received an Autism Spectrum Disorder diagnosis since being tested at age 5. Therefore, because this study focused on a typically developing population, these children were removed from both samples. This provided a final sample of 302 children for the age 5 (with no follow-up) sample and 132 children for the follow-up subsample (i.e., age 5 with follow-up data). Tables 1 and 2 present the descriptive statistics for the Full Age 5 sample and the follow-up subsample. The Full Age 5 sample included 133 boys (44%) and 169 girls (56%), composed of 106 MZ (35.4%) and 196 DZ (64.6%) twins. Children in the follow-up subsample were tested at ages 7 to 13 (M = 9.31, SD = 1.98), included 51 boys (38.6%) and 81 girls (61.4%), and were comprised of 54 MZ (40.9%) and 78 DZ (59.1%) twins.

Sample Comparisons. After data collection was completed, each of the follow-up subsamples (THAnx follow-up and the current follow-up) were examined to determine if any meaningful differences existed across observed motor behavior, temperamental activity, internalizing problems, and household chaos at age 5, as well as body-mass index and stressful life events at follow-up (because these may have been impacted by the COVID-19 pandemic). Each sample was also compared for socioeconomic status at both age 5 and follow-up. Two distinct subsamples with independent participants were created by randomly selecting one child from each family for either subsample (Random Subsample 1, Random Subsample 2). Two MANOVAs were conducted to compare the two subsamples. No significant sample differences were found (see Table 3) – Random Subsample 1: $F(8, 48) = 0.55$, $p = .815$, Wilks' $\lambda = 0.92$, partial eta^2 = 0.08; Random Subsample 2: $F(8, 50) = 0.51$, $p = .846$, Wilks' $\lambda = 0.93$, partial eta^2 = 0.08. This provided support for combining the THAnx and current follow-up into one subsample (n = 132).

Considering that families who participated in follow-up were compensated, it was also necessary to determine whether families who participated in either follow-up (THAnx or the current project) significantly differed in socioeconomic status at age 5 from families who did not participate, given this may have influenced whether they participated. Similarly, it was also important to examine whether families who participated at follow-up significantly differed in age 5 household chaos compared to families who did not participate (because, intuitively, we might imagine that more chaotic households would be less likely to participate in research). Again, for each follow-up period (THAnx and the current follow-up), two MANOVAs were run, one for each random subsample. No significant differences were found for either variable at either follow-up period. Families who participated in the THAnx follow-up did not significantly differ from families who did not participate – Random Subsample 1: $F(2, 71) = 0.71$, $p = .497$, Wilks' $\lambda = 0.98$, partial $eta^2 = 0.02$; Random Subsample 2: $F(2, 73) = 1.01$, $p = .370$, Wilks' $\lambda = 0.97$, partial $eta^2 = 0.03$. Similarly, families who participated in the current follow-up did not significantly differ from families who did not participate – Random Subsample 1: $F(2, 32) = 0.45$, $p = .644$, Wilks' $\lambda = 0.97$, partial $eta^2 = 0.03$; Random Subsample 2: $F(2, 33) = 0.35$, $p = .708$, Wilks' $\lambda = 0.98$, partial $eta^2 = 0.02$.

Next, it was necessary to determine if any meaningful differences existed in the 5-year-old data (observed motor behavior, temperamental activity levels, internalizing problems, socioeconomic status, and household chaos) between children who did have follow-up data (n = 132 children) and children who did not participate in follow-up testing (n = 170 children), in order to justify using the Full Age 5 sample for hypotheses 1 and 2. Again, using the two random child subsamples, two MANOVAs were run to compare the children who participated to those who did not participate, separately for each subsample, across the 5-year-old independent variables (observed motor behavior, parent-reported temperamental activity, internalizing problems). Results indicated that the two samples did not significantly differ from one another for either random subsample (see Table 4) - Random Subsample 1: $F(5, 120) = 0.70$, $p = 0.622$, Wilks' $\lambda = 0.97$, partial $eta^2 = 0.03$; Random Subsample 2: $F(5, 123) = 0.63$, $p = 0.680$, Wilks' λ

= 0.98, partial eta^2 = 0.03. This provided support for using the Full Age 5 sample (*n* = 302), rather than conducting the age 5 analyses (Hypotheses 1 and 2) with only children who participated in follow-up (*n* = 132), which would be a smaller sample.

Finally, important for Hypothesis 3, a MANOVA was run to determine if boys and girls significantly differ in physical activity or internalizing. Results indicated a significant difference at the multivariate level for both random child subsamples - Random Subsample 1: $F(3, 139) = 4.49$, $p = .005$, Wilks' $\lambda = 0.91$, partial eta^2 = 0.09; Random Subsample 2: $F(3, 138) = 5.63$, $p = .001$, Wilks' $\lambda = 0.89$, partial eta^2 = 0.11. Univariate analyses indicated that boys were rated as higher in temperamental activity than girls (see Table 11) - Random Subsample 1 (boys: *M* = 4.05, *SD* = 0.68; girls: *M* = 3.60, *SD* = 0.59); Random Subsample 2 (boys: *M* = 4.01, *SD* = 0.72; girls: *M* = 3.57, *SD* = 0.69). Therefore, an interaction term between temperamental activity and child sex (BSQxSex) was included in the analyses for Hypothesis 3. To avoid multicollinearity in these analyses, variables were first mean-centered before running the planned MLM analyses (Aiken et al., 1991). Centering was also beneficial because it allowed for the interpretation of unique estimates across the predictors that were independent of each other (Field, 2013).

Missing Data. For a variety of reasons, complete data for all variables of interest were not available for all children in each sample. If data were missing, the individual cases with missing data were not included in the respective analyses. Tables 1 and 2 provide descriptive statistics for the measures of interest for each sample. For the Full Age 5 sample, all children had data on child sex and zygosity; however, two children were missing observed motor behavior (because the family refused to have the parent-child interaction filmed), eight children did not have temperament questionnaire data, and six children were missing data on internalizing problems. Of those children with missing data at age 5, the two children who were missing observed motor behavior data and two (of the eight) children who were missing temperament data took part in follow-up testing (i.e., had follow-up data) and, therefore were included in the follow-up subsample. Thus, taken together, analyses for Hypotheses 1 and 2 were conducted without including the missing parent-child interaction and temperament data (i.e., two and eight children, respectively).

For the follow-up subsample, all children had complete data for child sex, zygosity, age 5 internalizing problems, and age 5 household chaos. For one family, the parent provided responses for only one twin (and not the other), which explains one of the missing cases for body-mass index, follow-up internalizing problems, and household health behaviors. This same family (in addition to one other) did not complete the questionnaire assessing stressful life events; therefore, four children were missing those data. Additionally, four children were missing body-mass index data because the child's height was not reported and, subsequently, body-mass index could not be calculated for those children. In sum, excluding the children with missing data, Hypotheses 3a, 3b, and 3c had a final sample of 127, 130, and 131 children, respectively.

Power Analysis

To determine the appropriate sample size necessary to detect significant effects, several considerations were made for each hypothesis. For Hypothesis 1, correlational analyses were used to investigate the relationship between observed motor behavior and temperamental activity. Using G*Power, a power analysis was conducted to investigate the sample necessary for small, medium, and large effect sizes (Faul et al., 2009). For a small effect size ($r = 0.10$), 1,077 participants were needed; for a medium effect size ($r = 0.30$), 98 participants were needed; for a large effect size ($r = 0.50$), 38 participants were needed. Given that the two measures of physical activity were intended to measure the same overarching construct (i.e., physical activity), albeit in differing ways (temperamental activity versus observed motor behavior), Hypothesis 1 predicted a strong association between these variables and, thus, the estimates for medium and large effect sizes (98 and 38 participants, respectively) were used to inform the current project. These criteria were met by the 302 children in the Full Age 5 sample, even after one child from each family was selected for each random subsample.

The proposed path analysis for Hypothesis 2 (i.e., ACE/ADE modeling for physical activity) was investigated with analyses that use structural equation modeling (SEM). Regarding power, large sample sizes are typically desired for SEM analyses. However, sample size adequacy is a complex topic and recommendations vary considerably (Kline, 2016; Mueller & Hancock, 2019). For Hypothesis 2, it is recommended that a simple ACE/ADE univariate model using a twin design employ a sample of approximately 200 participants (i.e., 100 MZ and 100 DZ twins) to detect genetic effects ranging from .20 to .50, which is typical for most behaviors (Schmitz et al., 1998) and close to the range of those heritability estimates found for physical activity (i.e., 35 to 68%; Hoad et al., 2013; Horimoto et al., 2011; Gielen et al., 2014; Missiziti et al., 2013).

Finally, for Hypothesis 3, the analytic approach selected (mixed multilevel modeling; MLM) is beneficial, in terms of power, because it allowed for the entire sample of children (twins/triplets) to be examined (i.e., rather than selecting one child per family to avoid violating the basic assumption of independence of sample). In other words, using MLM is favorable in a family study because this approach accounts for siblings within families being included in analyses (i.e., a hierarchical dataset) and examines whether effects within families vary differently across families. This approach allowed for the entire sample to be included in those regression analyses for Hypothesis 3 (i.e., instead of only one child per family). A power analysis was conducted using the software Optimal Design (Raudenbush et al., 2011; Spybrook et al., 2011), to determine the necessary sample size to detect significant effects, with 80% power, for Hypothesis 3. Similar to G*Power (Faul et al., 2009), this program allows users to enter in various parameters (e.g., α, effect size, sample size) and, based on a series of formulas (e.g., *t*-tests to calculate standard error), presents the user with a graphical representation of a power curve depicting the parameters of interest, such as the sample size necessary to achieve the desired level of power (Scherbaum & Ferreter, 2009). Because little research has investigated the influence of preschoolers' physical activity levels and internalizing problems on later health outcomes, and exact effect sizes were not apparent after reviewing the literature, estimates for small, medium, and large effects sizes were examined, per the recommendations provided by Cohen (1988). In the MLM analyses for Hypothesis 3, the main effects of the age 5 factors (physical activity, internalizing) and stressors on each individual follow-up health outcome (body-mass, index, internalizing, and household health behaviors) were examined. If the effect size were small (δ = 0.20), 787 participants were needed; if the effect size were medium (δ = 0.50), 129 participants were needed; if the effect size were large (δ = 0.80), 52 participants were needed. The follow-up subsample (*n* = 132) met these criteria for medium and large effects.

Measures - Time 1 (Age 5)

Physical Activity

Preschoolers' physical activity was assessed using two different approaches, observation and parent-report, to examine both the motor behavioral component of physical activity (i.e., the overt action) and the underlying predisposition to engage in those behaviors (i.e., temperament). Observational behavioral coding provided a rating of the amount of motor behavior displayed by children in the lab during 5-year-old testing, whereas parent-reported temperament ratings were used to assess the child's basic tendency for engaging in physical activity.

Observed Behavioral Coding: Motor Behavior – Parent-Child Interaction (PC-INT). The parent-child interaction (PC-INT) task is a 10-minute structured play task that is completed at the end of a testing session after children have been individually tested. By this time, families have typically been in the lab for at least half an hour (often more) and have become comfortable with the surroundings. This comfortability is important to ensure that children (and the parent) behave during the task in ways that are relatively natural and normal for them. For this task, the parent and children were brought into an empty playroom and presented with two age-appropriate puzzles to work on. Parents were instructed to help the children complete the puzzles however they would like. These interactions were recorded through a one-way mirror and were coded by a trained research assistant at a later time. For the current study, these 10-minute PC-INT task video recordings were coded for the motor behavior (i.e., physical activity) displayed by each child using a measure that I created for this project.

Observational Coding Scheme. To provide a systematic approach for measuring the amount of physical activity displayed by children during the PC-INT task (described above), an innovative observational coding scheme was designed to investigate preschoolers' motor behavior. The development of this coding scheme was in part based off the previously developed Observational System for Recording Activity in Children (OSRAC), which is an observational technique for assessing physical activity in children (Brown et al., 2006; Larsen et al., 2011; McIver et al., 2009). However, to use the OSRAC, extensive training is required. Therefore, using this validated measure as an example, I designed a new coding scheme for the current study to assess motor behavior observed in the lab.

This coding measure (see Appendix A) was conceptualized to rate three underlying dimensions of movement (magnitude, intensity, and variability) and provides an individual score for each. Using the PC-INT task, children's motor behavior was coded in 30-second intervals throughout the 10-minute video recording (20 total intervals). A 5-point, Likert-type scale was used to code both the magnitude and intensity dimensions, whereas the variability dimension included a summative score (across 3 postures, 1 posture-related behavior, and 12 motor behaviors, which were rated dichotomously) that captured the variability in the number of different motor behaviors engaged in. Ratings were averaged across those 20 intervals to create a single score for each of the three dimensions (magnitude, intensity, and variability). For magnitude and intensity, these single scores range from 0 to 4. For variability, depending on the number of different behaviors displayed, scores can range from 1 to 16. The following paragraph describes these dimensions (and how they were coded) in greater detail. The coding sheet is provided in Appendix B.

For each 30-sec interval, to assess magnitude, the amount of spatial movement (i.e., the overall distance traveled) displayed by the child was rated on a 5-point scale ranging from 0 (*no torso movement across space*) to 4 (*greater than 15 feet traveled*). A miniature 3-dimensional replica model of the testing room was built (see Appendix C) to assist coders in conceptualizing spatial dimensions and aid in the rating of total distance traveled. The testing room also has posters on each wall, which serve as visual markers in the room and help to orient coders. To measure intensity, the overall physical activity rating of the child was also scored on a 5-point scale consisting of 0 (*motionless/stationary*), 1 (*stationary with movement of limbs/trunk*), 2 (*slow/easy movement, which may involve translocation*), 3 (*moderate movement involving translocation*), and 4 (*fast movement involving translocation)*. Finally, to capture variability, the total number of unique motor behaviors displayed by the child were recorded. These behaviors included 3 main posture types (sit/squat, lie down, and stand) and 1 posture-related behavior (shift position), as well as 12 motor behaviors that the child might engage in, including: crawl, dance, jump/skip, kick/hit, pick/place, pull/push, rough/tumble play, roll, run, spin, stretch, and walk. A specific focus was given to these motor behaviors either because 1) other coding schemes, like the OSRAC (Brown et al., 2006; Larsen et al., 2011; McIver et al., 2009), focused on similar behaviors and/or 2) they encompassed various gross and fine motor behaviors that children were predicted to engage in when completing a task involving puzzles in an empty room (e.g., pick/place, stretch). Throughout each 30-sec interval, engagement in each of these 16 various motor behaviors was scored dichotomously (i.e., did the behavior occur or not?). These dichotomous scores were then tallied to provide a value for the total number of unique motor behaviors displayed (i.e., variability).

This coding provided both microanalytic ratings for each individual behavior (i.e., the 3 main positions and 13 behaviors) and macroanalytic ratings across the three higher-order conceptual dimensions (magnitude, intensity, and variability). Principal components analysis was used to determine whether these items loaded onto distinct factors (see the Factor Analysis: Principal Components Analysis subsection below). The validity of this coding scheme was assessed by correlating observed motor behavior with temperamental activity, as reported by the parents. As mentioned, this was the focus of Research Question 1 and is presented in the Results section. The complete coding scheme, which is presented in Appendix A, provides additional details for each individual item and the three underlying conceptual dimensions. These three conceptual dimensions were used for training and development (i.e., reliability), which is described next.

Training and Development. The motor behavior coding for the current project was completed by trained coders who watched the video recordings of the PC-INT. Two undergraduate research assistants and I coded the preschoolers' overt motor behavior. I coded approximately one-third of the 5-year-old children in the current sample (31.5%) and trained research assistants coded the remaining two-thirds. The development of keys for training occurred over a 10-week period in the Spring 2020 semester, with the first 3 weeks serving as an initial exposure phase and the next 7 weeks serving as the development and training phase. Reliability across these 10 weeks was checked to ensure adequate inter-rater reliability of at least .70 was achieved and maintained throughout (see below for more details). To avoid any confound of rater bias, only one child per family was coded by each rater at random and in a random order (i.e., twin 1 was not coded by the same rater every time, nor was the order of coding always twin 1 then twin 2, or vice-versa).

Before beginning training, to familiarize research assistants with the coding scheme, an initial 6 children (3 sets of twins) were assigned to be coded over three weeks (1 set per week). I coded these tapes beforehand and my ratings served as keys to compare the ratings of the research assistants and ensure acceptable inter-rater reliability. Note that, during this time, the coding scheme was being revamped and finalized, which might have resulted in slightly lower reliability estimates. Our collective ratings had to achieve a reliability of .70 or above on each of the three dimensions – magnitude (spatial movement), intensity (activity rating), and variability (number of motor behaviors engaged in). The criteria used for inter-rater reliability followed recommendations from Cohen (1968) and was calculated using intra-class correlation coefficients. Although an attempt was made to reach 80% or better inter-rater reliability, this type of reliability calculation is rigorous and, thus, 70% reliability is considered acceptable and adequate (Fleiss et al., 2003). These values were intended to provide initial evidence in support of the potential reliability (and, in turn, efficacy) of the newly developed coding scheme. Once the research assistants completed assigned coding, they met with me to discuss this coding and clarify any discrepancies between us. During this initial three weeks, adequate inter-rater reliability across all three dimensions was achieved: .79 (spatial movement), .81 (activity rating), and .90 (variability: motor behavior). This concluded the exposure phase and marked the beginning of the training and key development phase. Over the next 7 weeks, the two research assistants and I coded an additional 14 children (7 sets of twins) and met weekly to discuss our ratings, resolve any discrepancies, and develop the final keys. At the conclusion of training and key development, acceptable inter-rater reliability was maintained: .70 (spatial movement), .72 (activity rating), and .76 (variability: motor behavior). This concluded the 10-week period of exposure, training, and development.

Once trained undergraduates reached acceptable reliability, they began coding on their own. Due to a 4-week break between spring and summer semesters, it was necessary to double-check reliability before coding resumed. The original 6 tapes assigned during the initial 3-week exposure phase (now almost 12 weeks later) were revisited and coded for reliability. Once again, inter-rater reliability was not only maintained, but excellent, across all three dimensions for the undergraduate coder and me (.95 for spatial movement, .98 for activity rating, and .97 for variability: motor behavior). Similarly, our test-retest reliability scores were excellent (.93 - .95, .92 - .93, and .96 - .97). A second undergraduate coder was trained during the beginning of the fall semester, and after an 8-week training period (i.e., an initial 'exposure' week, in addition to the same 7-week training that other trained coders received), her test-retest reliability scores were not only adequate, but excellent (.91, .93, and .93). At the conclusion of coding, reliabilities across and within coders were checked one final time. Test-retest reliability scores were favorable for both the first undergraduate coder (.99, .99, and .95) and second undergraduate coder (.90, .95, and .94), as well as the inter-rater reliability across raters (.89, .98, and .88). Table 5 presents the reliability scores (both inter-rater and test-retest) from training, as well as the reliability scores at the outset of coding.

Factor Analysis: Principal Components Analysis. Using the Full Age 5 sample (n = 302), a final sample size of 149 children in each random subsample provided a ratio of close to 10 cases per variable. Next, to prepare for factor analysis, data were first screened for univariate outliers; no out-of-range values were identified. Finally, because factor analysis makes use of item variance, the variance of each individual item was examined. The following items were sufficiently variable: spatial movement, activity rating, the three postural behaviors (sit/squat, lie down, and stand), the posture-related behavior (shift), and one of the dichotomous (yes/no) motor behaviors (pick/place). Very little variability ($s^2 \leq .01$) was seen in the remaining dichotomous items, including crawl, dance, jump/skip, kick/hit, push/pull, rough and tumble, roll, run, spin, stretch, and walk. Therefore, the 12 dichotomous items were summed to create a total score for the number of motor behaviors engaged in. This decision was conceptually in line with one of the constructs initially proposed in this project (i.e., variability: motor behavior) and was statistically favorable, given this method provided an item with sufficient variability (s^2 = .05). In sum, the final items used in the factor analysis included spatial movement, activity rating, the four posture-related behaviors (sit/squat, lie down, stand, and shift), and variability: motor behavior. Because some the items varied in the scale of measurement, these final items were z-scored to standardize measurement across items. The standardized z-scores were then subsequently used for the factor analysis.

Principal components analyses were employed, given the primary purpose of these analyses was to identify and compute composite scores for the factors underlying observed motor behavior. An oblimin rotation was applied, rather than a varimax rotation, because the factors of interest were expected to be at least partially correlated (i.e., all items assess motor behavior, albeit varying aspects of these behaviors).

The factorability of the seven items for observed motor behavior was examined using several different criteria. The Kaiser-Meyer-Olkin measure of sampling adequacy was .73 (Random Subsample 1) and .67 (Random Subsample 2), which exceeded the recommend criteria of .60, and indicated that an adequate sample was used. Similarly, Bartlett's test of sphericity was significant for Random Subsample 1, χ^2 (21) = 900.85, p < .001, and for Random Subsample 2, χ^2 (21) = 754.61, p < .001, indicating that the variables displayed adequate covariance for analyses. Finally, the communalities for all items were above the recommend criteria of .30 (see Table 6), which suggests that each item shares some common variance with other items. Taken together, these criteria indicate that factor analysis is suitable with the final seven items.

In the first subsample, initial eigenvalues indicated a two-factor solution that accounted for 51.73% and 24.38% of the variance, respectively. A third factor with an eigenvalue of just under 1 (0.99) was also found. This third factor had a strong primary loading (> .98) and a weak loading on the other two factors (< .03), as well as accounted for an additional 14.25% of the variance. (When included in the two-factor solution, this item had a weak loading, .16 and .32, on each of the two factors). Therefore, it was preferable to retain the three-factor solution, which explained 90.35% of the total variance, because of: 1) adherence to eigenvalue conventions (i.e., the scree plot 'leveling off' after the third factor) and 2) the third factor failing to meet the primary loading criteria of .40 (or above) in the two-factor solution. The decision to retain the three-factor solution was also supported by reliability analyses for Factor 1; this factor displayed more favorable reliability in the three-factor solution (α = .90), in comparison to the two-factor solution (α = .83). Similar results were replicated using the second subsample, which provided additional evidence of the robustness of these analyses. The factor loading matrix for the final three-factor solution in both subsamples is presented in Table 6.

Factor labels were created according to the individual items that loaded onto each factor: Factor 1 was named Motor Behavior because it consisted of 4 items (spatial movement, activity rating, stand, and variability: motor behavior) that captured a general propensity for engagement in motor behavior; Factor 2 was named Sedentary Behavior because it was made up of 2 items (sit/squat and lie down) that were mainly non-locomotive; Factor 3 was named Postural Shift because it was comprised of the posture-related item, Shift (Position), which conceptually did not fit well with the other two factors. A composite score for each of the three factors was created based on the mean of the items for each factor. Higher scores indicated greater engagement in that form of motor behavior. Descriptive statistics for each sample are presented in Table 7. Overall, these analyses indicated that three distinct factors (Motor Behavior, Sedentary Behavior, and Postural Shift) underlie the motor behaviors observed during the age 5 parent-child interaction task.

Temperamental Activity Levels - Behavioral Style Questionnaire (BSQ). To assess child temperament, parents completed the Behavioral Style Questionnaire (BSQ; McDevitt & Carey, 1978; 1996) when children were tested at age 5 years. The BSQ is a 100-item questionnaire designed for children ages 3 to 7 years, which provides scores across nine general temperament categories. These categories correspond with the nine dimensions of temperament identified by Thomas and Chess (1977), including Activity Level, Rhythmicity, Adaptability, Approach/Withdrawal, Threshold, Intensity, Mood, Distractibility, and Persistence. Items are rated on a 6-point scale ranging from 1 (*almost never*) to 6 (*almost always*) and a single score is calculated for each dimension by averaging scores across 12 items. The current study used the Activity Level dimension, which is defined as the “level, tempo, and frequency with which a motor component is present in a child’s functioning” and includes items such as, “The child runs ahead when walking with the parent,” “The child enjoys games that involve running and jumping,” “The child sits quietly while waiting” (reverse-scored), and “The child speaks so quickly that it is sometimes difficult to understand him/her” (McDevitt & Carey, 1996). Psychometric evaluations of the BSQ provide support for its validity and reliability in assessing temperament in typically developing children (McDevitt & Carey, 1978). Regarding construct validity, the BSQ has been found to provide profile clusters (i.e., easy, slow-to-warm, and difficult) with about the same frequency as those reported in seminal temperament research (Thomas et al. 1963, 1968) and, regarding external validity, the BSQ significantly correlates with other measures of temperament (in infancy), assessed 2.5 to 6.5 years earlier (McDevitt & Carey, 1978). For the Activity Level dimension specifically, adequate internal consistency (Cronbach’s α = .76) and high test-retest reliability (r = .93) have been demonstrated (McDevitt & Carey, 1996). The Activity Level dimension demonstrates adequate internal consistency in both the overall SITSS sample (Cronbach’s α = .77) and the already-collected THAnx sample (Cronbach’s α = .80), as well as the augmented follow-up sample collected for this project (Cronbach’s α = .75).

Confusion, Hubbub, And Order Scale (CHAOS)

The Confusion, Hubbub, and Order Scale (CHAOS) is a standardized parent-report measure that will be used to assess the level of household chaos/confusion within the home

(Matheny et al., 1995). The CHAOS is a 15-item questionnaire that describes a range of potentially stressful experiences that occur in the household and may detrimentally affect the child. Using a scale ranging from 1 (*very much like your home*) to 4 (*not at all like your home*), parents are instructed to rate the level of chaos/confusion in the household. Example items include, "No matter how hard we try, we always seem to be running late," "You can't hear yourself think in our home," and "There is often a fuss going on at our home". Matheny and colleagues (1995) have demonstrated adequate internal consistency (Cronbach's α = .79), moderate test-retest reliability (r = .74), and relative stability in scores over a 12-month interval. Similarly, the CHAOS displays adequate internal consistency (Cronbach's α = .85) in the overall SITSS sample, the already-collected THAnx sample (Cronbach's α = .87), and the augmented follow-up sample collected for this project (Cronbach's α = .78). This project includes household chaos as an estimate of stress experienced at age 5.

Child Behavior Checklist (CBCL)

Parents complete the standardized Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2001) when children are 5 years old to provide ratings of their child's behavioral and emotional problems. The CBCL is a validated and normed questionnaire designed for use in school-age children (i.e., ages 6 to 18). Previously, the SITSS study used an earlier version of the CBCL designed for children ages 4 to 18 years old (Achenbach & Edelbrock, 1991). Since then, the CBCL now has two versions that are called: the preschool-form (ages 1.5 to 5) and the school-aged form (ages 6 to 18). However, per recommendations from the scale developer, the new school-aged form best matches the version used previously in the SITSS study (Achenbach & Rescorla, 2001). Thus, this new form was used with the current sample of preschoolers (as well as in follow-up, see below) because it is most like the original (4- to 18-year-old) form used.

Across 113 items, parents are asked to rate their child over the past 6 months using a 3-point scale (0 = *never true*, 1 = *sometimes true*, 2 = *very/often true*). These items measure eight distinct subscales, including withdrawal problems, somatic complaints, anxious/depressed, social problems, thought problems, attention problems, delinquent behavior, and aggressive behavior. Additionally, from these various subscales, two higher-order factors (internalizing and externalizing problems) also exist. The current project was specifically interested in internalizing problems, which includes the anxious/depressed, withdrawn, and somatic complaints subscales.

The psychometric properties of the internalizing scale demonstrate excellent internal consistency (Cronbach's $\alpha = .90$) and high test-retest reliability, $r = .91$ (Achenbach & Rescorla, 2001). Furthermore, strong construct validity has been indicated by the CBCL's comparable results to other similar measures in predicting long-term outcomes. These psychometric findings were specifically found in a 7- to 9-year-old sample, although similar results have also been found across the age range (6 to 18 years) that this measure assesses. For the SITSS sample, the internalizing scale has been shown to have adequate internal consistency (Cronbach's $\alpha = .78$). Furthermore, specific sex-normed scores (i.e., standardized T-scores) have also been suggested for boys and girls but are specifically recommended when studying these behaviors in a clinical population. Therefore, the current project used raw scores because a non-clinical (typically developed) population was examined (Achenbach & Rescorla, 2001). It is worth mentioning, a previous project found no sex differences in internalizing for the SITSS sample (Jamnik, 2018).

A post-hoc decision was made to also include a composite score comprised of 8 items from the CBCL that capture 'attentional-deficit hyperactivity disorder' (ADHD) symptoms, which may be important to consider in relation to young children's physical activity (observed motor behavior and temperamental activity). These items include questions such as "fails to finish things he/she starts," "can't sit still, restless, or hyperactive," and "talks too much." To provide a non-clinical measurement of ADHD symptoms, raw scores are used when assessing a typically developing population. Descriptive statistics for the Full Age 5 sample and for the follow-up subsample are provided in Tables 1 and 2, respectively.

When assessing clinically relevant symptoms, it is recommended that standardized T-scores be used; according to Achenbach and Rescorla (2001), T-scores greater than 70 indicate clinically significant problems. In the Full Age 5 sample, 17 (out of 296) children had a T-score at age 5 that exceeded 70 which suggests those 17 children meet the criteria for clinical ADHD symptoms. Of those 17 children with high ADHD symptoms scores at age 5, only 7 children were included in the follow-up subsample (i.e., because they took part in follow-up testing). In the follow-up subsample, 10 (out of 130) children had a T-score in middle childhood that exceeded 70 and, therefore, met criteria for clinical-level ADHD symptoms at follow-up (i.e., ages 7 to 13). Of these 10 children, only 3 children had clinical-level ADHD symptoms at age 5; this indicated that 4 children had ADHD symptoms that decreased from clinical-level at age 5 to normal range at follow-up, whereas 7 children had normal-level symptoms at age 5 but met clinical-level criteria in middle childhood.

After initial analyses were completed, all were reconducted, post-hoc, with the 17 children with clinical-level ADHD symptoms at age 5 removed from the Full Age 5 sample (and follow-up subsample) and the 10 children with follow-up clinical-level ADHD symptoms removed from the follow-up subsample. This decreased both the Full Age 5 sample (n = 279) and the follow-up subsample (n = 116) and did not change the results of any of the analyses; therefore, these children were retained in both samples.

Family Information Sheet

Each year of testing, all SITSS families are mailed a demographic questionnaire to collect background information that describes the family in terms of race, family structure, and income, as well as parental age, education, and occupation (see Appendix D). Using family income, as well as parental education and occupation (for both partners), the socioeconomic status (SES) of the family can be computed by averaging the standardized scores (*z*-scores) across the five indices. Across a 5-point scale, parental education is rated from 1 (*some high school*) to 5 (*advanced degree beyond college degree*). Parental occupation is rated on a 7-point scale (1 = *high level professional* to 7 = *unskilled laborer*), per the Hollingshead index (Bonjean et al., 1967). Family income is rated using a 19-point scale (1 = *less than $5,000,* to 19 = *over $90,000*). Demographic characteristics for the age 5 sample are presented in Table 8.

Zygosity Assessment

The similarity/dissimilarity in genetic relatedness between two twins (and/or multiples) is known as zygosity. Twins (and/or pairs within multiples) share either approximately 50% or 100% of their genetic material and, based off this similarity, are either classified as DZ or MZ (Knopik et al., 2016). Zygosity is assessed in two distinct manners in the SITSS sample: 1) buccal cell collections and 2) similarity ratings. The collection of buccal cells is most favorable because this method is more precise compared to similarity ratings, but it is expensive. Buccal cells in SITSS are collected when children are tested in the lab between 1 to 5 years old. During testing, buccal cells are collected at three different times: before testing either twin, upon having tested one twin, and after testing both twins. To collect buccal samples, the inside of each cheek is swabbed for 20 seconds at each of those time points. These samples are then labeled and frozen until they are ready for analysis, at which point they are mailed to a lab for analysis.

During the years of 2003 to 2013, the buccal samples were mailed to Dr. Andrew Smolen at the Institute for Behavioral Genetics at Colorado University. However, beginning in 2015, these samples began being mailed for zygosity analysis to Dr. John McGeary at the VA Medical Center in Providence, Rhode Island. Zygosity for families of multiples in the SITSS sample has been determined via buccal cell analysis for 63% of the sample, or 241 families (230 twin pairs, 10 sets of triplets, and 1 set of quadruplets). For those families who did not have buccal cells collected (147 families; 145 twin pairs and 2 triplet sets), zygosity was determined using the method of similarity ratings (as described below). Overall, when compared to the buccal cell samples in SITSS, these similarity rating measures are 94% accurate in determining zygosity (DiLalla & Jamnik, 2019).

To provide a similarity rating, at each age tested, both the parent and a trained research assistant rate the physical characteristics of the twins and/or triplets. That is, based on a questionnaire developed by Nichols and Bilbro (1966), parents and trained research assistants are asked to assess phenotypic similarity for each same-sex pair. Because all opposite-sex pairs are dizygotic, these pairs are not assessed for zygosity. This zygosity measure is provided to parents as part of the questionnaire packet mailed before the testing session, whereas the lab assistant completes this similarity rating measure while families are in the lab for their testing session. This measure includes items that assess the physical characteristics of each twin, such as hair type/color (e.g., brown/wavy) and eye color, which are rated on a 5-point scale (1 = *very similar* to 5 = *not at all similar*). Each of these rating forms also includes a question asking how often the twins get mixed up by friends and/or relatives (for the parent version) or by the rater (for the lab assistant version). The parent and rater responses to these measures are then compared, and these characteristics analyzed across multiple levels, to determine zygosity (i.e., whether the children are MZ or DZ). The first level of zygosity scoring examines the differences in eye color and hair type/color. If distinctive differences in these characteristics are seen, the twin pair is classified as DZ. If these characteristics are not different, and the parent indicates that the twins are often confused (by parents or relatives), the twin pair is classified as MZ at the first level. When the first level of analysis cannot determine zygosity, the subtler differences in physical characteristics, such as hair/eye color and shape of facial features, and whether the twins are mixed up by others (e.g., close friends or acquaintances of the family) are examined in subsequent scoring levels.

Measures - Follow-up (Ages 7-13)

Body-Mass Index (BMI)

During THAnx testing, measurements of children's height (inches) and weight (pounds) were collected in the lab in a manner similar to the guidelines recommended by the Centers for Disease Control and Prevention (CDC, 2020) regarding how to accurately measure children's height and weight. For both height and weight, children were instructed to remove shoes and any bulky clothing. First, height was measured by having the child stand, with feet flat, against a closed door (flat surface) that had been marked inch-by-inch from 2.5 feet (30 inches) to 6 feet (72 inches). Using a clipboard as a flat headpiece, this was lowered to the crown of the child's head to form a right angle with the wall, which was then used to mark the respective height accurately to the nearest 1/2 inch. Next, weight was measured to the nearest decimal fraction (e.g., 55.2 lbs) using a digital scale and by having children stand, with both feet flat, in the center of this scale. These measurements are then converted into metric units to calculate overall BMI, which is done by dividing weight (kg) by height (in meters) squared.

BMI in childhood is not as clearly defined as in adulthood partly because of both the rapid (physical) growth and varying latency in maturation that occurs during early life development (i.e., children grow at different rates and ages). Thus, it is important to use normed BMI scores to account for developmental differences that occur as the result of age and sex. Therefore, BMI scores were normed separately for boys and girls, as well as by age (years), per recommendations provided by the CDC (2020). These guidelines include normed charts that provide a BMI-for-age percentile. During childhood, using standardized growth charts and cut-offs for BMI to provide a rough estimate of physical development and health is common practice in pediatrics (Yücel et al. 2011), which is how the utility of this measure was conceptualized for the current project.

Children's height and weight measurements were collected for the current follow-up in a different manner than THAnx. Because the current follow-up was conducted online, it was not possible to objectively measure children's height and weight in the manner described above. Instead, parents were asked to report on these measurements. To get the most accurate measurements possible, Huybrechts and colleagues (2011) suggest parents be encouraged to objectively measure children's height and weight at home. These authors found that more accurate measurements are provided when parents were encouraged to take these measurements at home (Huybrechts et al., 2011). Therefore, in the recruitment email (Appendix E), parents were informed of these measurements ahead of time and told, if possible, to (objectively) measure their children's height and weight (e.g., using a tape measure and scale) before participating in the study. However, previous research also indicates that, when objective measures are unavailable, online parent-reported measurements provide a reasonable estimate of children's height and weight (Skinner et al., 2013; Vendula et al., 2018). Chai and colleagues (2011) demonstrated that parent-reported height and weight measurements were substantially correlated with, and comparable to, objective measurements of children's height and weight (94% and 96%, respectively). Thus, if the parent would not or could not take these measurements at home, they were asked to report the children's height and weight as accurately as possible.

Child Behavior Checklist

At follow-up, the CBCL was once again used to collect a parent rating of children's behavioral and emotional problems. The same school-aged (i.e., ages 6-18) form that was collected at age 5 was also used at follow-up (age 7 to 13), thereby providing a longitudinal assessment of children's behavioral and emotional problems from preschool-aged to middle childhood. Again, like age 5, this project specifically examined the internalizing problems higher-order factor. Additionally, the 8 items that form the ADHD symptoms subscale were also examined and used in analyses for research question 1.

Family Health Behavior Scale (FHBS)

The Family Health Behavior Scale (Moreno et al., 2011) provides an assessment of the overall health behaviors of the child and family. Specifically, the FHBS is a parent-report measure consisting of 27 items rated on a 5-point scale (0 = *almost never*, 4 = *nearly always*). An overall score for household health behaviors is provided as a higher-factor solution, in addition to four lower-order subscales including: parent health-promoting behaviors (e.g., "I serve fresh fruits or vegetables" and "I work out, exercise, or participate in physical activity"), child physical activity behaviors (e.g., "My child participates in physical activities with parents/caregivers"), child eating habits (e.g., "My child frequently asks for unhealthy snacks" (reverse-scored)), and household mealtime routines (e.g., "My child eats three meals a day"). Because of this project's focus on health, globally, the total score for overall household health behaviors was examined. The FHBS has been shown to have favorable psychometric properties, including excellent internal consistency (Cronbach's $\alpha = .86$) and adequate test-retest reliability ($r = .85$) for the overall scale (Moreno et al., 2011). Additionally, strong convergent validity of the FHBS is supported by a significant inverse correlation found between the overall FHBS score and children's zBMI scores ($r = -0.28$, $p < .01$), which suggests a lower score for household health behavior is associated with higher levels of BMI in children (Moreno et al., 2011).

Family Information Sheet

The Family Information Sheet was used again at follow-up to collect demographic information on the family, including race, family structure, and income, in addition to the parent's age, education, and occupation. As described above, an overall household SES score will be calculated using the family income, as well as the parental education and occupation scores. Table 8 displays the demographic characteristics for the follow-up sample and reports the comparative analyses between timepoints. A paired-samples *t*-test revealed no significant difference in SES from time 1 (age 5) to time 2 (follow-up) for either random subsample - Random Subsample 1: $t(62) = 0.47$, $p = .641$, $\delta = 0.34$; Random Subsample 2: $t(62) = 0.36$, $p = .718$, $\delta = 0.34$. Rather than include both measures in analyses, because the two measures of SES were strongly correlated (see Table 9), a decision was made to use follow-up SES as an estimate of concurrent stress experienced during middle childhood (along with stressful life events).

Life Change Index (SRRS)

Parents completed the Life Change Index (The Social Readjustment Rating Scale; SRRS) to provide an overall estimate of various stressful life events that were experienced by the household over the past year (Holmes & Rahe, 1967). The SRSS lists 43 common life events that vary in severity, and parents report on the occurrence (yes or no) of those stressful events, in addition to the frequency (how many times) of their occurrence. These experiences are considered stressful because they capture change events; that is, those events that precipitate movement from one equilibrium, or steady state, to another (Holmes & Rahe, 1967).

The following four example items illustrate the wide range of events that are captured by this scale: “vacation,” “changes in routines, habits, household activities,” “family social problems,” and “death of a family member.” Furthermore, these items also capture the variability seen in event severity. For example, “death of a family member” receives a 100 for severity, whereas “vacation” only receives a 13. All 43 individual events are listed on the questionnaire form and, for each, participants indicate the number of times the event has occurred in the past year (or is expected to occur in the near future).

To account for the respective severity of each (i.e., more severe events are ‘weighted’ more heavily), a ‘weighted’ score for each event is calculated by multiplying the severity of that event by the number of times that specific event occurred (i.e., accounts for chronic stressors that may have occurred frequently). These ‘weighted’ scores are then summed across all 43 events to provide a total ‘stressful life events’ score for the entire scale. In this way, theoretically, the range of scores is nearly limitless depending on how many events the family has experienced (i.e., some events may not be experienced at all, whereas other events may occur more than once). Therefore, Holmes and Rahe (1967) provide the following classifications and cut-offs: less than 150 (low stress), 150-299 (moderate stress), and 299+ (high stress).

After 30 years of use, Scully and colleagues (2000) revisited the SRRS to reevaluate the ‘weight’ of those stressful events in present day (i.e., in terms of being experienced in the 21^{st} rather than 20^{th} century) and reassess the psychometric properties of this scale. Although the results of this study indicated the respective ‘weight’ of items slightly differed from the original study, these authors concluded that, overall, the SRRS is a useful tool for studying stress and stress-related health outcomes (Scully et al., 2000). Along with follow-up SES, stressful life events were included as one of the estimates for concurrent stress experienced during middle childhood.

Procedure

Given the current project features a longitudinal design assessing behaviors from preschool-age to middle childhood, several different procedures are provided below. First, SITSS testing is described because the 5-year-old data used here were collected as part of that original study. For follow-up, data for some of this subsample were already collected (i.e., as part of THAnx) but some had yet to be collected (i.e., the augmented sample collected here as part of the current project). The THAnx follow-up describes the testing procedure for the 45 families that participated in that follow up, whereas the current follow-up describes the procedure used to augment the THAnx subsample with those additional 20 families that were recruited for the current project. These two follow-up procedures are similar but differ in that THAnx testing was in-person and the current follow-up was conducted online (see below for details).

For the already collected data (as part of SITSS and THAnx), all paperwork was stored for later entry in a locked laboratory filing cabinet. Data were then entered into a computer database by trained undergraduate research assistants and were double entered by a second undergraduate (to check for errors). To ensure proper data entry, data are cleaned by the SITSS PI and a graduate assistant prior to analysis. Data cleaning involves comparing the two undergraduate entries for inconsistencies by using SPSS to compare each dataset (first and second entry) for any non-perfect correlations. If found, these discrepancies are corrected, and the error fixed appropriately, by referring to the original paperwork and the original item in question. Because the current follow-up was online (and data were already in a digital format), data entry was not necessary.

SITSS Testing

Families who express interest in participating in SITSS are contacted to schedule an appointment for face-to-face testing at the laboratory located on-campus at Southern Illinois University Carbondale. The SITSS Lab Coordinator is the person in charge of handling scheduling the testing appointments for families, which are typically scheduled around the day of the children's birthdays (i.e., to control for the rapid development that occurs early in life). For younger children (ages 1-4), testing generally occurs within either 1 week (age 1), 2 weeks (age 2), 3 weeks (age 3), or 4 weeks (age 4) of the children's birthdays, whereas 5-year-old testing occurs within 2 months of the fifth birthday. Previously, from 2016 to 2018, I was the SITSS Lab Coordinator and, thus, served an essential role in the recruitment, scheduling, and testing of families for SITSS. Since 2018, I have remained an integral part of this research by continuing to assist with data collection and testing (as a trained graduate research assistant). Once the testing session has been scheduled, parents are mailed a questionnaire packet prior to testing. This packet includes measures that assess zygosity (if same-sex twins), demographic and family information, home environment, and child temperament and problem behaviors. Parents are asked to complete this packet before arriving to the lab for testing and to bring this paperwork with them to be turned in at the testing session. This packet slightly varies depending on the age of the twins because age-appropriate measures are used for each specific age.

Once parents arrive at the lab but before testing begins, information regarding the purpose of the study, the potential risks and benefits, and confidentiality are discussed with families. At that time, signed consent for the children's participation in testing, as well as the video recording of those testing sessions, is obtained from parents. Once completed, the testing session may begin. First, one child is brought into a testing room by a trained tester who then gives the child several different tasks, which are intended to measure social and cognitive development. After the first child is tested, the testing procedure is repeated with the next child. None of the individual testing at age 5 was used in the present project and, thus, details regarding this aspect of the SITSS protocol are not provided here. After each child has been individually tested, the children and one of the parents participate in a 10-minute parent-child interaction (PC-INT) task (as described above), which is part of the 5-year-old testing that was used in this project. This task takes place in an otherwise empty room, aside from two puzzles that are provided. The individual testing sessions and the PC-INT are filmed for later coding. After testing, all children receive toys and books to thank them for participating and, at age 5, parents are mailed a $50 check to thank them for participating in the SITSS study. As discussed above (see Measures), the current project used several questionnaires (BSQ, CBCL, and CHAOS) that are collected as part of the parent paperwork packet and, for observational motor behavior coding, the recording of the PC-INT task was used.

THAnx Follow-up

At follow-up (2017 - 2018), families with children within the desired age range (7-13 years old) were once again invited to the lab for face-to-face testing. Those families who expressed interest and agreed to participate were contacted to schedule their follow-up appointments. Of all possible families who were eligible to participate, 12 families were unreachable, 20 families declined to participate in this follow-up project, and 2 families were scheduled but did not show up for their appointment. Before beginning testing, consent was collected from the parents and, now that children were old enough (i.e., age 7 or older), assent was received from the children. The American Academy of Pediatrics (1995) advises that, starting at age 7, children's assent should be collected in research studies (Nicholson, 1986). During testing, children participated in face-to-face testing with a trained graduate research assistant while parents completed a questionnaire packet in another room. This packet included several different measures regarding the children's health and anxiety, in addition to the family's health behaviors. The current project specifically used the measures pertaining to children's behavioral and emotional functioning (CBCL), in addition to family demographic information (i.e., SES), stressful life events (SRRS), and household health behaviors (FHBS). Aside from the questionnaires collected, the children's height and weight were also measured in order to provide an estimate of body-mass index (as described above). Upon testing completion, families were thanked for their time and children were each given a SITSS baseball cap, a $5 gift card, and a book to compensate them for their help.

The Current Follow-up

To augment the THAnx subsample, this project recruited families whose children were tested at age 5 and are currently between ages 7 to 13 years old, but who did not participate in the original THAnx follow-up. However, unlike THAnx, this follow-up was different in three ways. First, the follow-up for this project was given to families online rather than conducted in-person. Because of the current COVID-19 global pandemic, and recent guidelines to maintain social distancing and limit face-to-face interactions (especially indoors), conducting this follow-up study online was preferable (and safer). Second, only parents participated in this follow-up because the measures of interest (internalizing problems, household health behaviors, stressful life events, and family demographic information) were all parent-reported. The paper questionnaires of interest (i.e., a subset of the complete THAnx measures), which were previously administered in person, were adapted into an online survey for parents to complete.

Finally, because children's height and weight measurements were not measured in the lab, parents instead reported on these measurements (which, again, differed from how originally collected in THAnx).

The decision to administer this follow-up online was highly desirable for research, given that our ability to safely interact in-person has been severely hindered by COVID-19. Furthermore, this format was also desirable for participants because it allowed families to complete the survey whenever and wherever they choose (i.e., the survey remained open throughout the entire data collection period). Previous research indicates that online testing can provide data that are of high psychometric quality (Jamnik & Lane, 2017) and are comparable to information collected during in-person testing (Casler et al., 2013). Hence, it was expected that the measures collected as part of this proposed follow-up would be similar to those collected during THAnx and, therefore, they would be able to be aggregated together.

Before data collection began, approval from the Human Subjects Committee (HSC) was obtained. The 40 potential families identified for this follow-up were sent a recruitment email (see Appendix E) with both a brief description of the study and an HTML link that leads participants to an online informed consent (Appendix F) and questionnaire packet. Families who were interested in participating clicked this link to advance to the survey itself, which was posted online using Surveymonkey.com. If families did not participate within two weeks of the initial email, they were sent a follow-up email (Appendix E). Families were contacted a total of four times over a 2-month period. This initial recruitment period only yielded three out of the 40 potential families and, therefore, the protocol was revised to include a series of two follow-up phone calls using a phone call script (Appendix G). This revision coincided with my having received two grants that would provide funding to help compensate families for participation (rather than receiving a raffle entry for a gift card, which was the compensation method originally proposed). Families who were unable to be reached by phone were left a voicemail. This method of recruitment, along with the prospect of receiving monetary compensation, proved much more successful and yielded an additional 17 families. Once consent was provided, parents advanced through the questionnaires. To minimize differences across follow-up collection, these questionnaires were presented to parents in the same order as those given during in-person THAnx testing, which alternated from 1) the first child, to 2) household information, to 3) the other child (and, if triplets, 4) the final child). Specifically, the measures were presented in the following order: 1) the FHBS, CBCL, and parent-reported height and weight for child 1, 2) the family information sheet and life change index test (for the overall household), and 3) the FHBS, CBCL, and height/weight for child 2 (and, if applicable, the FHBS, CBCL, and height/weight for child 3). After completing testing, parents were thanked and compensated for their time. For each family, compensation included mailing an age-appropriate book for each child and emailing a $60 Amazon.com gift card to the parent.

CHAPTER 4

RESULTS

Once data collection was completed for the current follow-up, the final overall dataset was prepared for analyses (comprised of SITSS, THAnx, and the current follow-up). I used IBM SPSS Statistics Version 27 to organize all data and compile the various datasets. Because the age 5 (SITSS) and THAnx data were already collected (i.e., archival), these data were already cleaned and, therefore, no additional steps were necessary to prepare the datasets for analyses. One exception to this included the 5-year-old observational motor behavior data, given these data were newly coded for this project. Because coding occurred virtually due to COVID-19, observational scores were recorded on a computer using a coding sheet (Appendix B) that was in a digital format (i.e., Excel spreadsheet); this method allowed for the data to be easily imported from this format into SPSS.

Also noted in the Procedure, data collected as part of the current follow-up were already in a digital format because the survey was conducted online; thus, no data entry was needed. However, because those data included raw scores for each item, it was necessary to create the composite scores for each measure (household health behaviors, internalizing problems, body-mass index, socioeconomic status, and stressful life events). These calculations were done per the psychometric guidelines provided for each measure.

Finally, to prepare the final dataset for analyses, the remaining step included merging the data files from each sample (SITSS, THAnx, and the current follow-up) into one overarching dataset. This provided a final sample of 302 children in the age 5 (no follow-up) dataset and 132 children in the follow-up subsample (see Tables 1 and 2).

Next, it was necessary to double-check the normality statistics for the dependent variables of interest at follow-up (i.e., body-mass index, internalizing problems, and household health behaviors). As I had proposed, first, if transformations were necessary, measures with positive skew (clustered at lower values) would be square-rooted and measures with negative skew (clustered at higher values) would be squared. Then, if still skewed, the natural log and cube of each variable would be calculated and assessed. The only dependent variables that displayed skewness were body-mass index and internalizing problems at follow-up, which were both positively skewed. A square-root transformation was applied to these variables and this corrected the skewness for both (see Table 2).

Research Question 1

Research Question 1 assessed the validity of the newly developed observational coding scheme by comparing preschoolers' observed motor behavior to (parent-reported) temperamental activity levels. This was done by examining the correlations among these two variables using only one twin per family (to avoid violating the basic assumption of independence of sample), which provided two distinct subsamples with independent participants for analyses (Random Subsample 1 and Random Subsample 2). Bivariate correlations for each random subsample were examined.

Hypothesis 1

It was predicted that 5-year-old observed motor behavior and temperamental activity levels would be significantly positively correlated. Correlation analyses indicated that, contrary to my hypothesis, age 5 observed motor behavior did not significantly correlate with 5-year-old temperamental activity in either random subsample for the Full Age 5 sample (see Table 12) - Random Subsample 1: $r(144) = 0.12$, $p = .141$; Random Subsample 2: $r(144) = 0.15$, $p = .070$. This was also true for the follow-up subsample (see Table 16) - Random Subsample 1: $r(61) =$

0.08, $p = .563$; Random Subsample 2: $r(63) = 0.21$, $p = .098$. These findings indicated that Hypothesis 1 was partially supported. That is, although the relationship between these measures was in the hypothesized direction, it appeared that observed motor behavior and temperamental activity assessed different aspects of preschoolers' physical activity. However, it is worth noting that, for Random Subsample 2 in the Full Age 5 sample, the correlation between observed motor behavior and temperamental activity trended towards significance. Given that it was necessary to split the sample (i.e., select one child from each family), which decreased the sample size by one-half, it is likely that a loss of power affected the current results. Future work examining this association with a larger sample and more powerful analytic approach is needed.

Using the Full Age 5 sample, a post-hoc decision was made to examine the associations between the age 5 physical activity measures (observed motor behavior and temperamental activity) with 5-year-old observed sedentary behavior and 5-year-old ADHD symptoms (from the CBCL). It was predicted that greater physical activity (whether observed or parent-reported) would be negatively associated with observed sedentary behavior and positively associated with ADHD symptoms. A significant negative association was found for age 5 observed motor behavior and observed sedentary behavior for both Random Subsample 1, $r(148) = -0.29$, $p < .001$, and Random Subsample 2, $r(148) = -0.23$, $p = .006$. These findings indicated an inverse relationship between motor and sedentary behavior. Furthermore, in both random samples, a significant positive association was found for 5-year-old observed motor behavior and ADHD symptoms - Random Subsample 1: $r(144) = 0.19$, $p = .025$; Random Subsample 2: $r(146) = 0.22$, $p = .007$. A significant positive association was also found for age 5 temperamental activity and ADHD symptoms - Random Subsample 1: $r(142) = 0.49$, $p < .001$; Random Subsample 2: $r(143) = 0.56$, $p < .001$. Children who were rated higher in activity, whether observer- or parent-reported, were also rated as higher in ADHD symptoms (see Table 12), which provides some evidence in support of the validity of the age 5 observational coding scheme.

Research Question 2

Research Question 2 investigated the underlying etiology of preschoolers' physical activity by examining the relative amount of variance in 5-year-old observed motor behavior and temperamental activity that were attributable to genetic and environmental influences. The use of a twin design allowed me to perform biometric modeling (ACE/ADE) to explore Research Question 2 and investigate Hypothesis 2. A sample diagram depicting a full theoretical ADCE path model is provided in Figure 1.

Using structural equation modeling (SEM) and path analysis, biometric model fitting is a technique that is commonly used in behavioral genetic studies to examine the underlying etiology of a phenotype of interest (Nivard et al. 2017). Specifically, this analytic approach affords the ability to tease apart the relative contribution of additive (A) and dominant (D) genetic effects, as well as shared (C) and non-shared (E) environmental influences. Notably, E also includes measurement error. To perform these sophisticated analyses, the varying genetic similarity between MZ and DZ twin groups is relied upon (i.e., MZ twins share nearly 100% of their genes, whereas DZ twins only share approximately 50%).

In this path modeling approach, the covariances between MZ twins (MZs) and DZ twins (DZs) for the phenotype of interest are used (Knopik et al., 2016). The results of the intra-class correlations among MZ-pairs and DZ-pairs are provided in Table 13 because these values are standardized and, thus, interpretable. The following steps are undertaken in these path analyses (see Figure 1). To investigate the additive (A) genetic effects, because MZs and DZs each share 100% and 50% of their genes, respectively, the correlation between the A1 and A2 paths were set to 1.0 for MZ twins and 0.50 for DZ twins. On the other hand, non-additive (D) genetic effects capture the interactive, or combined, influence between genes (paths D1 and D2). Therefore, again, the D paths were perfectly correlated ($r = 1.0$) for MZ twins because they share all their genetic makeup (i.e., for both additive and dominant genetic variance); however, for DZ twins, because only 50% of genes are shared, they only have a 25% chance of sharing the same combination of genes inherited from each parent (i.e., one allele from each of the parents' two alleles) and, thus, the D paths will be set to 0.25 for DZ twins. The correlation between the C1 and C2 paths were set to 1.0 for both groups because, by definition, the shared (C) environmental effects contribute equally to similarity among both MZ and DZ twins. Finally, E1 and E2 were uncorrelated for both MZs and DZs, given non-shared (E) environmental effects include all components of experience that contribute to the dissimilarity between both twin pairs (in addition to measurement error). Model fitting for the full (theoretical) ADCE model cannot be examined using SEM because this model would have negative degrees of freedom (Ozaki et al., 2011), which violates assumptions of path analysis and results in a model that cannot be identified (Kline, 2016). Thus, this full model is hypothetical and cannot be tested with four variables (see Figure 1).

Therefore, using these set parameters and analytic approach, a series of nested models were tested by inputting the intra-class covariance matrices for both measures of physical activity for both the MZs and DZs into a series of two-group models. These analyses began with the overall identified model (ACE or ADE) and then, subsequently, tested alternative nested models (AE, CE, and E). The ADE model is more appropriate when the MZ correlation is greater than twice the DZ correlation because this would indicate that dominant genetic effects (D) may be influencing the phenotype of interest.

Within the overall ACE model, the path estimate for the h, c, and e paths can be squared to estimate the percent of variance in the latent construct (physical activity levels), within the current sample, that is accounted for by genes, shared environment, and non-shared environment, respectively. In other words, squaring the 'h' path yields an estimate of heritability for physical activity levels, squaring the 'c' path estimates the amount of variance attributable to shared environment, and squaring the 'e' path provides an estimate for the amount of variance accounted for by the non-shared environment, including error (Roysamb & Tambs, 2016). This can also be done within the overall ADE model. However, in this model, the 'c' path is replaced by a 'd' path, which accounts for the variance attributable to dominant genetics.

Finally, before conducting the planned analyses, it was important to conduct a zygosity comparison to determine if MZ twins significantly differed from DZ twins in physical activity (observed motor behavior and temperamental activity). The Full Age 5 sample was used for comparative analyses because both measures of physical activity were assessed at the age 5 timepoint. This was necessary because an underlying assumption of ACE/ADE modeling is that children who are MZs and children who are DZs are assumed to be comparable. That is, comparing MZ children to DZ children, MZs and DZs should not significantly differ in terms of similarity or differences for the phenotype of interest. Thus, a MANOVA was run to determine if MZs and DZs differed significantly in either measure of physical activity. Results indicated no significant differences at the multivariate level (see Table 10) for either random subsample - Random Subsample 1: $F(2, 140) = 0.51$, $p = 0.510$, Wilks' $\lambda = 0.99$; Random Subsample 2: $F(2, 141) = 2.88$, $p = 0.06$, Wilks' $\lambda = 0.96$. Therefore, modeling could proceed because the assumption that MZs and DZs would not significantly differ was met.

Hypothesis 2

It was predicted that preschoolers' physical activity (observed motor behavior and temperamental activity) would be significantly influenced by both genetic and environmental influences. Although, specifically, given the age of focus in the current project, it was expected that environmental influences would account for a larger portion of variance in physical activity compared to genetic influences.

As mentioned, to identify the most appropriate overall model (ACE or ADE), the intra-class correlations between MZ twins (*r*MZ) and DZ twins (*r*DZ) were first examined (i.e., how similar are physical activity levels across MZ co-twins, how similar are physical activity levels across DZ co-twins) and then compared (i.e., *r*MZ to *r*DZ). If *r*MZ was more than double *r*DZ, the ADE model would be used, but if not, then the ACE model would be used instead. By nature, MZ twins are same-sex pairs, whereas DZ twins may be either same-sex (SSDZ) or opposite-sex (OSDZ); for the analyses for Hypothesis 2, in the interest of power (sample size), both types of dizygotic twins (SSDZ and OSDZ) were retained in the sample together as one DZ group. For both measures of physical activity, *r*MZ was found to be more than double *r*DZ (see Table 13) which indicated the ADE model was most appropriate for these data. Analyses examined this overall model, as well as the models nested within (AE and E), to determine the model that best fit the data. After the overall model and all nested models were examined, the path estimates for the most parsimonious model were accepted as best fit using the procedure and indices described below.

Using the OpenMx (Version 2.17.2) software package (Neale et al., 2016) for RStudio Version 3.5 (RStudio Team, 2020), biometric model fitting analyses were employed to conduct the ADE path modeling. The path modeling process is an iterative procedure that uses a predefined model to simultaneously assess the relationship between variables (DiLalla, 2000). This predefined model is informed by theory, and the fit of the data to the predefined model of observed and latent variables is tested using OpenMx. To assess the goodness of fit of the data in a model, various guidelines can be followed (Kenny, 2020) using several indices provided by the OpenMx output.

The relationship between variables can be examined using absolute fit indices, which compare observed variance/covariance matrices to expected matrices (DiLalla, 2000). The absolute fit index is essentially a measure of "badness" of fit (Kenny, 2020) because, in the best fitting model, it assumes a difference of zero between the observed and expected covariance matrices. Chi-square (χ^2) is one commonly used measure of this type. A smaller χ^2, along with a non-significant *p* value, suggests the data are consistent with the fitted model; a larger χ^2 and a significant *p* value ($p < .05$) indicates a significantly worse fitting model. However, the use of other measures of fit in conjunction with absolute fit indices is recommended, given chi-square values are sensitive to sample size and are likely to reject a model that fits well, but not perfectly (Knopik et al., 2016).

Thus, alternatively, comparative fit indices may also be used to estimate the fit of the model compared to other standard models (DiLalla, 2000). Examples of comparative fit indices include the Tucker-Lewis Index (TFI; also called the non-normed fit index or NNFI), in addition to the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The non-normed fit index (or TFI) is preferred over the normed fit index (NFI) because it contains a penalty for adding additional parameters to the model (which the NFI does not) and, thus, penalizes the model for complexity (Kenny, 2020). Similarly, the AIC and BIC fit indices also contain a built-in penalty based on the number of parameters estimated. However, unlike the

TFI, these measures can be computed for saturated models with zero degrees of freedom (Kenny, 2020). Although the AIC and BIC are very similar, the BIC has a built-in correction for sample size (i.e., increases the penalty as sample size increases) and, therefore, the AIC is often preferred (i.e., given large sample sizes are typically desired).

Using these two indices (absolute or comparative fit), one can determine how well the data fit to a model. For hypothesis 2, models were compared using chi-square and AIC indices. Model fitting relies on the principle of parsimony, which states models that are more simple are preferred over more complex models, so long as this simpler model shows no significant worsening of fit ($p > .05$) in comparison to the full model (Blokland et al., 2013). Thus, after running an initial model (in this case, ADE), nonsignificant paths or variables from the model were dropped and successive (nested) models run to determine if the fit of the data improved in more simple models (e.g., AE and E). The simplest model that best fit the various indices used was considered the best-fitting (or most parsimonious) model (Roysamb & Tambs, 2016), which, for this project, was the model with the lowest chi-square and AIC values.

For age 5 observed motor behavior, analyses began by examining the fit of the overall ADE model to examine the effects of additive genetic (A) effects, dominant genetic (D) effects, and non-shared environmental influences (E) before then testing the submodels nested within (AE and E). Model fit indices for the ADE model were χ^2 (311) = 778.40 and AIC = 786.40. Next, to examine whether the absence of dominant genetic effects made the model fit significantly worse (i.e., dominant genetic effects do not contribute to covariation among twins), the D path was dropped and the fit of the AE submodel was tested, χ^2 (312) = 778.96 and AIC = 784.96. The AE model had a lower AIC value and did not fit the data significantly worse, $\Delta\chi^2$ (1) = 0.56, $p = .454$. Therefore, the AE model was retained. Finally, the A path was also dropped to test the fit of the simplest submodel (i.e., only non-shared environmental influences), the E model. This model provided a significantly worse fit to the data, χ^2 (313) = 883.09 and AIC = 837.09. The best fitting model was the AE model, which indicated that additive genetic (A) effects and non-shared environmental influences (E) account for approximately 66% and 34%, respectively, of the variance in age 5 observed motor behavior. The results of these analyses are summarized in Table 14 and the path estimates for the best fitting model are illustrated in Figure 2.

Similarly, for 5-year-old temperamental activity, the fit of the overall ADE model was first tested before then examining the submodels nested within (AE and E). The fit indices for the ADE model were χ^2 (304) = 609.05 and AIC = 617.05. Next, the fit of the AE submodel was tested by dropping the D path. This model had larger fit indices, χ^2 (305) = 621.84 and AIC = 627.84, which indicated that the AE model fit the data worse than the overall ADE model. Finally, the fit of the most simple submodel (Model E) was tested by dropping the A path. This model also fit the data worse, χ^2 (306) = 640.52 and AIC = 644.52. Therefore, the ADE model was retained as the best fitting model. These results indicated that 5-year-old temperamental activity was influenced by both additive genetic (A) and dominant genetic (D) effects, as well as non-shared environmental influences (E). Interestingly, although the ADE model fit the data best, the path estimates indicated that 00% of the variance in age 5 temperamental activity was accounted for by A, whereas 72% and 28% of the variance was attributable to D and E, respectively. These findings are summarized in Table 15 and the path estimates for the ADE model are depicted in Figure 3.

Research Question 3

Research Question 3 investigates the main effects of preschoolers' physical activity (observational motor behavior and temperamental activity) and internalizing problems on subsequent health outcomes (i.e., body-mass index, internalizing problems, and household health behaviors) in middle childhood. To test this research question, separate mixed multilevel model (MLM) regression analyses were run for each dependent variable (i.e., body-mass index, internalizing problems, and household health behaviors) to examine the unique contribution of 5-year-old observed motor behavior, temperamental activity, and internalizing problems, as well as stressors experienced by the child. Therefore, Hypothesis 3 is split into three distinct parts (Hypothesis 3a, 3b, and 3c), which were all conducted using MLM analyses to examine six distinct models.

This method of analysis was preferred because it avoids violating the independence of sample assumption, given these analyses include both twin type and family effects to be examined within the models. Furthermore, multilevel analyses also account for the hierarchical nature of the data by allowing for varying slopes and intercepts across families to be included. All of this was preferable, because it allowed for the entire follow-up subsample (n = 132 children) to have been used for analyses, rather than only one child per family if multiple regression were to have been used. As previously stated in Chapter 3 (see Missing Data), the sample size varies slightly across the variables examined because complete data were not available for all children in the study (see Table 2 for descriptive statistics). Table 16 presents the bivariate correlations among the age 5 and follow-up variables.

As mentioned in Chapter 2 (see Research Question 3), I had proposed that if the stress variables at each time point (household chaos, SES, and stressful life events) were significantly correlated, a single stress factor would be created because it would decrease the number of independent variables included in analyses and, in turn, increase power by lowering the number of parameters estimated. These measures were not highly correlated (see Table 9). That is, they appeared to assess different aspects of stressors experienced by children and, therefore, these measures were retained as separate variables and examined individually in analyses for Hypothesis 3.

All models included family (i.e., sibship) as a random effect to control for the hierarchical nature of the dataset (e.g., analyses include siblings within families). Model 1 examined the influence of sex, age of follow-up testing, and zygosity. These variables were retained in subsequent models to account for the variance in health outcomes accounted for by these covariates. In Model 2, the fixed effects of 5-year-old observed motor behavior, temperamental activity, and internalizing problems on follow-up health outcomes were added. Models 3 and 4 examined the fixed effects of the various stressors assessed in this project; Model 4 examined the longitudinal influence of stress by adding a fixed effect for age 5 household chaos, whereas Model 5 assessed the influence of concurrent stressors by adding fixed effects for SES and stressful life events at follow-up. Next, models containing random slopes for each physical activity measure and internalizing problems were examined, given these factors were operationalized at the individual-level (i.e., each child), rather than household-level (i.e., stressors), to investigate whether the within-family effect differs across families. The models containing the random slopes were only retained if they provided a better fit to the data; if they did not, analyses continued without a random slope effect. Lastly, because a significant sex effect was found for temperamental activity, a final model added BSQxSex to investigate the interaction effect.

Maximum likelihood estimation was used to compare these models statistically (Field, 2013). To determine the best fitting model, the likelihood ratios across models were compared using chi-square difference scores and the Akaike Information Criterion corrected (AICc; Akaike, 1974) was examined. The corrected AIC was used here, as it is most appropriate for small sample sizes (Field, 2013). A significant chi-square difference ($p < .05$) indicated better fitting models. All model fitting results for Hypothesis 3a-c are presented in Tables 17, 18, and 19.

Hypothesis 3a

The first part of Hypothesis 3 stated that body-mass index in middle childhood would increase as age 5 physical activity decreased, 5-year-old internalizing increased, and stressors increased.

The first MLM analysis included follow-up body-mass index as the dependent variable and the independent variables as fixed factors (see Table 17). Model 1 indicated that only age at follow-up was a significant covariate, AICc = 178.73; $\chi^2 = 166.03$; older children had higher body-mass index scores. Adding the 5-year-old variables did not result in a better fit for Model 2, AICc: 183.16; $\Delta\chi^2 = 2.46$, $p = .116$, although child sex was significant when accounting for the age 5 variables, indicating that boys had higher body-mass index than girls. The third model added the effect of household chaos and did not result in a better fitting model, AICc = 185.28; $\Delta\chi^2 = 0.25$, $p = .617$. Model 4 included the two follow-up stress measures, SES and stressful life events, and resulted in a better fitting model, AICc = 180.26; $\Delta\chi^2 = 10.23$, $p = .001$. In this model, follow-up SES was a significant predictor, indicating that children from lower SES homes at follow-up had higher body-mass index scores. One by one, a series of models added in random slopes for age 5 observed motor behavior, temperamental activity, and household health behaviors, respectively; these models did not result in a better fitting model and, therefore, were not retained for the final model. Finally, Model 5 tested the interaction between temperamental activity and sex (BSQxSex), which did not result in a better fitting model, AICc = 182.67; $\Delta\chi^2 = 0.11$, p =.740. Therefore, the best fitting model for Hypothesis 3a was Model 4, which included a significant within-family effect, Wald $Z = 3.11$, p =.002, and a significant fixed effect for age-at-follow-up, $t = 3.57$, $p = .001$, child sex, $t = 2.08$, $p = .039$, and follow-up SES, $t = -2.36$, $p = .022$. Table 17 provides the model fit indices and parameter estimates for the five models tested.

Hypothesis 3b

The second part of Hypothesis 3 stated that internalizing problems in middle childhood would increase as 5-year-old physical activity decreased, age 5 internalizing increased, and stressors increased.

The second MLM analysis included follow-up internalizing problems as the dependent variable, with the independent variables as fixed factors (see Table 18). Model 1 indicated that none of the covariates were significant predictors of internalizing, AICc = 400.18; $\chi^2 = 166.03$. Adding the 5-year-old variables resulted in a better fit in Model 2, AICc = 361.97; $\Delta\chi^2 = 45.08$, $p < .001$, and indicated that age 5 internalizing problems predicted follow-up internalizing problems, suggesting stability in the measure and (potentially) stability in internalizing. The third model added in the effect of household chaos, which was not significant and did not result in a better fitting model, AICc = 364.24; $\Delta\chi^2 = 0.09$, p =.764. The two follow-up stress measures, SES and stressful life events, were included in Model 4 and resulted in a better fitting model, AICc = 353.82; $\Delta\chi^2 = 15.43$, $p < .001$. In this model, follow-up stressful life events were a significant predictor, indicating that children who experienced greater stressful life events had increased follow-up internalizing problems. Random slopes for age 5 observed motor behavior, temperamental activity, and household health behaviors, respectively, were added one by one in a series of models. Only the model with random slopes for temperamental activity resulted in a better model fit, AICc = 349.95; $\Delta\chi^2 = 6.38$, $p = .011$, and, therefore, was retained for the interaction model. The BSQxSex interaction effect was examined in Model 6 and did not result in a better fitting model, AICc = 350.75; $\Delta\chi^2 = 1.75$, $p = .185$. Therefore, the best fitting model for Hypothesis 3b was Model 5, which included a significant within-family effect, Wald $Z = 3.44$, $p = .001$, and a significant fixed effect for age 5 internalizing problems, $t = 6.33$, $p < .001$, and stressful life events, $t = 2.26$, $p = .028$. Table 18 provides the model fit indices and parameter estimates for the six models tested.

Hypothesis 3c

The third part of Hypothesis 3 stated that household health behaviors in middle childhood would decrease as age 5 physical activity decreased, 5-year-old internalizing increased, and stressors increased.

The third MLM analysis included follow-up household health behaviors as the dependent variable, with the independent variables entered as fixed factors (see Table 17). Model 1 indicated that none of the covariates were significant predictors of household health behaviors, AICc = 876.93; $\chi^2 = 889.61$. Model 2 added the 5-year-old variables, which resulted in a better fit, AICc = 842.23; $\Delta\chi^2 = 54.24$, $p < .001$, and indicated that child sex and age 5 temperamental activity significantly predicted follow-up household health behaviors. Results showed that boys were rated higher in health behaviors and children with high temperamental activity had lower health behavior scores. Household chaos was added in the third model and did not result in a better fitting model, AICc = 841.71; $\Delta\chi^2 = 2.88$, $p = .089$. Model 4 included the two follow-up stress measures, SES and stressful life events, and also resulted in a better fitting model, AICc = 826.11; $\Delta\chi^2 = 23.39$, $p < .001$. A series of models were tested one by one, adding in random slopes for age 5 observed motor behavior, temperamental activity, and household health behaviors, respectively. Once again, the model with random slopes for temperamental activity resulted in a better model fit, AICc = 824.47; $\Delta\chi^2 = 4.14$, $p = .041$, and, therefore, was retained for the interaction model. Model 6 included the BSQxSex interaction effect and did not result in a better fitting model, AICc = 826.78; $\Delta\chi^2 = 0.23$, $p = .631$. Therefore, the best fitting model for Hypothesis 3c was Model 5, which included a significant within-family effect, Wald $Z = 4.91$, $p < .001$, and a significant fixed effect for child sex, $t = 2.92$, $p = .004$, and 5-year-old temperamental activity, $t = -3.94$, $p = < .001$. Table 19 provides the model fit indices and parameter estimates for the six models tested.

CHAPTER 5

DISCUSSION

The major aim of the present study was to further our understanding of health across childhood by examining important health predictors at age 5 and health-related outcomes in middle childhood (ages 7 to 13). A coding tool was developed, psychometrically evaluated, and used to assess age 5 motor behavior. Results provided support for the reliability and validity of this observational coding scheme, providing a useful methodological tool for future studies to employ. These observational ratings were used in conjunction with parent-reported temperamental activity levels to provide an assessment of observable in-the-moment motor behavior and, more generally, the predisposition to engage in those behaviors (i.e., temperament). This multimethodological approach provided the current study with a holistic assessment of young children's physical activity. Relatedly, given that limited research has focused on early childhood physical activity (Schmutz et al., 2018) and few such studies have employed a twin design (Fisher et al., 2015), a behavioral genetic approach was used to further examine the genetic and environmental factors underlying preschoolers' physical activity. Findings revealed a significant contribution of genetic and environmental influences, albeit to varying degrees for each measure of activity. Finally, analyses investigated whether physical activity and internalizing problems at age 5, as well as potentially salient stressors (household chaos, socioeconomic status, and stressful life events), significantly affected health outcomes at follow-up (body-mass index, internalizing problems, and engagement in health behaviors). Results showed that age, child sex, temperament, and stress affected health in middle childhood.

Preschoolers' Physical Activity

The first main objective of this project was to design and employ an observational coding scheme to assess preschoolers' movement, as well as investigate the validity of this new measure. Findings indicated that age 5 motor behavior and temperamental activity were not significantly correlated (although, there was a trend in the predicted direction). This was unexpected, given that other observational measures have been shown to correspond with other measurements of physical activity (Howie et al., 2012). It may be that each measure of physical activity captures a slightly different aspect of preschoolers' movement. This would help to explain the small, but not significant, effect for the association found between each of these distinct measures of children's physical activity levels. Conceptually, this explanation makes sense, considering that the observational coding scheme was designed to assess the overt behaviors displayed by the child, whereas temperament is defined to include more than simply the frequency of behavior. For example, temperamental activity might assess the child's likelihood to engage in movement, rather than the actual amount of movement that is exhibited by the child (i.e., overt motor behavior) in a particular situation (such as the PC-INT task), which the observational coding scheme was designed to assess. Studies interested in examining the broad tendency to have a high activity level may benefit most from a more holistic measure, like temperamental activity levels, whereas the current project's coding scheme may be more useful for evaluating in-the-moment motor behavior, specifically. Although Hypothesis 1 was not directly supported, conceptually this null finding supports the distinction made in the current project between temperamental activity levels and overt motor behavior. That is, instead of temperament (which is what the parent ratings measured), the observational coding scheme provided an assessment of the actual amount of physical activity displayed by a child during a specific period.

Related to this conceptual distinction, it could also be that the PC-INT setting captures the amount of motor behavior that the child would normally display over a short period of time in a small room doing a task like this but does not elicit motor behavior in a way that accurately represents the ‘typical’ overall level of physical activity that the child would display throughout many situations across an entire day; this explanation seems plausible, given that previous research suggests childhood physical activity (age 2 to 13 years old) is highly influenced by the environment (shared and non-shared environment combined = 79%; Fisher et al., 2015). Lastly, the difference between children’s ratings of motor behavior that was observed in-lab and parent-reported temperamental activity might also be explained, in part, by children’s motor coordination; that is, if motor coordination is poor, a temperamentally active child may appear “low” in observed motor behavior because of this deficit in motor ability. Although reasonable, this does not seem likely because 1) children in SITSS, when enrolled for the study, are asked a list of symptoms to ensure they are typically developing and 2) by age 5 a typically developed child will have attained the basics of motor behavior (Adolph & Franchak, 2017), which was the focus of the observational coding used here, not any complicated or advanced motor behaviors.

Although observed motor behavior was not significantly associated with temperamental activity, other analyses did offer evidence in support of the validity of the observational coding scheme. For one, observed motor behavior and temperamental activity were both positively associated with age 5 ADHD symptoms, indicating that higher ratings of activity corresponded with higher reported attentional/hyperactivity symptoms. This provided support for the construct validity of the observational measure. Additionally, an inverse relationship was found between observed motor behavior and observed sedentary behavior at age 5 (i.e., more motor behavior, less sedentary behavior), which provided support for the discriminant validity of observer-rated motor behavior. These post-hoc findings help to provide evidence supporting the validity of the observational coding scheme. When considered along with the excellent reliability this measure displayed, the coding scheme developed for this project proved to be a valid, reliable method for assessing motor behavior in young children. This newly developed methodological tool offers researchers and professionals a relatively easy-to-use measure to assess the amount of motor behavior and sedentary behavior exhibited by children. Employing this measure in a variety of other settings (e.g., the playground, gym class, free play) will be helpful for further illuminating factors that affect movement (or lack thereof) in children.

Etiology of Age 5 Physical Activity

As a secondary aim of the first objective, the underlying etiology of childhood physical activity was investigated. A twin design was employed to investigate the relative amount of variance in age 5 observed motor behavior and parent-reported temperamental activity that was accounted for by underlying genetic and environmental factors. Overall, results indicated that, in the current sample, both measures of preschoolers' physical activity were significantly influenced by genetic and environmental factors, albeit to differing magnitudes. This provided evidence in support of Hypothesis 2.

The overall model identified for both measures of physical activity was the ADE model (i.e., because *r*MZ was greater than twice *r*DZ). When MZs appear more phenotypically similar than DZs, this suggests that dominant genetic effects are likely. Unlike additive genetic effects (which assess the independent effects of allelic variation), dominant genetic effects measure interactive (or multiplicative) allelic effects across genotypes (Knopik et al., 2016). In other words, we can think of additive genetic effects as a main (independent) effect and dominant genetic effects as an interaction effect (i.e., allele X allele). Due to the varying genetic similarity across MZs and DZs, dominant genetic effects contribute to greater similarity among MZs because, by nature, they will always share the alleles that interact. Put differently, both alleles must be shared by both twins to have an interactive effect; thus, there is a lower likelihood that DZs will share both alleles for a dominant genetic effect because DZs share, on average, only 50% of their genes.

Analyses revealed that, for observed motor behavior, additive genetic effects and non-shared environmental influences accounted for approximately 66% and 34% of the variance in children's observed behavior. For temperamental activity, it was found that approximately 72% and 28% of the variance in parent-reported scores were attributable to dominant genetic effects and non-shared environmental influences, respectively. This provided additional support for the conceptual distinction made in this project for each physical activity measure and, additionally, indicated that observed motor behavior and temperamental activity differ in underlying etiology. These results are in line with other behavior genetic studies that suggest that etiological differences may arise as the result of varying methodological assessment for children's physical activity (e.g., Saudino & Cherny, 2001; Saudino, 2009). The two measures that were used to assess 5-year-old physical activity were presumed to be conceptually distinct from one another (i.e., observed motor behavior captured the actual amount of movement the child displayed, which differs from parent ratings of global child temperament). Parent ratings may be biased toward rating MZ twins more similarly than they are, which would inflate MZ correlations and, therefore, contribute to higher dominant genetic influences.

Taken together, these results suggest that 5-year-old physical activity is influenced more strongly by genetic effects compared to environmental influences. Given that variation in physical activity levels is influenced by individual differences (e.g., temperament), and temperament is strongly biologically based (Shiner et al., 2012), it is not surprising that genes were more salient than environmental influences. This is supported by other research indicating stronger genetic effects for physical activity (e.g., Smith et al., 2017), especially temperamental activity (Strelau & Zawadzki, 2012), which stands in contrast with studies that underscore the importance of environmental influences for physical activity in childhood (Fisher et al., 2010; 2015; Saudino, 2012; Saudino & Cherny, 2001), such as parental factors (e.g., support and encouragement of movement), the availability and/or access to equipment/facilities for exercise, and other environmental characteristics (i.e., some settings may promote, whereas others restrict, physical activity). One study examining the physical activity levels of children (age 8-13) from contemporary lifestyles versus traditional lifestyles (i.e., Amish, Mennonite) found that lower levels of physical activity were associated with the modern environment (Eslinger et al., 2010). As suggested by these results, it could be that the modern environment may not afford the level of movement that is provided by more traditional ways of living. From an evolutionary theoretical perspective, there likely exists a mismatch between the modern environment and contemporary lifestyle that humans live today in comparison to the lives of our ancestors. Although, considering the age examined in this project, it may be that environmental influences (e.g., kindergarten enrollment, participation in structured exercise activities and/or sports, engagement in daily chores) have not yet begun to alter these behaviors beyond the child’s own natural predisposition for physical activity and, therefore, genetic influences may be most salient at this developmental period.

Middle Childhood Health Outcomes

The other main objective of this project was to investigate the influence that preschoolers’ physical activity and internalizing problems, as well as the experience of stressors, have on various health-related outcomes (body-mass index, internalizing problems, and household health behaviors) at follow-up. A focus was placed on these specific indices of health because they were conceptualized to encompass both physical and mental health (body-mass index and internalizing problems, respectively), as well as assess engagement in a healthy lifestyle (household health behaviors). This conceptualization afforded a holistic assessment of health in childhood, an approach that is supported by other work emphasizing that health problems are often a combination of bodily (physical) and emotional (mental) problems (Johnson, 2017; Løhre et al., 2010; Simms et al., 2012; van Eck van der Sujis et al., 2017). By employing a multi-measure assessment of middle childhood health, my project followed this recommendation.

Body-Mass Index (BMI)

For physical health in middle childhood, the main independent variables of interest (age 5 observed motor behavior, temperamental activity, and internalizing problems) did not predict BMI in middle childhood. Similarly, no main effect for household chaos or stressful life events were found. However, follow-up socioeconomic status (SES) inversely predicted BMI. The best-fitting model indicated that children who were older, were boys, and lived in lower SES households had the highest BMI scores at follow-up. These findings emphasize the negative impact that stressors have for health outcomes (Cohen et al., 1998) and, more specifically, the risk that low SES poses for BMI (Jang et al., 2019). Above all else, importantly, they highlight the pervasive harm that poverty and/or economic hardship poses for children (Kim et al., 2017), which provides evidence in support of the socioeconomic-health gradient (i.e., health differences related to economic disparities; Adler et al., 1994; Adler, 2009).

Contrary to my hypothesis, BMI was not significantly impacted by 5-year-old physical activity or internalizing problems. These null results stand in contrast to a very robust literature that supports the benefit of movement for improving weight-related outcomes, such as decreasing BMI (Carson et al., 2017; Saunders et al., 2017). To that end, it would be informative to further investigate whether BMI moderates any associations between physical activity and health outcomes. Perhaps children with higher BMI experience difficulties with motor behaviors and, in turn, are less inclined to engage in movement. These findings also differ from the results of a different project that used 5-year-old SITSS singletons, not twins, data (but followed up at ages 12 to 20 with a completely different subsample of children than the current project) and found that internalizing problems predicted BMI (Jamnik & DiLalla, 2019). It may be that BMI was not necessarily a good indicator of overall physical health during the developmental period assessed (ages 7 to 13), given the rapid growth and development that occurs during childhood (Levine & Munsch, 2018). For example, some children may have already entered the early stages of puberty and, therefore, the measurements assessed may reflect more transitory times for children's ever-changing physiques (Santrock, 2019). Another possibility is that the current study did not have adequate power to detect significant effects, despite efforts taken to circumvent this possibility (e.g., using MLM to include all children, not just one per family). Power analyses did indicate that, for a small effect size, 787 participants were needed. A small overall effect may have been expected, given the multitude of influences that likely contribute to a multifaceted metric like BMI.

Follow-up Internalizing Problems

For mental health in middle childhood, findings demonstrated a main effect of 5-year-old internalizing problems, but not physical activity, on internalizing problems at follow-up. Above and beyond stability of internalizing across time, a main effect of stressful life events was found which highlights the negative influence that stress has on mental health (Klemfuss et al., 2018).

It was surprising that physical activity did not predict follow-up internalizing problems, given the benefit that movement offers for alleviating anxiety and decreasing depressive symptomology (Brown et al., 2013; Spruit et al., 2016). It could be that parent rater bias contributed to an inaccurate assessment of children's internalizing. Other work has shown that parent-reported internalizing problems may not accurately capture the internalizing problems that children experience (De Los Reyes et al., 2015). Indeed, using a different subsample from SITSS, another study found that parent-reported internalizing was not associated with child-reported internalizing (Jamnik & DiLalla, 2019). The null findings for 5-year-old household chaos and follow-up SES predicting to internalizing problems at follow-up may be partly explained by the heightened anxiogenic response that stressors cause in-the-moment, in comparison to the 'wear and tear' stress causes over time (McEwen, 2000). That is, in line with bioecological theory (Bronfenbrenner, 1977; Bronfenbrenner & Ceci, 1994), concurrent stressors, like stressful life events, will have a more salient impact on the child than those that are less proximate, either ecologically (e.g., SES) or temporally (e.g., household chaos).

Household Health Behaviors

To assess healthy lifestyle engagement in middle childhood, household health behaviors were examined at follow-up. Results demonstrated that boys and children with lower age 5 temperamental activity were rated as having higher engagement in health behaviors (compared to girls and children with higher temperamental activity). Although this effect is in the opposite direction from what I predicted, it seems reasonable that parents may be more inclined to promote engagement in healthy behaviors (e.g., healthy diet, increased exercise) for children that are low in temperamental activity. Put differently, temperamentally active children may be seen as being 'active enough' and, thus, not at risk for poorer health outcomes.

The lack of support for an effect of 5-year-old observational motor behavior and internalizing problems on household health behaviors was unexpected, given that the health benefits of motor behavior (Tompsett et al., 2017) and the health repercussions of internalizing problems (Herrenkohl et al., 2010; Caserta et al., 2011; Slopen et al., 2012; Woods et al., 2012) are both well-supported. These null findings stand in opposition to the psychometric evaluation of the household health behavior questionnaire (FHBS), which reported that this measure significantly related to BMI scores (Moreno et al., 2011), and previous research that found preschoolers' internalizing problems affected health behaviors in adolescence (Jamnik & DiLalla, 2019), although this latter result was found using *adolescent*-reported health behaviors at follow-up.

Considering the null findings, it is useful to remind the reader that the household health behavior score is 1) parent-reported (compared to the children themselves, parents may under or over report behavior) and 2) encompasses health behaviors across the *household* (which the parents are, theoretically, in charge of). Therefore, this measure may not actually reflect the health behaviors of the children, but, rather, might instead capture the parents' own health behaviors (and/or the idealized behaviors for their family). However, this explanation seems unlikely, considering that young children have limited autonomy over their daily routines and, thus, parents or caregivers largely determine the health behaviors of children (Pate et al., 2013). At this age, given that the parent/caregiver ultimately makes the decisions, a child's health behaviors (e.g., diet, mealtime routines) may closely mirror the behaviors of their parents; although additional research is needed to investigate whether this is supported or not. Therefore, like BMI, it seems likely that the current study was underpowered for detecting any significant effects. A construct as all-encompassing as household health behaviors may be more nuanced than expected, in which case, each predictor would likely only contribute a small effect. Hence, employing a sample size closer to 787 participants may have proven more fruitful.

Strengths

There are several strengths to the current study. For one, very little research has examined physical activity in preschoolers or younger (Schmutz et al., 2018). Having a better understanding of these behaviors in early childhood is important, given that the few studies that have investigated physical activity in young children have found differing results (e.g., Carson et al., 2017; Kuzik et al., 2017) and others suggest that these inconsistent results are likely due to the limited research examining young children (Timmons, Proudfoot, et al., 2012); therefore, focusing on 5-year-old physical activity was a major strength of this project. Relatedly, this project was also strengthened by the use a multimethod, multirater approach; that is, having employed two distinct measures across separate raters (observer and parent) to assess preschoolers' physical activity. The observational motor behavior coding scheme that I designed was both reliable and valid, and it provided an unbiased, observer rating; the use of this newly developed measure was a major benefit to the current study because it allowed for the assessment of children's *actual* motor behavior that was observed in-lab, rather than an approximation provided by the children or parents (which may be biased). In this way, this coding scheme provides an important tool for future studies to assess motor behavior engagement in childhood. Further exploring the utility of this measure in other more naturalistic settings, like on the playground or during children's free play, will be beneficial for advancing our understanding of the way contextual factors may influence physical activity levels in early life. Indeed, the current findings indicated that 34% and 28% of the variation in age 5 observed motor behavior and temperamental activity levels, respectively, were influenced by non-shared environmental factors. Exploring how the environment may encourage (or discourage) children's physical activity will offer insight into potential avenues for prevention and intervention.

Furthermore, employing a longitudinal design from age 5 to ages 7-13 to investigate health in middle childhood was particularly advantageous, given that this allowed for partial inference of causation for the significant associations between the 5-year-old predictors and follow-up health outcomes, such as the stability in internalizing problems (Hypothesis 3b) and the inverse relationship found between age 5 temperamental activity and follow-up health behaviors (Hypothesis 3c). Like the multimethod assessment of physical activity, the use of several different indices of health was a major strength of this project because it afforded a thorough assessment of children's health, both physically and mentally.

Finally, and most importantly, another strength of this study was the use of a twin design. By employing a twin methodology and behavioral genetic approach, this design allowed me to assess the relative contribution of genetic and environmental influences of preschoolers' physical activity. Examining the underlying etiology of these behaviors provides insight into whether genes or the environment are a more salient influence for 5-year-old physical activity; information that will be useful for guiding prevention and intervention work. Although the current findings demonstrate that 5-year-old observed motor behavior and temperamental activity were both most strongly influenced by genetic effects (additive and dominant genetic effects, respectively), the results also highlight that a significant proportion of these behaviors were affected by non-shared environmental influences (34% and 28%, respectively).

Limitations

Aside from age 5 observed motor behavior and follow-up BMI (only for the THAnx subsample, n = 93, given the current follow-up subsample did not include objective height/weight measurements), a major limitation of the current project surrounded the use of parent-report questionnaires to assess the variables of interest. Because these other measures were reported by the parents, they may have been subject to rater bias and may not reflect an accurate portrayal of the measures assessed. Therefore, it would have been beneficial to collect child reports of these variables. This recommendation is especially true for the three measures of stress (household chaos, SES, and stressful life events) that were employed, given that the children are the individuals who *experience* these environmental factors. It is important to consider the child's *perceptions* of stress because children actively influence the construction of their perceived environment (Piaget, 1954; Scarr, 1992). Thus, parents may have reported a more or less stressful environment than what the child experienced. However, given that children were only 9 years old, on average, at follow-up, they would likely have a less accurate understanding of the environmental stressors in this study (e.g., SES and stressful life events) and, therefore, employing parent-report for the current study was appropriate. It may be that the current study did not measure the stressors that are most relevant for young children and, therefore, further investigation into other measures of stress is warranted (e.g., parental factors, family dynamics).

Another issue for the current study is that it was underpowered to detect small effect sizes, which may have been expected given how multifaceted and multiply determined certain outcome measures likely are (e.g., BMI and household health behaviors). Despite this, however, I did find a significant effect for follow-up SES on concurrent BMI and age 5 temperamental activity predicting follow-up health behaviors. The use of multilevel models provided a beneficial approach to help mitigate this limitation (i.e., by allowing for the analysis of both twins in the sample). Given that the power analysis indicated that a sample closer to 800 would have allowed for the ability to detect small effects sizes (δ = 0.20) and the current follow-up subsample only included 132 children, it seems likely that power was an issue here. Additionally, the trending association between observed motor behavior and temperamental activity that was in the direction hypothesized (i.e., higher reported temperamental activity, greater observed motor behavior) was likely affected by sample size; that is, albeit marginal, the association between each measure of physical activity levels was a small effect size (r = .12 - .15); thus, a larger sample might have provided the power necessary to elucidate this finding.

Future Directions

This study provides a necessary contribution to help supplement the current literature, given the paucity of research examining physical activity in young children and, most alarmingly, the few studies investigating the influence that these behaviors have for health outcomes in early childhood (Cliff et al., 2017; Schmutz et al., 2018; Timmons, Proudfoot, et al. 2012). Additionally, this project offers several interesting directions for future research to investigate. It will be particularly fruitful to further examine the observational coding scheme and various predictors/outcomes that may relate to children's observed motor behavior. Given that current trends indicating engagement in physical activity and motor behavior may not be sufficient for recommended guidelines, using this newly developed methodological tool offers an important contribution for additional investigation into early life physical activity levels. Likewise, employing the other factors from this measure, particularly observed sedentary behavior, offers an interesting route for future work to explore. A robust literature highlights the benefits of movement for health outcomes, as well as underscores the health consequences that accompany greater sedentariness (e.g., Pate, Lau, et al., 2015). Investigating whether the level of physical activity or the amount of sedentary behavior an individual engages in is most salient for health outcomes will be interesting to explore further. It could be that excess sedentary behavior is more costly for health than an inadequate amount of physical activity. If the foundation for good health can be laid early in life (Halfon et al., 2018), promoting healthy lifestyle behaviors in children offers a fruitful direction for prevention and intervention work focused on improving health outcomes (Bremer & Cairney, 2018). It is therefore important to further investigate the associations among health behaviors and outcomes, especially in young children (e.g., preschoolers).

Furthermore, it would be interesting to further examine the correlations found among observed motor behavior, temperamental activity, and ADHD symptoms. The current findings indicate that greater 5-year-old observed motor behavior and temperamental activity predict higher ADHD symptomology at age 5. Conducting analyses that either include, or control for, children's temperamental effortful control may help to further elucidate these associations. That is, perhaps the shared commonality among these measures simply reflects the *hyper*activity component of ADHD, rather than any sort of attentional difficulties the child may have; including effortful control may help capture this distinction.

More broadly, it would also be beneficial for future work to consider how individual differences, such as temperament, may affect the variables and associations under investigation. Temperament is a broad construct, which features distinct higher-order factors (negative affectivity, extraversion/surgency, effortful control), as well more specific subcomponents (e.g., adaptability, biological rhythmicity, behavioral inhibition, low- and high-intensity pleasure). Investigating how individual differences, such as temperamental adaptability and inhibition, may affect children's observed behavior would be an interesting avenue to explore further. Additionally, examining how health outcomes may be differentially influenced by individual differences is an important endeavor for future studies. It seems reasonable to hypothesize that children who differ in temperamental rhythmicity may have different outcomes due to underlying biological differences. Exploring the way these individual differences may contribute to variation in health behaviors or health outcomes will be important to investigate further.

Despite this project's thorough examination of stress using factors across various levels of influence, per bioecological theory (Bronfenbrenner, 1977), such as household-level (age 5 household chaos), family-level (follow-up stressful life events), and community-level (SES), only a couple of main effects of stress on health outcomes were seen. Although significant results were found for follow-up SES and stressful life events (predicting to concurrent BMI and internalizing problems, respectively), it was unexpected that age 5 household chaos did not significantly impact health outcomes in middle childhood. Other work has demonstrated that, after controlling for SES disparities, greater household chaos was related to poorer health outcomes (Coley et al., 2015; Kamp Dush et al., 2013). To this end, it may be informative to examine the potential interactive effects among stressors, given that the accumulation of stress (i.e., the 'wear and tear') may be most detrimental (McEwen, 2000). It certainly seems plausible that families who experience high stress, whether due to high household chaos, low SES, or a higher occurrence of stressful life events, would be less likely to participate in research than families who did not experience these stressors. However, this was not true; comparing participating families to non-participating families, no significant differences were found. Furthermore, families included in this project displayed a wide range of stress, from very low to relatively high (see Table 2).

As mentioned above, it might be that children did not *perceive* these factors to be as stressful as predicted (or as experienced by the parents) and, therefore, were relatively unaffected by these experiences. It is also possible that, despite the parent's perceptions of the stressors experienced, families in the current study provided a "good enough" environment for their children (Scarr, 1992); in other words, evolution has provided humans with a certain robustness and ability to adapt that, unless great perturbations occur, species-typical development takes place across a wide range of genotypic and environmental landscapes (Gottlieb, 1991). That said, stressors pose a pervasive threat to health throughout the lifespan (NIHM, 2019) and, therefore, continued investigation into other potential stress-related environmental risk factors that may potentially contribute to health outcomes, as well as assessing the child's *perceptions* of these experiences, is greatly important for future studies.

Implications

The current project provides several important implications that offer practical takeaways for real-world settings. For one, the biometric analyses indicated that both measures of 5-year-old physical activity were more strongly influenced by underlying genetic effects compared to environmental influences and, additionally, that environmental influences were attributable to non-shared, rather than shared, factors. It is useful to keep this second point in mind, given it suggests that idiosyncratic factors that are unique to the child are more salient contributors to differences in physical activity than household-/family-level factors that are shared among twins; prevention and intervention work that is tailored to the specific child may provide the most fruitful avenue for treatment approaches. Considering that individualized treatment catered to every child may not be possible for a variety of reasons (e.g., cost, time), it might also be useful to expand the application of this 'individualized' approach to groups of individual children who share similar characteristics (e.g., children who all endorse not enjoying sports). That is, by grouping similar children together, the benefits afforded by individual-level assessment could be utilized in combination with application at the group-level. Furthermore, when taken together, the analyses suggest that several different factors across differing systems of influence (e.g., child-, family-, and community-level) contribute to health outcomes in childhood, which is useful information for both professionals working with children (e.g., developmental researchers, pediatricians, clinicians, teachers) and other non-professionals, like parents and caregivers. A strong theoretical foundation supports the use of a multilevel approach to study both child development (Bronfenbrenner & Ceci, 1994) and the development of health across the lifespan (Halfon, Forrest, & Wise, 2014).

Specifically, the current findings indicated that low SES (community-level), high stressful life events (family-level), and high temperamental activity (child-level) related to poorer health outcomes in middle childhood (high BMI, high internalizing problems, and low household health behaviors, respectively). This information is applicable for child-care professionals and non-professionals alike because it both underscores the need to be conscientious of factors at the family-level (e.g., the experience of stressful life events) and highlights the broader impact that systemic disparities, like SES, have on differences in health outcomes (e.g., socioeconomic-health gradient; Adler, 2009). Steps need to be taken to address these systemic issues and decrease the widening economic gap; however, policy change is difficult and takes time. Therefore, focusing on factors at the family-level, like stressful life events, may offer a particularly fruitful direction for prevention and intervention work.

Conclusion

The current project sought to examine the impact of genetic effects and environmental influences on the emergence of 5-year-old physical activity, using both a behavioral and temperamental conceptualization. By employing a twin design and behavioral genetic approach, the underlying etiology of observer-rated motor behavior and parent-reported temperamental activity levels could be assessed. Furthermore, a longitudinal design was used to investigate the relationship between indices of preschoolers' physical and mental health and various health outcomes assessed at follow-up during middle childhood (ages 7 to 13). The health outcomes examined here were selected because they were conceptualized as providing a proxy for children's physical and mental health (body-mass index and internalizing problems), as well as reflect engagement in a healthy lifestyle (household health behaviors). Furthermore, as part of this longitudinal component, analyses also included three different stressors (age 5 household chaos, follow-up socioeconomic status, and follow-up stressful life events) that reflected three distinct levels of influence (household-, family-, and community-level), which were important to consider given the pervasive risk that stress poses to health (NIHM, 2019). Together, the utilization of this multimethodological approach afforded the current project the ability to thoroughly assess an important health behavior, like physical activity, as well as investigate indices of physical and mental health across childhood (i.e., from age 5 to ages 7-13).

Several important takeaways for the current study were provided by the results. First, and most importantly, the observational coding scheme that was designed for this project was found to be both reliable and valid. Future studies that employ this measure will provide important insights into motor behavior and sedentary behavior in early childhood, an area that would greatly benefit from additional work. Additionally, results from the biometric analyses revealed that preschoolers' physical activity is more strongly influenced by underlying genetic factors than by environmental influences. Specifically, additive genetic effects accounted for a large proportion of the variance in age 5 observed motor behavior (66%; non-shared environmental influences: 34%) and variation in 5-year-old temperamental activity was largely attributable to dominant genetic effects (72%; non-shared environmental influences: 28%). These findings emphasize the biological basis of physical activity and, also, highlight the environmental component as well (albeit to a lesser extent). Together, the results illustrate that the etiology of preschoolers' physical activity arises from a combination of both genetic and environmental factors (and may even differ depending on the measure employed). Finally, important insights into health across childhood are offered by the longitudinal analyses. For body-mass index, a significant effect of age at follow-up, child sex, and follow-up socioeconomic status was found; the latter finding may be of most interest because it indicates that socioeconomic disparities contribute to disparities in health (i.e., lower SES related to higher BMI). For internalizing problems at follow-up, findings indicated a significant effect of 5-year-old internalizing problems and stressful life events at follow-up; this speaks to the stability in internalizing problems over time, which underscores the benefit of early intervention work for preventing later difficulties, and also highlights the risk that excess stressors pose for health (Cohen et al., 1998; McEwen, 2000). Finally, for household health behaviors, child sex and 5-year-old temperamental activity were found to significantly predict engagement in health behaviors at follow-up. In sum, a complex constellation of factors across various levels of influence contribute to health outcomes in middle childhood.

Table 1

Descriptive Statistics for Full Age 5 Sample (n = 302)

Variable	**Mean**	**SD**	**N**	**Min**	**Max**	**Skewness**	**Kurtosis**
Child Sex (133 boys, 169 girls; 44% and 56%)			302				
Zygosity (106 MZ, 196 DZ; 35.4% and 64.6%)			302				
PC-INT Observed Motor Behavior (Age 5)	0.00	0.90	300	-1.30	4.40	2.35	6.11
BSQ Temperamental Activity Levels (Age 5)	3.78	0.70	294	2	5.85	0.10	-0.08
CBCL Internalizing Problems (Age 5)	3.48	4.19	296	0	24	2.02	4.48
CBCL ADHD Symptoms (Age 5)	2.73	2.94	296	0	13	1.17	0.85

Note. PC-INT = Parent-Child Interaction; BSQ = Behavioral Style Questionnaire; CBCL = Child Behavior Checklist.

Table 2

Descriptive Statistics for Follow-up Sample (n = 132)

Variable	Mean	SD	N	Min	Max	Skewness	Kurtosis
Age of Follow-up Testing	9.31	1.98	132	7	13	0.56	-0.94
Child Sex (51 boys, 81 girls)			132				
Zygosity (54 MZ, 78 DZ)			132				
PC-INT Observed Motor Behavior (Age 5)	-0.09	0.85	130	-1.30	3.79	2.38	6.15
BSQ Temperamental Activity Levels (Age 5)	3.72	0.69	130	2	5.77	0.41	0.36
CBCL Internalizing Problems (Age 5)	3.75	4.26	132	0	24	1.84	3.24
CBCL ADHD Symptoms (Age 5)	2.62	2.84	132	0	13	1.39	1.82
Household Chaos (Age 5)	38.89	9.42	132	22	65	0.47	0.04
Socioeconomic Status (Follow-up)	-0.05	0.64	132	-1.30	1.32	0.05	-0.51
Stressful Life Events (Follow-up)	167.49	161.13	128	0	1,095	3.21	15.8
Body-mass Index (Follow-up) [a]	19.20	5.07	127	9.82	41.59	1.23	2.78
Transformed Body-mass Index	4.35	0.55	127	3.13	6.45	0.75	1.16
CBCL Internalizing Problems (Follow-up) [a]	5.60	6.32	130	0	31	1.99	4.68
Transformed Follow-up Internalizing	1.99	1.29	130	0	5.57	0.48	0.04
CBCL ADHD Symptoms (Follow-up)	2.97	3.38	130	0	14	1.41	1.22
Household Health Behaviors (Follow-up)	66.55	9.22	131	40	91	-0.14	0.09

[a] Positively skewed

Note. PC-INT = Parent-Child Interaction; BSQ = Behavioral Style Questionnaire; CBCL = Child Behavior Checklist.

Table 3

MANOVA Comparing THAnx Follow-up to the Current Follow-up

	Random Subsample 1 (THAnx: *n* = 43; Current Follow-up: *n* = 14)			Random Subsample 2 (THAnx: *n* = 43; Current Follow-up: *n* = 16)		
	F	*p*	Partial Eta^2	*F*	*p*	Partial Eta^2
Age 5 PC-INT MB	0.65	0.425	0.01	0.00	0.992	0.00
Age 5 BSQ	0.10	0.749	0.00	1.14	0.289	0.02
Age 5 CBCL Int	0.47	0.495	0.01	0.68	0.415	0.01
Age 5 SES	0.23	0.636	0.00	0.12	0.728	0.00
Age 5 CHAOS	0.64	0.427	0.01	0.43	0.515	0.01
Follow-up BMI	0.09	0.766	0.00	0.44	0.512	0.01
Follow-up LifeEvents	1.84	0.181	0.03	0.82	0.369	0.01
Follow-up SES	0.35	0.559	0.01	0.29	0.591	0.01

Note. One twin from each family was randomly selected for analyses. PC-INT MB = Observed Motor Behavior; BSQ = Temperamental Activity; CBCL Int = Internalizing Problems; SES = Socioeconomic Status; CHAOS = Household Chaos; BMI = Body-mass Index; LifeEvents = Stressful Life Events.

Overall Model for Random Subsample 1: $F(8, 48) = 0.55$, $p = .815$, Wilks' $\lambda = 0.92$, partial eta^2 = 0.08.

Overall Model for Random Subsample 2: $F(8, 50) = 0.51$, $p = .846$, Wilks' $\lambda = 0.93$, partial eta^2 = 0.08.

Table 4

MANOVA Comparing the Full Age 5 Sample to the Follow-up Subsample

	Random Subsample 1 (Age 5 Only: *n* = 79; Follow-up: *n* = 63)			Random Subsample 2 (Age 5 Only: *n* = 79; Follow-up: *n* = 64)		
	F	*p*	Partial Eta^2	*F*	*p*	Partial Eta^2
Age 5 PC-INT MB	0.98	0.324	0.01	1.69	0.196	0.01
Age 5 BSQ	0.20	0.656	0.00	1.31	0.254	0.01
Age 5 CBCL Int	0.76	0.385	0.01	0.00	0.998	0.00
Age 5 SES	1.35	0.248	0.01	0.99	0.322	0.01
Age 5 CHAOS	0.12	0.731	0.00	0.29	0.593	0.00

Note. One twin from each family was randomly selected for analyses. PC-INT MB = Observed Motor Behavior; BSQ = Temperamental Activity; CBCL Int = Internalizing Problems; SES = Socioeconomic Status; CHAOS = Household Chaos.

Overall Model for Random Subsample 1: $F(5, 120) = 0.70$, $p = 0.622$, Wilks' $\lambda = 0.97$, partial $eta^2 = 0.03$.

Overall Model for Random Subsample 2: $F(5, 123) = 0.63$, $p = 0.680$, Wilks' $\lambda = 0.98$, partial $eta^2 = 0.03$.

Table 5

Reliability Scores for the Observational Motor Behavior Coding Measure

	Observational Physical Activity		
Coder	Spatial Movement	Activity Rating	Variability: Motor Behavior
Test-retest: Matt	0.95	0.93	0.96
Test-retest: Undergrad #1	0.93 (0.99)	0.92 (0.99)	0.97 (0.95)
Test-retest: Undergrad #2	0.91 (0.90)	0.93 (0.95)	0.93 (0.94)
Inter-rater	0.95 (0.89)	0.98 (0.98)	0.97 (0.88)

Note. Scores that are listed in parentheses reflect the final reliability check conducted at the completion of coding.

Table 6

Factor Loadings and Communalities Based on a Principal Components Analysis with Oblimin Rotation for 7 Items from the Observational Motor Behavior Coding Scheme (Full Age 5 Sample; n = 302)

	Random Subsample 1 (*n* = 149)				Random Subsample 2 (*n* = 149)			
Items	Factor 1: Motor Behavior	Factor 2: Sedentary Behavior	Factor 3: Postural Shift	Communalities	Factor 1: Motor Behavior	Factor 2: Sedentary Behavior	Factor 3: Postural Shift	Communalities
Spatial Movement	0.97			0.94	0.94			0.89
Activity Rating	0.96			0.93	0.96			0.92
Posture: Stand	0.90			0.84	0.85			0.77
Variability: Motor Behavior	0.86			0.77	0.85			0.72
Posture: Sit/Squat		0.95		0.93		0.93		0.92
Posture: Lie down		-0.96		0.94		-0.98		0.92
Shift (Position)			0.99	0.98			0.99	0.98

Note. One twin from each family was randomly selected. Factor loadings < 0.40 are suppressed.

Table 7

Descriptive Statistics for the Three Observed Motor Behavior Factors (Full Age 5 Sample; n = 302)

	Random Subsample 1 (*n* = 149)					Random Subsample 2 (*n* = 149)				
Factors	# of items	*M* (*SD*)	Skewness	Kurtosis	Cronbach's α	# of items	*M* (*SD*)	Skewness	Kurtosis	Cronbach's α
Motor Behavior	4	2.73 (0.99)	2.43	6.07	.90	4	2.71 (0.86)	2.28	6.66	.90
Sedentary Behavior	2	1.81 (0.32)	-2.59	8.61	.89	2	1.82 (0.31)	-2.73	9.80	.89
Postural Shift	1	0.30 (0.17)	0.58	-0.17	-	1	0.29 (0.18)	0.28	-0.76	-

Note. One twin from each family was randomly selected for analyses.

Table 8

Family Demographic Information

Variable	Time 1 (Age 5)			Time 2 (Follow-up; Ages 7-13)			Comparison: Time 1 vs. Time 2
	Minimum	Maximum	Mode	Minimum	Maximum	Mode	
Mothers' Education	1	5	4	2	5	4	
Mothers' Occupation	1	7	6	1	6	2	
Fathers' Education	1	5	2	2	5	2	
Fathers' Occupation	1	7	3	1	7	3	
Household Annual Income	Less than $5k	Over $90k	$55 – 65k	$10 – 15k	Over $90k	Over $90k	
Overall Socioeconomic Status	-1.48	1.43	*M* = -0.04, *SD* = 0.69	-1.30	1.32	*M* = -0.05, *SD* = 0.64	Random Subsample 1 Time 1: *M* = -0.03, *SD* = 0.70 Time 2: *M* = -0.05, *SD* = 0.65 Random Subsample 2 Time 1: *M* = -0.04, *SD* = 0.69 Time 2: *M* = -0.05, *SD* = 0.64

Note: Rating scales: maternal/paternal education (1 = *some high school* to 5 = *advanced degree beyond college degree*); maternal/paternal occupation (1 = *unskilled laborer* to *8 = high level professional*). A paired samples *t*-test was used to compare the overall SES across Time 1 and Time 2, using one child randomly selected from each family. No significant differences were found. Random Subsample 1: $t(62) = 0.47$, $p = .641$, $\delta = 0.34$; Random Subsample 2: $t(62) = 0.36$, $p = .718$, $\delta = 0.34$.

Table 9

Bivariate Correlation Table for Stress Measures for Follow-up Sample (n = 132)

	1.	2.	3.	4.
1. Age 5 CHAOS	--	-0.12	-0.15	0.07
2. Age 5 SES	-0.12	--	0.88***	-0.31*
3. Follow-up SES	-0.15	0.87***	--	-0.34**
4. Follow-up Stressful Life Events	0.06	-0.30*	-0.33**	--

* p < .05; ** p < .01; *** p < .001.

Note. Random Subsample 1 (above diagonal) and Random Subsample 2 (below diagonal).

Table 10

MANOVA Examining Potential Zygosity Differences in Observed Motor Behavior and Parent-Reported Temperamental Activity

	Random Subsample 1 (MZ: *n* = 51; DZ: *n* = 92)				Random Subsample 2 (MZ: *n* = 51; DZ: *n* = 93)			
	Wilks' Lambda	F	p	Partial Eta^2	Wilks' Lambda	F	p	Partial Eta^2
Overall Model	0.99	F (2, 140) = 0.68	0.510	0.01	0.96	F (2, 141) = 2.83	0.059	0.04

Note. One twin from each family was randomly selected for analyses. The Full Age 5 sample (*n* = 302) was used for analyses, given the variables of interest were collected at age 5. Variables included in MANOVA analysis were Age 5 Observed Motor Behavior and Age 5 Temperamental Activity. MZ = monozygotic; DZ = dizygotic.

Table 11

MANOVA Examining Potential Sex Differences in Physical Activity and Internalizing Problems at Age 5

	Random Subsample 1 (Boys: *n* = 67; Girls: *n* = 75)			Random Subsample 2 (Boys: *n* = 60; Girls: *n* = 83)		
	F	*p*	Partial Eta^2	*F*	*p*	Partial Eta^2
Age 5 PC-INT MB	0.19	0.662	0.00	0.63	0.428	0.00
Age 5 BSQ	**17.09**	**< 0.001**	**0.11**	**13.40**	**< 0.001**	**0.09**
Age 5 CBCL Int	0.02	0.887	0.00	0.21	0.645	0.00

Note. One twin from each family was randomly selected for analyses. The Full Age 5 sample (*n* = 302) was used for analyses, given the variables of interest were collected at age 5. Significant results are bolded. PC-INT MB = Observed Motor Behavior; BSQ = Temperamental Activity; CBCL Int = Internalizing Problems.

Overall Model for Random Subsample 1: $F(3, 138) = 5.63$, $p = .001$, Wilks' $\boldsymbol{\lambda} = 0.89$, partial eta^2 = 0.11.

Overall Model for Random Subsample 2: $F(3, 139) = 4.49$, $p = .005$, Wilks' $\boldsymbol{\lambda} = 0.91$, partial eta^2 = 0.09.

Table 12

Bivariate Correlation Table for Full Age 5 Sample (n = 302)

	1.	2.	3.	4.	5.	6.
1. PC-INT MB	--	-0.29***	0.09	0.12	0.02	0.19*
2. PC-INT SB	-0.23**	--	0.24**	0.01	0.05	0.04
3. PC-INT PS	-0.03	0.03	--	-0.01	0.05	0.00
4. BSQ Activity	0.15	-0.02	0.08	--	0.07	0.49***
5. CBCL Int	-0.00	-0.10	-0.00	0.03	--	0.44***
6. CBCL ADHD	0.22**	-0.01	0.08	0.56***	0.36***	--

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

Note. Random Subsample 1 (above diagonal) and Random Subsample 2 (below diagonal). PC-INT MB = Age 5 Observed Motor Behavior; PC-INT SB = Age 5 Observed Sedentary Behavior; PC-INT MB = Age 5 Observed Postural Shift; BSQ Activity = Age 5 Temperamental Activity; CBCL Int = Age 5 Internalizing Problems; CBCL ADHD = Age 5 Attention-Deficit / Hyperactivity Disorder Symptoms.

Table 13

Intraclass Correlation Coefficients Among Monozygotic (MZ) and Dizygotic (DZ) Twins for the Full Age 5 Sample (n = 302 children; n = 158 pairs)

	MZ (n = 57)	DZ (n =101)
PC-INT MB	0.76 (p < .001)	0.20 (p = .023)
BSQ Activity	0.69 (p < .001)	-0.07 (p = .746)

Note. For dizygotic twins, in the interest of power, same-sex (SSDZ) and opposite-sex (OSDZ) pairs were both retained in the sample together as one DZ group. PC-INT MB = Age 5 Observed Motor Behavior; BSQ = Age 5 Temperamental Activity.

Table 14

Model Fit Statistics and Estimates for Age 5 Observed Motor Behavior

	Standardized Path Estimates				Model Fit Indices		
Model	A	C	D	E	-2ln(L) (df)	RMSEA [95% CI]	AIC
ADE	.33		.34	.33	778.40 (311)	.14 [.07; .21]	786.40
AE	**.66**			**.34**	**778.96 (312)**	**.12 [.06; .19]**	**784.96**
E				1.00	833.09 (313)	.24 [.19; .28]	837.09

Note. Best model in bold. The Full Age 5 sample (*n* = 302 children; *n* = 158 pairs) was used for analyses.

Table 15

Model Fit Statistics and Estimates for Age 5 Temperamental Activity

	Standardized Path Estimates				Model Fit Indices		
Model	A	C	D	E	-2ln(L) (df)	RMSEA [95% CI]	AIC
ADE	**.00**		**.72**	**.28**	**609.05 (304)**	**.00 [.00; .17]**	**617.05**
AE	.61			.39	621.84 (305)	.13 [.07; .20]	627.84
E				1.00	640.52 (306)	.17 [.11; .23]	644.52

Note. Best model in bold. The Full Age 5 sample (*n* = 302 children; *n* = 158 pairs) was used for analyses.

Table 16

Bivariate Correlation Table for Follow-up Sample (n = 132)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Follow-up Age	--	-0.03	0.01	0.01	-0.05	0.02	0.00	-0.06	0.18	0.33*	-0.10	-0.15
2. Child Sex	-0.03	--	0.18	0.22	0.07	0.07	0.00	-0.02	-0.21	0.25	-0.12	-0.07
3. Zygosity	0.03	0.20	--	-0.05	0.14	0.05	0.03	-0.15	0.07	0.20	-0.06	-0.16
4. PC-INT MB	-0.27*	0.02	-0.03	--	0.08	0.08	0.27*	-0.09	0.03	-0.04	-0.05	-0.02
5. BSQ Activity	-0.09	0.18	-0.03	0.21	--	0.14	0.23	0.04	0.02	0.04	-0.00	-0.22
6. CBCL Int	0.03	0.04	0.28*	0.08	0.10	--	0.12	-0.27*	0.38**	0.07	0.63***	-0.29*
7. CHAOS	-0.01	0.15	0.03	0.02	0.18	0.08	--	-0.15	0.07	-0.11	-0.03	-0.30*
8. SES	-0.06	0.05	-0.17	-0.17	-0.17	-0.16	-0.15	--	-0.34*	-0.27*	-0.17	0.22
9. LifeEvents	0.17	-0.30*	0.04	0.05	-0.07	0.45***	0.06	-0.33**	--	0.06	0.48***	-0.22
10. BMI	0.39*	0.17	0.11	-0.01	-0.06	-0.15	-0.01	-0.23	-0.04	--	-0.13	-0.27*
11. IntFollow-up	-0.02	-0.10	0.02	0.12	0.06	0.68***	0.16	-0.07	0.37**	-0.16	--	-0.27*
12. FHBS	-0.17	-0.12	-0.03	-0.02	-0.35**	-0.26*	-0.23	0.17	-0.28*	-0.17	-0.33*	--

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

Note. Random Subsample 1 (above diagonal) and Random Subsample 2 (below diagonal). Correlations for child sex and zygosity are nonparametric Spearman's rho. All information in this table is for untransformed variables. PC-INT MB = Age 5 Observed Motor Behavior; BSQ Activity = Age 5 Temperamental Activity; CBCL Int = Age 5 Internalizing Problems; CHAOS = Age 5 Household Chaos; SES = Follow-up Socioeconomic Status; LifeEvents = Follow-up Stressful Life Events; BMI = Body-mass Index; IntFollow-up = Follow-up Internalizing Problems; FHBS = Follow-up Household Health Behaviors.

Table 17

MLM Regression Modeling Parameter Estimates Predicting Follow-up BMI

n = 127	Model 1	Model 2	Model 3	Model 4 Best Fit	Model 5
	Estimate	Estimate	Estimate	Estimate	Estimate
<u>Fixed Effects</u>					
Intercept	4.35 (.05)***	4.35 (.05)***	4.35 (.05)***	4.36 (.05)***	4.36 (.06)***
Follow-up Age	0.09 (.03)**	0.10 (.03)**	0.10 (.03)**	0.10 (.03)**	0.10 (.03)**
Child Sex	0.17 (.09)	0.19 (.10)*	0.19 (.09)*	0.20 (.10)*	0.20 (.10)*
Zygosity	0.13 (.11)	0.13 (.11)	0.13 (.11)	0.11 (.11)	0.11 (.11)
Age 5 PC-INT MB		0.03 (.05)	0.03 (.05)	0.03 (.05)	0.03 (.05)
Age 5 BSQ Activity		-0.05 (.06)	-0.04 (.06)	-0.06 (.06)	-0.06 (.06)
Age 5 CBCL Int		-0.00 (.01)	-0.00 (.01)	-0.00 (.01)	-0.00 (.01)
Age 5 CHAOS			-0.00 (.01)	-0.00 (.01)	-0.00 (.01)
Follow-up SES				-0.22 (.09)*	-0.22 (.09)*
Follow-up Stressful Life Events				-0.00 (.00)	-0.00 (.00)
Sex X Age 5 BSQ Activity					-0.04 (.12)
<u>Random Effects</u>					
Residual	0.13 (.02)***	0.13 (.02)***	0.13 (.02)***	0.13 (.02)***	0.13 (.02)***
Within-family effect	0.12 (.04)**	0.13 (.04)**	0.12 (.04)**	0.11 (.04)**	0.11 (.04)**
-2LL (df)	166.03 (6)	163.57 (9)	163.32 (10)	153.34 (12)	153.23 (13)
AICc	178.73	183.16	185.28	180.26	182.67

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

Note. AICc (Hurvich & Tsai, 1989) = AIC + [2 k(k + 1)/(n – k - 1)], where k = number of estimated parameters and n = sample size. Model 4 was the best fitting model, with the lowest AICc value and a significantly better fitting chi-square than other models. PC-INT MB = Age 5 Observed Motor Behavior; BSQ Activity = Age 5 Temperamental Activity Levels; CBCL Int = Age 5 Internalizing Problems; CHAOS = Household Chaos; SES = Socioeconomic Status

Table 18

MLM Regression Modeling Parameter Estimates Predicting Follow-up CBCL Internalizing

n = 130	Model 1	Model 2	Model 3	Model 4	Model 5 Best Fit	Model 6
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
Fixed Effects						
Intercept	1.98 (.15)***	2.01 (.11)***	2.01 (.11)***	2.00 (.11)***	1.97 (.11)***	1.96 (.11)***
Follow-up Age	-0.08 (.07)	-0.08 (.06)	-0.08 (.06)	-0.07 (.06)	-0.08 (.06)	-0.08 (.06)
Child Sex	-0.16 (.20)	-0.29 (.19)	-0.29 (.19)	-0.18 (.19)	-0.11 (.18)	-0.12 (.17)
Zygosity	-0.06 (.27)	-0.19 (.22)	-0.19 (.22)	-0.23 (.22)	-0.23 (.21)	-0.23 (.21)
Age 5 PC-INT MB		0.05 (.10)	0.05 (.10)	0.07 (.10)	0.04 (.10)	0.03 (.10)
Age 5 BSQ Activity		-0.06 (.12)	-0.06 (.12)	-0.05 (.12)	-0.09 (.16)	-0.13 (.16)
Age 5 CBCL Int		0.14 (.02)***	0.14 (.02)***	0.13 (.02)***	0.14 (.02)***	0.14 (.02)***
Age 5 CHAOS			-0.00 (.01)	-0.01 (.01)	-0.01 (.01)	-0.01 (.01)
Follow-up SES				0.11 (.19)	0.23 (.19)	0.23 (.19)
Follow-up Stressful Life Events				0.00 (.00)*	0.00 (.00)*	0.00 (.00)*
Sex X Age 5 BSQ Activity						0.33 (.25)
Random Effects						
Residual	0.49 (.09)***	0.48 (.09)***	0.48 (.09)***	0.46 (.08)***	0.31 (.08)***	0.31 (.08)***
Within-family effect	1.13 (.25)***	0.58 (.16)***	0.58 (.16)***	0.54 (.15)***	0.49 (.14)**	0.48 (.14)**
Random slopes: BSQ Activity					0.45 (.29)	0.46 (.30)
-2LL (df)	387.50 (6)	342.42 (9)	342.33 (10)	326.99 (12)	320.61 (13)	318.86 (14)
AICc	400.18	361.97	364.24	353.82	349.95	350.75

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

Note. AICc (Hurvich & Tsai, 1989) = AIC + [2 k(k + 1)/(n – k - 1)], where k = number of estimated parameters and n = sample size. Model 5 was the best fitting model, with the lowest AICc value and a significantly better fitting chi-square than other models. PC-INT MB = Age 5 Observed Motor Behavior; BSQ Activity = Age 5 Temperamental Activity Levels; CBCL Int = Age 5 Internalizing Problems; CHAOS = Household Chaos; SES = Socioeconomic Status

Table 19

MLM Regression Modeling Parameter Estimates Predicting Follow-up Household Health Behaviors

n = 131	Model 1	Model 2	Model 3	Model 4	Model 5 Best Fit	Model 6
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
Fixed Effects						
Intercept	66.55 (1.07)***	66.42 (1.04)***	66.38 (1.02)***	66.49 (1.03)***	66.45 (1.03)***	66.42 (1.04)***
Follow-up Age	-0.76 (.54)	-0.79 (.53)	-0.80 (.52)	-0.69 (.52)	-0.64 (.53)	-0.65 (.53)
Child Sex	1.02 (1.19)	2.81 (1.07)*	2.80 (1.06)*	2.70 (1.08)*	3.06 (1.05)**	3.05 (1.05)**
Zygosity	-2.24 (1.87)	-2.03 (1.77)	-1.92 (1.74)	-1.38 (1.77)	-1.64 (1.72)	-1.66 (1.72)
Age 5 PC-INT MB		0.48 (.57)	0.53 (.57)	0.68 (.58)	0.65 (.56)	0.64 (.56)
Age 5 BSQ Activity		-3.63 (.65)***	-3.56 (.65)***	-3.67 (.66)***	-3.12 (.79)***	-3.34 (.81)***
Age 5 CBCL Int		-0.26 (.14)	-0.24 (.14)	-0.19 (.14)	-0.18 (.14)	-0.17 (.14)
Age 5 CHAOS			-0.19 (.11)	-0.18 (.11)	-0.20 (.11)	-0.20 (.11)
Follow-up SES				1.00 (1.76)	0.90 (1.77)	0.90 (1.76)
Follow-up Stressful Life Events				-0.01 (.01)	-0.01 (.01)	-0.01 (.01)
Sex X Age 5 BSQ Activity						0.64 (1.29)
Random Effects						
Residual	15.26 (2.67)***	10.90 (1.95)***	10.89 (1.95)***	10.90 (1.96)***	8.47 (1.81)***	8.53 (1.82)***
Within-family effect	70.00 (13.25)***	62.54 (12.36)***	59.61 (11.81)***	59.00 (11.87)***	59.37 (12.09)***	59.35 (12.08)***
Random slopes: BSQ Activity					5.63 (4.21)	5.27 (4.13)
-2LL (df)	876.93 (6)	822.69 (9)	819.81 (10)	799.30 (12)	795.16 (13)	794.93 (14)
AICc	889.61	842.23	841.71	826.11	824.47	826.78

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

Note. AICc (Hurvich & Tsai, 1989) = AIC + [2 k(k + 1)/(n – k - 1)], where k = number of estimated parameters and n = sample size. Model 5 was the best fitting model, with the lowest AICc value and a significantly better fitting chi-square than other models. PC-INT MB = Age 5 Observed Motor Behavior; BSQ Activity = Age 5 Temperamental Activity Levels; CBCL Int = Age 5 Internalizing Problems; CHAOS = Household Chaos; SES = Socioeconomic Status

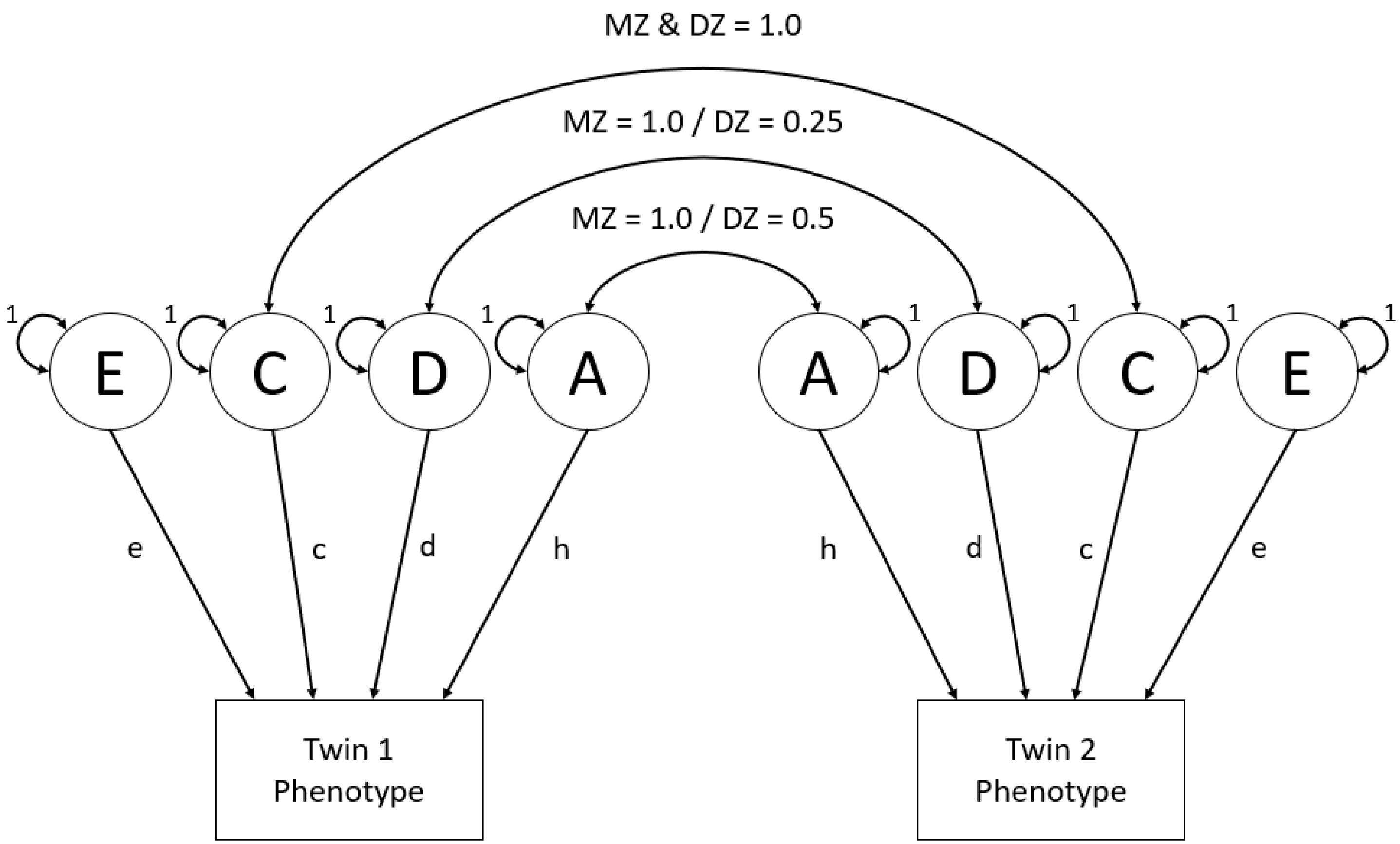

Figure 1. Path diagram depicting the theoretical ADCE model, which is not testable with four variables and, thus, is hypothetical. Notes: MZ = monozygotic; DZ = dizygotic; A = additive genetic influences; D = dominance genetic influences; C = shared environmental influences; E = non-shared (unique) environmental influences; h = additive genetic path coefficient; d = dominance genetic path coefficient; c = shared environmental path coefficient; e = non-shared (unique) environmental path coefficient. Circles represent latent, unobservable variables; Squares represent manifest, observable variables; Single-headed arrows represent influences of latent variables on observed variables; Double-headed arrows represent (co)variances.

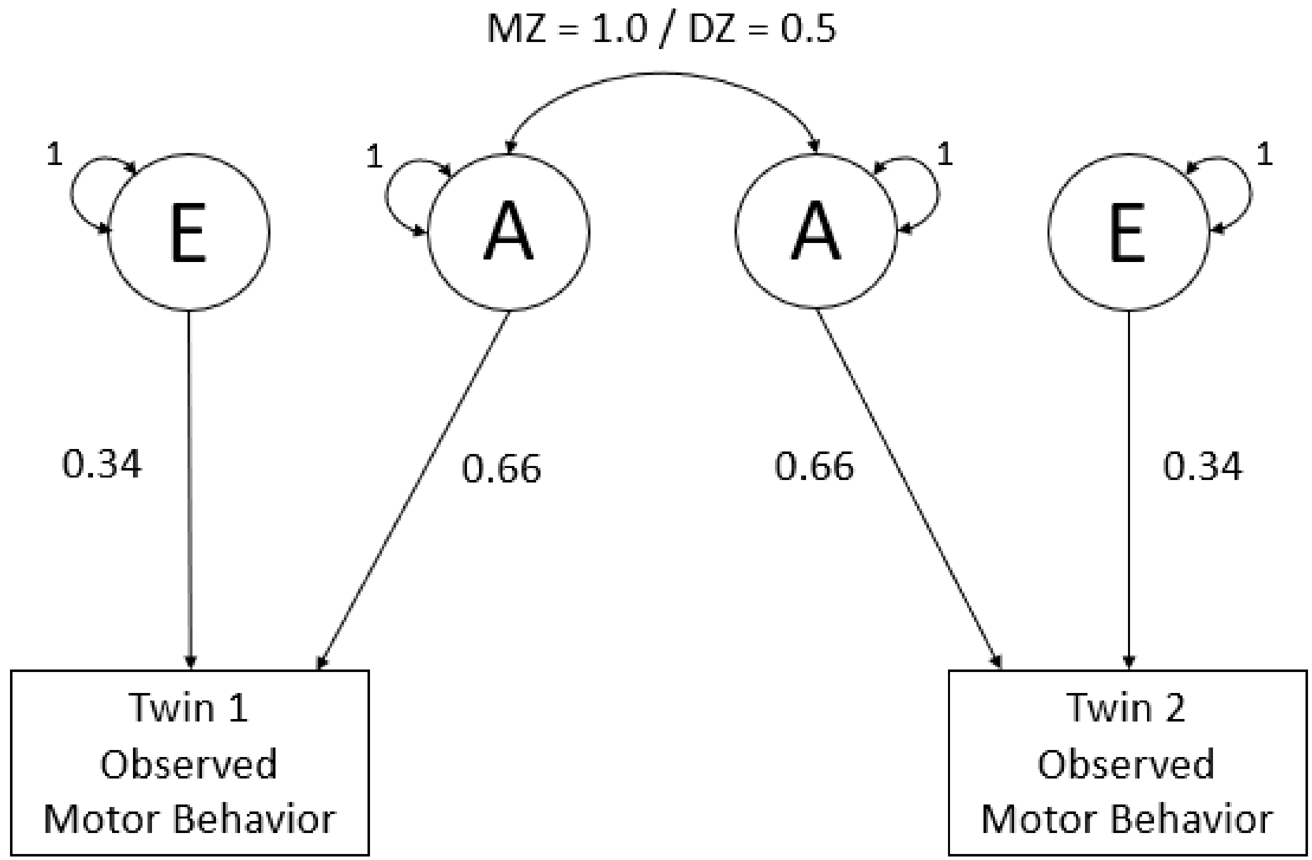

Figure 2. Path diagram depicting the best-fitting (AE) model for age 5 observed motor behavior. Note: MZ = monozygotic; DZ = dizygotic; A = additive genetic influences; E = non-shared (unique) environmental influences. Circles represent latent, unobservable variables; Squares represent manifest, observable variables; Single-headed arrows represent influences of latent variables on observed variables; Double-headed arrows represent (co)variances.

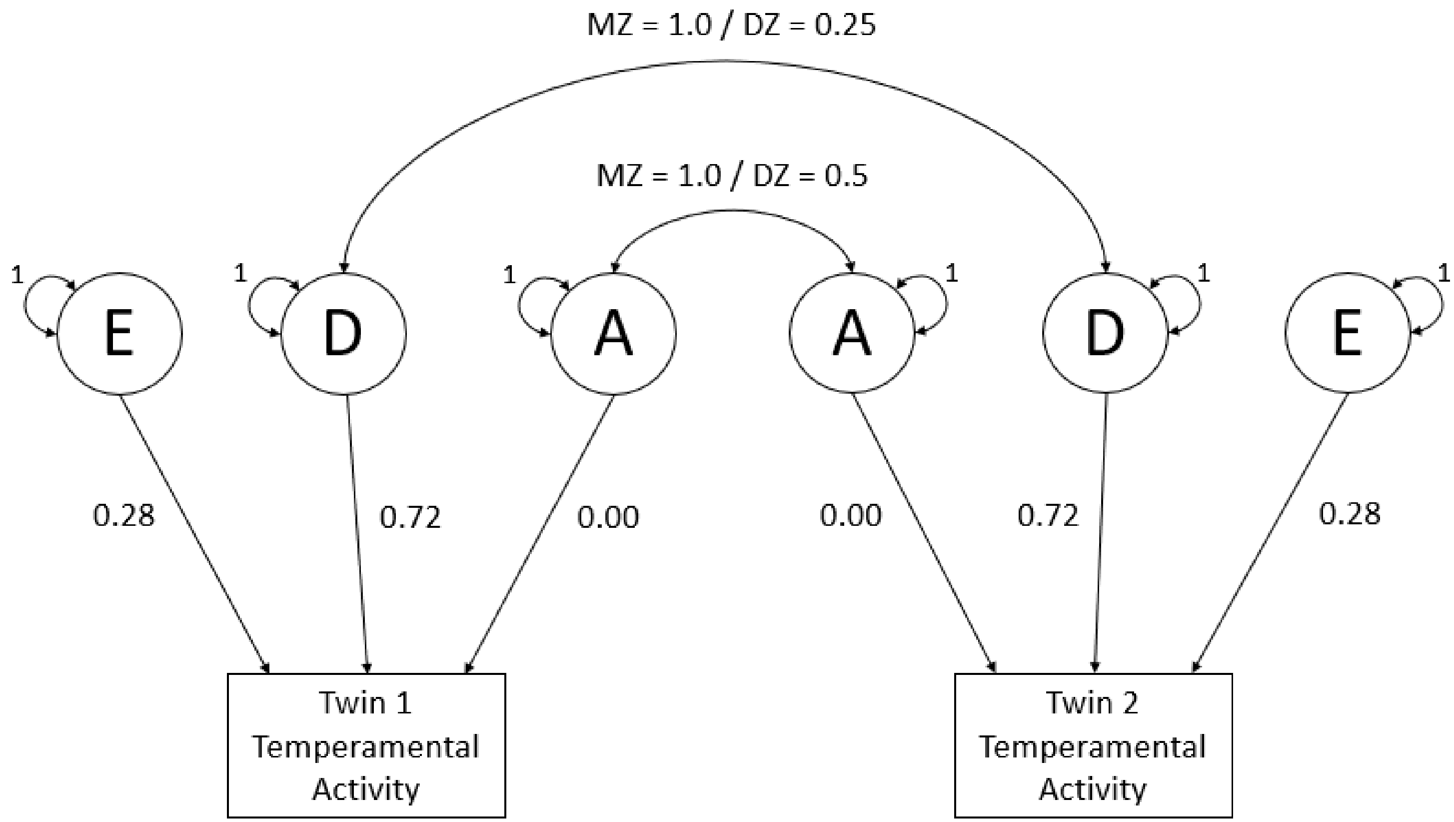

Figure 3. Path diagram depicting the best-fitting (ADE) model for age 5 temperamental activity levels. Note: MZ = monozygotic; DZ = dizygotic; A = additive genetic influences; D = dominance genetic influences; E = non-shared (unique) environmental influences. Circles represent latent, unobservable variables; Squares represent manifest, observable variables; Single-headed arrows represent influences of latent variables on observed variables; Double-headed arrows represent (co)variances.

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APPENDIX A

PC-INT OBSERVATIONAL MOTOR BEHAVIOR CODING SCHEME

General Overview

Rating Instructions:

- Watch the 10-minute PC-Interaction and rate the child's physical activity across each of the categories (listed below) for every 30-sec interval, only for the individual child assigned.
- Record behaviors using the descriptions/codes provided (see below) on the coding sheet.
    - Remember to note the "Start time" for the PC-Int task, as this will influence the 30-second intervals
        - eg, PC-Int starts 15 seconds into the video → thus, the first "0-30" will be 0:15 through 0:45 in the video
    - Always be sure to code each appropriate 30-sec interval only (ie, 20 intervals total)

- See 2D schematic or 3D model for Room Orientation
    - Camera 1: Dalmatian's poster (Head-On View)
    - Camera 2: 'Window' (Side-View)
    - Camera 3: 'Corner' (Bird-eye View)

Observational Ratings and Codes:

-Spatial Movement- [MAGNITUDE]

- Focus on the child's 'spatial movement' (i.e., distance traveled) in relation to the child's body size and record the amount of movement using the codes below…To do so, we will use the following coding..

  0 = no torso movement across space
  1 = small spatial movement (1 body length total – e.g., ~3ft) (1 occurrence)
  2 = 2-3 occurrences (i.e., ~3 to 9ft of total distance traveled)
  3 = 4-5 occurrences (i.e., ~9 to 15ft of total distance traveled)
  4 =5+ occurrences (i.e., >15ft of total distance traveled)

-Activity Rating- [INTENSITY]

- Rate the overall activity level of child (across all activities during each 30-sec interval)
    0. Stationary – motionless/stationary (eg, no movement)
    1. Limbs – stationary with movement of limbs/trunk
    2. Slow-Easy – slow/easy movement (may translocate – i.e., spatial movement)
    3. Moderate – moderate movement (translocates – i.e., spatial movement)
    4. Fast – fast movement (translocates – i.e., spatial movement)

- Translocation means to move or relocate (i.e., 'spatial movement')
    - 0 and 1 for 'intensity' corresponds with 0 for 'magnitude'
    - 2 for 'intensity' may involve a 0 for 'magnitude' (but also might not)
    - 3 and 4 for 'intensity' will always correspond with a 'magnitude' of 1 or more

-Activity Types- [VARIABILITY]

- Using the list of activities below, note those the child engages in throughout each 30-sec interval. Activities may occur once/several times, or possibly not at all.
    - DO NOT 'tally' engagement in the same activity multiple times during each interval
    - DO tally engagement in separate activities during each interval

- For example, during the 30-sec interval…
    - If the child were **sitting** and engaged in puzzle work (**pick/place**) before then **standing** up and **walking** around, and then returns to **sitting** and continuing puzzle work (**pick/place**)…
        - 4 separate activities would be 'coded' (bolded above)
            - ie - Sitting, pick/place, stand, walk

Main Positions (Mark all positions seen)

- Sit/Squat – sitting (criss-cross, legs folded in), squatting, kneeling
- Lie Down – lying down
- Stand – standing (in-place)

1. Shift (Position) - within main positions above (see examples below)
    - Sit/Squat – ex) from criss-cross to legs outstretched
    - Lie down – ex) begins on tummy and rolls over onto back
    - Stand – ex) from standing on both feet to balancing on one foot

2. Crawl – crawling (i.e., on hands & knees)
    - However, may also only be on butt (e.g., butt scoot)
3. Dance – dancing, expressive movement
4. Jump/Skip – jumping, skipping, hopping, galloping
5. Kick/Hit
    - Kicking, stomping, punching, slapping , clapping, poking/tapping (parent/sibling)
6. Pick/Place – pick/place an object (also – throwing, flicking)
7. Pull/Push – pulling or pushing an object or child/parent
8. R&T (Rough & Tumble Play) – e.g., wrestling, tumbling (e.g., headstand, cartwheel)
9. Roll - rolling
10. Run – running, jogging, sprinting
11. Spin – spin body
12. Stretch – gross motor movement (arms/legs/torso) without moving spatially
13. Walk – walking, marching, skipping (i.e., while standing)
    - However, may also be only on knees (e.g., knee-walking)

APPENDIX B

OBSERVATIONAL MOTOR BEHAVIOR CODING SHEET

Coder: Date Coded: Start [PC-Int] Time: ___________

Child ID: Age: Sex: Mother/Father/Other:

Minute	Spatial Movement	Activity Rating	Activity Type(s)															
			Sit/Squat	Lie Down	Stand	Shift (Position)	Crawl	Dance	Jump/Skip	Kick/Hit	Pick/ Place	Pull/ Push	R & T	Roll	Run	Spin	Stretch	Walk
0:00—0:30																		
0:30—1:00																		
1:00—1:30																		
1:30—2:00																		
2:00—2:30																		
2:30—3:00																		
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9:00—9:30																		
9:30-10:00																		

APPENDIX C

MINIATURE 3-D REPLICA OF TESTING ROOM

Front-side (View when facing the entrance)

Back-side (View when facing the exit)

Note: The circles depict the three camera locations, which correspond with the colors indicating the surface area captured. The colored paper illustrates the varying surface areas captured by each camera; the red rectangle reflects the back-side camera, the yellow rectangle reflects the side-located camera, and the pink rhomboid reflects the 'birds-eye' corner-located camera.

APPENDIX D

FAMILY INFORMATION SHEET

INFORMATION SHEET

Date__________ ID Number_______

Age of Child/ren _______ DOB of child/ren__________

Your Relationship to the child/ren (mother or father; please note if adoptive parent):______.

Your Age: _______

Marital Status:

Single, never married________ Married__________ Divorced/Separated ________

Widowed ________ Living with a significant other__________

Approximate Total Family Income:

___ less than $5,000 ___ $20,000 - 25,000 ___ $40,000 - 45,000 ___ $60,000 - 65,000 ___ $80,000 - 85,000

___ $5,000 - 10,000 ___ $25, 000 - 30,000 ___ $45,000 - 50,000 ___ $65,000 - 70,000 ___ $85,000 - 90,000

___ $10,000 - 15,000 ___ $30,000 - 35,000 ___ $50,000 - 55,000 ___ $70,000 - 75,000 ___ over $90,000

___ $15,000 - 20,000 ___ $35,000 - 40,000 ___ $55,000 - 60,000 ___ $75,000 - 80,000

Race of Child's Parents: Mother ________ Father ________

Race of Children in Study: _______

	Occupation (JOB TITLE)	Finished High School?	Attended College?	Years of College (undergraduate & graduate)	College Degrees (AA, BA, etc.)
Self		Yes No	Yes No		
Spouse or Partner if Living in Home with Children		Yes No	Yes No		

Please list the birthdates of all siblings of the children in this study, and please note if they are half-siblings, step-siblings, or adopted siblings of the children in this study:

____

____

Please list everyone living in your household and their relation (e.g., father, grandmother, etc.) to the children in the study. (First names only, example: Ben – grandfather)

____

____

We are interested in whether changes in the family, such as divorce or remarriage, affect children's behaviors. If applicable, please indicate if you have ever been divorced or remarried and the year this occurred.

Not applicable_____ Divorced _____ Remarried _____

Year_______ Year_______

APPENDIX E

RECRUITMENT EMAILS

INITIAL RECRUITMENT

From: Southern Illinois Twins/Triplets and Siblings Study (sitss.siu@gmail.com)
Subject: Research Request

Dear Parent:

Thank you for your past participation in Dr. Lisabeth DiLalla's Southern Illinois Twins/Triplets and Siblings Study (SITSS) in previous years! My name is Matthew Jamnik, and I am a doctoral student who works in the Twin Play Lab under Dr. DiLalla. Your email address was obtained from the paperwork collected during your previous participation in SITSS. This email was sent using a blind copy format so that the list of recipients does not appear in the header.

We are now conducting a follow-up study in middle childhood (ages 7 to 13) that we hope will interest you! It involves filling out an online survey about your children and family. This survey asks about your child's behavioral and emotional development, as well as includes questions regarding various aspects of health for your children and overall household. We will also ask you to report your children's height (in feet/inches) and weight (in pounds); therefore, if possible, we ask that you use a tape measure and scale to measure your children's height and weight before completing the survey. Your family was selected to participate in this follow-up because of your having completed 5-year-old testing as part of SITSS.

The entire survey should only take approximately 30 minutes to an hour of your time to complete. If you choose to complete these surveys, please provide your name so we may link these data to your previous data. Once that is done, your name will be removed so the information you provide during this follow-up is not linked to you. After you complete the survey, your name will be entered in a drawing for a $50 gift card and you will be mailed an age-appropriate book for each of your children. Alternatively, if additional grant funding is received, you will be provided a $25 gift card for participating (instead of a raffle entry). Thank you for your commitment to the SITSS!

We do not anticipate any risks to you while participating in this study.

If you are willing to voluntarily participate in this follow-up, please do so within the next few weeks! Importantly, please do not begin the survey until you have an uninterrupted block of time to complete the survey (because you cannot log back in to complete it later). To begin the survey, please click on the link below:

https://www.research.net/r/HealthFollowupStudy

If you would like your name and email address to be removed from our mailing list, please respond to this email asking us to do so. Otherwise, if you do not reply to this email with an opt-out message, you will be contacted again with this request three times during the next eight weeks (i.e., once every two weeks for two months).

Questions about this study can be directed to the Lab Director, Dr. Lisabeth DiLalla, SIUC School of Medicine, Department of Family and Community Medicine, Carbondale, IL 62901. Her phone number is (618) 453-1855.

All information that we receive from you will be held as strictly confidential. Only people directly involved with this project will have access to the questionnaires you complete. All data collected are only identified by an identification number that is assigned to your family and your children's names will never be included with the data that we receive. Your contact information (name, address, phone number, email) is stored in a confidential file on a password-protected computer in Dr. DiLalla's lab. Similarly, your responses to this questionnaire will also be kept in a confidential and password-protected location.

Thank you for taking the time to assist us in this research.

Lisabeth DiLalla	Matt Jamnik
Professor	SITSS Graduate Assistant
(618) 453-1855	(618) 453-5206
ldilalla@siu.edu	matthew.jamnik@siu.edu

This project has been reviewed and approved by the SIUC Institutional Review Board. Questions concerning your rights as a participant in this research may be addressed to the committee chairperson, Office of Research Compliance, SIUC, Carbondale, IL 62901- 4344. Phone (618)-453-4533. E-mail: siuhsc@siu.edu

EMAIL FOLLOWUP FOR FAMILIES WHO DO NOT RESPOND TO THE RECRUITMENT EMAIL AFTER 2 WEEKS

From: Southern Illinois Twins/Triplets and Siblings Study (sitss.siu@gmail.com)
Subject: Research Request Reminder

Dear Parent:

Thank you for your past participation in Dr. Lisabeth DiLalla's Southern Illinois Twins/Triplets and Siblings Study (SITSS) in previous years! My name is Matthew Jamnik, and I am a doctoral student who works in the Twin Play Lab under Dr. DiLalla. Your email address was obtained from the paperwork collected during your previous participation in SITSS. This email was sent using a blind copy format so that the list of recipients does not appear in the header.

We are now conducting a follow-up study in middle childhood (ages 7 to 13) that we hope will interest you! It involves filling out an online survey about your children and family. This survey asks about your child's behavioral and emotional development, as well as includes questions regarding various aspects of health for your children and overall household. We will also ask you to report your children's height (in feet/inches) and weight (in pounds); therefore, if possible, we ask that you use a tape measure and scale to measure your children's height and weight before completing the survey. Your family was selected to participate in this follow-up because of your having completed 5-year-old testing as part of SITSS.

The entire survey should only take approximately 30 minutes of your time to complete. If you choose to complete these surveys, please provide your name so we may link these data to your previous data. Once that is done, your name will be removed so the information you provide during this follow-up is not linked to you. After you complete the survey, your name will be entered in a drawing for a $50 gift card and you will be mailed an age-appropriate book for each of your children. Alternatively, if additional grant funding is received, you will be provided a $25 gift card for participating (instead of a raffle entry). Thank you for your commitment to the SITSS!

We do not anticipate any risks to you while participating in this study.

If you are willing to voluntarily participate in this follow-up, please do so within the next few weeks! Importantly, please do not begin the survey until you have an uninterrupted block of time to complete the survey (because you cannot log back in to complete it later). To begin the survey, please click on the link below:

https://www.research.net/r/HealthFollowupStudy

If you would like your name and email address to be removed from our mailing list, please respond to this email asking us to do so. Otherwise, if you do not reply to this email with an opt-out message, you will be contacted again with this request three times during the next eight weeks (i.e., once every two weeks for two months).

Questions about this study can be directed to the Lab Director, Dr. Lisabeth DiLalla, SIUC School of Medicine, Department of Family and Community Medicine, Carbondale, IL 62901. Her phone number is (618) 453-1855.

All information that we receive from you will be held as strictly confidential. Only people directly involved with this project will have access to the questionnaires you complete. All data collected are only identified by an identification number that is assigned to your family and your children's names will never be included with the data that we receive. Your contact information (name, address, phone number, email) is stored in a confidential file on a password-protected computer in Dr. DiLalla's lab. Similarly, your responses to this questionnaire will also be kept in a confidential and password-protected location.

Thank you for taking the time to assist us in this research.

Lisabeth DiLalla	Matt Jamnik
Professor	SITSS Graduate Assistant
(618) 453-1855	(618) 453-5206
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This project has been reviewed and approved by the SIUC Institutional Review Board. Questions concerning your rights as a participant in this research may be addressed to the committee chairperson, Office of Research Compliance, SIUC, Carbondale, IL 62901- 4344. Phone (618)-453-4533. E-mail: siuhsc@siu.edu

APPENDIX F

INFORMED CONSENT PAGE

Consent Form

SITSS
Play Lab

Hello! My name is Matthew Jamnik, and I am a doctoral student from Dr. DiLalla's Twin Play Lab who is currently conducting a follow-up study for my dissertation project. This research project is a study on the physical and mental health of typically developing children. The purpose is to help better understand the association between activity levels and internalizing at age 5 and related health behaviors/outcomes in middle childhood. After you complete the survey, your name will be entered in a drawing for a $50 gift card and you will be mailed an age-appropriate book for each of your children. Alternatively, if additional grant funding is received, you will be provided a $25 gift card for participating (instead of a raffle entry). Thank you for your commitment to the SITSS!

During the online questionnaire, you will be asked a series of questions about your children and family. Some of these questions will ask you about your child's behavioral and emotional development, height/weight, and various health behaviors. Another set of questions will ask about your household's overall atmosphere and demographic information, as well as life events your family may have experienced over the past year. If at any time you would like to stop, you can exit the survey and stop immediately. There will be no penalty for this.

We do not foresee any significant risks involved with this project. In fact, we expect that you may even find this survey and the questions asked quite interesting.

After the data collected during this follow-up has been linked to your previously collected data, your name will be removed so the information provided during this follow-up cannot be linked back to you. Once this has been done, all questionnaire data collected will be identified only by an identification number that is assigned to your family. Names will never be included in this dataset. Your name, address, phone number, and email will be maintained in a confidential file that is password-protected. All information is strictly confidential and will never be shared with anyone outside of this laboratory. Only Dr. DiLalla, people directly involved with this project, and I will have access to the information collected here. The confidential list of names will be maintained so that we can contact families again in the future for follow-up studies. We will take all reasonable steps to protect your identity.

If you have any further questions about this research project, please feel free to contact the Lab Director, Dr. Lisabeth DiLalla, at the SIUC School of Medicine, Department of Family and Community Medicine, (618) 453-1855. For your records, a copy of this contact information was also included in the cover letter that was emailed to you.

By clicking NEXT, you are indicating…

- 1) you have read the material above and understand the explanation of the study provided
- 2) you realize that you may withdraw without prejudice at any time
- 3) you agree to participate in this project and provide information on your family and children

[NEXT]

APPENDIX G

FOLLOW-UP PHONE CALL SCRIPT FOR FAMILIES UNABLE TO BE REACHED VIA EMAIL

Hello, my name is _[your name]_. I am a research assistant for Dr. Lisabeth DiLalla in the Psychology Department at Southern Illinois University. I am trying to reach _[parent name]_. Are they available to speak?

If not available (or unable to talk right now):

- No problem. Is there a better time for me to call back?
  [Get a better time to call and then ***call back at that time!***]

If yes:

- Hi _[parent name]_! Nice to speak with you. Once again, my name is _[your name]_ and I work in Dr. DiLalla's Twin Play Lab, here at SIU. We recently sent you an email regarding a new study that we are conducting but have yet to hear back from you. Is this a good time for us to chat briefly about this project?

  - *If no:*
    - No problem. Is there a better time for me to call back? And/or, would it be easier for us to communicate via email?
      [Get a better time to call and then ***call back at that time!***]
      - *If yes, contact again:*
        - Great, I will try contacting you again at that time.
      - *If yes, email:*
        - What is the best email address to reach you at?
      - *If no:*
        - No problem. Thank you for considering this. We appreciate your commitment to the SIU Play Study.
  - *If yes:*
    - Great! Participation in this study involves filling out an online survey about your children and family. This survey asks about your children's behavioral/emotional development, as well as various aspects of health for your children and overall household. We will also ask you to report your children's height and weight; therefore, if possible, please take these measurements before completing the survey.

    - The entire survey should only take approximately 30-45 minutes to complete. After participating, you will be mailed a book for each of your children and sent a $60 gift card to thank you for your time.

    - Does this sound like something you might be willing to participate in?

If yes:

- Great! If you would like, I can provide you with the link to the survey now. Otherwise, if it is easier, I can also send you an email with this information. Which do you prefer?

    - *If link:*
        - https://www.research.net/r/HealthFollowupStudy
    - *If email:*
        - What is the best email address to send this information to?
    - *For all families that say yes:*
        - I would like to confirm your mailing address so I can send the books. Is it [give address in file]?

- *If no:*
    - No problem. Thank you for considering this. We appreciate your commitment to the SIU Play Study.

- *Voicemail Script (if no one answers)*
    - Hello! My name is _[your name] and I work in Dr. DiLalla's Twin Play Lab at Southern Illinois University. I was hoping to reach _[parent name], so I could discuss a new study that we are conducting. We recently sent you an email about this follow-up project but have yet to hear back from you. This would require about 30-45 minutes of your time and, to thank you, we would send you a $60 gift card and a book for each of your children. If you could give us a call back at [phone number] or reply to the email that we sent so that we know whether or not you are interested, we would greatly appreciate it! Thanks in advance for your consideration and commitment to the SIU Play Study.

VITA

Graduate School
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Matthew R. Jamnik

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McHenry County College
Associate of Science, Psychology, May 2012

Southern Illinois University Carbondale
Bachelor of Arts, Psychology, May 2014

Southern Illinois University Carbondale
Master of Arts, Psychology, May 2018

Special Honors and Awards:

Rose and Essie Padgett [Outstanding Research] Award (2021), Sigma Xi: SIUC Chapter
2021 Distinguished Service Award, SIUC Graduate & Professional Student Council
1st Place (Tied) (2020), Undergraduate Poster Presentation – Sigma Xi: SIUC Chapter
Grants in Aid of Research (2020), Sigma Xi: Scientific Honors Society
Mamie Phipps Clark Diversity Research Grant (2020), Psi Chi: Int'l Honor Society
1st Place, Graduate Student Paper Presentation (2020), Sigma Xi: Scientific Honors Society
Regional Research Award (2020), Psi Chi: Int'l Honor Society
Regional Travel Grant (2020), Psi Chi: Int'l Honor Society
Regional Travel Grant (2019), Psi Chi: Int'l Honor Society
Award: Best Graduate Student Paper (2018), Midwestern Psychological Association
Regional Travel Grant (2017), Psi Chi: Int'l Honor Society
Regional Travel Grant (2015), Psi Chi: International Honor Society in Psychology
Robert C. Radtke Leadership Award (2014), Southern Illinois University Carbondale
Illinois Community College Scholarship (2012-2013)

Dissertation Title:

A Behavior Genetic Investigation of Activity Levels and Internalizing Problems Across Childhood

Major Professor: Lisabeth F. DiLalla, Ph.D.

Publications:

DiLalla, D., DiLalla, L.F., **Jamnik, M.R.**, Marshall, R., & Pali, E. (in press). Twins and Psychopathology. In A.D. Tarnoki, D.L. Tarnoki, J.R. Harris, N. Segal, & L. Littvay (Eds.), *Twin Research*, Elsevier Publishers.

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