Early Development of Medically At-Risk Twins: An Analysis of Mastery Motivation and Executive Function

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Abstract
Increasing prevalence of twin births prompts the need for progress in our efforts to understand unique developmental characteristics of twins compared to singletons. When considering differences in twins’ and singletons’ cognitive, psychological, and social development, previous literature has demonstrated inconsistencies depending on the construct. Therefore, a global assumption that twins will differ from singletons in early development is refutable, and specific constructs must be examined individually. One consistency found in the literature is that early medical risk factors (e.g., prematurity, low birth weight) contribute to developmental differences found between twins and singletons. The purpose of this study was to examine differences between medically high-risk twins’ and singletons’ executive function and mastery motivation development during the first few years of life. Forty twins and 40 singletons who participated in a Neonatal Intensive Care Unit (NICU) follow-up evaluation were matched for three risk variables: birth weight, gestational age, and number of days spent in the NICU. Existing clinical data, including demographic information and scores from the Bayley Scales of Infant and Toddler Development, Third Edition (Bayley III) and the Dimensions of Mastery Questionnaire, 17 were analyzed. A chi-square test revealed no significant differences between twins’ and singletons’ executive function scores, as measured by object permanence items on the Bayley III. Results from an analysis of variance revealed differences between twins and singletons on the mastery motivation subscale of negative reaction to failure, and this finding approached significance at the adjusted p-value. No other group differences were found for mastery motivation subscales. This study serves as a catalyst for additional research into differences between twins’ and singletons’ executive function and mastery motivation development. Improved understanding of twins’ unique development will promote optimum clinical service delivery (e.g., developmental evaluations, early intervention, parent support, etc.), as well as better early childhood outcomes.

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EARLY DEVELOPMENT OF MEDICALLY AT-RISK TWINS

EARLY DEVELOPMENT OF MEDICALLY AT-RISK TWINS: AN ANALYSIS OF
MASTERY MOTIVATION AND EXECUTIVE FUNCTION

A DISSERTATION
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# TABLE OF CONTENTS

ABSTRACT ......................................................................................................................... iii  
ACKNOWLEDGEMENTS ................................................................................................. v  
INTRODUCTION ............................................................................................................... 1  

BIRTH PLURALITY: TWINS VERSUS SINGLETONS ....................................................... 2  
MASTERY MOTIVATION ................................................................................................. 7  
EXECUTIVE FUNCTION ................................................................................................. 10  
RELATING MASTERY MOTIVATION AND EXECUTIVE FUNCTION .......................... 14  
MEDICALLY HIGH-RISK INFANTS ............................................................................... 16  
SUMMARY ....................................................................................................................... 17  

AIM OF THE PRESENT STUDY .................................................................................... 19  

METHOD ......................................................................................................................... 21  

PARTICIPANTS ............................................................................................................... 21  

PROCEDURE .................................................................................................................... 22  

MEASURES ..................................................................................................................... 23  

ANALYSES ..................................................................................................................... 25  

RESULTS ......................................................................................................................... 26  

DISCUSSION ................................................................................................................... 36  

CONCLUSION .................................................................................................................. 46  

REFERENCES .................................................................................................................. 48
Abstract

Increasing prevalence of twin births prompts the need for progress in our efforts to understand unique developmental characteristics of twins compared to singletons. When considering differences in twins’ and singletons’ cognitive, psychological, and social development, previous literature has demonstrated inconsistencies depending on the construct. Therefore, a global assumption that twins will differ from singletons in early development is refutable, and specific constructs must be examined individually. One consistency found in the literature is that early medical risk factors (e.g., prematurity, low birth weight) contribute to developmental differences found between twins and singletons. The purpose of this study was to examine differences between medically high-risk twins’ and singletons’ executive function and mastery motivation development during the first few years of life. Forty twins and 40 singletons who participated in a Neonatal Intensive Care Unit (NICU) follow-up evaluation were matched for three risk variables: birth weight, gestational age, and number of days spent in the NICU. Existing clinical data, including demographic information and scores from the Bayley Scales of Infant and Toddler Development, Third Edition (Bayley III) and the Dimensions of Mastery Questionnaire, 17 were analyzed. A chi-square test revealed no significant differences between twins’ and singletons’ executive function scores, as measured by object permanence items on the Bayley III. Results from an analysis of variance revealed differences between twins and singletons on the mastery motivation subscale of negative reaction to failure, and this finding approached significance at the adjusted p-value. No other group differences were found for mastery motivation subscales. This study serves as a catalyst for additional research into differences between twins’ and singletons’ executive function and mastery motivation development. Improved understanding of twins’ unique development will promote optimum
clinical service delivery (e.g., developmental evaluations, early intervention, parent support, etc.), as well as better early childhood outcomes.
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The prevalence of twin gestations has steadily increased in America, with the most recent report indicating approximately 1 in 30 live births in 2009 comprised twins (Martin, Hamilton, & Osterman, 2012). This trend is hypothesized to relate, in part, to the increased likelihood of multiple gestation following assisted fertilization, which has been increasing in popularity. In addition, improved conditions in neonatal health care have resulted in higher survival rates for twins due to decreasing mortality rates for prematurity (i.e., defined as < 37 weeks gestation), and improved low birth weight and other early medical complications for which twins are at greater risk than singletons (Choi, Vishai, & Minkovitz, 2009). The expansion of the twin population elicits the need for increased understanding of twins' early developmental trajectories and differences relative to singleton counterparts.

Twin development differs from singleton development early in life, when the influence of environment is often more indicative of outcomes than the influence of heredity. In comparison to singletons, twins have been shown to be at higher risk for various delays in early development. Following a critical review of literature on twin development, Sutcliffe and Derom (2006) found the majority of studies indicated twins are at elevated risk for developmental and psychosocial difficulties in comparison to singletons. In a longitudinal analysis of twins' early development, Nan et al. (2013) revealed healthy twins demonstrated early delays in communication, gross motor, fine motor, problem solving, and personal-social development. DiLalla (2006) also found twins to have delayed prosocial skills development. On the other hand, twins have been shown to develop similarly to singleton peers in some domains of functioning. By school age, twins demonstrate similar or fewer behavioral disturbances than singleton peers based on parent, child, and teacher reports (Moilanen et al., 1999). Academic achievement is also comparable between twins and singletons (Christensen et al., 2006). Overall, many differences observed between
twins and singletons during the first few years of development appear to decline throughout childhood.

Studies examining differences between multiples and singletons in neurodevelopment, academic, social, and behavioral functioning have indicated mixed results depending on the aspect and stage of development assessed. Thus, determinations regarding twins’ global developmental trajectories compared to singletons cannot be made, and individual constructs must be examined. To date, no studies have examined the impact of birth plurality (i.e., twin births) on the development of executive function and mastery motivation. Mastery motivation and executive function are two areas of emerging competency found to predict young children’s cognitive, achievement, social, behavioral, and emotional functioning. Thus, individual differences in early mastery motivation and executive function may have significant impacts on long-term developmental outcomes. High-risk medical status is another factor influencing early development. As noted, twins are at greater risk for negative birth outcomes including low birth weight, prematurity, early medical complications and inpatient hospitalization following delivery (Choi et al., 2009). High-risk medical factors are likely to affect mastery motivation and executive function development for both twins and singletons, but may be differentially impactful for twins. The purpose of this study is to examine the influence of birth plurality on early executive function and mastery motivation of medically high-risk twins and singletons during the first few years of life.

**Birth Plurality: Twins versus Singletons**

**Definitions and differences in prenatal family characteristics, gestation, and perinatal complications for twins and singletons.** The term “twins” refers to two fetuses in one gestation, and “singletons” refers to one fetus in one gestation. Twins can be
monzygotic/identical (same genetic material) or dizygotic/fraternal (different genetic material). Fetuses who share a chorionic sac, or placenta, are referred to as monochorionic, whereas fetuses with separate chorionic sacs are termed dichorionic. In general, monzygotic and monochorionic twins are at highest risk for developmental delays as compared to singletons or dizygotic/dichorionic twins (Sutcliffe & Derom, 2006). In some contexts, varying genetic and chorionic statuses are the focus of inquiry, whereas in other studies, plurality is the focus of the investigated differences. The present study focuses on plurality and does not distinguish genetic or chorionic similarities or differences between twins.

Differences between twins and singletons are observable prior to conception, throughout gestation, and during delivery. A large study compared 7293 mothers of singletons with 776 mothers of multiples for the purpose of identifying group differences (Choi et al., 2009). Significant differences were found between groups, with mothers of multiple infants found to be older, Caucasian, and married; have higher education and socioeconomic status levels; and be less likely to be primipara (i.e., giving birth for the first time) in comparison to mothers of singletons. With regard to perinatal factors, multiple infants showed higher rates of prematurity, low birth weight, delivery via cesarean section, and complications during labor and delivery. No significant differences were found between mothers of multiples and singletons when history of maternal mental illness was assessed (Choi et al., 2009). In some aspects of development, twins have been found to show lower morbidity risk than singletons. In an analysis of preterm infants, singletons had significantly higher rates than twins for 5-minute Apgar scores less than 7, postnatal steroid use for chronic lung disease, and systemic infections (Gnanendran et al., 2015). Findings regarding perinatal morbidity indicate twins generally have higher risks for perinatal morbidities than term singletons. However, in comparison to preterm singletons, preterm twins
have similar or lower risks for some morbidity factors (Gnanendran et al., 2015). These findings suggest premature birth may be related to other prenatal complications moreso for singletons than for twins.

In summary, some important medical characteristics found to relate to differences between twins and singletons include Apgar scores, chronic lung disease, and other systemic infections (Gnanendran et al., 2015). Important contextual factors that significantly differ between twins and singletons include maternal age, maternal education, parental income, and use of assisted reproductive technologies (Lung, Shu, Chiang, & Lin, 2009).

**Cognitive and neurological outcomes.** Despite historically mixed findings, recent studies regarding early cognitive outcomes consistently demonstrate comparable findings between twins and singletons. Studies that show poor neurodevelopmental outcomes for twins compared to singletons are most often explained by differences in gestational age and birth weight, which are generally lower for higher-order pregnancies. One study explored cognitive and executive function differences in triplets compared to twins and singletons, from 6-months to 5-years of age (Feldman & Eidelman, 2009). After matching groups for several known risk factors including birth weight, gestational age, and maternal age and education, the authors found weight-concordant triplets and weight-discordant triplets (i.e., triplets with significant differences in weight between fetuses from the same gestation) scored lower on cognitive measures at 6 months than twins and singletons. Further, at 12- and 24-months of age, weight-concordant triplets scored higher than weight-discordant triplets (although still below twins and singletons). By 5 years of age, weight-concordant triplets no longer showed significant differences in cognitive performance or executive function in comparison to twins and singletons, whereas weight-discordant triplets did (Feldman & Eidelman, 2009). The Feldman and Eidelman (2009)
study demonstrated that as children age, trends in cognitive differences due to plurality decrease. In addition, the study emphasized the importance of considering low birth weight’s impact on cognitive and executive function development. In general, recent studies controlling for gestational age and birth weight do not find significant differences between multiples and singletons regarding cognitive outcomes (Einaudi et al., 2008; Gnanendran et al., 2015; Lorenz, 2012) as compared to early literature in this area.

In terms of neurological development, twins have consistently been found to have higher prevalence rates of cerebral palsy than singletons. Beginning in 1952, it was observed that twins were nearly three times as likely as singletons to develop cerebral palsy (Benda, 1952). More recent data has found twins’ rates of cerebral palsy to be up to 8 times as high as singletons’ rates (Petterson, Nelson, Watson, & Stanley, 1993). Unlike differences in cognitive outcomes, which are often explained in part by younger gestational ages, cerebral palsy rates were found to be higher for twins with gestation greater than 32 weeks (Alberman, 1964). Bonellie, Currie, and Chalmers (2005) also found twins to be at elevated risk for cerebral palsy compared to singletons, even after controlling for gestational age and birth weight. Further, birth weight discordance (i.e., significant difference in weight between fetuses in utero) was found to predict higher rates of cerebral palsy with equal risk for lighter and heavier twins. Studies examining cerebral palsy have found less variance related to weight for twins than singletons, suggesting other factors unique to birth plurality and multiple gestation may predict cerebral palsy development for twins (Bonellie et al., 2005).

**Behavioral, academic and social differences.** Behavioral and academic differences between twins and singletons have received limited attention. Analysis of parent- and self-reports of behavioral problems in childhood revealed no significant differences between twins
and singletons; however, teachers’ reports of twins’ behaviors indicate fewer behavioral problems than singleton peers (Moilanen et al., 1999). With regard to academic performance, recent findings suggest twins perform similarly to singletons in adolescence (Christensen et al. 2006). However, comprehensive information regarding early behavioral and academic differences between twins and singletons is lacking in the literature.

There is also limited research explaining how twins’ social development differs from singletons’ social development, despite theoretical underpinnings that would suggest differences exist. Twins who are raised together share unique developmental conditions, including relatively frequent opportunity for peer-socialization and decreased direct parental attention due to the shared environment. Twins’ social development is particularly interesting because of their unique environmental conditions compared to singletons. Twins raised together must share time interacting with caregivers and competition for adult attention and direction is natural. In addition, increased stress in parenting twins compared to parenting singletons has been documented and may influence parent-child interactions, which can foster or impede infant social development (DiLalla, 2006; Feldman & Eidelman, 2009; Thorpe, 2003). At the same time, twins have nearly constant peer-contact during infancy, which is theorized to enhance social development with peers. Despite these unique conditions to support peer interactions, surprisingly, DiLalla (2006) found delayed development of prosocial skills in 5-year-old twins compared to singletons, which faded by 10 years of age. Thus, more research is needed to clarify twins’ social development.

Research exploring twins’ unique development across domains has progressed as understanding of key variables influencing findings has increased. Studies seeking to expand and clarify literature regarding twins’ early development need to build upon the current literature
base to consider additional outcomes that may be affected by plurality. The current study focuses on two relatively unexplored areas: infant mastery motivation and executive function.

**Mastery Motivation**

The construct of mastery motivation evolved from Robert White’s theory describing motivation as an intrinsic competency in which children are driven to interact effectively with their environments in order to learn and master new skills (White, 1959). One of the most commonly cited contemporary definitions describes mastery motivation as “a psychological force that stimulates an individual to attempt independently, in a focused and persistent manner, to solve a problem or master a skill or task which is at least moderately challenging for him or her” (Morgan, Harmon, & Maslin-Cole, 1990; p. 319). Initially, mastery motivation was conceptualized in relation to inanimate objects. MacTurk, Hunter, McCarthy, Vietze, and McQuiston (1985) extended the concept to include mastery motivation in social contexts and thereafter, gross motor persistence was added to the theory and measurement of mastery motivation (Morgan & Shim, 1993). Currently, the concept of mastery motivation comprises *instrumental aspects*, which describe persistence at mastering challenging tasks, and *expressive aspects*, which refer to affective responses to outcomes following persistent effort toward tasks (Morgan et al., 1990). The expressive aspect of mastery motivation may be further deconstructed into mastery pleasure and negative reactions to failure (Morgan, Busch-Rossnagel, Barrett, & Harmon, 2009). In its current conceptualization, the four distinct domains of instrumental mastery motivation include (1) persistence at object or cognitive tasks, (2) gross motor persistence, (3) social mastery motivation with adults, and (4) social mastery motivation with peers/children.
Mastery motivation is influenced by both biological and environmental factors. Biological risk factors include neurological insults and abnormalities impacting the development of mastery motivation. For example, seizure disorders and prematurity have been found to be related to lower mastery motivation presumably due to impacts on neurological development (Hauser-Cram, 1996). Social-emotional variables influencing mastery motivation include children’s caregiving environments in which positive and effective parenting practices enhance children’s mastery motivation. Over time, a reciprocal interaction between parenting characteristics and infants’ mastery motivation develops. It has been documented that parent sensory stimulation positively relates to children’s task-persistence (Yarrow et al., 1984), and increased mastery motivation is related to less parental interference of children’s autonomous exploration (Hauser-Cram, 1993). Specific parenting behaviors that appear to elicit children’s motivation to persist with challenging tasks include giving clear directions, offering verbal and nonverbal support and praise, and teaching tasks (Hauser-Cram, 1996). Parental behaviors found to negatively correlate with mastery motivation include over protectiveness, overstimulation and structure, negative affective exchanges, maternal depression, and parental stress (Hauser-Cram, 1993).

Children’s degree of mastery motivation may differ when measured via clinician observation rather than parental report. Mothers of children with developmental delays have been found to rate their children lower on the Dimensions of Mastery Questionnaire, 17 than clinicians’ who are rating the children based on their own observations of the child’s persistence with challenging tasks (Wang, Morgan, Hwang, & Liao, 2013). This discrepancy in reports is important because parents’ perceptions of children’s mastery motivation influences their interactions with children, impacting children’s behaviors (Wang, Hwang, Liao, Chen, & Hsieh...
Thus ideally, assessments of children’s mastery motivation would integrate parent report measures with clinician observation.

Mastery motivation in twins. To date, no studies have empirically or theoretically examined the direct impact of birth plurality on mastery motivation development. However, as a construct that depends on early environmental context (e.g., Hauser-Cram, 1996), mastery motivation is likely influenced by the unique experience of developing as a twin. For example, the early social context of twins differs from singletons’ due to the frequent presence of another same-aged child. Twins have unique opportunities for frequent peer-interaction, as well as the potential to learn through observation, both of which may foster development of social persistence. On the other hand, one expected area of difference relates to the amount of time and attention distributed by parents toward each twin compared to a singleton. Naturally, twins must share parental attention, to an extent. In situations when parental time and attention correspond with scaffolding behaviors (i.e., progressively helping children achieve skills just beyond their reach) and teaching opportunities for children, it is presumed twins will have fewer parent-directed learning opportunities than singleton counterparts. In addition, an indirect link between birth plurality and mastery motivation can be drawn when parental stress is considered. Parents of twins and triplets have been found to report elevated levels of stress compared to parents of singletons (Glazebrook, Sheard, Cox, Oates, & Ndukwe, 2004; Golombok, 2007). Further, Sparks, Hunter, Backman, Morgan, and Ross (2012) demonstrated a relationship between maternal stress and infant mastery motivation. Specifically, maternal stress when infants were 6 months old predicted infant mastery motivation at 18 months of age. The links between birth plurality and maternal stress, and maternal stress and mastery motivation, suggest birth plurality would influence mastery motivation development, in part due to the impact of elevated maternal stress.
stress. Due to several noted differences between developmental contexts, there is reason to speculate differences in early mastery motivation between twins and singletons.

**Executive Function**

Similar to mastery motivation, executive function is another important construct that begins developing early in life, is influenced by biological and environmental variables, and has been found to influence later competencies. Executive function refers to several cognitive processes that are utilized in conscious, active mental exertion and regulation, which are often necessary in goal-directed behaviors and solving novel problems. Executive function also includes the concepts of cognitive control, effortful control, or supervisory attention (Miller & Cohen, 2001; Shallice, 1988). While several distinct definitions and theories of executive function exist, one commonality across conceptualizations is that executive function is considered to comprise several distinct yet related processes. The most commonly identified executive function processes include attentional control, cognitive flexibility, goal setting, information processing, problem solving, inhibition, and working memory (Anderson, 2002; Diamond, 2006; Zelazo et al., 2003). Diamond (2006) highlighted inhibition, working memory, and cognitive flexibility as the foundational processes of executive function. She elaborated that inhibition influences attentional, emotional, and behavioral control. Further, working memory, as part of executive function, supports planning and fosters problem solving by allowing individuals to relate disparate constructs creatively, which also requires cognitive flexibility (Diamond, 2006). In combination, inhibition, working memory, and cognitive flexibility allow individuals to adapt to different circumstances, problem solve and plan their actions, and navigate new and challenging tasks.
**Infant executive function.** In infants, executive functions are less well developed and distinct, and the infant research literature is less defined than the childhood literature given the natural developmental trajectory of executive function development. However, several executive function processes are thought to emerge between 8-12 months of age. Rudimentary attentional control, working memory, inhibition, and planning have been demonstrated by infants as they engage in different behaviors including finding hidden objects, using one object to obtain a desired object, and navigating physical barriers to obtain a desired object (Anderson, 2002; Zelazo et al., 2003). Response control, the ability to inhibit an action after establishing the intention to act, is one of the earliest executive function processes to be measured and observed. Response control is theorized to be one of the executive processes behind early behavioral demonstrations of object permanence (Zelazo et al., 2003). Piaget (1954) described object permanence as the ability to maintain a mental representation of an object after it has been removed from sight. Early object permanence is often assessed using the A-not-B error task design, in which infants are shown an object that is initially hidden in one location, and then conspicuously moved to a new hidden location (Piaget, 1954). Response control and working memory are some of the executive processes involved in the A-not-B error task.

It has been noted that many tasks from standard cognitive and developmental measures reflect aspects of executive function (Zelazo et al., 2003). Several items from the Bayley III cognitive subtest capture early working memory in infants, including one item reflective of the A-not-B task design (e.g., Lowe et al., 2013). These object permanence tasks require infants to (1) know an object continues to exist after it is hidden, (2) remember where the object is hidden, and (3) navigate barriers to accessing the object. Thus, there is evidence that executive function
is an important emergent developmental construct for infants that may be measureable with early infant developmental tests.

**Genetic and environmental influences on executive function.** The development of executive function is impacted by genetic and environmental factors. Genetic factors support the stability of executive function from 5- to 7-years of age, and genetic variation is the strongest contributor to individual differences in executive function (Polderman et al., 2007). A study completed by Friedman and colleagues (2008) led to the conclusion that processes comprising executive function share one common, highly heritable genetic influence in addition to distinct genetic influences of which heritability rates are currently unknown.

Individual differences in executive function are also impacted by environmental conditions. Experiences during infancy influence brain development, which is closely related to executive function development (De Bellis, 2005; Zelazo, Carlson, & Kesek, 2008). These experiences are biopsychosocial in nature and may include early nutrition, sleep quality, and cognitive stimulation as well as parental behaviors. During infancy, parenting behaviors comprise a significant portion of environmental influences on executive function. Scaffolding is one parental behavior that promotes development of infants’ executive function. Parental scaffolding refers to parents supporting their children to achieve skills just beyond their current developmental abilities (Vygotsky, 1978). Landry, Miller-Loncar, Smith, and Swank (2002) found that parent-initiated scaffolding via verbal input when children were 3 years old predicted executive processes at 6 years of age. Bernier, Carlson, and Whipple (2010) also examined parental behaviors in relation to executive function. They found maternal sensitivity, mind-mindedness (i.e., use of verbal descriptions of infants’ behaviors and mental state), and autonomy-support measured when children were 12-15 months of age related to executive
function at 18-26 months of age. After controlling for general cognitive ability and maternal education level, autonomy-support contributed most to children’s executive function performance (Bernier et al., 2010). The findings from these various studies demonstrate the importance of parenting behaviors on early executive function development.

Understanding factors influencing neurodevelopment in general, may also provide insight into factors influencing executive function. In the infant literature, key biological factors found to relate to neurodevelopment include birth weight and gestational age (Einaudi et al., 2008; Gnanendran et al., 2015; Lorenz, 2012). Environmental factors relating to early neurodevelopment include parent education level, socioeconomic status, and maternal age at delivery (Ronalds, De Stavola, & Leon, 2005). Parenting behaviors, including positive affect, sensitivity, facilitation, and synchrony also positively correlate with cognitive development in preterm children at 2 years of age (Treyvaud et al., 2009). Because executive function is a specific aspect of neurodevelopment, these biological and environmental factors are presumed to influence the development of executive function. Therefore, these variables should be explored more clearly in relation to early executive function development.

Executive function in twins. There is a lack of research literature on differences between twins and singletons with regard to executive function development. Due to executive function’s susceptibility to social and environmental factors (e.g., Bernier, Carlson, Deschenes, & Matte-Gagne, 2012), it is important to investigate how developmental environments differentially foster executive function skills in twins and singletons. As noted in one example published by Bernier and colleagues (2010), executive function development progresses from regulation via external processes (e.g., parent-imposed structure) to internal processes (i.e., self-regulation). It is presumed less parental attention and scaffolding for twins compared to singletons would hinder
executive function development, which initially depends in part on external processes. It is important to examine whether differences in environmental conditions between twins and singletons are influential enough to elicit differences in early executive function over and above demographic characteristics and medical risk factors.

**Relating Mastery Motivation and Executive Function**

Seminal studies on mastery motivation have demonstrated its relation to cognitive performance (e.g., Yarrow, Morgan, Jennings, Harmon, & Gaiter, 1982). However, the relationship between mastery motivation and executive function is only beginning to be examined, particularly in infants and young children. There are few studies, if any, that have examined mastery motivation and executive function in infants. One related study looked at the predictive relationship between these variables from childhood to adulthood. Hauser-Cram, Woodman, and Heyman (2014) completed a longitudinal study in which they found mastery motivation at 3 years of age predicted executive function 20 years later among a sample of individuals with developmental disabilities. This study suggests an ongoing link exists between mastery motivation and executive function. However, it does not provide evidence of the strength of that relationship in infancy.

Despite a lack of literature, there is reason to suggest that these two constructs should be linked. Many elements of executive function and mastery motivation support conceptual relationships between the two constructs. Executive function and mastery motivation are both self-regulation processes, which are initially influenced by external input (i.e., parental scaffolding and regulation support) and gradually internalized (Henderson & Mundy, 2013). Mastery motivation is the intention to persist at goal-directed behaviors, despite being moderately challenged. Executive function allows individuals to adapt to and navigate novel,
challenging circumstances and tasks in efforts to enact goal-directed behavior. Initiative and motivation are disrupted by executive dysfunction (Anderson, 2002), and neurodevelopmental delays are known to affect both areas of development. Thus, it is likely that executive function and mastery motivation develop in tandem.

**Theoretical linkages.** The self-regulation hypothesis described above is one example of a theory that supports a linkage between executive function and mastery motivation. The problem solving theory of executive function is another description that demonstrates a connection between executive function and mastery motivation. The problem solving theory of executive function includes a process in which problems are identified, appropriate actions toward achieving solutions are determined and attempted, and outcomes are evaluated (Zelazo et al., 2003). At the point of evaluation, if the completed actions have been unsuccessful in achieving the desired solution, actions are modified until corrected. The described process of evaluating and re-attempting actions until a problem is resolved is the key function of task persistence, a pivotal component of mastery motivation. Thus, it appears that executive function and mastery motivation may be partially intertwined and each is necessary for the success of the others’ process.

Another theoretical linkage that may be drawn from the literature relates to the role of objects in mastery motivation and executive function during infancy. In infants, executive function is often assessed with object permanence type tasks (Anderson, 2002; Zelazo et al., 2003). Similarly, mastery motivation was originally focused on persistence with objects (e.g., Yarrow et al., 1982). The emphasis on examining infants’ executive function and mastery motivation with cognitive tasks may be explained, in part, by children’s tendency to learn through interaction with objects in the environment during critical developmental periods (e.g.,
Piaget, 1952). While executive function likely interacts with the various components of mastery motivation due to links with persistence and affective regulation, further exploration is needed to identify whether executive function is more closely related to specific components of mastery motivation (i.e., persistence with objects) than others.

The conceptual overlap between mastery motivation and executive function suggests these developmental constructs likely influence each other. Mastery motivation fosters initiation and persistence with challenging tasks that often require problem solving, an element of executive function. Executive function organizes processes involved in goal-directed behaviors, which often includes task persistence. While Hauser-Cram et al. (2014) found mastery motivation to predict later executive function, conceptual and theoretical understanding of mastery motivation and executive function suggests these constructs are inter-related. At this point, both executive function and mastery motivation are considered different components of regulatory processes, influenced by biological and environmental factors, and important in the development of later competencies. Additional exploration is needed to clarify the degree and directionality of relationships between mastery motivation and executive function.

**Medically High-Risk Infants**

The consideration of medical variables that determine infants to be high risk is relevant both for studies examining early developmental functioning as well as studies of plurality’s impacts. Gestational age, birth weight, and length of stay in NICU are common risk characteristics identified among infants, the latter of which generally approximates the extent of other pre- and perinatal complications. With regard to assessment of developmental functioning, premature infants have been found to demonstrate poorer functioning than full-term infants in areas of language development (Stolt, Haataha, Lapinleimu, & Lehtonen, 2009), motor skills
development (Evensen, Skranes, Brubakk, & Vik, 2009), executive function (Sun, Mohay, & O’Callaghan, 2009), and mastery motivation (Harmon & Murrow, 1995). In a study of children with multiple risk factors—including low birth weight, prematurity, increased length of stay in a neonatal intensive care unit, and need for ventilation—endorsement of high-risk medical variables was significantly correlated with lower performance on measures of cognitive and motor development (Laucht, Esser, & Schmidt, 1997).

Twins consistently demonstrate higher prevalence of key medical risk variables examined in the literature, including prematurity; low birth weight (< 2500 g) and very low birth weight (< 1500 g); and pregnancies complicated by pre-eclampsia, intrauterine growth restriction, and premature preterm rupture of membranes (Martin et al., 2010). Given the higher incidence of medical risk factors for twins, contemporary studies seeking to isolate the impact of plurality among medically high-risk infants control for variables such as gestational age and birth weight (e.g., Gnanendran et al., 2015) so as to better explain variance solely due to plurality. Early medical risk factors are more prevalent in twins than singletons and significantly impact infant development; thus, they are worth particular consideration in the examination of plurality’s impact on early mastery motivation and executive function.

Summary

Increasing success with fertility treatments and improved infant survival conditions have led to increases in the prevalence of twin births. Twins and singletons experience differing biological and environmental conditions influencing early neurocognitive and psychosocial development. Research findings indicate twins’ functioning relative to singletons’ varies by domain, and current understanding of specific aspects of early twin development is insufficient. Recent studies reveal no significant differences between twins and singletons with regard to
cognitive ability (Einaudi et al., 2008; Gnanendran et al., 2015; Lorenz, 2012). However, problem solving, gross motor, and social development have been found to be significantly delayed in twins compared to singletons (Nan et al., 2013). Mixed findings in the research literature indicate twins appear to differ from singleton counterparts in some domains of functioning and not in others.

Mastery motivation and executive function are two regulatory processes that have been found to predict different aspects of behavior and performance; yet, to date, no information is available regarding birth plurality’s impact on the development of these constructs. Mastery motivation, the impetus to persist at challenging tasks in an effort to master new skills, and executive function, cognitive processes oriented toward goal-directed behaviors, are both influenced by early environmental conditions. Specifically, the development of both of these regulatory processes is impacted by neurodevelopmental factors and parenting behaviors, including scaffolding and balancing the provision of structure with encouragement for infants’ independent exploration. Thus, conditions in which rates of neurodevelopmental impacts and/or parenting behaviors differ—such as with the presence of twin births—likely impact infant mastery motivation and executive function development.

Biological complications also impact mastery motivation and executive function development. Specifically, gestational age and birth weight are two key variables associated with developmental outcomes. Twins are at increased risk for preterm delivery and low birth weight (Martin et al., 2010). While twins’ higher prevalence of medical risk factors puts them at risk for poorer developmental outcomes than singletons in general, it is important to consider how at-risk twins compare to at-risk singletons. Empirical examination is needed to better understand whether characteristics of being a twin relate to mastery motivation and executive
function development beyond what is expected due to medical risk factors (e.g., low birth weight and prematurity).

**Aim of the Present Study**

Findings regarding differences between twins’ and singletons’ early development are mixed and depend on the construct of interest. It is clear the presence of two infants compared to one creates a different environment with regard to parenting behaviors and opportunities for peer socialization. Thus, competencies greatly influenced by environmental conditions are anticipated to differ between twins and singletons. Mastery motivation and executive function are two such competencies that depend on external input. However, no information is available regarding the difference between twins and singletons with regard to early development of mastery motivation or executive function. The purpose of this study is to establish a preliminary conceptualization of twin-singleton differences in early mastery motivation and executive function. This study will demonstrate whether differences in mastery motivation and executive function are present between twins and singletons during the first 3 years of life. Further, the relationship between mastery motivation and executive function will be examined along with medical characteristics thought to influence the development of these competencies. Additional demographic variables will be explored in relation to birth plurality, mastery motivation, and executive function.

Based on the preceding literature review, the following hypotheses have been identified for this study:

**Demographic Characteristics**

1. It is hypothesized there will be significant differences between twins and singletons with regard to maternal age, parental education level, and parental socioeconomic status.
Mastery Motivation and Executive Function

2. It is hypothesized that mastery motivation will be positively related to executive function.

Risk Characteristics, Mastery Motivation and Executive Function

3. It is hypothesized that high-risk medical characteristics will be negatively related to executive function and will be associated with lower mastery motivation scores.

Plurality and Mastery Motivation

4. It is hypothesized twins will have lower scores than singletons on all five measured domains of mastery motivation (i.e., persistence at object or cognitive tasks, gross motor persistence, social mastery motivation with adults, social mastery motivation with peers/children, negative reactions to failure).

Plurality and Executive Function

5. It is hypothesized twins will have significantly lower scores than singletons with regard to measures of early executive function, specifically object permanence scores on the Bayley III.

Risk Characteristics, Plurality, Mastery Motivation and Executive Function

6. It is hypothesized that twins with high-risk medical characteristics will differ from singletons with high-risk medical characteristics with regard to executive function and lower mastery motivation scores.

Mastery Motivation

7. It is hypothesized that the subscale of mastery motivation with objects (i.e., persistence at object or cognitive tasks) will show the strongest relationship to executive function relative to the other five subscales of mastery motivation to executive function in twins and singletons.
Method

Participants

Participants included 80 infants and toddlers (40 twins and 40 singletons), between 9 and 40 months of age, who received an evaluation through a Neonatal Intensive Care Unit (NICU) follow-up clinic at a university hospital in the Pacific Northwest between 2009 and 2015. The demographic variables of participants generally reflected the population comprising the geographic area served by the NICU follow-up clinic (see Table 1). The majority of the sample represented children and families from Caucasian, English-speaking backgrounds. Only infants and toddlers whose parents completed English- or Spanish-language forms were included in this study.

Groups. Participants were separated into two groups: Twins and Singletons. Participants were matched for birth weight, gestational age, and days in the NICU in order to reduce threats to internal validity. The matching process took place by first identifying all eligible twin participants (i.e., twins without missing data on key variables), because the number of eligible twins limited the size of our sample due to fewer twins than singletons. Birth weight was the first category upon which singletons were matched with twins. Birth weight matching was designated by the following standards commonly accepted in research and clinical practice: (1) birth weight < 2,500 g = low birth weight (LBW), (2) birth weight < 1,500 g = very low birth weight (VLBW), and (3) birth weight < 1,000 g = extremely low birth weight (ELBW); twins were matched with singletons in the same birth weight category. Gestational age was the second variable for which groups were matched. Twins were matched with singletons within 1-2 weeks of the same gestation, with effort made to match as closely to the same gestational age as possible. The number of days in the NICU was the final variable for which groups were
matched, due to this variable possessing the greatest variability. Twins were matched with singletons within the following categories regarding days in NICU: (1) < 1 week, (2) 1 – 4 weeks, (3) 4 – 12 weeks, (4) > 12 weeks, with effort made to match as closely to the same number of days as possible. During each matching round, a narrowing pool of potential singleton matches were selected for each twin for each criterion (e.g., birth weight, gestational age, days in NICU) until all qualifying twins had a matching singleton.

**Exclusion Criteria.** Infants and toddlers with identified congenital anomalies and syndromes were excluded from this study due to the impact of many congenital syndromes on global development. Infants and toddlers whose parents’ did not complete English or Spanish forms (i.e., DMQ and demographic questionnaire) were excluded from this study. Higher-order multiples, that is greater than two fetuses per gestation, were excluded from this study.

**Procedures**

The procedures for this study were approved by the Institutional Review Boards of the medical institution from which the data were collected and Pacific University. All data were collected via chart review. Original data were obtained between 12/18/2009 and 2/27/2015 during participants’ clinical appointments in the NICU follow-up clinic. The NICU follow-up clinic includes medical, audiology, and developmental assessments for children with histories of NICU admission. Children typically attend the follow-up program at 3-months post-discharge from the NICU, which often corresponds with 3-6 months of age (i.e., chronological age). Children are typically followed annually for the first three years of life, corresponding with evaluations at ages 12-18, 22-26, and 36 months.

All participants in this study completed full administration of the Bayley Scales of Infant and Toddler Development, Third Edition (Bayley III) per the follow-up clinic protocol. The
Dimensions of Mastery Questionnaire, 17 (DMQ and a brief demographic questionnaire were completed by parents of participants during their developmental evaluation appointments. Bayley III item scores were derived from standardized administration by trained clinical personnel. Data gathered through chart review were de-identified and extracted for analysis using IBM SPSS Statistics 23.0.

Measures

**Demographic Information.** Participant demographic information was obtained during clinic visits and extracted from participants’ electronic medical records. Demographic variables pertinent to this study included whether neonates were singletons or twins, gestational age, birth weight, length of stay in NICU, insurance type, parental education level, and maternal age. Gender, race, primary language, delivery method (e.g., vaginal, cesarean section), enrollment in early intervention services, and age at evaluation were additional demographic variables collected to describe the sample. Gestational age was reported in number of weeks at delivery. Parental education level was reported by parents of participants. Insurance type was coded as public or private and served as a proxy for socioeconomic status (e.g., Marcin, Schembri, He, & Romano, 2003).

**Infant Mastery.** The Dimensions of Mastery Questionnaire, 17 (DMQ) is an adult-report (e.g., teacher, parent) measure of children’s mastery motivation (Morgan et al., 2009). Mastery motivation refers to an intrinsic intention to persist at challenging tasks and is theorized to require problem solving and goal-directed behaviors. The DMQ assesses mastery motivation in seven distinct domains of childhood functioning: object-oriented persistence (persistence at cognitive tasks), gross motor persistence, social persistence with adults, social persistence with children, mastery pleasure, negative reactions to failure, and general competence. All subscales
were used in this study with the exception of the general competence and mastery pleasure scales.

The DMQ normative data are composed of 800 individuals from ages 6 months to 19 years. Approximately 300 members of the sample were infants. Participants in the normative sample were primarily Caucasian, American, typically developing youth. However, international, racially diverse, and medically diverse (e.g., premature) youth also represented a portion of the normative sample (Morgan et al., 2009). The internal consistency reliabilities for the subscales in an infant sample ranged from .69 to .84: Objective Persistence: .80, Gross Motor Persistence: .84, Social Persistence with Adults: .71, Social Persistence with Children: .81, Mastery Pleasure: .82, Negative Reaction to Failure: .77, and General Competence: .69 (Morgan et al., 2009). Test-retest reliability ranged from .68 (Negative Reaction to Failure) to .89 (Social Persistence with Children). Raw subscale scores for the five domains were utilized for this study.

**Executive function.** The Bayley Scales of Infant and Toddler Development, Third Edition (Bayley III) is a measure of developmental functioning for infants and toddlers ages 0-42 months designed to identify developmental delay and support intervention planning. The clinician-administered portion of the Bayley III is composed of cognitive, language, and motor composite scores comprising five subtest scores: Cognitive, Receptive Language, Expressive Language, Fine Motor, and Gross Motor. Parent-report social/emotional and adaptive functioning measures are also available, although they are not administered in this NICU follow-up clinic and were not analyzed for this study.

The Bayley III was normed with 1700 participants representative of the 2000 census and stratified by sex, age, parent education level, race and ethnicity, and geographic location (Bayley, 2006). Participants were excluded from the normative sample for many medical and
psychosocial complications including prematurity and low birth weight (e.g., Bayley, 2006). Data from nine “special groups” were later added to comprise 10% of the Bayley III normative sample (e.g., Bayley, 2006). Reliability findings for the Bayley III range from moderate to high with the following average internal consistency coefficients: Fine Motor $\alpha = .86$; Receptive Communication $\alpha = .87$; Cognitive, Expressive Communication, and Gross Motor $\alpha = .91$. The Bayley III also has established average internal consistency coefficients from the nine special groups, which equal or exceed the findings from the standardization sample: Fine Motor $\alpha = .94$, Receptive Communication $\alpha = .95$, Cognitive and Expressive Communication $\alpha = .96$, and Gross Motor $\alpha = .98$ (Bayley, 2006).

Several items from the Bayley III cognitive subtest are considered to reflect early executive function skills (i.e., working memory, planning, inhibition, and attentional control; Piaget, 1954 as cited in Diamond, 2006; Lowe et al., 2013). In these items, children are asked to find a displaced item in three different scenarios (i.e., object permanence). Children’s performance on these items served as measures of early executive function. Children received a score of 1 (pass) or 0 (fail) for each of the three administered items, as well as a total score comprising the sum of three object permanence items (score range 0-3). For this study, children’s total scores (e.g., sum of raw scores on three object permanence items) were analyzed as a continuous dichotomous variable with factors of pass and fail.

**Analyses**

All data for this study were analyzed using SPSS 23.0. To correct for risk of Type 1 error that may occur with multiple analyses, Bonferroni corrections were applied to individual hypotheses with multiple analyses.
Pre-analysis data screening. All data were initially examined for missing data, outliers, and meeting test assumptions. There were five missing data points for the days in NICU variable. These missing data were determined to be missing at random due to absence of the specific information in subjects’ charts. These five missing values were estimated using multiple imputation. Visual inspection of histograms and examination of skewness and kurtosis values were used to determine whether continuous variables met the normality assumption. The distributions for maternal and paternal education levels were not normal, thus parental education levels were adjusted to dichotomous variables described as 1) less than or equivalent to high school and 2) greater than high school. Homogeneity of variances was assessed using Levene’s test. The assumptions for chi-squared tests were also considered and met, such that sample sizes were large enough that each cell was expected to have values greater than five and the examined variables were independent. There were missing data for most demographic variables. Missing data were determined to be missing completely at random, primarily due to absence of information reported in patients’ electronic medical records. Cases with missing demographic data were excluded via pairwise deletion rather than listwise deletion in order to maximize the power of each analysis.

Results

Demographic Data

Table 1 presents demographic characteristics of participants in this sample. Analysis of demographic information revealed the majority of the sample comprised children between 12- and 18-months of age (45.1%) with slightly more males (57.5%). There were fewer participants with birth weight in the extremely low range (20%) than in the very low (40%) and low (40%) ranges and the mean birth weight was 1415.03 g ($SD = 401.54$ g; see Table 2 for means and
standard deviations). The mean gestational age was 30.5 weeks ($SD = 2.61$ weeks). The mean number of days in the NICU was 49.63 days ($SD = 27.64$ days). As expected based on the community demographics, the majority of the sample comprised Caucasian (65.%) and English-speaking (87%) participants. Mean maternal age at time of birth was 30.61 years ($SD = 6.86$ years) and cesarean-section predominated as delivery type (73.91%). The majority of mothers and fathers had post-high school level education (70.1% and 61.5%, respectively). There were approximately equal percentages of families reporting private and public insurance, with 54.1% of participants endorsing private insurance. Among participants in our sample, 69.8% qualified for early intervention services and 56.7% were enrolled in early intervention at the time of the evaluation.

Table 1

**Participant Characteristics**

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<th>%</th>
<th>Singletons</th>
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</table>

**Initial relationships**

Table 2 presents the zero-order correlations among the measured variables as well as variable means and standard deviations. A Bonferroni correction was applied based on 13 analyses, setting the $p$ value to less than .004 (.05/13) as the required significance level. Only significant relationships that met the .004 significance level are discussed. The three risk
variables of birth weight, gestational age, and number of days in NICU were significantly related to one another. Due to the high intercorrelations among these variables, each risk variable was considered individually in later analyses with other variables. There was a significant positive relationship between gestational age and DMQ social persistence with children scores. Maternal and paternal education levels were significantly related to DMQ social persistence with adults scores; therefore, these variables were considered as covariates in later analyses. Maternal age was significantly correlated with paternal education and insurance type.

Table 2

*Bivariate correlations among variables of interest*

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Birth weight (g)</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Gestational age (weeks)</td>
<td>.82***</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Days in NICU (days)</td>
<td>-.80**</td>
<td>-.85***</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Maternal Age (years)</td>
<td>.20</td>
<td>.22</td>
<td>-.06</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Maternal education</td>
<td>.11</td>
<td>.15</td>
<td>-.10</td>
<td>.38**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Paternal education</td>
<td>.06</td>
<td>.08</td>
<td>.09</td>
<td>.47***</td>
<td>.70***</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Insurance type</td>
<td>.12</td>
<td>.12</td>
<td>-.06</td>
<td>.37***</td>
<td>.53***</td>
<td>.49***</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>8. Executive functioning</td>
<td>.17</td>
<td>.23</td>
<td>-.14</td>
<td>-.22</td>
<td>.07</td>
<td>.04</td>
<td>.06</td>
<td>-</td>
</tr>
<tr>
<td>9. OOP</td>
<td>.35***</td>
<td>.33***</td>
<td>-.35***</td>
<td>.20</td>
<td>.08</td>
<td>.15</td>
<td>.08</td>
<td>.05</td>
</tr>
<tr>
<td>10. SPA</td>
<td>.07</td>
<td>.11</td>
<td>-.14</td>
<td>.14</td>
<td>.41***</td>
<td>.43***</td>
<td>.27*</td>
<td>.39**</td>
</tr>
<tr>
<td>11. SPC</td>
<td>.26*</td>
<td>.30***</td>
<td>-.38**</td>
<td>.08</td>
<td>.01</td>
<td>.20</td>
<td>.01</td>
<td>-.08</td>
</tr>
<tr>
<td>12. GMP</td>
<td>.30**</td>
<td>.32***</td>
<td>-.32**</td>
<td>.09</td>
<td>.15</td>
<td>.20</td>
<td>-.04</td>
<td>.34*</td>
</tr>
<tr>
<td>13. NRF</td>
<td>.24*</td>
<td>.08</td>
<td>-.18</td>
<td>.00</td>
<td>-.02</td>
<td>-.03</td>
<td>.08</td>
<td>-.09</td>
</tr>
</tbody>
</table>
Correlations among DMQ subscale scores are illustrated in Table 3. The following DMQ subscale scores were significantly positively interrelated: Objected oriented persistence, social persistence with adults, social persistence with children, and gross motor persistence. The subscale of negative reaction to failure was not significantly related with other DMQ subscale scores, which is consistent with intercorrelations found from the Dimensions of Mastery Questionnaire, 17 (DMQ) normative sample (Morgan et al., 2009).

Table 3

<table>
<thead>
<tr>
<th>DMQ Subscale (N = 80)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Object Oriented persistence</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Social Persistence with Adults</td>
<td>.28*</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Social Persistence with Children</td>
<td>.39***</td>
<td>.33***</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Gross Motor Persistence</td>
<td>.53***</td>
<td>.42***</td>
<td>.39***</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>5. Negative Reaction to Failure</td>
<td>-.02</td>
<td>-.19</td>
<td>.19</td>
<td>-.05</td>
<td>-</td>
</tr>
<tr>
<td>Mean</td>
<td>3.46</td>
<td>3.92</td>
<td>3.60</td>
<td>3.74</td>
<td>2.79</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>.68</td>
<td>.68</td>
<td>.99</td>
<td>.70</td>
<td>.86</td>
</tr>
</tbody>
</table>

* * p < .05, ** * p < .01, *** * p < .004

**Hypothesis 1: Demographic Characteristics and Covariate Analyses**

Hypothesis 1 predicted that maternal age, parental education levels, and parental socioeconomic status would differ between twins and singletons.

**Hypothesis 1a.** The relationship between plurality and maternal age was measured using an independent samples t-test. Results from Levene’s test indicated equal variances, \( F = .44, p = .51 \). The t-test was not significant, \( t(64) = 1.80, p = .08 \), suggesting maternal age at delivery was not statistically significantly different between mothers of singletons (\( N = 30, M = 28.97, SD = \))
6.92) and mothers of twins ($N = 36, M = 31.97, SD = 6.60$). The difference between maternal ages produced a small to medium effect size, $d = .44$ (Cohen, 1988).

**Hypothesis 1b.** The relationship between plurality and parental education level was examined using a chi-square test. Neither maternal education, $\chi^2_{\text{Maternal Education}} = (1, N = 57) = 1.60, p = .21$, nor paternal education, $\chi^2_{\text{Paternal Education}} = (1, N = 52) = 1.25, p = .26$, significantly differed between twins and singletons.

**Hypothesis 1c.** The relationship between plurality and parental socioeconomic status was also examined using a chi-square test. Results from the chi-square test indicated no significant differences between twins and singletons with regard to parental socioeconomic status, as measured by insurance type, $\chi^2 = (1, N = 74) = .80, p = .37$.

Hypothesis 1 was not supported by the findings from this sample. There were no significant differences between twins and singletons with regard to maternal age at birth, parental education levels, or parental socioeconomic status.

**Hypothesis 2: Mastery Motivation and Executive Function**

Hypothesis 2 predicted a significant positive relationship between mastery motivation and executive function scores. The relationships between mastery motivation subscale scores and executive function scores were examined using Biserial correlations (see Table 2). For these comparisons, a Bonferroni correction for five analyses was applied, setting the $p$ value to less than .01 (.05/5). Executive function scores and DMQ social persistence with adults scores were significantly positively correlated ($r_b = .39, p = .005$). Executive function scores and DMQ gross motor persistence scores were correlated at the $p < .05$ level but not at the corrected significance level ($r_b = .34, p = .02$). No other correlations between executive function and mastery motivation scores were significant.
Hypothesis 3: High-Risk Medical Characteristics and Outcomes

It was hypothesized that high-risk medical characteristics would be negatively related to executive function and associated with lower mastery motivation scores.

**Hypothesis 3a.** Biserial correlations revealed no significant relationships between gestational age, birth weight, or days in NICU and executive function. With regard to mastery motivation, object oriented persistence, social persistence with children, and gross motor persistence were positively related to birth weight and gestational age and negatively related to the number of days in the NICU. The relationship between negative reaction to failure and birth weight approached significance at the corrected significance level ($r = .24, p = .004$).

**Hypothesis 3b.** Linear regression analyses were conducted to further examine the degree of prediction and the confidence intervals among relationships between risk variables and mastery motivation subscale scores, which were found to be significantly correlated at the zero-order level (see Table 4). The Bonferroni correction for these analyses was a significance level of $p < .008 (.05/6)$ based on six regression equations. Mastery motivation object oriented persistence scores were significantly predicted by birth weight, gestational age, and number of days in the NICU. The social persistence with children subscale scores were significantly predicted by gestational age and days in NICU but not by birth weight. The gross motor persistence subscale scores were also significantly predicted by gestational age and days in NICU; the relationship between birth weight and gross motor persistence approached significance at the corrected p-value.

This hypothesis was partially supported by the data. Executive function was not negatively related to the identified risk characteristics of birth weight, gestational age, or days in the NICU. With regard to mastery motivation, three of the five subscale scores were
significantly related to the risk variables. Further, risk variables were found to predict DMQ object permanence, social persistence with children, and gross motor persistence and accounted for between 9-14% of the variance of these DMQ subscale scores, depending on the variables (see Table 4).

**Table 4**

*Reporting results that met original Bonferroni correction and providing Confidence Interval and $R^2$ (N = 80)*

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Dependent Variable</th>
<th>$F$-ratio</th>
<th>$p$-value</th>
<th>$R^2$</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA</td>
<td>OOP</td>
<td>9.65</td>
<td>.003</td>
<td>.11</td>
<td>.03 – .14</td>
</tr>
<tr>
<td>NICU</td>
<td>OOP</td>
<td>10.90</td>
<td>.001</td>
<td>.12</td>
<td>-.01 – -.00</td>
</tr>
<tr>
<td>BW</td>
<td>OOP</td>
<td>10.94</td>
<td>.001</td>
<td>.12</td>
<td>.00 – .01</td>
</tr>
<tr>
<td>GA</td>
<td>SPC</td>
<td>7.68</td>
<td>.007</td>
<td>.09</td>
<td>.03 – .20</td>
</tr>
<tr>
<td>NICU</td>
<td>SPC</td>
<td>12.99</td>
<td>.001</td>
<td>.14</td>
<td>-.02 – -.01</td>
</tr>
<tr>
<td>GA</td>
<td>GMP</td>
<td>9.133</td>
<td>.003</td>
<td>.09</td>
<td>.03 – .14</td>
</tr>
<tr>
<td>NICU</td>
<td>GMP</td>
<td>8.92</td>
<td>.004</td>
<td>.09</td>
<td>-.00 – -.00</td>
</tr>
<tr>
<td>BW</td>
<td>GMP</td>
<td>7.52</td>
<td>.008</td>
<td>.09</td>
<td>.00 – .00</td>
</tr>
</tbody>
</table>

*Note: GA = Gestational Age, NICU = Days in NICU, BW = Birth weight, OOP = Object oriented persistence score, SPC = Social persistence with children score, GMP = Gross motor persistence score; Bonferroni correction (.05/6) = $p < .008$*

**Hypothesis 4: Plurality and Mastery Motivation**

It was hypothesized that twins would have significantly lower scores than singletons on all five measured mastery motivation subscales. The relationship between plurality and mastery motivation was examined using an Analysis of Covariance (ANCOVA) controlling for parental education level. Preliminary chi-square analyses were conducted between maternal and paternal education and plurality to ensure independence of the covariates and independent variable. The
results of the chi-square tests were not significant, indicating no differences between twins and singletons with regard to parental education (paternal education: $\chi^2 = 1.25, p = .38$; maternal education: $\chi^2 = 1.60, p = .25$). Table 5 illustrates twins’ and singletons’ mean scores and standard deviations for each DMQ subscale. Results from the ANCOVA demonstrated no significant differences between twins and singletons with regard to mastery motivation subscale scores. The difference between twins’ and singletons’ on the DMQ negative reaction to failure subscale approached significance at the corrected $p$-value, $F(1, 48) = 4.59, MSE = .50, p = .04, \eta^2_p = .09$, indicating twins tend to have greater difficulty responding to failure than singletons.

The hypothesis that twins would have lower scores than singletons on the mastery motivation questionnaire was not supported.

Table 5

<table>
<thead>
<tr>
<th>DMQ subscale</th>
<th>Twins</th>
<th></th>
<th>Singletons</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Object Oriented Persistence</td>
<td>3.60</td>
<td>.75</td>
<td>3.32</td>
<td>.57</td>
</tr>
<tr>
<td>Social Persistence with Adults</td>
<td>4.05</td>
<td>.69</td>
<td>3.79</td>
<td>.64</td>
</tr>
<tr>
<td>Social Persistence with Children</td>
<td>3.47</td>
<td>1.14</td>
<td>3.74</td>
<td>.79</td>
</tr>
<tr>
<td>Gross Motor Persistence</td>
<td>3.78</td>
<td>.69</td>
<td>3.70</td>
<td>.72</td>
</tr>
<tr>
<td>Negative Reaction to Failure</td>
<td>2.51</td>
<td>.73</td>
<td>3.07</td>
<td>.90</td>
</tr>
</tbody>
</table>

**Hypothesis 5. Plurality and Executive Function**

It was hypothesized that twins would have lower executive function scores than singletons. The relationship between plurality and executive function was examined using a chi-
EARLY DEVELOPMENT OF MEDICALLY AT-RISK TWINS

square test. The results were not statistically significant, indicating no significant differences between twins and singletons with regard to executive function performance ($\chi^2 = 1.88, p = .17$). Thus, this hypothesis was not supported.

**Hypothesis 6. Risk Characteristics, Plurality, Mastery Motivation and Executive Function**

It was hypothesized twins with high-risk medical characteristics would differ from singletons with high-risk medical characteristics with regard to executive function and lower mastery motivation scores. The impact of the interaction of high-risk medical characteristics and plurality on mastery motivation scores was examined using multivariate analysis of covariance (MANCOVA) analyses, in which plurality was the independent variable, birth weight, gestational age, and days in the NICU were covariates, and mastery motivation subscale scores were the dependent variables. As noted above, due to intercollinearity between the three variables comprising risk characteristics, each relationship was examined individually. The DMQ negative reaction to failure subscale scores were the only scores to be significantly different between twins and singletons when degree of medical risk was considered. Twins with lower birth weights had significantly lower DMQ negative reaction to failure scores than singletons with lower birth weights, $F(1, 77) = 10.07, MSE = .64, p = .002, \eta_p^2 = .12$. Twins with younger gestational ages had significantly lower DMQ negative reaction to failure scores than singletons with younger gestational ages, $F(1, 77) = 9.21, MSE = .68, p = .003, \eta_p^2 = .11$. Twins with more days spent in the NICU had significantly lower DMQ negative reaction to failure scores than singletons with younger gestational ages, $F(1, 77) = 8.50, MSE = .67, p = .005, \eta_p^2 = .10$. The effect sizes for each of these relationships were small to medium (Cohen, 1988).
Earlier analyses revealed no significant relationships between high-risk medical characteristics and executive function or plurality and executive function in our sample. Therefore, the interaction of high-risk medical variables and plurality on executive function performance was not analyzed.

**Hypothesis 7.** The hypothesis comparing the strongest relationship between executive function and mastery motivation was not formally analyzed. Social persistence with adults was the only subscale significantly related to executive function scores and gross motor persistence approached statistical significance. It can be inferred that social persistence with adults has the strongest relationship with executive function because it was the only significant relationship among all five mastery motivation subscales examined.

**Discussion**

The rising prevalence of multiple births calls for increased knowledge of developmental trajectories unique to twins. Previous studies examining differences between twins and singletons have produced mixed findings depending on the construct of interest and the stage of child development. In addition, some differences found between twins and singletons have been attributed to medical risk factors (e.g., prematurity, birth weight) rather than plurality, per se. Differences in mastery motivation and executive function development have yet to be explored among twins and singletons. Mastery motivation (i.e., persistence with challenging, goal-directed behaviors) and executive function (i.e., cognitive processes applied in goal-directed behaviors and adaptation to novelty) are both influenced by early environmental conditions and have been found to predict later functioning. Thus, differences in mastery motivation and executive function are worth examining between twins and singletons during the earliest stages of development. The current study is a preliminary investigation of differences in mastery
motivation and executive function between young twins and singletons with high-risk medical characteristics.

**Explanation of Findings**

The primary aim of this study was to examine whether differences exist between twins and singletons with regard to early mastery motivation and executive function development. The hypothesis that twins would present with lower mastery motivation and executive function scores than singletons was partially supported in this sample of medically high-risk infants and toddlers. When birth weight, gestational age, and days spent in the NICU were controlled, twins demonstrated more difficulty emotionally regulating in response to failure and moved on from uncompleted challenging tasks more quickly than singletons. Interestingly, the only domain in which twins and singletons differed reflected emotional regulation skills more so than persistence.

Emotional regulation in response to failure has not been previously examined in literature regarding twin-singleton differences. Thus, this result has implications for further exploration into potential mediating factors explaining differences between young twins’ and singletons’ reactions to failure. One explanation for this difference is that emotional regulation in response to failure is strongly influenced by parental modeling; thus, shared adult attention may hinder opportunities for social learning for twins compared to singletons. Another theory is that negative responses to failure may function as a means to increase parental attention, which is consistent with literature indicating parents are more likely to interfere with children’s development when mastery motivation and autonomy are less developed (Hauser-Cram, 1993). Because twins may need to vie for parental attention more than singletons, reacting negatively to failure may be an adaptive strategy for drawing parental support.
The absence of other differences between twins and singletons for early mastery motivation and executive function was a surprising finding given the theoretical background in early childhood development emphasizing the role of parent-infant relations and modeling. For example, teaching tasks, scaffolding, and providing contingent reactions to children’s task-based efforts influence mastery motivation and executive function development (Hauser-Cram, 1996; Landry et al., 2002). It was hypothesized that due to differences in parent-infant relations and learning opportunities that naturally result from the presence of multiple infants, the early developmental constructs of executive function and mastery motivation would be impacted. The findings from this study indicating no differences between twins’ and singletons’ performances with regard to executive function and mastery motivation should be interpreted with caution. Several extraneous factors may have impacted the robustness of these results, including the measurement tools; thus, these considerations will be elaborated upon in the limitations section.

A secondary aim of this study was to explore whether other demographic and medical characteristics influenced early mastery motivation and executive function scores. Results from these data demonstrated several demographic and medical characteristics impacted mastery motivation scores. Specifically, birth weight, gestational age, and days spent in the NICU correlated with mastery motivation object oriented persistence scores. Gestational age was positively related to social persistence with children and gross motor persistence, which is consistent with previous research demonstrating prematurity significantly relates to mastery motivation (Harmon & Murrow, 1995; Hauser-Cram, 1996) and motor development (Evensen et al., 2009; Laucht et al., 1997). As expected, high-risk medical characteristics were linked with hindered mastery motivation development in cognitive, social, and motor domains. Due to high
intercorrelation between birth weight, gestational age, and days spent in the NICU, examining the unique impacts of all three high-risk medical characteristics may not have been necessary.

Surprisingly, there were no significant relationships between high-risk medical characteristics and executive function, which is contrary to previous literature demonstrating a relationship between low birth weight and prematurity with neurodevelopment (Einaudi et al., 2008; Gnanendran et al., 2015; Lorenz, 2012). These results may indicate early executive function, mainly object permanence, is not impacted by perinatal risk factors such as prematurity, low birth weight, and time spent in the NICU. However, considering prior research findings consistently demonstrate a relationship between early risk factors and cognitive functioning, it is more likely that our measure of executive functioning was not robust enough to produce accurate statistics. Alternatively, object permanence may be a highly canalized skill and thus, not easily disrupted by medical factors. Object permanence as a measure of executive function may show limited variation among infants.

Another demographic characteristic found to relate to mastery motivation in this study was parental education levels. Specifically, maternal and paternal education levels were found to be related to social persistence with adults, which is consistent with previous literature demonstrating a link between parental education, parenting beliefs, and child mastery motivation (Turner & Johnson, 2003). Unfortunately, due to missing data, the impact of parental education levels on other aspects of mastery motivation and executive function development may not have been captured in this sample.

The relationship between mastery motivation and executive function during infant and toddler development was also examined in the current study. Previous findings have indicated early mastery motivation predicts later executive function (Hauser-Cram et al., 2014). However,
the concurrent relationship between these constructs is less clear. In the current study, there were no significant relationships when the significance level was adjusted for multiple analyses; however, some correlations approached the more stringent significance level. Executive function was marginally associated with mastery motivation gross motor persistence. Previous studies have found a relationship between executive function and gross motor performance, and this relationship appears to be mediated by response inhibition (Hartman, Houwen, Scherder, & Visscher, 2010; Livesey, Keen, Rouse, & White, 2006). The results from the current study suggest the link between executive function and motor performance may extend to mastery motivation, such that infants and toddlers with underdeveloped executive function skills will be less persistent with challenging motor tasks.

The relationship between executive function and mastery motivation social persistence with adults also approached significance in this study. Executive function and social communication have been examined together extensively and found to relate concurrently and longitudinally (e.g., Riggs et al., 2006). In early stages of development, this correlation appears to be related to environmental factors, specifically parent-child interaction patterns. Parent-child interaction patterns, such as scaffolding and synchrony, have been found to influence executive function (e.g., Landry et al., 2002) and social communication development (Feldman & Eidelman, 2009), respectively. The finding of a relationship between executive function and social persistence with adults in the current study may be related to parent-child interaction patterns.

A third aim of this study was to explore whether plurality was related to demographic characteristics as a replication of previous studies. There were no significant differences between twins and singletons with regard to maternal age, socioeconomic status, or parental education levels. The findings that maternal age at delivery and maternal education level did not
differ between twins and singletons was in contrast to previous findings in the research, in which it has been reported that, as a group, mothers of twins are older at time of delivery, have higher education levels, and have higher socioeconomic status than mothers of singletons (Choi et al., 2009; Lung et al., 2009). Several considerations may help explain this discrepancy.

Sample size is one important difference to consider regarding inconsistencies between this study and previous studies that have demonstrated significant demographic differences between mothers of twins and singletons. The studies completed by Choi and colleagues (2009) and Lung and colleagues (2009) had over 8,000 to 21,000 subjects, respectively, whereas our entire sample comprised 80 participants. In addition, missing demographic data reduced the sample size further for some analyses. The difference between twins and singletons for mean maternal age at delivery approached significance ($p = .08$) and may have been significant if the sample size was larger.

Measurement and methodology are important considerations when examining the inconsistency between this study’s and previous studies’ findings. For example, in this study, socioeconomic status was estimated using insurance type as a proxy. Previous studies have incorporated more comprehensive assessments of socioeconomic status that include household income, education, and occupation (Choi et al., 2009). Using a more comprehensive and detailed measure of socioeconomic status may have influenced the findings to be more consistent with previous literature revealing a relationship between socioeconomic status and plurality. Due to sample size and methodological limitations, the conclusion that maternal age, education level, and socioeconomic status do not differ between twins and singletons are not well supported in this study.

**Limitations**
Several limitations must be considered when drawing interpretations from these data. The most salient limitations in this study include sample size and measurement tools. Additional limitations include sample characteristics and the cross-sectional design of the study.

The data in this study were drawn from a larger set of pre-existing data. Therefore, the sample size was limited to the number of twins without missing data on key variables of interest. Unfortunately, this limited the sample to 40 participants per group, which likely precluded statistically significant findings due to low power among multiple analyses.

Several issues related to the measurement of constructs also likely limited the findings produced in the current study. First, regarding executive function, three object permanence items from the Bayley III were used to represent the entire construct of early executive function. The object permanence items were scored as pass or fail, which significantly reduced the variability of scores. Further, while all clinicians are trained to administer the Bayley III in a standardized manner, individual differences in administration may have contributed to a degree of error. A continuous measure of executive function scores would have better compensated for administration error and allowed for more variability leading to stronger analyses.

Another measurement-related limitation pertains to the mastery motivation scores. The DMQ is a psychometrically supported measure of mastery motivation development (Miller et al., 2009). However, as Wang et al. (2013) demonstrated, discrepancies have been found between parent-report and clinician-report of children’s mastery motivation behaviors. This study only used parent-report of children’s mastery motivation. Multiple informants of children’s mastery motivation skills may have increased the reliability of findings.

The final measurement-related consideration worth mentioning refers to the construct of socioeconomic status. Although the use of insurance type has been used as a proxy for
socioeconomic status before (e.g., Marcin et al., 2003), its utility as such was limited in this study. Using insurance type—public or private—to estimate socioeconomic status allowed for only two categories—upper socioeconomic status and lower socioeconomic status. This type of categorization failed to capture greater variability in socioeconomic status, which may have provided a more accurate reflection of any relationships between socioeconomic status and plurality, mastery motivation, or executive function.

Sample characteristics are worth examining when considering the generalizability of findings. The homogenous demographic composition of this sample may be considered a limitation because the findings may not be generalized to other diverse populations. Another consideration is that all infants in this sample were classified as medically high-risk and experienced at least some time spent in the NICU. Only examining medically high-risk twins and singletons may have produced a restricted range of scores and may have reduced variability among other participant characteristics. Further, because there were no comparisons drawn that involved medically healthy twins and singletons, results from this study may not be generalizable to infants who do not experience time spent in the NICU after birth.

Sample biases may have also influenced these results by impacting the patients who presented to the NICU follow-up clinic. First, only examining participants from one setting reduced variability in the members of the population captured by this study, especially among participants from more rural areas. Second, this study was unable to control for any differences between twins’ and singletons’ appointment attendance rates that may exist. For example, it may be hypothesized that twins have higher rates of referrals to, and subsequent enrollment in, Early Intervention following NICU discharge, thus families of twins do not find it necessary to attend
this preventative clinic. Other confounding variables may also be attributing to unique characteristics of this sample that impact both internal and external validity of these results.

This study’s design and analysis procedures also presented some limitations. The cross-sectional design of this study is considered a limitation. This study design only allowed us to identify correlations and mean differences related to plurality, mastery motivation, and executive function. Previous research has demonstrated a predictive relationship between mastery motivation and later executive function (Hauser-Cram et al., 2014) among individuals with developmental disabilities. It would be valuable to examine the impact of plurality on mastery motivation and executive functioning longitudinally.

Bonferroni corrections applied to the multiple comparisons made in this study generated conservative significance values that may have contributed to type 2 errors. Because birth weight, gestational age, and days spent in the NICU were highly intercorrelated, use of all three variables may be considered superfluous. Choosing one high-risk medical characteristic in future studies may foster more accurate findings that are not tampered by conservative significance-level corrections.

**Future Research Directions**

To this author’s knowledge, this is the first study examining the relationship between plurality, early mastery motivation, and executive function among medically high-risk infants and toddlers. Although there are limitations to the outcomes and generalizability of the findings produced in this study, it also serves as a preliminary demonstration of these early relationships. Future research should continue to explore these relationships and address the limitations acknowledged in this study.
Future research should re-evaluate differences between twins and singletons with more rigorous methodology, including a larger sample size, a different measure of executive function, and the addition of observational measures of mastery motivation. A large, multi-site study would address many limitations presented in this study, including sample biases. As noted above, future research should examine the relationships between plurality, mastery motivation, and executive function using a longitudinal design. Measurement over time will produce a more thorough understanding of differences in early developmental trajectories for twins and singletons. In addition, a longitudinal design will allow for analyses of predictive relationships.

Future research can also build upon preliminary findings produced by this study. For example, the finding that plurality influences infants’ reactions to failure poses an argument for further examining early emotional regulation skills among twins. This study also found potential relationships between executive function, social persistence with adults, and gross motor persistence. In addition to clarifying the relationship between these constructs, future research can elaborate upon the role of parent-child interaction patterns in infants’ development of executive function and social persistence with adults.

This study was targeted at twins and singletons with high-risk medical characteristics. Future research may extend this research question of differences between mastery motivation and executive function development between twins and singletons to infants without early medical complications.

**Implications**

Some clinical implications may be drawn from the results of this preliminary investigation of early mastery motivation and executive function development in medically high-risk twins and singletons. Currently, the NICU follow-up clinic from which these data were
gathered does not utilize mastery motivation scores as evidence to refer for early intervention services. Based on the findings from this study, it is recommended that clinicians evaluating early childhood development consider mastery motivation scores, in addition to Bayley III scores, when determining early intervention referrals. Specifically, clinicians should be particularly attentive to social persistence with adults, gross motor persistence, and negative reaction to failure scores. Lower social persistence with adults and gross motor persistence scores may justify early intervention services targeted at supporting parent-child relations and environmental stimulation. With regard to negative reaction to failure, clinicians may consider assessing emotional regulation more thoroughly for infants and toddlers with lower scores, paying particular attention to twins. Subsequent early intervention referrals may allow children to receive additional support targeting emotional regulation development. Overall, the implications of this study suggest more clinical utility for the mastery motivation questionnaire as a way to determine infants’ and toddlers’ qualifications for services and connect them accordingly.

**Conclusion**

The purpose of this study was to explore whether plurality impacted mastery motivation and executive function skills in the first few years of life. Twins and singletons were matched on medical risk characteristics, including birth weight, prematurity, and time spent in the NICU. This matching process differed from previous studies but was considered to be essential given previous findings that these risk variables mediate twin-singleton differences. The findings from this study indicated twins demonstrate greater emotional dysregulation and move on from tasks more quickly than singletons after failing to accomplish a challenging task. Although there were no additional significant findings regarding the impact of plurality, other relationships between
executive function and mastery motivation were identified. These findings contribute to knowledge in the field of early childhood development, where less attention has been directed toward mastery motivation and executive function during the first 3 years of life.

As noted, the current study had several limitations precluding extensive conclusions to be drawn regarding the presence or absence of differences between twins’ and singletons’ mastery motivation and executive function development. This sample comprised infants and toddlers with high-risk medical risk characteristics, including days spent in the NICU; different findings may result from an examination of healthy twins and singletons. Despite its limitations, this study should serve as a catalyst for extending research focused on the role of plurality on integral developmental attributes. A deepened understanding of twin development will aide clinicians who provide services for this growing population.
References


