THE BLOCK- BUILDING INVARIANCE TEST (B-BIT.): QUANTIFYING INVARIANCE THROUGH OPERATIONALIZED PLAY

By

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To all the families looking for answers

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Autism is characterized by impairments in social interaction and communication, as well as the presence of restricted and repetitive behaviors. The behavioral expression of restricted and repetitive behaviors can be quite varied, spanning from preferences to verbal responses to motoric movements. The common link among this heterogeneous group of behaviors is the idea of invariance. There currently is no method of objectively evaluating invariance. Therefore, the present study developed and subsequently determined the psychometric properties of a measure designed to evaluate invariance in children diagnosed with an autism spectrum disorder. The Block-Building Invariance Test (B-BIT), an experimental task conceived after reviewing Goetz & Baer's research article (1973), was created to provide a standardized method of assessing variability in young children diagnosed with autism. The B-BIT is distinct as it is play-based and does not require fully intact cognitive functioning or receptive/expressive language skills.

Invariance reflects the desire for sameness and the extreme resistance to change. This behavioral phenotype can adversely affect both brain and behavior development, as it prevents children with autism from exploring novel environments and engaging flexibly with elements within their environments (Pierce and Courchesne, 2001). Such behavioral sequelae can be attributed not only to the defining features of autism, but also to modifications that parents make

to the environment with the hopes of preventing the negative responses that often follow changes to daily routine or exposure to unfamiliar settings and stimuli (Twoy et al., 2006). In fact, children with autism often grow up in a world dictated by their own preference for invariance.

The adverse brain and behavioral effects of an invariant state are illustrated via other bodies of literature that function as paradigms for the behavioral invariance seen in children with autism. More specifically, neurophysiological research demonstrates that a state of positive health is characterized as high dimensional complexity and low neuronal synchronicity; it is only through unpredictable patterns (i.e. variability) of underlying dynamic brain systems that the body can respond adaptively and flexibly to internal and external environmental changes (Stam et al., 2005). Similarly, animal research demonstrates that active, non-restricted engagement with an enriched environment promotes brain and behavioral development (Nithianantharajah & Hannan, 2006); this too promotes skills that facilitate adaptive and flexible response to change.

Perhaps the most salient exemplar of the negative implications of invariance is seen through research conducted with human orphans (Groark et al., 2005). Orphans often spend much of their early childhood in sterile, impoverished environments; they have limited opportunity for exposure to novel stimuli and in fact their behavior can mirror the self-stimulation behaviors seen in children with autism (i.e. body-rocking, hand-flapping). Opportunities to learn adaptive skills are limited and a strong resistance to change develops (Groark et al., 2005).

Through these analogs, which demonstrate the potential negative implications of invariance, a mechanism for change emerges. Research indicates that early intervention can reverse the adverse brain and behavioral implications for animals and children who are reared in impoverished settings; this is achieved through exposure and the promotion of flexible engagement with novel environments and elements within the environment (Nithianantharajah & Hannan, 2006). This model can be utilized to guide early intervention efforts for children with autism. If we can promote active engagement with novel environments and flexible interaction with elements within the environment, perhaps the same beneficial brain and behavioral effects can be attained. Before this can be achieved it is important for us to have a reliable and valid method of measuring the construct of variability.

An intervention study conducted by Goetz and Baer (1973) successfully increased the variability of block play in typically developing preschoolers. However, this study did not utilize a standardized method of assessing invariance. Using their treatment success as a reference, the first aim of the current study was to develop an instrument and standardized scoring system to assess invariant play-based behavior. This measure has been named the Block-Building Invariance Test (B-BIT). The second phase of the present study was to determine the psychometric properties of the B-BIT. Results suggest that the B-BIT must be modified; findings of reliability and validity parameters do not meet criteria for a psychometrically acceptable measure. Findings suggest that the B-BIT may be capturing task engagement as opposed to the intended construct of behavioral invariance. This pilot psychometric study represents the necessary initial step in a line of research designed to reduce the invariant behavior seen in children with autism through the promotion of flexible material engagement.

CHAPTER 1
INTRODUCTION

Behaviors of Children with Autism

Stereotyped, repetitive behavior is an established feature of autism that frequently dominates the daily lives of children with autism and can significantly interfere with learning and the development of adaptive behavior (Pierce & Courchesne, 2001). Despite the clinical significance of repetitive behavior seen in children with autism, the literature devoted to this area of study is relatively small compared to the extensive literature on other aspects of autistic symptomatology and associated features (Baron-Cohen, 1989; Shao et al., 2003).

Repetitive behavior is an umbrella term used to refer to the broad and often disparate class of behaviors linked by common features of repetition, rigidity and inappropriateness. In children with autism, repetitive behaviors include spontaneous dyskinesias, tics, stereotyped movements, repetitive manipulation of objects, repetitive self-injurious behavior, specific object attachments, compulsions, rituals and routines, an “anxiously obsessive desire for sameness” (Kanner, 1943), repetitive use of language, and narrow and circumscribed interests. This broad range of behavior can be subdivided into two conceptual categories: “lower-order” motor actions that are characterized by repetition of movement (dyskinesias, tics, stereotyped movements, repetitive manipulation of objects and repetitive forms of self-injurious behavior) versus more complex or “higher-order” cognitive behaviors that are characterized by an adherence to some rule or mental set (compulsions, rituals, insistence on sameness, needing to have things “just so” and circumscribed interests; Turner, 1999; Lewis & Bodfish, 1998; Rutter, 1985).

Parents will comment on these restricted, repetitive behaviors demonstrated by their children, the impact of such behaviors on their families and their own behavioral modifications. For example, parents often describe that when they drive to a certain location they use the *same* route when their child with autism accompanies them. This is done to prevent the crying and screaming that can occur when they take a short-cut or try to avoid traffic. Similarly, at home, children with autism often sit at the *same* place at the table, are given the *same* cup to drink from and the *same* foods to eat; they require the *same* bedtime story in order to go to sleep, and that their room be set up the *same* way before they enter. If any of this deviates from "*the same*" a child with autism frequently become distressed; tantrums, as well as self-injurious behaviors such as head-banging often ensue. In order to prevent these negative reactions, parents often accommodate to such *invariance*. In fact, children with autism are described to live in a "static environment of their own creation" (Cashin & Waters, 2006). This over-regulated environment prevents exposure to unfamiliar settings and stimuli, thereby alleviating unwanted behavioral responses (Twoy et al., 2006).

Additionally, parents describe that their child with autism engages in the *same* type of play over and over again. For instance, she/he will use a toy in the *same* way and cannot accept that it may serve a different function (i.e. a basket can only hold toys and cannot be used as a hat). Cars have to be lined up in the *same* linear order and only the *same* size and shape Lego can be used to build an object. Parents comment that despite the presence of many toys and materials, their child with autism prefers to play with the *same* one, in the *same* way (Twoy et al., 2006). This creates an environment that is barren and non-enriched; despite available resources, the child with autism's interaction is *restricted*.

Taken together, it is clear that a significant feature of the phenotype of autism can be captured through the idea of *sameness,* or behavioral *invariance*. Notable is that in general typically developing young children prefer routines and structure (Evans et al., 2004). In fact, research by Evans et al. (2004) suggests that by the age of two, children engage in repetitive behaviors and begin to establish routines. Compulsivity, as demonstrated by typically developing children, includes exactness with respect to detail, sensory-perceptual awareness and sequentiality of events (Evans et al., 2004). Further, typically developing children often engage in “just so” behavior (i.e. behavior that is continued until some subjective criteria are met or a subjective criterion is believed to be met). It is important to recognize however, that it is the extreme resistance to change and the intense desire for the *same* that characterizes the child with autism and differentiates him/her from the typically developing child. Despite this fundamental knowledge, assessment tools are lacking in terms of ways to objectively measure observed behavioral invariance. It is important to assess invariance in typically developing children, as well as children with autism to objectively quantify the differences in this behavioral expression.

Definition of Invariance

Although many of the behaviors seen in children with autism reflect invariance, scientifically defining, and subsequently measuring this term is a greater challenge. Based on standard definitions, invariance is characterized as “the nature of a quantity or property or function that remains unchanged even when a given transformation is applied to it” (WordNet, 2006). How do we translate this definition into science and the empirical study of behavior?

In neuropsychology, an observed behavior is linked to the cognitive domain and brain region that supports it. There are a variety of well-accepted and well-studied areas of cognition (such as attention or memory), but ‘invariance’ is not generally a behavior described as a discrete cognitive construct. Rather, this is a behavior sometimes discussed within the context of performance on other cognitive tasks. It may be possible, however, to conceptualize invariance as a unique and important behavioral aspect to measure. First, it is important to understand the relationship between invariance and similar elements within the cognitive construct of executive function.

Defining Invariance through Executive Functions

Executive functions are defined as self-regulatory skills that coordinate specific cognitive processes to achieve goal-oriented behavior and appropriate emotional response (Duncan, 1986). This cognitive construct is thought to involve several overlapping, but potentially dissociable mental operations such as inhibition, working memory, cognitive flexibility, creativity and fluency (Isquith et al., 2005). Research suggests that individuals with autism have a distinctive profile of executive dysfunction. Specifically, working memory (i.e. information processing of material or events in a short period of time) and inhibition (i.e. ability to inhibit a prepotent response) are found to be spared (Kleinhans et al., 2005), while cognitive flexibility is generally believed to be impaired (Ozonoff et al., 1991; Ozonoff & Strayer, 1997). Intuitively this makes sense, as cognitive flexibility is the ability to shift adaptively and flexibly in response to stimuli; this skill is observed to be impaired in the daily lives of children with autism. A deficit in cognitive flexibility is often reflected in perseverative behavior. However, perseverations are always dependent on the preceding action; this is inherently different from the behavior demonstrated by children with autism, as their invariance extends beyond repeating the antecedent to repeating a sequence of events often on a daily basis. Research pertaining to other sub-domains of executive function, including fluency (i.e. rapid generation of nonrepresentational designs or speeded lexical production; Baron, 2004) and creativity (i.e. imaginative use of objects; Zwaigenbaum, 2001), suggest inconsistent results in terms of the general performance of children with autism (Kleinhans et al., 2005).

Despite several inconsistencies, a general pattern of executive strengths and weaknesses emerges for children with autism. This permits behavioral correlates between the executive profile and autistic symptomatology. Such associations suggest that invariance in autism may be mediated by the presence of executive impairment (Cummings, 1993; Masterman & Cummings, 1997). However, if we re-examine the behaviors of *invariance* that often dictate the lives of children with autism and then review the definitions of the sub-domains that together comprise executive functions, it becomes clear that we do not have substantial evidence to claim that executive dysfunction is the cause of invariance. This is further supported by the notion that the behaviors attributed to the construct of executive function often overlap with functions subsumed under other cognitive domains (e.g. the role of attention in executive function). This explains the difficulty in determining linear associations between executive functions and observed behavior (Baron, 2004).

Additionally, perhaps invariance, similar to executive function, is an umbrella term that encompasses multiple sub-domains each of which must be independently assessed. For example, children can be invariant in their exploration of their surroundings or invariant in their use of toys. Further, children can be invariant in their preference for something and therefore choose to engage with the same material item repetitively (i.e. response topography invariance) or children can be invariant in their preference for a sequential order of materials and therefore choose to engage with materials in a structured pattern (i.e. response sequence invariability). The different sub-types of invariance support the idea that executive dysfunction may only partially mediate the invariance seen in children with autism, as there are only some subparts of these constructs that overlap. This idea is further supported when we focus on research pertaining to the most salient exemplar of invariance, the presence of restricted, repetitive behaviors as they are traditionally conceptualized.

Defining Invariance through Restricted Repetitive Behaviors in Autism

Due to the notion that restricted, repetitive behaviors frequently dictate the daily activities of children with autism and can hinder the development of adaptive and functional behavior (Pierce & Courchesene, 2001), many research groups have tried to determine which brain regions support their expression. This research is conducted to ultimately guide intervention efforts and treatment. Current evidence suggests that the presence of restricted, repetitive behaviors is mediated through abnormal frontal-striatal circuitry. In fact, neuroimaging studies of autism have demonstrated an association between abnormalities in fronto-striatal brain regions and the frequency and severity of repetitive behavior in autism (Sears et al., 1999).

As executive functions are supported via frontal brain regions, this bolsters researchers' hypothesize that executive functions mediate the presence of traditional restricted behaviors (Cummings, 1993; Materman & Cummings, 1997). Despite the theoretical support for the mediation of repetitive behaviors via executive function, research shows only modest correlations (Lopez et al., 2005). As this association clearly does not indicate causation, we are left with the notion that executive functions may affect the expression of some, but not all, restricted behaviors. Further, it is possible that repetitive behaviors are supported via more primitive cognitive domains (e.g. brain stem functions, cerebellar circuitry), as opposed to frontal lobe functioning (Webb et al., 2009; Allen et al., 2004). Perhaps this varies based on whether the repetitive behavior involves a singular behavior as opposed to a sequential action.

Do We Have Ways in Which to Measure Invariance?

Currently, there are no neuropsychological test measures that have been designed to measure the behavior described here as invariance. Traditional behavior questionnaires (e.g. Behavior Rating Inventory of Executive Functions; Guy et al., 2005, Repetitive Behavior Scale; Lewis et al., 19991) have been developed to measure components of this conceptualization of invariance (i.e. executive functions and repetitive behaviors), but fail to fully capture the behavioral phenotype of invariance as described by parents. The closest approximation to measures of invariance is in the form of experimental tasks. Such experimental measures operationalize invariance via objective play-based tasks that can be completed by individuals of all ages and across a range of cognitive functioning.

For example, Pierce & Courchesne (2001) aimed to determine the impact of cognitive and behavioral rigidity (i.e. invariance) on both brain and behavioral development through the use of an exploration task. Based on the assumption that lack of environmental exploration causes children with autism to miss learning opportunities, they studied brain-behavior correlates of exploratory behavior. Results supported their prediction, as children with autism spent significantly less time in active exploration and significantly more time engaging in repetitive movements when compared to a healthy control group (Pierce & Courchesne, 2001). Additionally, these findings were associated with overall cerebellar and frontal lobe brain development. In sum, this experimental measure suggested that children with autism engage in more restricted behavior with respect to environmental exploration.

Other experimental tasks designed to measure invariance have also concluded that individuals with autism are less variable than typical controls (Miller & Neuringer, 2000). For example, Frith (1972; reviewed in Miller & Neuringer, 2000) determined that when asked to place colored stamps on a piece of paper, children with autism will create rigid sequences, while chronologically and mentally matched controls show enhanced response sequence variability. Similarly, when asked to choose one of two arms of a maze, children with autism will repeatedly chose the same pathway, while typically developing children will vary between the two. Although there are preliminary experimental measures to assess the presence of invariance, such methods are limited. Researchers failed to describe their tasks and scoring criteria in detail, which impedes the ability to replicate their tools, as well as to determine the empirical value of their findings. Further, the experimental tasks were never evaluated in terms of their psychometric properties further hindering the conclusions and findings that can be drawn from using such measures.

Implications of Invariance

The examples of invariance described above suggest that lack of variability can be a detriment, specifically when it interferes with adaptive responding (Miller & Neuringer, 2000). Although invariance in responding may be important to achieve some goals, generally invariance hinders adaptability and learning opportunities. This suggests that the valence of variability is actually task dependent and a problem arises when children with autism cannot perform in a variable manner when such behavior is adaptive. This leads to an important question: when is invariance a problem?

Impact of Physiological Invariance

To fully appreciate the broad implications of invariance, it is helpful to refer to a body of literature often not connected to the study of autism. Although the focus up to this point has been on observable behaviors, it is important to also understand invariance as it relates to biological and physiological systems. In fact, it is suggested that "the condition of health is associated with a higher degree of chaos [variability]" (Paul, 1989). This explains why in clinical neurophysiology, systems are often modeled based on the Chaos Theory or the theory of nonlinear dynamics. Nonlinear dynamic system is a term used to refer to anything that is characterized by a "state" that changes over time (Stam, 2003). In other words, although unpredictability is often conceptualized as negative, variability modeled within the nonlinear equations of Chaos Theory provides a mechanism through which to explain adaptability and flexibility of biological function (Stam, 2003).

To further understand the impact of invariance, or the loss of complexity, it is helpful to refer to a more concrete example. Epilepsy is a disease-state that is in part characterized through the use of EEGs. Researchers suggest that analyzing EEGs based on nonlinear dynamical equations provides a model through which seizure activity may be predicted (Stam, 2005). Babloyantz and Destexhe (1986) reported that epileptic seizures might be attributable to a pathological loss of complexity based on EEG activity analyzed via nonlinear dynamical equation modeling. This finding was further supported by Iasemidis et al. (1990) whose research team noted a decrease in the measure of “chaoticity” during an epileptic seizure (Chaovalitwongse, et al., 2005). In other words, pre-ictal convergence of a dynamical system (i.e. invariance) predicted seizure activity (Chaovalitwongse, et al., 2005); loss of complexity (i.e. narrow, repetitive or restricted) seen in the neuronal systems preceded the undesirable onset of negative physiological occurrences (i.e. seizures).

This research suggests that in order for the body to adapt flexibly to changing internal and external stimuli, the baseline state of the body must be “near-chaotic” (Breton, 1999). In other words, “chaos is ubiquitous; it is stable; it is structured” (Gleik, 1987, pg. 73). This claim is further supported by research with indicates that healthy controls demonstrate high dimensional complexity and low neuronal synchronicity (i.e. variability) while disease states are generally reflected by hypersynchronicity and predictable patterns of underlying brain dynamic systems (Stam, 2005).

The notion that reduced physiological complexity (i.e. invariance) reflects impaired central nervous system functioning is a paradigm for understanding the invariant behavior demonstrated by children with autism. More specifically, the ability of children with autism to adapt to internal and external change flexibly is impeded by their invariant or less complex way of interacting with the environment (Cashin & Waters, 2006). Loss of complexity in their behaviors limits opportunities to learn adaptive functioning skills (Goldberger, 1996). Taken together, this suggests that the self-created invariant settings, in which children with autism often grow-up, actually limits their learning with respect to gaining variable and flexible ways in which to interact with the environment.

Impact of Impoverished Environments

Failure to interact fully within an environment is similar to being placed in an impoverished setting. Behavioral, cellular, and molecular studies of animals demonstrate that enriched environments significantly impact neuronal connectivity and plasticity. In fact, increasing levels of sensory, cognitive and motor stimulation through rich environments induce dramatic effects on overall brain development (Nithianantharajah & Hannan, 2006).

In wild-type mice and rats, enriched environments have been found to increase dendritic spines. Further, enrichment increases hippocampal neurogenesis and facilitates the integration of these newly born cells into functional circuits (Nithianantharajah & Hannan, 2006). In wild-type mice and rats, environmental complexity is also found to impact the expression of genes associated with synaptic function and cellular plasticity. Behaviorally, enrichment is linked to enhanced learning and memory function, as well as to a decrease in anxiety and an increase in exploratory behavior (Nithianantharajah & Hannan, 2006). It is important to remember that these benefits of enriched environments are dependent on whether or not the animal model chooses to interact with the resources provided (Nithianantharajah & Hannan, 2006). This idea will be readdressed when the impact of enriched environments is discussed with respect to children with autism (Pierce & Courchesne, 2001). First, it is important to examine human neurobiological studies, as these also demonstrate the relationship between engaging with an enriched environment and the promotion of healthy brain development (Greenough et al, 1999).

Perhaps the most poignant illustration of the impact of impoverished environments is from research on children reared in orphanages. It is suggested that children who are raised in impoverished, non-interactive environments experience altered biochemistry and brain circuitry due to somatosensory deprivation (Bylinsky, 1973). In fact, research indicates that orphans often have developmental delays, exhibit stereotypical behavior (i.e. body rocking), and are withdrawn, aggressive, overactive and distractible (Bylinsky, 1973; Groark et al., 2005). More specifically, infants and toddlers in orphanages often lie, stand or sit still. When in fact they do interact with toys their play behavior is simplistic, repetitive and stereotypic (The St. Petersburg-USA Orphanage Research Team, 2005). Of note, orphans behavioral and biological responses to environmental enrichment suggests that such behaviors are environmentally mediated and do not have a biological etiology.

In sum, invariant behavior can be conceptualized as negative when it interferes with adaptive, flexible responding both physiologically and behaviorally (Miller & Neuringer, 2000). This provides a mechanism for intervention; if we can intervene with invariant behavior on tasks during which such actions are limiting, perhaps we can promote more adaptable and flexible behavior.

Can we Intervene and Promote Variable Behavior?

Research suggests that we can intervene to promote variable behavior. Animal research not only illustrates the benefits of a complex environment compared to an impoverished environment, but it demonstrates the ability of environmental richness to attenuate invariant behavior (Lewis et al., 2007). In fact, exposing animals to enriched environments has been shown to reverse the sequelae of brain insults (Lewis et al., 2007). Of note, exposure to these enriched environments only has the aforementioned positive effects when the animal model engages with the environmental elements (Nithianantharajah & Hannan, 2006).

Similar effects of exposure to enriched environments are seen in human research. A study by Groark et al. (2005) focused on the impact of early intervention for children in orphanages.

This research team determined that enhanced environmental interaction and enrichment promoted physical and cognitive growth. Language, motor skills and affective development were all recorded and the youngest children, who initially demonstrated the greatest impairments, progressed most rapidly (Groark et al., 2005). Additionally, negative behaviors (i.e. body rocking, sterotypies) decreased, while active exploration and engagement with the environment increased (Groark et al., 2005). These findings suggest that the younger a child is exposed to and encouraged to interact with enriched environments, the greater the brain-behavior impact (Nithianantharajah & Hannan, 2006).

Taken together, this literature suggests that it is possible to promote variable, adaptive behavior through an increase in novel engagement and interaction with elements in an environment. Research indicates that increasing behavioral variability has positive effects on brain development, as well as on the ability to engage appropriately and flexibly within a changing environment. As the failure of children with autism to engage with their environment is somewhat analogous to children reared in impoverished settings, a mechanism for intervention in autism emerges. If we can encourage young children with autism to engage more variably with the materials in their environment, perhaps we can offset the negative implications of early deprivation (Groark et al., 2005). This premise is based on our ability to effect behavioral change: Is it in fact possible to intervene and increase behavioral variability in autism?

Current Efforts to Reinforce Variability in Autism

Based on the above research, which suggests that increasing complexity will have a positive impact, researchers have begun to study the ability to intervene with the invariant behavior demonstrated by individuals with autism. In fact, the focus of such research has shifted from understanding the cause and effect of repetitive behaviors to inducing change using parameters defined by behaviorists (Lee et al., 2005). This line of research has been met with much success, as reinforcement has been found to modify stereotyped responding (Handen et al., 1984; Iwata et al., 1994; Kennedy & Haring, 1993). Specifically, differential reinforcement of other behavior and low rates of responding has been found to decrease self-injurious behaviors, repetitive speech, pica, and disruptive actions. In contrast, reinforcement of new behavior types each time they appear has been found to increase desired behavior (Miller & Neuringer, 2000; Pryor et al., 1969).

Despite well-intentioned overall goals to reduce nonfunctional, maladaptive responding and increase variable response, the findings of these studies are limited. For example, Lee and colleagues (2002) demonstrated that a lag schedule of differential reinforcement of varied and appropriate verbal responding increased the percentage of unique responses to a social question. However, this finding was made with an extremely small sample (n = 3). Further, age range of participants varied widely (age 7 to 27) and behavioral change was only found in two participants (ages 7 and 27). Similarly, a study by Miller and Neuringer (2000) determined that reinforcing varying sequence of responses increased variability of response across all subject groups studied (i.e. 5 adolescents with autism, 5 adult control participants and 4 child control participants), suggesting no autism-specific findings. This study was limited by a small sample size and a heterogeneous clinical group. Overall, studies aiming to reinforce variability within an autistic population are hampered by heterogeneous group composition, poor representation of the autism spectrum, loosely defined control groups, large age ranges and lack of standardized measurement tools.

Further, although these studies targeted maladaptive behavior, they did not take into account that the most beneficial period to intervene with autism is during the preschool years. This suggests the need to develop new interventions that target the invariant behavior of young children with autism across a range of cognitive functioning. Perhaps the most effective way to do this is to operationalize typical pre-school activities (Goetz & Baer, 1973).

A study by Goetz and Baer (1973) illustrated that typically developing preschoolers can be systematically “taught” to engage in more variable and creative play behavior. By objectively defining play with blocks, these researchers were able to determine children’s baseline level of play variability and then effect behavioral change by increasing such variability through social reinforcement (Goetz & Baer, 1973).

Developing a Measure of Behavioral Invariance

Although it is generally accepted that variable play (as opposed to limited, repetitive, or stereotyped) is necessary for educational gains and to increase adaptability, the study conducted by Goetz & Baer (1973) was the first attempt to objectively diversify play behavior. As such, the focus of the study was not to quantify play, but rather to determine if it could be changed. The researchers successfully demonstrated increased block play variability in three typically developing preschoolers who received reinforcement for variable behavior based on behavioral principles (Goetz & Baer, 1973). Specifically, verbal praise was given every time a child created a novel block form and the authors concluded that “diversity of response, within this delimited sphere of activity, is readily modified by simple, everyday reinforcement contingencies” (Goetz & Baer, 1973). However, similar to other intervention research, the framework for the study was limited by the use of an experimental task (i.e. block play) for which psychometric properties are unknown.

Therefore, the current study developed a new measure called the Block-Building Invariance Test (B-BIT) to systematically assess play. Goetz and Baer (1973) began this process when they developed a scoring method by which to define different block forms (i.e. structures or configurations). However, since their aim was not to objectively quantify play, but rather to change it, their coding system was complex and their administration procedures unsystematic. Therefore, the B-BIT has been created as a modified block building task that includes a formal administration protocol, as well as standardized coding and scoring systems, to objectively assess behavioral invariance. Reliability and validity properties were determined to assess the empirical nature of this experimental measure.

Importance of Determining Psychometric Properties

Psychometrics is a field of study focused on the science of psychological assessment (Bagner et al., 2006). It evaluates psychological instruments for their reliability and validity, indicating the extent to which a measure accurately reflects a domain of interest. A test measure that does not have acceptable psychometric properties is limited in its ability to provide meaningful assessment results and information. Therefore, before an instrument can be used as an intervention tool, it is imperative that psychometric properties indicate true measurement (i.e. accurate evaluation that occurs independently of the specific rater; Lachenmeyer, 1974) of a specified construct (i.e. targeted variable; Kazdin, 1998).

This is particularly important when the ultimate goal is to develop an intervention tool for a neurodevelopmental population, such as autism. When parents receive a diagnosis they are often inundated with information from professionals and supplement such information with articles found on the internet and other unregulated resources. Claims about ‘cures’ and experimental treatments often give parents much hope; however, since they are generally not founded on science, these therapies are often limited in value and detract from resources (both financial and time) that could be spent engaging in empirically–supported treatments. It is vital that interventions designed for this population are founded in science. Therefore, the first step in the process of developing an intervention tool is to determine if the instrument created to facilitate change has acceptable psychometric properties. Specifically, for the aforementioned experimental measure that has been developed (B-BIT) there are certain types of reliability and validity properties that must be evaluated.

Measurement Reliability

Reliability reflects the consistency of an assessment tool across time, raters, settings and items (Bagner et al., 2006). It is particularly important to evaluate reliability when working with young children due to the potential developmental changes that occur during early childhood that can affect the consistency of behavior (Yule, 1993). *Test-retest reliability* must be assessed to ensure that the B-BIT is a temporally stable measure. Acceptable test-retest reliability indicates that change measured by an instrument has occurred due to treatment effects rather than traditional development or exposure (Bagner et al., 2006). Additionally, it is necessary to establish *inter-rater reliability*, as this determines the extent to which scores on a measure demonstrate true variance in the intended construct (Haynes et al., 1999), as opposed to rater subjectivity. Acceptable inter-rater reliability determines whether the coding and scoring systems developed for the B-BIT are clear and replicable.

Validity of Block Building

Validity is defined as the extent to which an instrument accurately assesses the specified construct (Haynes et al., 1999). Validity is important in the development of behavioral assessment tools, as well as in the selection of measures when trying to evaluate a certain behavior (Bagner et al). All types of validity are not necessary to evaluate for each test measure; rather the specific validity parameters assessed depend on the overall purpose of the instrument and whether there are multiple items as opposed to a singular task to be measured. Inasmuch as a primary reason for developing the B-BIT is to determine if this task correctly classifies children into diagnostic groups based on performance (Robins et al., 2003), it is imperative for *discriminative validity* to be evaluated. In fact, the B-BIT has been specifically designed with the intent of differentiating preschoolers with autism from typically developing preschoolers. Furthermore, it is important that experimental tasks have *convergent validity*. Ideally, we would determine if the B-BIT captures invariance as determined by gold standard measures (i.e. measures that already have been evaluated for acceptable reliability and validity properties). However, as the B-BIT was developed to capture a novel behavior (i.e. invariance), no gold standards currently exist. Therefore, since invariance has overlapping characteristics with restricted repetitive behaviors and aspects of executive function, it is important to determine the relationship between empirically validated measurements of these behaviors and our tool. Additionally, as the B-BIT was created to capture a novel construct (i.e. invariance), it is important this instrument measures a unique skill. Thus, d*ivergent validity* must also be evaluated.

The Current Study

Research suggests that increasing behavioral variability in autism can have a positive impact on brain and behavioral development. This notion is supported through both animal and human research. Relevant studies not only characterize the negative impact of invariance (or opportunity for exposure to novel elements and environments), but suggest that early intervention can produce positive results. However, these studies do not have a method of objectively measuring invariant behavior.

The relationship between impoverished environments and disrupted development further supports the potential benefits of intervening on the way children with autism interact with their environment. Although children with autism are often presented with enriched environments that promote variable behavior and interaction, the core deficits that define the phenotype of autism (i.e. sameness and invariance) often simulate and foster an impoverished environment. This has implications for brain and behavior development and potentially perpetuates the presence of autistic symptomatology. Therefore, if we can intervene on the invariant behaviors displayed by preschoolers with autism and promote more variable behavior and environmental interaction, brain and behavior development may be positively impacted. However, before we can intervene we must first develop a valid and reliable tool for measuring the construct of variability.

Thus, the current pilot study extends early work on a block play task (Goetz & Baer, 1973) by standardizing administration, coding and scoring methods and then determining the psychometric properties. This formalized assessment task is named the Block-Building Invariance Test (B-BIT). Previously, Goetz & Baer (1973) conducted an intervention study to increase play-based variability using block-play. Although their intervention was successful, it was limited by the use of an experimental measure to observe change. Therefore, the current study evaluates the reliability and validity parameters of the B-BIT to determine the extent to which the B-BIT (our newly developed tool) approximates a true measurement of behavioral variability, while differentiating between young children diagnosed with autism and typically developing children. If the B-BIT is found to be a psychometrically sound test measure, it will be the first step in a line of research designed to mitigate the invariance that defines autism both behaviorally and with respect to overall brain development. Future directions would include targeting invariance through intervention.

Research Goals and Hypotheses

Currently, there is no standardized tool designed to capture the invariant behavior displayed by preschoolers across a broad range of cognitive functioning. Therefore, the overall aim of the present study was to develop and determine the psychometric properties of an experimental task, the Block-Building Invariance Test (B-BIT), which was designed to measure behavioral invariance using a structured play approach. By evaluating validity and reliability parameters of this task, the extent to which the B-BIT uniquely captures the domain conceptualized as invariance, and its utility in differentiating children diagnosed with autism from typically developing preschoolers was determined. The current study had two phases:

Phase I: Development of the B-BIT

Aim I: Adapt the intervention introduced by Goetz & Baer (1973) into an assessment tool (named the Block-Building Invariance Test) to objectively quantify behavioral invariance.

a) Develop a standardized administration protocol
b) Adapt the existing coding system to operationalize block play behavior
c) Create a formal scoring system

Phase II: Examination of B-BIT Psychometric Properties

Aim I: Determine the measurement reliability of the Block-Building Invariance Test.

a) **Test-Retest Reliability:** determine performance consistency over a brief period of time

b) **Inter-Rater Reliability:** determine the degree to which independent raters were able to consistently code behavior based on the developed scoring system.

Hypothesis I*:* Overall it was hypothesized that the Block-Building Invariance Test would be a reliable measure.

a) **Test- Retest Reliability**: Repeat testing will demonstrate moderate to high correlations suggesting that the Block-Building Invariance Test is a temporally stable measure.

b) **Inter-Rater Reliability**: Correlations between two independent raters will be moderate to strong, indicating that the developed scoring system facilitates consistency among individual coders. Additionally, differences in scores are then attributable to performance differences as opposed to rater subjectivity.

Aim II*:* Assess the validity of the Block-Building Invariance Test.

a) **Discriminative Validity:** determine whether the B-BIT differentiates between children diagnosed with an autism spectrum disorder and typically developing children.

b) **Convergent Validity:** illustrate whether the experimental instrument is related to its theoretical basis, as determined by previously established, psychometrically sound assessment tools.

c) **Divergent Validity**: determine if the B-BIT encapsulates a novel behavior (i.e. invariance) not measured by other standardized instruments.

Hypothesis II: It was predicted that overall the B-BIT would be a valid measure of behavioral variability.

a) **Discriminative Validity**: The B-BIT will discriminate between children diagnosed with autism and typically developing children on outcome variables.

b) **Convergent Validity:** The B-BIT will not be significantly correlated to parent reports of repetitive behavior (specifically the Sameness Behavior Subscale from the Repetitive Behavior Scale-Revised) and parent reports of executive function (specifically the Flexibility Index from the Behavior Rating Inventory of Executive Function-Preschool Version). As there is no "gold-standard" described in the literature to measure invariance, the B-BIT will show only modest relationships with questionnaires developed to quantify aspects (i.e. repetition, inflexibility) of invariant behavior.

c) **Divergent Validity**: The B-BIT will not be related to the Multiple Boxes Test, a measure of working memory (a different sub-domain of executive function). This finding will suggest that our measure uniquely captures an aspect of executive function in preschoolers not assessed by already existing tools.

CHAPTER 2
PHASE I METHOD - DEVELOPMENT OF THE BLOCK-BUILDING INVARIANCE TEST (B-BIT)

A review of the literature indicated no existing published clinical measures designed to assess behavioral variability in young children across a broad range of cognitive functioning. An intervention study conducted by Goetz and Baer (1973) aimed to increase behavioral variability through play. However, their methodology lacked consistent procedures, as well as a standardized tool through which to measure change. Despite these inherent flaws, the notion of operationalizing play was used as a model from which the current instrument, the Block-Building Invariance Test (B-BIT), was created.

The current project developed the B-BIT as a tool to quantify behavioral variability in young children, some of whom may be cognitively compromised. Therefore during the formulation, adaptation and development phase of the B-BIT, there were a number of criteria that were taken into consideration:

1. Reduce structured cognitive demands
2. Employ less structured "play"
3. Minimize fine motor skills
4. Create simple and replicable administration protocol
5. Design "user-friendly" system for recording responses/block configurations
6. Develop objective, structured, and comprehensive scoring system

CHAPTER 3
PHASE I RESULTS

Block-Building Invariance Test (B-BIT)

The Block-Building Invariance Test (B-BIT; adapted from Goetz & Baer, 1973) assesses a child's natural block play behavior through the use of a standardized administration protocol, as well as an objective coding and scoring system, in children ages 3 years, 0 months to 6 years, 0 months. The goal of developing this instrument was to construct a reliable and valid play-based measure of invariant behavior. The B-BIT utilizes a widely available set of toy wooden blocks called Barkley Blocks (Barclay Wood Toys & Blocks.Inc). The kit includes 21 blocks, representing ten different shapes: 2 unit rectangles, 4 half unit rectangles, 2 unit columns, 2 half unit columns, 2 long narrow roof planks, 2 medium narrow roof planks, 1 Roman arch, 2 quarter circles, 2 triangles, 2 round columns.

Administration Protocol

The B-BIT was designed to be administered in a controlled setting. It should be recorded using a video camera to facilitate future coding. Start by placing all 21 blocks in front of the child. Use gestures and other nonverbal cues to indicate that the child should begin to play (Roid & Miller, 2002). Pair these actions with the phrase "Go play" (Pierce & Courchesne, 2001). No additional verbal instructions are to be given.

Each block play session includes a total of 3 trials. A trial is considered complete if any of the following occurs: a) all 21 blocks have been used (i.e. moved by the child to a different location) b) child ceases to play with the blocks for one minute and does not respond to one physical prompt that leads him/her back to play with the blocks c) 5 minutes have elapsed.

When a child has completed a trial continue to record for 10 additional seconds; this allows the child to speak spontaneously about what he/she has created. After these 10 seconds, use nonverbal cues and gestures to illustrate that the child can “knock down” his/her block formation. Repeat this protocol 3 times to collect 3 trials of block play. The B-BIT administration is complete at this time.

Coding System

In the 1973 study by Goetz and Baer, twenty different possible block forms were defined in order to evaluate if a child was creating variable block configurations. From their original twenty block form definitions, seven were selected and adapted for the B-BIT (see Table 3-1). Modifications were made to align with the goal of developing a systematic scoring system that was not dependent on child verbalizations and intricate fine motor skills.

Table 3-1: Definition of Block forms (adapted from Goetz & Baer, 1973)

FENCE:	two blocks (any shape) placed side by side in contiguity
PATH:	three blocks (any shape) placed at regularly spaced intervals in a straight line
STORY:	two blocks (any shape) placed one atop another
INTERFACE:	arrangement of any two blocks with curved contours to fit precisely together (i.e. half-circle into arc shaped block)
SPONTANEOUS UTILIZATION:	child uses a block in place of an object (i.e. picks up a block and pretends to eat it like a cookie); you do not have to know what object is being represented to code it here
SPONTANEOUS VERBALIZATION:	child spontaneously offers information about a real-life shape or object that his/her block construction represents
DIAGONAL:	a block is placed diagonally (or leaning) against another block

Please refer to appendix A for the associated coding form for the B-BIT. The following criteria should be adhered to when coding block play:

1) A block is recorded when a child releases his/her grip on the block (even if just momentarily).

2) If a child releases his/her grip and then moves the same block to a different location record both the 1st and 2nd block placements.

3) If the block falls after child removes his/her hand, still record block placement (i.e. if a child is trying to balance a block on top of another one, record block placement even if it is unsuccessful).

4) If a child inadvertently knocks down his or her blocks and proceeds to place them in the exact same positions do NOT score twice.

5) Block placement can be scored as more than one form (i.e. a block placed on top of one block and next to another one can be scored as a fence and a story).

Scoring System

There are three outcome variables calculated after B-BIT administration.

1) **Form Diversity**: Percentage score calculated by dividing the number of different block forms created in a block trial by the total number of blocks used. This number is multiplied by 100. {(# of different forms/total # of blocks used) x 100}.

    - Note: something marked as two forms (i.e. block placement meets criteria for a fence and a story) counts as an overall different block form

2) **Form Repetition**: Percentage score calculated by dividing the number of times a block form is repeated within a trial by the total number of blocks used. This number is multiplied by 100. {(# of times form 1 is repeated throughout trial + # of times form 2 is repeated +…./total # of blocks used) x 100}.

    - Note: start counting repetitions the second time a block form is created
    - Note: something marked as two forms (i.e. block placement meets criteria for a fence and a story) counts as an overall different block form

3) **Form Sequential Repetition**: Percentage score calculated by dividing the number of times each block form is repeated sequentially divided by the total number of blocks used. __{(# of times block form 1 is repeated sequentially + # of times form 2 is repeated sequentially +…/total # of blocks used) x 100}.

    - Note: start counting repetitions the second time a block form is created
    - Note: something marked as two forms (i.e. block placement meets criteria for a fence and a story) counts as an overall different block form

CHAPTER 4
PHASE II METHOD

Psychometric Properties of the Block-Building Invariance Test (B-BIT)

Subsequent to B-BIT development, the next phase of the project was to conduct a pilot study examining the psychometric properties of the B-BIT (our task designed to capture variability within play) for typically developing preschoolers and preschoolers diagnosed with autism.

Sample

The final sample of participants included 15 preschoolers diagnosed with autism and 12 typically developing preschoolers. Of note, preliminary data collected in the Pediatric Neurodevelopmental Lab at the University of Florida suggested that preschoolers with autism (n = 8) are rated as demonstrating significantly more executive dysfunction than typically developing preschoolers (n = 6) on the General Executive Composite Index of the BRIEF-P. Using these scores, the necessary sample size to detect significant group differences in this class of behaviors was estimated to be 4 (G-power version 3). To take into account the experimental measure and the goal of determining pilot psychometric properties beyond discriminative validity, a larger sample of children was recruited for this pilot study.

Children were eligible for the study if they met the following criteria: between the ages of 36 months and 72 months (i.e. 3-6 years) and full-term delivery (i.e. $\geq$38 weeks). Children taking psychoactive medication were included in the study and information regarding medication status was recorded. In contrast, children were excluded from the study if there was a history of parent-reported neurological disorder or injury (i.e. history of seizures, tumor, severe head injury, stroke, brain lesion or disease) or if there was documentation or report of a psychiatric disorder with a primary feature of repetitive behavior (i.e. obsessive-compulsive disorder, schizophrenia).

Children were included in the autism group children if they met criteria on either the Social Communication Questionnaire (SCQ $\geq$ 15) or the Autism Diagnostic Observation Schedule (ADOS Communication Total $\geq$ 3, ADOS Social Interaction Total $\geq$ 6). In contrast, children were included in the typically developing group if they did not meet criteria on the SCQ. It is important to state that all children were initially screened using the SCQ. Children whose scores on the SCQ were equal to or exceeded 15 were administered the ADOS; if a child's score was less than 15 the ADOS was not administered unless there was concern based on clinical judgment.

Measures

To determine measurement reliability (test-retest reliability, inter-rater reliability) and validity (discriminative validity, convergent validity, divergent validity) of the Block-Building Invariance Test (B-BIT) the following diagnostic and demographic measures were administered to characterize our sample population:

Diagnostic Measures

1) *Social Communication Questionnaire* (SCQ; Rutter et al., 2003) is a screening instrument to evaluate communication skills and social functioning in children who may have an autism spectrum disorder. The forty questions were derived from the Autism Diagnostic Interview-Revised (ADI-R; Lord et al., 1994). A cutoff score of 15 indicates the likelihood that a child has an Autism Spectrum Disorder. This parent questionnaire took approximately 10 minutes to complete.

2) *Autism Diagnostic Observation Schedule* (ADOS; Lord et al., 1997) is a semi-structured observational assessment administered directly to the child. It consists of four different modules, each adapted for a different level of language ability. The ADOS was administered to all preschoolers whose score on the SCQ was $\geq$ 15. Additionally, the ADOS was administered if clinical judgment suggested the possibility of an autism spectrum diagnosis based upon informal observation and interaction with the child. Administration time was approximately 45 minutes.

Group Characterization Measures

1) *Leiter International Performance Scale- Revised (Leiter-R*; Roid & Miller, 1997*)* is a clinical instrument for assessing cognitive abilities. This measure is well-suited for young children, including children with autism, as it assesses nonverbal intelligence and therefore eliminates potential confounding factors. Fluid Reasoning (consists of the following subtests: Sequential Order and Repeated Patterns) and Brief IQ (consist of the following subtests: Figure Ground, Form Completion, Sequential Order, Repeated Patterns) scores were derived. Administration time was approximately 25 minutes.

2) *Childhood Development Inventory* (CDI; Ireton, 2001) is an assessment instrument used to obtain information regarding a child's overall development. Specifically, parents answer questions regarding their child's strengths and weaknesses in the following domains: social, self-help, gross motor, fine motor, expressive language, receptive language, letters, numbers, and behaviors. This assessment tool took approximately 40 minutes for the parents to complete.

3) *Demographic questionnaire* is a structured self-created form used to standardize the collection of demographic information for preschoolers and their families. Medication status, comborbid diagnoses, family income, preferred food reinforcement and current and past treatments/services was collected to aid with overall sample characterization. Information was also collected on age, sex, race/ethnicity and educational history. This form took approximately 10 minutes to complete.

Parent Ratings of Restricted, Repetitive Behaviors and Executive Function

4) *Behavior Rating Inventory of Executive Function- Preschool Version* (BRIEF-P; Isquith et al., 2004) is a 63-item caregiver report scale that rates a child's (2 years, 0 months to 6 years, 11 months) executive functioning skills within the context of his/her everyday environment. Aspects of executive function measured include Inhibit, Shift, Emotional Control, Working memory, and Plan/Organize. These clinical scales form three broad indexes (Inhibitory Self-Control, Flexibility, and Emergent metacognition). Due to the focus of the current study our particular interest was in the Flexibility index. Sample items include "Becomes upset with new situations", "Has trouble adjusting to new people", "Has trouble changing activities" and "Is upset by a change in plans or routines". This questionnaire took approximately 15 minutes for caregivers to complete.

5) *Repetitive Behavior Scales –Revised* (RBS-R; Bodfish et al., 1995; Bodfish et al., 1999, 2002) is an empirically derived, standardized, and psychometrically sound rating scale for identifying and measuring a range of repetitive behaviors. The RBS-R yields an overall total score and six subscale scores (Motor Stereotypy, Repetitive Self-injury, Compulsive Behavior, Ritualistic Behavior, Sameness Behavior, Restricted Behavior). Due to the focus of the current study our particular interest was in the Sameness Behavior Subscale Sample items include "Insists that things remain in the same place(s)", "Objects to visiting new places", "Insists on the same routine, household, school or work schedule everyday" and "Resists changing activities". This questionnaire took approximately 15 minutes for caregivers to complete.

Performance Based Measures of Invariance and Executive Function

6) *Multiple Boxes Test* (MBT; Llamas & Diamond, 1991 reviewed in Mahone & Hoffman, 2007): For this game-based spatial working memory task stickers are hidden in nine small boxes that are put together to create a larger square. A child chooses one box at a time until all nine stickers are found. The boxes are hidden with a screen for 10 seconds between each choice and the goal is to find all the stickers in the fewest number of moves. Variables collected include how many boxes the child reopens prior to locating all the stickers (repetition error) and how many attempts are needed to find all of the stickers. This task took approximately 10 minutes for children to complete.

7) *Block- Building Invariance Test (B-BIT)*: For this play-based measure of invariance children are instructed, using both verbal and nonverbal cues, to play with 21 blocks that are placed in front of them. Block play is recorded and coded later based upon the coding system that was developed (see Phase I Results). Outcomes variables collected include Form Diversity, Form Repetition, and Form Sequential Repetition. This task took approximately 15 minutes for children to complete.

Procedure

Children diagnosed with autism were recruited in one of three ways: during a meeting at the University of Florida's Center for Autism and Related Disabilities (CARD), during a visit to the University of Florida's Autism Outpatient Program through the Department of Psychiatry, or via flyers posted in approved locations throughout Shands UF Hospital in Gainesville, Florida.

The initial autism sample included 18 participants. Approximately 12 children were recruited from meetings held at CARD, 5 children were recruited through the Autism Outpatient Program and 1 child was recruited via a professional connection. Of the 18 children initially recruited for the autism group, 13 children met criteria on both the SCQ and the ADOS, and 2 children only met criteria on one of these diagnostic measures. Three children did not meet diagnostic criteria on either the ADOS or SCQ. These 3 children were not included in the final sample; this was based on clinical judgment which suggested that symptoms demonstrated were consistent with a developmental disability not commensurate with an autism spectrum disorder.

Our typically developing group consisted of 12 participants. Eleven of the healthy controls were recruited via flyers posted at Shands UF Hospital in Gainesville, Florida and local day care centers. One healthy control was identified and recruited because he was the sibling of a participant with autism. None of the typically developing children met criteria on the SCQ or exhibited symptoms consistent with an autism spectrum disorder based on clinical judgment. Therefore, all of these children were included in the final sample.

Preschoolers, with the exception of 4 typically developing children, attended two study visits at the Pediatric Neurodevelopmental Laboratory. These 4 children in the typically developing group were tested at Baby Gator, a local daycare center, on two separate occasions. At the first study visit, preschoolers who had previously received a diagnosis of autism, or were expected to demonstrate symptoms consistent with autism, and typically developing preschoolers underwent a diagnostic assessment to determine true group eligibility. All children suspected of an autism spectrum diagnosis were administered the Autism Diagnostic Observation Schedule (ADOS) and the Social Communication Questionnaire (SCQ). Parents of children suspected to have an autism spectrum disorder completed the Childhood Development Inventory (CDI) and the Demographic Questionnaire. To be included in the autism group children had to meet criteria on either the SCQ (SCQ $\geq$ 15) or on the Autism Diagnostic Observation Schedule (ADOS Communication Total $\geq$ 3, ADOS Social Interaction Total $\geq$ 6). Children who were thought to be typically developing were not initially administered the ADOS; rather parents of typically developing children completed the SCQ, CDI and Demographic Questionnaire. Of note, typically developing children who met criteria on the SCQ or were observed to display symptoms consistent with an autism spectrum disorder were then administered the ADOS. At this first visit, children were also administered Trial 1 of the B-BIT. After completing Visit 1 participants received a $10.00 gift card to either Blockbuster or Target.

At Visit 2 all preschoolers were administered Trial 2 of the B-BIT, the Leiter-R, and the Multiple Boxes Test. Parents completed the BRIEF-P and RBS-R. After all tasks and questionnaires were completed, participants received another $10.00 gift card to either Blockbuster or Target.

CHAPTER 5
PHASE II RESULTS

Data Analysis

For all statistical tests, the level of significance was set at $\alpha = 0.05$. All statistical tests were performed using the SPSS statistical analysis package. Among the final 27 participants there was missing data across screening measures, experimental measure and parent-report questionnaires. Missing data was handled differently based upon the statistical analysis; this is documented and detailed for each analysis. Raw scores generated from published measures were converted to norm referenced scores according to the guidelines presented in the manuals (i.e. raw scores were transformed into Standard Scores, T-scores, Scaled Scores, z-scores, age-equivalents). B-BIT raw scores were converted to raw percentage scores according to the scoring system outlined above (page 35). All dependent variables were evaluated for evidence of symmetry in their distribution by using a test of skewness. A cut-off point of 2.0 was applied to the test of skewness as an indication for normality. Based on these criteria, all dependent variables were normally distributed. Therefore, no further normalization calculations were necessary.

Specific Aim I: Determine Measurement reliability of the B-BIT

Test-Retest Reliability

In order to determine temporal stability of the B-BIT, the experimental measure was administered on two separate occasions to a sample of 11 typically developing children and 10 children diagnosed with an autism spectrum disorder. Test-retest reliability was calculated for the mixed sample ($N = 21$). Mean age was 4 years, 7 months ($SD = 11.5$ months) and mean time between study visits was 11.9 days ($SD = 12.4$ days). A two-tailed partial correlation, accounting for time between study visits, was calculated to determine performance consistency for the three outcome variables of the B-BIT, Form Diversity, Form Repetition, and Form Sequential Repetition. In the mixed sample (typically developing children and children diagnosed with autism), partial correlations ranged from r (19) = .522 (Form Sequential Repetition) to r (19) = .664 (Form Repetition).

To determine whether temporal stability differed in the autism sample versus the typically developing sample, partial correlations were conducted for the two separate samples. For children diagnosed with autism mean age was 4 years, 2 months (SD = 9.778 months) and mean time between study visits was 14.40 days (SD = 13.874 days). For typically developing children mean age was 5 years, 1 month (SD = 10.856 months) and mean time between study visits was 9.55 days (SD = 10.921 days). Results suggest significant test-retest reliability for typically developing preschoolers across all outcome measures. In contrast, children diagnosed with autism did not demonstrate temporal stability with the exception of their scores on the Form Repetition variable. Test-retest reliability for the mixed sample, as well as the separate autism and typically developing groups is depicted in Table 5-1.

Inter-rater Reliability

To determine the extent to which the B-BIT provides consistent findings when scored by two separate raters, Pearson correlations were calculated for the three B-BIT outcomes variables (Form Diversity, Form Repetition, Form Sequential Repetition). Specifically, two independent raters (undergraduate research assistants, J.S. and S.B., trained by the dissertation author) coded block-play performance by 5 children diagnosed with autism and 3 typically developing children. Due to resource limitations, inter-rater reliability was calculated only for the mixed sample (n = 8). Mean age was 4 years, 5 months (SD = 13.058 months). Findings suggest a high level of agreement (i.e. $r >$ 0.70; Quittner et al., 2007) on Form Repetition and Form

Sequential Repetition outcome variables. Inter-rater reliability across B-BIT outcome variables is illustrated in Table 5-2.

Specific Aim Two: Determine Validity of the B-BIT

Demographics

Demographic variables between groups were compared using ANOVAs and Chi-square analyses. A comparison of the two groups' demographic information is presented in Table 5-3. The mean age of the autism group was 4 years, 2 months, while mean age of the typically developing group was 5 years, 1 month. This represented a significant between-group difference. The autism group consisted of 14 males and 1 female, while the typically developing group included 7 males and 5 females. Within the autism group, 13 of the participants described themselves as Caucasian, and 2 as African-American. Within the typically developing group, 9 of the participants identified as Caucasian, 2 as Asian, and 1 as African American. Chi-square analysis indicated that the autism group and typically developing group had a similar proportion of participants from minority groups. In contrast, chi-square analysis revealed significant between group differences in male: female ratio with the autism group having a significantly larger male representation.

In addition to the demographics reported above, data specific to the autism group was collected. Within the autism group, 13 of the children met criteria for a diagnosis of an autism spectrum disorder on both the ADOS and SCQ, while 2 of the children met criteria only on the ADOS. Two of the children were taking medication at the time of testing prescribed for the purpose of managing behavior. Specifically, 1 child was taking Depakote and 1 child was taking a non-traditional herbal medication for symptoms consistent with inattention and hyperactivity. A number of children were taking medication for allergies. Early intervention services had been initiated for 12 of the children in the autism group.

Developmental and cognitive measures included the Leiter-R and the Childhood Development Inventory (CDI). Four of the 15 children in the autism group did not complete the Leiter-R due to behavioral difficulties. Therefore, scores represented in Table 5-4 reflect the performance of 11 children (73%) in the autism group and 12 children (100%) in the typically developing group. For the purpose of later analyses that use the Leiter-R as a covariate, missing data for children in the autism group is managed by inserting the mean group score (mean Brief IQ = 97.83). Similarly, CDI questionnaires were not completed for 3 children in the typically developing group and 2 children in the autism group. Scores represented in Table 5-5 reflect parent ratings of developmental skills for 12 children (80%) in the autism group and 10 children (83%) in the typically developing group. For future analyses that incorporate CDI scores the mean value for each group is used (autism group General Development mean = 30.83 months; typically developing group General Development mean = 67.20 months). Scores on these screening measures were compared between the two groups (see Tables 5-4 and 5-5). Results indicate significant between-group differences across both measures. Specifically children in the autism group performed significantly poorer across all sub-tests of the Leiter-R with the exception of the Figure Completion sub-test. Similarly, children with autism were rated as having achieved fewer developmental skills across all sub-domains of the CDI.

Of note, for the following analyses scores derived from children’s performances on the B-BIT from study visit 1 were used. Similarly, scores depicted were coded and calculated by Rater 1 (J.S.).

Discriminative Validity

In order to determine whether children with autism demonstrated more invariant behavior than typically developing preschoolers on the B-BIT, multiple ANCOVAs, with two levels of the independent variables (Autism vs. Typically Developing) were conducted. The three dependent variables were Form Diversity, Form Repetition, and Form Sequential Repetition percentage scores derived from the B-BIT. Covariates included Brief IQ (Leiter-R) and General Development (CDI), as the two groups differed significantly across these measures. Of note, 2 children in the autism group were not included in this analysis as they did not engage in the B-BIT. Results revealed no significant between group differences. Effect sizes ranged from small to moderate and were calculated with Cohen's d with the pooled standard deviation used for between-group comparisons (Cohen, 1988; Rosnow & Rosenthal, 1996). A summary of these findings is depicted in Table 5-6.

There is research to suggest that overall IQ should not be used as a covariate in group comparisons involving children with neurodevelopmental disorders (Dennis et. al., 2009). Therefore, the data was re-analyzed without controlling for non-verbal IQ and general development. Findings remain insignificant between the groups; however, a trend is seen on the Form Sequential Repetition variable. Specifically, typically developing children are found to demonstrate increased sequential repetition on the B-BIT compared to the autism group ($\underline{F}(1,23) = 3.436$, $\underline{p} = .077$; effect size = .526).

In order to determine whether parent reported symptom severity accounted for invariant play behavior, three separate linear regression analyses were employed with total score on the SCQ as the dependent variable and the B-BIT outcome percentage scores as the predictor variables. Three regressions were conducted due to multicollinearity among the three outcome variables. Overall, the B-BIT outcome variables did not predict a significant amount of variance in these analyses over and beyond chronological age, developmental age, and Brief IQ; however, the Form Sequential Repetition score showed a trend towards predicting SCQ score (Form Diversity: $\underline{F}\ (1,23) = .388$, $\underline{p} = .539$, $\underline{R}^2 = .017$; Form Repetition: $\underline{F}\ (1,23) = .963$, $\underline{p} = .337$, $\underline{R}^2 =$

.040; Form Sequential Repetition: $\underline{F}$ (1,23) = 3.888, $\underline{p}$ = .061, $\underline{R}^2$ = .145). Of note, findings suggest that the more sequential repetition behavior a child displayed, the less likely it was for parents to endorse symptoms consistent with autism on the SCQ.

Follow-up Discriminative Validity Analyses

A review of the mean percentage scores of the B-BIT outcome variables suggests that the typically developing group demonstrated more, although not statistically significant, invariant behavior compared to the autism group. Qualitative review of the raw video data of the participants was reviewed and revealed that the typically developing children were more engaged in block play (i.e. interacted with the blocks as building material). Therefore, a between-group ANOVA was conducted to determine if the overall number of blocks used differed between the autism and typically developing groups. This also enabled the two children with autism who did not engage in block play to be included in analyses. Findings suggested that overall number of blocks used did not distinguish between the groups ($\underline{F}$(1,28) = 0.837, $\underline{p}$ = .368; effect size = .174).

Subsequently, analyses were conducted to determine if the criteria met to terminate block play trials differed between our groups (i.e. did block play trials end because the 5 minute endpoint was reached or because the child had used all of the blocks). Data was only available for 17 participants. Trials for 6 children with autism were ended because the 5 minutes time restriction ended, while only 1 child with autism reached the end of the trial because all of the blocks had been used. In contrast, 6 typically developing children completed the block trial because they used all of the blocks, while 4 typically developing children used the entire 5 minutes ($\underline{X}^2$ {1, N = 17}) = 3.553, p = .059, effect size = 0.457). Findings suggest that termination criteria met did not differentiate between the autism and typically developing groups;

however, a notable trend was demonstrated. Specifically, block trials of typically developing children were more likely to be completed because all of the block pieces had been used.

Convergent Validity

As noted previously, inasmuch as no single measure has been designed to fully capture our conceptualization of invariance, measures of restricted, repetitive behavior and executive function were used to determine the extent to which the B-BIT is related to aspects of its theoretical basis. Ten children in the autism group and 10 children in typically developing group were included in these analyses. Analyses were conducted both when controlling for IQ and general developmental level and without controlling for these covariates. Findings did not differ and therefore results without covariates are presented. To begin, Pearson correlations between the B-BIT outcome variables and parent ratings on Repetitive Behavior Scale-Revised were conducted for the mixed sample (N = 20). Findings illustrated that the Form Diversity score was significantly correlated to the Sameness Behavior scale on the RBS-R (r (18) = .513). In other words, the more diverse block forms a child created on the B-BIT, the higher they were rated by their parents on the Sameness Behavior scale (Table 5-7). Pearson correlations were also conducted between the B-BIT outcome variables and the BRIEF-P scales for the mixed sample. Findings did not indicate any relationship between parent ratings of executive function and invariance as measured by the experimental task (Table 5-8).

Pearson correlations were also conducted for the autism and typically developing groups separately. We wanted to determine if group membership impacted on whether invariant behavior as measured by the B-BIT was related to parent ratings of restricted, repetitive behavior and executive function.

For children diagnosed with autism, findings suggest that performance on the B-BIT was significantly correlated to the Sameness Behavior scale on the RBS-R. Specifically, Form

Diversity was positively related to Sameness Behavior (*r* (8) = .675), while Form Repetition was negatively correlated with the Sameness Behavior scale (*r* (8) = -.665). In other words, for children diagnosed with autism, more repetitive behavior as reported by parent ratings, indicated less invariant (or more variable) block play on the B-BIT. Table 5-9 summarizes these results. In contrast, findings suggest that invariant behavior as measured by the B-BIT is not significantly correlated to parent ratings of executive function for children in the autism group (see Table 5-10).

The play of typically developing preschoolers, as measured by the B-BIT, was not found to be significantly related to parent ratings of repetitive behavior (RBS-R; see Table 5-11) or parent ratings of executive function (BRIEF-P; see Table 5-12).

Divergent Validity

In order to demonstrate that the B-BIT uniquely measures invariance and does not overlap with unrelated sub-domains of executive function, divergent validity was separately calculated for the mixed sample (N = 25), as well as for the Autism group (n = 13) and Typically Developing group (n = 12). Specifically, Pearson correlations were calculated for the total sample to determine if B-BIT performance was related to the working memory sub-domain of executive function. Correlations were calculated among the three B-BIT outcome variables, and scores derived from the MBT (the number of repetitions and z-score). Findings for the mixed sample, as well as the separate autism and typically developing groups, indicated no significant relationship between measures of invariance (B-BIT) and working memory (MBT; please refer to Tables 5-13, 5-14 and 5-15)

Table 5-1. Test-Retest Reliability: Mixed Sample, Autism Group and Typically Developing Group

Group	B-BIT Outcome Variables	Test-retest Partial Correlation	M (SD) Time 1	M (SD) Time 2
Mixed Sample (N= 21)				
	Form Diversity	.547**	8.30 (5.129)	8.03 (4.175)
	Form Repetition	.664**	77.58 (13.779)	76.22 (14.144)
	Form Sequential Repetition	.522*	46.01 (12.945)	46.65 (14.732)
Autism Spectrum Disorders (N = 10)				
	Form Diversity	.327	9.79 (6.081)	8.53 (4.446)
	Form Repetition	.695*	71.46 (15.650)	74.08 (15.322)
	Form Sequential Repetition	.396	42.53 (13.678)	49.68 (15.214)
Typically Developing (N = 11)				
	Form Diversity	.707*	6.95 (3.888)	7.58 (4.054)
	Form Repetition	.735**	83.15 (9.369)	78.18 (13.417)
	Form Sequential Repetition	.767**	49.17 (11.986)	43.90 (14.43)

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

Table 5-2. Inter-Rater Reliability for a Subset of the Mixed Sample

Group	B-BIT Outcome Variables	Inter-Rater Reliability	M (SD) Rater 1	M (SD) Rater 2
		Pearson Correlation		
Mixed Sample (N=8)	Form Diversity	.603	8.36 (3.300)	5.67 (2.978)
	Form Repetition	.831*	70.54 (17.159)	65.46 (22.438)
	Form Sequential Repetition	.740*	44.46 (18.804)	39.80 (16.211)

$p < .05$*

Table 5-3. Demographic Characteristics of Autism and Typically Developing Groups

Variable	Autism (N = 15)	Typically Developing (N= 12)	Test Statistic	p-value
Age (months)	50.47 (9.062)	60.92 (10.466)	7.730[1]	.010*
Gender (# males)	14	7	4.725[2]	.030*
Ethnicity (# Caucasian)	13	9	.649[2]	.420

Note. Values are presented as mean (SD) unless otherwise noted.

$p < .05$*

[1]F-value

[2]X^2-value

Table 5-4. Leiter-R Scores for the Autism and Typically Developing Groups

Leiter-R Variable[1]	Autism (N = 12)	Typically Developing (N= 12)	Test Statistic (*F*-value)	*p*-value
Brief IQ	97.83(17.341)	119.75 (14.124)	11.524	.003**
Figure Ground	9.25 (4.595)	13.00 (2.96)	4.844	.039*
Figure Completion	11.42 (4.01)	13.92 (3.423)	1.971	.175
Sequential Order	7.91 (2.508)	12.17 (2.406)	17.260	.000**
Repeated Patterns	8.91 (3.506)	12.50 (3.398)	6.219	.021*

Note. Values are presented as mean (SD)
[1]All scores are presented as Scaled- Scores (scale mean = 10; SD = 3) with the exception of Brief IQ which is presented as Standard-Score (scale mean = 100; SD = 15)
$p < .05$*, $p < .01$**

Table 5-5. CDI Ratings for the Autism and Typically Developing Groups

CDI Variable[1]	Autism (N= 12)	Typically Developing (N = 10)	Test Statistic (F-value)	p-value
Social	19.08 (5.28)	58.60 (14.48)	77.669	.000**
Self Help	26.92 (6.83)	58.80 (10.51)	73.661	.000**
Gross Motor	28.17 (7.10)	57.70 (13.02)	45.751	.000**
Fine Motor	39.92 (14.09)	56.70 (7.27)	11.548	.003**
Expressive Language	25.50 (8.23)	67.20 (8.85)	130.771	.000**
Language Comprehension	26.25 (10.75)	60.60 (9.57)	61.451	.000**
Letters	45.08 (16.46)	67.80 (7.642)	16.055	.001**
Numbers	36.33 (15.83)	64.20 (11.59)	21.359	.000**
General Development	30.83 (9.97)	67.20 (7.24)	92.174	.000**

Note. Values are presented as mean (SD)
[1]All scores are presented as Age in months
$p < .05$*, $p < .01$**

Table 5-6. Mean Group Scores on the Block-Building Invariance Test Controlling for Intellectual Ability and General Development

Variable	Autism (N = 13)	Typically Developing (N= 12)	Test Statistic (F-value)	p-value
Form Diversity	9.04 (5.783)	6.67 (3.833)	.310	.583
Form Repetition	72.40 (15.615)	79.94 (14.261)	.697	.413
Form Sequential Repetition	41.70 (12.789)	52.96 (17.404)	.090	.767

Note. Values are presented as mean (SD)
$p < .05^*$, $p < .01^{**}$

Table 5-7. Relationship Between the B-BIT Outcome Variables and the RBS-R Scales for the Mixed Sample

	Form Diversity	Form Repetition	Form Sequential Repetition	Stereotyped Behavior	Self-Injurious Behavior	Compulsive Behavior	Ritualistic Behavior	Sameness Behavior	Restricted Behavior	Overall
Form Diversity	1									
Form Repetition	-.582**	1								
Form Sequential Repetition	-.443	.132	1							
Stereotyped Behavior	.086	-.054	-.312	1						
Self-Injurious Behavior	.157	.070	-.127	.807**	1					
Compulsive Behavior	.351	-.250	-.303	.761**	.689**	1				
Ritualistic Behavior	.070	-.191	-.294	.567**	.398	.821**	1			
Sameness Behavior	.513*	-.445	-.303	.625**	.524*	.868**	.777**	1		
Restricted Behavior	.432	-.440	-.413	.635**	.494*	.836**	.840**	.858**	1	
Overall	.326	-.262	-.331	.838**	.749**	.960**	.843**	.910**	.892	1

Note: *indicates significant values at the p<.05. **indicates significant values at the p<.01 level

Table 5-8. Relationship Between the B-BIT Outcome Variables and the BRIEF-P Scales for the Mixed Sample (N = 20)

	Form Diversity	Form Repetition	Form Sequential Repetition	Inhibit	Shift	Emotional Control	Working Memory	Plan	Self-Control (Inhibit)	Flexibility	Emergent Meta-cognition	Composite
Form Diversity	1											
Form Repetition	-.582**	1	.									
Form Sequential Repetition	-.443	.132	1									
Inhibit	0.30	-.012	-.290	1								
Shift	.246	-1.41	-.281	.809**	1							
Emotional Control	.169	-.089	-.245	.909**	.893**	1						
Working Memory	-.175	.163	-.146	.880**	.645**	.753**	1					
Plan/ Organization	-.124	.080	-.158	.879**	.631**	.746**	.913**	1				
Self-Control (Inhibit)	.100	-.050	-.282	.982**	.870**	.970**	.842**	.840**	1			
Flexibility	.216	-.130	-.268	.883**	.968**	.976**	.721**	.711**	.948**	1		
Emergent Meta-cognition	-.165	.134	-.152	.900**	.654**	.768**	.990**	.961**	.861**	.734**	1	
Composite	.010	.017	-.242	.976**	.844**	.925**	.931**	.911**	.976**	.911**	.944**	1

Note: *indicates significant values at the p<.05. **indicates significant values at the p<.01 level

Table 5-9. Relationship Between Invariant Behavior (B-BIT) and Repetitive Behavior (RBS-R) in the Autism Group (N= 10)

	Form Diversity	Form Repetition	Form Sequential Repetition	Stereotyped Behavior	Self-Injurious Behavior	Compulsive Behavior	Ritualistic Behavior	Sameness Behavior	Restricted Behavior	Overall
Form Diversity	1									
Form Repetition	-.744*	1								
Form Sequential Repetition	-.140	.487	1							
Stereotyped Behavior	-.169	.170	-.144	1						
Self-Injurious Behavior	.022	.295	.176	.703*	1					
Compulsive Behavior	.307	-.214	-.081	.590	.538	1				
Ritualistic Behavior	-.048	-.153	-.149	.170	.038	.721*	1			
Sameness Behavior	.675*	-.665*	-.044	.166	.177	.778*	.579	1		
Restricted Behavior	.500	-.516	-.448	.154	.101	.707*	.722*	.690*	1	
Overall	.316	-.259	-.115	.610	.582	.981**	.717*	.794**	.740*	1

Note: *indicates significant values at the $p<.05$. **indicates significant values at the $p<.01$ level

Table 5-10. Relationship Between Invariant Behavior (B-BIT) and Executive Function (BRIEF-P) for the Autism Group (N = 10)

	Form Diversity	Form Repetition	Form Sequential Repetition	Inhibit	Shift	Emotional Control	Working Memory	Plan/ Organization	Self-Control (Inhibit)	Flexibility	Emergent Meta-cognition	Composite
Form Diversity	1											
Form Repetition	-.744*	1										
Form Sequential Repetition	-.140	.487	1									
Inhibit	-.279	.199	-.036	1								
Shift	.477	-.252	.127	.308	1							
Emotional Control	-.020	.103	.196	.755*	.712*	1						
Working Memory	-.621	.535	.220	.752*	-.125	.504	1					
Plan/ Organization	-.536	.389	.107	.703*	-.187	.398	.831**	1				
Self-Control (Inhibit)	-.161	.158	.057	.955*	.518	.913**	.687*	.612	1			
Flexibility	.179	-.044	.194	.624	.878**	.959**	.289	.183	.817**	1		
Emergent Meta-cognition	-.617	.498	.181	.769**	-.149	.493	.978**	.928**	.693*	.269	1	
Composite	-.366	.325	.150	.943**	.307	.824**	.869**	.785**	.951**	.674*	.878**	1

Note: *indicates significant values at the p<.05. **indicates significant values at the p<.01 level

Table 5-11. Relationship Between Invariant Behavior (B-BIT) and Repetitive Behavior (RBS-R) in the Typically Developing Group

	Form Diversity	Form Repetition	Form Sequential Repetition	Stereotyped Behavior	Self-Injurious Behavior	Compulsive Behavior	Ritualistic Behavior	Sameness Behavior	Restricted Behavior	Overall
Form Diversity	1									
Form Repetition	-.294	1								
Form Sequential Repetition	-.721*	-.252	1							
Stereotyped Behavior	-.067	.256	-.061	1						
Self-Injurious Behavior	.040	.348	-.026	.224	1					
Compulsive Behavior	.167	-.033	-.352	.327	-.018	1				
Ritualistic Behavior	-.403	.158	-.129	.207	-.104	.534	1			
Sameness Behavior	-.144	.167	-.309	.095	-.160	.730*	.822**	1		
Restricted Behavior	-.014	-.432	-.034	.120	-.302	.840**	.626	.674**	1	
Overall	-.113	.142	-.268	.459	.092	.879**	.819**	.865**	.765**	1

Note: *indicates significant values at the p<.05. **indicates significant values at the p<.01 level

Table 5-12. Relationship Between Invariant Behavior (B-BIT) and Executive Function (BRIEF-P) in the Typically Developing Group

	Form Diversity	Form Repetition	Form Sequential Repetition	Inhibit	Shift	Emotional Control	Working Memory	Plan/ Organization	Self-Control (Inhibit)	Flexibility	Emergent Meta-cognition	Composite
Form Diversity	1											
Form Repetition	-.294	1										
Form Sequential Repetition	-.721*	-.252	1									
Inhibit	-.279	.512	-.053	1								
Shift	-.441	.411	-.072	.685*	1							
Emotional Control	-.056	.213	-.173	.721*	.717*	1						
Working Memory	-.326	.385	.093	.762*	.310	.264	1					
Plan/ Organization	-.212	.290	.174	.843**	.370	.444	.805**	1				
Self-Control (Inhibit)	-.197	.400	-.117	.919**	.771*	.934**	.546	.679**	1			
Flexibility	-.251	.299	-.121	.741*	.921**	.928**	.295	.439	.912**	1		
Emergent Meta-cognition	-.314	.367	.134	.820**	.349	.328	.983**	.899**	.609	.355	1	
Composite	-.329	.446	.011	.964**	.672*	.684*	.861**	.865**	.886**	.721*	.900**	1

Note: *indicates significant values at the p<.05. **indicates significant values at the p<.01 level

Table 5-13. Relationship between Invariance (B-BIT) and Working Memory (MBT) in the Mixed Sample (N = 25)

	Form Diversity	Form Repetition	Form Sequential Repetition	Repetition errors	z-score
Form Diversity	1				
Form Repetition	-.618**	1			
Form Sequential Repetition	-.475*	.220	1		
Repetition errors	.165	-.272	-.247	1	
z-scores	.092	-.202	-.255	.925**	1

Note: *indicates significant values at the $\underline{p}<.05$. **indicates significant values at the $\underline{p}<.01$ level

Table 5-14. Relationship Between Invariance (B-BIT) and Working Memory (MBT) in the Autism Group (N = 13)

	Form Diversity	Form Repetition	Form Sequential Repetition	Repetition Errors	z-score
Form Diversity	1				
Form Repetition	-.755**	1			
Form Sequential Repetition	-.243	.567*	1		
Repetition Errors	.085	-.230	-.140	1	
z-score	.060	-.217	-.214	.970**	1

Note: *indicates significant values at the p<.05. **indicates significant values at the p<.01 level

Table 5-15. Relationship Between Invariance (B-BIT) and Working Memory (MBT) in the Typically Developing Group (N = 12)

	Form Diversity	Form Repetition	Form Sequential Repetition	Repetition Errors	z-score
Form Diversity	1				
Form Repetition	-.322	1			
Form Sequential Repetition	-.714**	-.224	1		
Repetition Errors	-.002	-.139	-1.81	1	
z-score	-.208	.116	-.097	.253	1

Note: *indicates significant values at the p<.05. **indicates significant values at the p<.01 level

CHAPTER 6
DISCUSSION

Overview

The current study aimed to develop a measure to capture behavioral invariability through the play based behavior of typically developing preschoolers and preschoolers diagnosed with autism. In order to achieve this overarching goal, the current study was divided into two phases. Phase one outlined the development of the measure named the Block-Building Invariance Test (B-BIT); specifically, administration, coding, and scoring parameters were detailed to enable this task to be replicated and standardized. In phase two, pilot psychometric properties of the B-BIT were evaluated to determine whether the measure was reliable and valid. It was necessary to assess reliability and validity parameters to ensure that the B-BIT was measuring the intended construct (invariance) and to make certain that findings could not be attributed to rater subjectivity or temporal instability (Haynes et al., 1999).

The presence of restrictive, repetitive behaviors is one of the core diagnostic features of an autism spectrum disorder and the behavioral expression spans from preferences to verbal responses to motoric movements. The common link among these heterogeneous behaviors is the notion of invariance, or the extreme need for sameness. The development and evaluation of the B-BIT was intended to enhance the selection of currently available measurement tools by providing an objective method to evaluate invariance; to the researchers' knowledge no traditional test measure exists that has been designed for this purpose. Once a standardized method to measure invariance is created and found to have acceptable psychometric properties, it then is feasible to intervene and promote variability. The benefit of promoting variability is illustrated through other bodies of literature. Such research suggests that exposure and interaction with novel environments, as well as flexible engagement with materials, mitigates the negative repercussions of behavioral invariance in terms of both brain and behavioral development (Groark et al., 2005).

Traditional empirically-based interventions for children diagnosed with autism primarily focus on reinforcing behavior to shape the acquisition of skills (Lovaas, 1987). Often this applied behavior analysis approach involves reinforcing the same behavior so each step becomes natural to a child and part of his/her typical repertoire (Lovaas, 1987). In contrast, the B-BIT was designed as the first step in a line of research which has the long-term goal of developing a new intervention approach focused on reinforcing variable behavior. By rewarding variable behavior, the intended outcome is for children diagnosed with autism to engage in greater exploration of their environments, thereby more closely mirroring the manner in which typically developing children learn.

Development of the Block-Building Invariance Test (B-BIT)

The Block-Building Invariance Test was adapted from the block intervention described by Goetz and Baer (1973). Goetz and Baer's (1973) intervention study aimed to increase behavioral variability in preschoolers through block play and as such the study contained a detailed block coding system. However, the intervention described by Goetz and Baer (1973) lacked systematic administration and scoring procedures. Therefore, the primary aim when developing the Block-Building Invariance Test (B-BIT) was to capture behavioral invariance using a systematic approach that accounted for the broad cognitive abilities of preschoolers, particularly those diagnosed with an autism spectrum disorder. Specifically, the study aimed to have a simple coding and recording system for block configurations, as well as a standardized administration protocol. The ability of the B-BIT to capture behavioral invariance is detailed in subsequent sections which review the reliability and validity properties. However, administration of the B-BIT to preschoolers revealed that certain block formations were not accounted for in the initial project development. Additionally, gaps in the administration protocol were revealed.

Specifically, the block coding system created did not take into account the following block configurations:

- Placement of a block other than the half-circle underneath the arch
- Purposeful placement of a block away from the main block construction
- Spontaneous verbalizations pertaining to the block formation that did not coincide with purposeful block placement

Furthermore, the B-BIT administration and recording/scoring protocol did not code for or outline the:

- Number of prompts that a child needed during a block play trial
- "Off-task" behavior
- Manner in which to distinguish between different types of "off-task" behavior (i.e. a child asking the test administrator to come play and trying to grab his/her hand versus a child holding a block up to his/her eye and moving it repetitively)
- Procedure to follow when it was difficult to see every angle on the video recording
- Procedure if a child failed to engage in the block trial from the start
- Explicit discontinue rules for block trials

Psychometric Properties of the B-BIT: Reliability

In phase two of the current study the psychometric properties of the B-BIT were evaluated. To begin, reliability parameters, specifically test-retest reliability and inter-rater reliability were assessed. Overall findings suggest that the B-BIT is a relatively reliable test measure. This is significant as reliability reflects the extent to which an instrument yields the same results across multiple trials. In order for researchers to draw conclusions on values obtained from a test measure, it is necessary for individual observers to replicate research procedures in a manner that yields these consistent, reliable measurements (DeVillis, 2003).

Test-Retest Reliability

Test-retest reliability was calculated for the mixed sample, which included both typically developing preschoolers and preschoolers diagnosed with autism, as well as for the two separate diagnostic groups. Findings suggest temporal stability in typically developing preschoolers across all three outcome variables of the B-BIT (Form Diversity, Form Repetition, Form Sequential Repetition). In contrast, children in the autism group only demonstrated significantly similar performance across test administrations on the Form Repetition outcome variable. Kelly and McGrath (1988) outline four factors to help explain why scores on the same measure may change across a period of time. According to these researchers, variance in scores across study visits may be attributed to a real change in the construct being measured, systematic oscillations, differences in subjects or measurement methods and/or temporal instability (DeVillis, 2003). Temporal instability is defined as the "inherent unreliability of the measurement procedure" (DeVillis, 2003) and is the only factor that suggests test-retest unreliability (DeVillis, 2003). The consistent performance of the typically developing preschoolers across the two study visits, suggests that the B-BIT is not temporally unstable; rather there may be a specific characteristic embodied by the autism group that resulted in less reliable B-BIT performance.

Research suggests that children with autism often demonstrate symptoms of inattention and hyperactivity that mirror the symptoms demonstrated by children diagnosed with attention deficit hyperactivity disorder (ADHD; Fein, Dixon, Paul, & Levin, 2005; Handen, Johnson & Lubetsky, 2000). Children with ADHD are known for variable performance on cognitive tasks; it is reported that children with ADHD may be able to demonstrate knowledge one day and not the next day (Schweitzer, 2009). This variability is also seen in other neurodevelopmental disorders including Spina Bifida, and may also be demonstrated by children diagnosed with autism. This could explain why test-retest reliability coefficients did not meet clinical significance across all B-BIT outcome variables for preschoolers in the autism group.

Regardless of the reason why typically developing children demonstrated greater temporal stability than the autism group, findings of the current study suggest that caution must be taken when administering the B-BIT on separate occasions to children diagnosed with autism. Due to test-retest inconsistencies, it is possible that changes detected in B-BIT outcome variable values may not reflect true behavioral change. It is important to note that variability in performance across study visits is different than engaging in variable play-based behavior within a study visit.

Inter-Rater Reliability

Inter-rater reliability measures the consistency of coding system implementation and is not focused on participant performance (Haynes et al., 1999). For the current study inter-rater reliability was calculated for a sub-group of the mixed sample (n = 8). Due to resource limitations, a second rater was only available to code and score this subset of study participant block play; therefore an inter-rater reliability coefficient could not be determined for the two separate diagnostic groups. It was not anticipated that inter-rater reliability would have differed across children diagnosed with autism and typically developing children (Haynes et al., 1999).

Findings from the current study indicate high inter-rater reliability across two of the B-BIT outcomes variables, specifically Form Repetition and Form Sequential Repetition. A moderate correlation was found in Form Diversity ratings between the two independent raters. These moderate to large correlations suggest that the B-BIT scores represent true values; differences among individual participants and groups cannot be attributed to rater subjectivity. Additionally, the moderate to large inter-rater reliability coefficients across B-BIT outcome variables confirm that the coding and scoring systems developed as part of the B-BIT were clearly defined thereby facilitating the similar ratings of block play performance across independent raters. One goal of the current study was to ensure that the B-BIT could be replicated by independent practitioners. Inter-rater reliability findings support this objective.

Validity

A test measure that is reliable must also be evaluated for validity parameters. Validity captures the extent to which an instrument accurately reflects the specific construct it has been designed to measure (DeVillis, 2003). The B-BIT was assessed to determine discriminative validity, convergent validity and divergent validity. Overall, findings indicate that the B-BIT is not a valid measure. The B-BIT was designed to capture behavioral invariance through the play-based behavior of typically developing preschoolers and preschoolers diagnosed with autism. Validity properties of the B-BIT suggest that although this measure captures a behavioral phenotype of preschoolers, it does not reflect the intended construct of behavioral invariance.

Discriminative Validity

Discriminative validity or known-groups validation is the extent to which a measure differentiates one group from another based on performance scores (DeVillis, 2003). The current study proposed that B-BIT performance would distinguish between children diagnosed with autism and typically developing children. In contrast to apriori hypotheses, findings suggest that performance on the B-BIT does not significantly differ between children diagnosed with autism and typically developing children. There are a number of explanations that may explain the reason as to why typically developing preschoolers and preschoolers diagnosed with autism are not distinguishable across B-BIT outcome variables.

To begin, it is generally accepted that repetitive behaviors are demonstrated by typically developing children (Leekam et al., 2007); in fact, these behaviors often emerge in the first year of life (Thelen, 1979), increase by age three, and then begin to decrease by age four (Evans et al., 1997). Despite the presence of repetitive behaviors in typical development, children with autism are described as having more frequent and persistent repetitive behaviors (Bodfish et al., 2000), thereby encompassing the definition of behavioral invariance. A study by Leekam and colleagues (2007) found that, based on parent report, typically developing two- year-olds engaged in a broad range of repetitive behavior similar to children diagnosed with autism across scales measuring repetitive movements, rigidity, preoccupations with restricted patterns of interests and sensory interests. Since the mean age of our typically developing group was approximately 5 years and research suggests that repetitive behavior decreases by age four (Evans et al., 1997), it is not hypothesized that developmentally appropriate invariant play was the driving force behind the insignificant between-group findings.

It was also speculated that heterogeneity within the autism group, with respect to symptom severity, was potentially clouding between-group B-BIT performance differences. However, findings did not support this hypothesis; increased levels of behavioral invariance, as determined by B-BIT performance, did not predict parent reported symptom severity as rated on the Social Communication Questionnaire (SCQ). In fact, findings suggested a surprising trend; the more sequential repetition behavior a child demonstrated on the B-BIT, the lower the rating a child received on the SCQ. This finding is consistent with the group mean scores on B-BIT outcome variables. Specifically, the autism group demonstrated less Form Repetition and less Form Sequential Repetition than the typically developing group.

Follow-up analyses were conducted to understand the reason why children with autism were engaging in more, albeit not significantly, variable play behavior compared to typically developing children. Available raw video data of block play trials was reviewed. Qualitative analyses suggested that typically developing children were more engaged in the block play task. In order to capture this observation quantitatively, the overall number of blocks used by the two groups was compared. Findings did not support the prediction that overall number of blocks used would be equivalent to degree of block play engagement, as the number of total blocks used did not differ between the groups. A block was recorded as being “used” if a child moved a block to a new location and released his/her grip on the block. Detailed review of the data suggested that some typically developing children moved each available block once (i.e. moved 21 blocks) while other children in the typically developing group modified their block design continuously, thereby moving available blocks a number of times. The broad range of blocks used within the typically developing group alone may explain why this variable did not capture between-group differences of degree of block-play engagement.

Therefore, the criteria met by preschoolers to terminate the block play trials were reviewed. Trials were considered complete if all 21 blocks were used, if a child did not play with the blocks for 1 minute and did not respond to one physical prompt to return to block play, or if 5 minutes elapsed. Available data suggests that block play trials for children with autism were more likely to end because 5 minutes had elapsed. In contrast, block play trials of typically developing preschoolers were more likely to end because all of the blocks were used. This finding supports the hypothesis that typically developing children were more engaged in the B-BIT, and thus used all 21 blocks in a timely fashion. Children with autism who were less engaged in block play did not use all of the blocks within a 5 minute window.

Taken together, data suggests that typically developing preschoolers, who as a group appeared more engaged in block play, demonstrated more invariant play behavior than children with autism. Perhaps the B-BIT, which was limited to 10 different block pieces (21 blocks overall), did not provide sufficient diversity of resources to allow for variable play. In other words, given the blocks provided for by the B-BIT, it is possible that there were only a certain number of block formations that children were able to create. Therefore, children who were more engaged in block play (i.e. typically developing children) had more opportunity, and perhaps no option, but to demonstrate invariant behavior as measured by B-BIT outcome variables. Additionally, as previously detailed, there are a number of block formations that the B-BIT coding system did not take into account; these structures may have affected ratings of overall block play.

Symmetrical block formation is another response style that could potentially differentiate the two groups. Research suggests that typically developing 3-6 year olds create more symmetrical than asymmetrical designs when working with building materials (Schuler, 2001). Additionally, as age increases, children's tendency to create symmetric forms out of building material also increases (Schuler, 2001). While research has not been conducted looking at this building approach in children with autism, it is possible that this could be an area of developmental difference. Although the B-BIT scoring system does not directly examine whether blocks are placed symmetrically, the existing scoring system would likely rate symmetric (i.e. complex repetitive) designs as high (i.e. 'abnormal') across the Form Repetition and Form Sequential Repetition variables (i.e. demonstrating high behavioral invariance). Thus, the existing scoring system may inadvertently rate a 'normal' developmental behavior (i.e. symmetrical block building) as representing higher levels of invariant behavior. This provides another potential explanation for the more invariant behavior that the typically developing group demonstrated on the B-BIT.

Taken together, discriminative analyses suggest that B-BIT performance does not distinguish between typically developing preschoolers and preschoolers diagnosed with autism. However, review of the data suggests a trend in which typically developing preschoolers demonstrate more invariant behavior, as rated by the Form Sequential Repetition variable of B-BIT. This finding, although in opposition to apriori hypotheses, indicates that B-BIT performance, as captured by the Form Sequential Repetition variable, may be useful in discriminating between typically developing preschoolers and preschoolers diagnosed with autism. Rather than measuring behavioral invariance, the B-BIT may be measuring level of task engagement. Additionally, Form Sequential Repetition may capture the tendency of typically developing children to make symmetric designs out of building materials. Children diagnosed with autism may not demonstrate this developmentally appropriate tendency. Evaluating the symmetry of block formations was beyond the scope of the current study.

Convergent Validity

Convergent validity assesses the extent to which an instrument is related to its theoretical basis. Traditionally, convergent validity is determined by evaluating the relationship between an experimental or newly created measure and a “gold-standard” measurement tool that has already been found to have acceptable psychometric properties (i.e. measures the intended construct; DeVillis, 2003). As the current study proposed a novel construct, behavioral invariance, no “gold-standard” measurement tool with which to determine convergent validity existed. Behavioral invariance is most closely related to restricted, repetitive behaviors and aspects of executive function; therefore, the relationship between the B-BIT outcome variables and gold-standard measures of restricted, repetitive behaviors (Restricted Repetitive Behavior Scale-Revised; RBS-R) and executive function (Behavior Rating Inventory of Executive Function; BRIEF-P) were determined. Based on the literature and individual scale items, apriori hypotheses suggested that the Sameness Behavior Scale from the RBS-R and the Flexibility Index from the BRIEF-P would be most closely related to behavioral invariance as measured by the B-BIT.

Analyses to determine the relationship between B-BIT outcome variables and the RBS-R and BRIEF-P were conducted for the mixed sample and for the separate diagnostic groups.

With respect to the RBS-R, findings for the mixed sample indicated that the Form Diversity outcome variable from the B-BIT was positively related to the RBS-R's Sameness Behavior Scale. The more diverse block forms a child created during block play, the more sameness behavior was rated by the child's parents. This was in contrast to initial predictions which proposed that the more behavioral invariance (i.e. higher ratings on Form Repetition and Form Sequential Repetition) the higher parent ratings would be on the Sameness Behavior Scale.

When the relationship between parent ratings of restricted, repetitive, behaviors was determined for the separate groups, it became clear that the autism group was the primary factor in the significant findings. In fact, B-BIT performance, as captured by the Form Diversity, Form Repetition and Form Sequential Repetition scores, by the typically developing group was not significantly related to parent ratings of repetitive behavior. However, B-BIT performance by the autism group, with respect to Form Diversity and Form Repetition scores, was significantly related to the Sameness Behavior Scale of the RBS-R.

Specifically, for the autism group, the Form Diversity score on the B-BIT was positively correlated with the Sameness Behavior Scale of the RBS-R, while the Form Repetition score on the B-BIT was negatively related to the Sameness Behavior Scale. In other words, the more invariant behavior demonstrated by a child with autism on the B-BIT, the fewer sameness behaviors were endorsed by his/her parents on the RBS-R. It is rare for "paper and pencil" test measures and parent ratings of behavior to be significantly correlated (Mahone & Hoffman, 2007). Therefore, the directionality of the relationship between two of the B-BIT outcome variables and the Sameness Behavior scale is particularly surprising. These findings lead to two questions; why are parent ratings of sameness behavior negatively related to performance-based behavioral invariance and why does B-BIT performance significantly relate to parent ratings of repetitive behavior only for the autism group.

To begin, it is important to refer to the section discussing discriminative validity which outlined a number of reasons as to why typically developing children were found to demonstrate more invariant behavior on the B-BIT compared to children diagnosed with autism. Specifically, greater degrees of task engagement and limited resources with which to engage in variable play were proposed as two possible explanations. Based on these assumptions, it is reasonable to expect that within the autism group, the children with autism who were more engaged in block play demonstrated greater invariant behavior on the B-BIT for reasons similar to that of the typically developing group. Therefore, within the autism group, children whose behavior was more consistent with that of the typically developing group would purportedly receive lower parent ratings of sameness behavior on the RBS-R. This would explain the significant negative correlation found between parent ratings of sameness behavior and B-BIT performance for the autism group.

Significant relationships were not found between the typically developing group's B-BIT performance and parent ratings of restricted, repetitive behavior on the RBS-R. In fact, correlation coefficients between B-BIT outcome variables and RBS-R scales all fell within the small to medium range ($r < .5$; Cohen, 1988) with the strongest correlation between Form Repetition and Restricted Behavior ratings. Similar to the autism group, the negative correlation between these variables suggests that the more behavioral invariance demonstrated on the B-BIT by the typically developing children, the less restricted behavior was endorsed by parents. No relationship was found between B-BIT performance and the Sameness Behavior scale. A review of parent ratings on the RBS-R suggest that typically developing children were not rated as demonstrating high levels of restricted, repetitive behaviors across any of the scales. Therefore, a relationship between parent ratings and performance-based behavioral invariance was difficult to determine.

The relationship between behavioral invariance as demonstrated by B-BIT performance and parent ratings of executive function on the BRIEF-P were also evaluated for the mixed sample, as well as for the two separate groups. Performance by the mixed sample on the B-BIT was not significantly related to any domains of executive function, including the Flexibility Index, as measured by the BRIEF-P. In fact, all correlation coefficients for the mixed sample fell within the small range (r = .1 - .3; Cohen, 1988). These insignificant results were consistent when correlation coefficients were calculated for the autism group and typically developing group separately.

However, although findings did not reach clinical significance, large correlation coefficients (Cohen, 1988) were found for the autism group when the relationships between the Form Diversity score on the B-BIT and the Working Memory, Plan/Organization and Emergent Metacognition domains on the BRIEF-P was examined. These variables were negatively correlated which suggests that the more diverse block forms children with autism created, the less impaired they were rated by their parents on factors of executive function. Similarly a large correlation coefficient was found between Form Repetition and Working Memory for the autism group. Directionality of this finding suggests that the more behavioral invariance a child with autism demonstrated on the B-BIT, the more likely it was for his/her parents to rate him/her as having difficulty in the working memory domain.

Apriori predictions suggested that B-BIT performance would be related to the Flexibility Index of the BRIEF-P; however, the relationship found between B-BIT outcome variables and the Working Memory domain is not unexpected. This finding suggests that children who created the same block form repetitively may have failed to remember which block formation they had just created, thereby increasing invariant play.

B-BIT performance was moderately correlated with two BRIEF-P sub-domains for the typically developing group. Specifically, medium correlation coefficients were found between the Form Repetition score and the Shift and Self-Control (Inhibit) domains of the BRIEF-P. Of note, Shift and Self-Control are two of the three factors that comprise the Flexibility Index, the factor predicted to be related to B-BIT performance at the initiation of this study. Correlations suggest that the more performance-based behavioral invariance typically developing children demonstrated, the more likely it was for parent ratings to reflect impairments across tasks requiring shifting attention and inhibition of behavior. This is somewhat consistent with apriori hypotheses, as the Flexibility Index was predicted to be positively correlated with the Form Repetition and Form Sequential Repetition outcome scores of the B-BIT. However, this finding was expected to be present in the autism group as well.

The fact that performance on the B-BIT by the typically developing group and autism group was related to different aspects of parent ratings of restricted, repetitive behaviors and executive functions, suggests that the B-BIT may capture different behaviors across diagnostic groups. This supports the hypothesis that the B-BIT may be measuring degree of engagement in a novel task, as opposed to behavioral invariance. It would be interesting to determine if level of engagement on a novel task, such as the B-BIT, is related to parent ratings of repetitive behavior and executive function. Unfortunately, the data collection system employed in the current study does not allow for this relationship to be ascertained quantitatively.

Overall, convergent validity findings are variable across the diagnostic groups and suggest that the B-BIT does not capture behavioral invariance. This conclusion can be drawn by the fact that greater levels of behavioral invariance on the B-BIT are not correlated with higher ratings of sameness behavior and increased flexibility impairment. However, the moderate to large correlation coefficients found between the B-BIT outcome variables and parent questionnaires supports the notion that the B-BIT is measuring a distinct behavior. This is particularly true for the autism group and procedures to identify the behavior measured by the B-BIT are detailed in the future direction section found on page 86.

Divergent Validity

Divergent validity is demonstrated when an experimental measure is not found to be related to an instrument designed to capture a similar but distinct trait. Theoretically, the B-BIT was developed to capture behavioral invariance, which by definition is related to repetitive behavior and aspects of executive function, particularly cognitive flexibility. In order to determine that the B-BIT was not related to other aspects of executive function, the relationship between the B-BIT and the Multiple Boxes Test (MBT) was ascertained. The MBT was developed to measure spatial working memory (Llamas & Diamond, 1991 reviewed in Mahone & Hoffman, 2007), thereby representing a different sub-domain of executive function.

Divergent validity was calculated for the mixed sample, as well as for the separate autism and typically developing groups. Results suggest that B-BIT performance is not related to performance on the MBT for the mixed sample or for the separate groups. This finding reflects acceptable divergent validity. In fact, correlation coefficients across all analyses fell within the small range (Cohen, 1988). This indicates that the B-BIT outcome variables are not related to a performance based test of working memory. Of note, it was previously determined that the Form Repetition score for the autism group was highly correlated to parent ratings of working memory. It is possible that working memory, as measured by the MBT, differs from the working memory construct evaluated through parent ratings. Research consistently suggests that executive function as assessed by the BRIEF-P is not related to executive function as measured by traditional neuropsychological tests (Mahone & Hoffman, 2007).

Overall Assessment of the B-BIT

Evaluation of the B-BIT indicates that in general this experimental measure does not have acceptable psychometric properties. The B-BIT was developed to capture a novel construct defined as behavioral invariance. Behavioral invariance dominates the lives of many children diagnosed with autism. Children diagnosed with autism show an extreme desire for sameness and often deviation from routine results in negative behavioral changes. Therefore, many parents will adhere to their child's preference for "the same" in order to avoid behavioral repercussions. The B-BIT aimed to capture this behavioral phenotype through play-based behavior that sought to eliminate cognitive confounds. The underlying hope was that a measure found to capture behavioral invariance could then be used as a mechanism through which an intervention could be developed.

Unfortunately, analysis of the B-BIT revealed that the coding and subsequent scoring system did not capture behavioral invariance as theoretical development would suggest. Additionally, the play-based behavior of children diagnosed with autism and typically developing children did not significantly differ. Granted, calculations of effect sizes suggest that the Form Sequential Repetition score would have differentiated between the two groups given a larger sample size; however, the directionality of this difference is unexpected, as typically developing children would be rated as having more sequential repetition.

Real-life observation of children diagnosed with autism and typically developing children reveal significant play-based differences per both researcher and parental report. The fact that the B-BIT does not capture these differences speaks to the difficulty in coding behavior, even when behavior is not considered to be subtle. However, a measure designed to capture invariance should be able to differentiate children with autism from typically developing children, as repetitive behavior is one of the core diagnostic features of the disorder. Moreover, test-retest unreliability found for the autism group across two of the three B-BIT outcome variables is also concerning, particularly as the ultimate purpose of designing the B-BIT was to develop a structured intervention. If the B-BIT in its current form was to be used as an intervention tool, it would be difficult to determine if changes in B-BIT scores reflected true modification of a child's behavior. Ideally, in this scenario a trend in B-BIT scores would be reflected through multiple block play trials. However, this would need to be assessed prior to using the B-BIT as an intervention tool and unfortunately such evaluation is beyond the scope of the current study.

Also important are the findings which suggest that greater performance-based invariance as measured by the B-BIT is related to lower parent ratings of dysfunction in terms of repetitive behavior. This data supports the idea that the B-BIT is not capturing behavioral invariance, which often has a negative connotation, but is rather capturing a positive behavioral dimension. In other words, the B-BIT may be measuring an adaptive behavior that is demonstrated by a sub-set of children in the autism spectrum group who display less severe autistic symptomatology and therefore are purportedly better able to interact with novel environments and materials.

When reliability and validity parameters are reviewed together, it appears likely that the B-BIT is actually measuring the degree to which children are engaged in block play, as opposed to their actual play behavior. This may explain why typically developing children receive higher ratings across B-BIT variables (i.e. greater invariant behavior) and why their play is more consistent across study visits. Children with autism, due to their behavioral invariance, may have difficulty engaging in play that does not include their preferred task. If this were the case, then they would have had less opportunity to create block formations and demonstrate invariant play. Similarly, instability of block play ratings for children with autism across study visits may reflect inconsistent task engagement rather than true changes in play behavior. Unfortunately, degree of task engagement is not formally measured by the B-BIT.

It is also possible that the B-BIT captures degree of task initiation as opposed to task engagement. Initiation is considered a sub-domain of executive function; although inconsistent, there is research to suggest that on parent ratings of initiation adolescents diagnosed with an autism spectrum disorder are rated as more impaired compared to typically developing children (Zandt et al., 2009). Similarly, a study by Zandt and colleagues (2009) determined that adolescents diagnosed with an autism spectrum disorder generate fewer responses on performance-based measures that require multiple responses compared to typically developing children. If the B-BIT captures ability to initiate play, then it is reasonable to expect that typically developing children would demonstrate greater development of these skills (i.e. receive higher percentage scores across B-BIT outcome variables). In fact, perhaps initiation is a pre-cursor skill to variance; this would suggest that decreased initiation would have to be the first targeted behavior of an intervention prior to focusing on increasing variability.

Of note, the B-BIT represents a contrived setting; in everyday life both typically developing children and children diagnosed with autism often receive external reinforcement and praise for their behaviors. In fact, children with autism who have been exposed to early intervention settings are likely accustomed to having adults comment positively on their behaviors. The B-BIT does not allow for any interaction between study participant and test administrator. It is possible that all children, but especially children in the autism group, did not understand the lack of interaction and verbalizations by the test administrator. Typically developing children may have more internal motivation to please adults and therefore were more engaged in the block play task. Children diagnosed with autism would not be expected to have this internal motivation for a task that extended beyond their preferred activity; as a result it is not surprising that many of the children in the autism group were less engaged in block play.

Limitations

It is important to note that the current study has a number of significant limitations that may have impacted psychometric data. To begin, the development of the B-BIT was primarily based on one study (Goetz and Baer, 1973). Therefore, more systematic observation of the block play behavior of children diagnosed with autism and typically developing children may have been useful prior to the initial description of block formations and coding criteria. Observing multiple children playing with the specific block pieces contained in the B-BIT also may have eliminated some of the difficulty raters encountered when a block formation a child created was not accounted for by the B-BIT block coding system.

The recruitment process of the current study represents another limitation. The majority of children in the autism group were recruited from the Autism Clinic which is part of the Department of Psychiatry at the University of Florida. Many children seen by this clinic group demonstrate atypical autism presentations and therefore the group may not represent the larger sample of children with an autism spectrum disorder. This is supported by the discrepancy seen for some of the children in the autism group across diagnostic scales. Ideally, children in the autism group would have met criteria on the SCQ, the ADOS and through clinical judgment; however, due to sample size limitations children were included in the autism group if they met criteria on either the SCQ or the ADOS and through clinical judgment. Similarly, there is reason to suspect that some parents may have difficulty fully understanding the wording of questions on the SCQ. This is one of the reasons why the Autism Diagnostic Interview- Revised (ADI-R) may more accurately reflect severity of autistic symptomatology. The ADI-R is a clinical interview and therefore is moderated by clinical judgment. Unfortunately, training on the ADI-R had not been complete at the initiation of this study. Diagnostic difficulties suggest that some children may have been included in the autism group even though their presenting symptoms may ultimately be more consistent with a developmental disorder not included on the autism spectrum.

Small sample size is another limitation of the present study. Large scale psychometric studies must include a large sample size. Specifically, typically developing individuals or healthy controls often represent the majority of the study sample, in order to have a normative sample for standardization purposes. Due to the small sample size the current study is best described as a pilot investigation. A larger sample would have enabled additional analyses to be conducted. Specifically, the impact of other factors on B-BIT performance, including type and intensity of intervention services received and amount of school attended, could have been evaluated. Furthermore, research supports the idea that the play behavior of children changes rapidly throughout development (Evans et al., 2004). To understand the effect of age on B-BIT performance, a larger sample would be needed.

Despite the small sample size, the current study conducted a large number of statistical analyses and bonferroni corrections were not implemented. This suggests that some of the results presented in previous sections may misrepresent the strength of the relationship between dependent variables. Additionally group discrepancies may have been overestimated.

To determine divergent validity, children's performance on the B-BIT was related to their performance on the MBT. Although the MBT has been reported to measure spatial working memory and self-ordered pointing (Mahone & Hoffman, 2007), a study documenting psychometric properties of this task was unable to be located after an extensive literature search. Therefore, it is possible that the MBT is not truly capturing the domains it was created to measure. This would affect the interpretation of the study's divergent validity results and therefore is a potential limitation of the current study.

Lastly, administration of the B-BIT did not adhere to the three block-trial termination criteria. Specifically, in the present study trials were concluded if all the blocks were used or if 5 minutes had elapsed. Trials were not ended if a child stopped engaging in the task for one minute and did not respond to a physical prompt to return to block play, even though this criterion had been outlined in the administration protocol. Although this oversight did not impact primary analyses, follow-up analyses that looked at block trial termination criteria were affected.

Future Directions

The current study was proposed as the first step in a line of research designed to measure and subsequently intervene on the behavioral invariance demonstrated by preschoolers diagnosed with autism. Based on the data presented throughout this document it is clear that the B-BIT fails to measure the intended construct of behavioral invariance. Therefore, the B-BIT needs to be modified or another measure needs to be developed. Modifications must occur prior to the creation of a structured intervention designed to promote behavioral variability. It is important that the instrument developed to measure behavioral invariance demonstrates acceptable psychometric properties before it is used as part of an intervention for children diagnosed with autism. Currently, parents of children with autism are presented with treatment options and interventions that are not founded in science. It is not the intent of the present study to add to the variety of intervention options that do not demonstrate empirical findings.

B-BIT Modifications

Review of the pilot psychometric properties of the B-BIT, as well as qualitative observation, supports the need for certain modifications to be incorporated in future versions of the B-BIT, if in fact one is developed (Block-Building Invariance Test-Revised; B-BIT-R). In terms of the block coding system, it is important that all block formations are coded. A more systematic evaluation of the current study's video data must be conducted to ensure that all potential block formations are provided with a label. Additionally, the coding system must take into account degree of task engagement.

Specifically, off-task behavior must be measured and different types of off-task behavior should be coded (e.g., failure to engage in block play at all, engaging in behavior without the blocks, engaging in a self-stimulation behavior with the blocks, etc.). In fact, some of the 'off-task' behaviors that children with autism engage in may actually represent 'lower level' invariant behaviors. For example, if a child held a block up to the corner of his/her eye and moved it back and forth, this might be an instance of a more simple behavioral expression of invariance (much like the hand-flapping and other self-stimulation behaviors seen in this population). Spontaneous verbalizations that do not coincide with a particular block movement should also be recorded. Furthermore, the tendency of typically developing children to build symmetric block creations should be taken into account. The current coding system likely codes symmetric designs as invariant play; however, since this is part of typical development it should not negatively impact block-play outcome variable scores.

Recording of the specific termination criteria used to end a block play trial is also important. Termination criteria must account for children who never engage in block play, as well as for the number of prompts that are given by an administrator to facilitate task re-engagement. The B-BIT-R should pilot providing reinforcement of task engagement for all preschoolers to determine if outcome variables differ when overall level of engagement is relatively consistent across participants. Ultimately, the current study suggests that in order for a child to benefit from an intervention, a basic level of task engagement must be demonstrated.

Capturing behavioral invariance is a difficult task. Motorically invariance can be measured through technological advancements that register distinct motor movements (Glzebrook et al., 2006). Perhaps play-based behavioral invariance could be captured through an analog system that assesses more fine motor skills (i.e. the discrete way in which a child moves the individual block pieces).

Despite the difficulty in measuring behavioral invariance, the original goal of the current study remains significant. Evidence gathered from multiple bodies of literature clearly supports the negative implications of behavioral invariance on brain and behavior development. Additionally, the positive brain-behavior effect when behavioral variance is promoted is clearly documented. In fact, there is research to support the notion that children with autism would benefit from novel environmental exploration and flexible material engagement; therefore, it remains vital to develop a psychometrically sound method of measuring and subsequently intervening on behavioral invariance.

APPENDIX A
SCORING SHEET

Block-Building Invariance Test (B-BIT)-Scoring Sheet

Block Used											*Block Form Created* (please place a check mark over the form the block is used to make)						
1)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
2)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
3)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
4)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
5)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
6)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
7)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
8)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
9)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
10)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
11)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
12)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
13)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
14)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
15)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
16)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
17)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
18)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
19)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
20)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG

21)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
22)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
23)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
24)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
25)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
26)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
27)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
28)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
29)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
30)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
31)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
32)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
33)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
34)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
35)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
36)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
37)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
38)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
39)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
40)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
41)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
42)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
43)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
44)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
45)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG

46)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
47)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
48)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
49)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG
50)	1	2	3	4	5	6	7	8	9	10	FENCE	PATH	STORY	INTERFACE	SPON.VERB	SPON.UTIL	DIAG

END 5:00 minutes

Block Shapes Used

1 2 3 4 5 6 7 8 9 10

Total Number of Shapes Used: ___________

Block Forms Created

FENCE PATH STORY INTERFACE SPON.VERB SPON.UTIL DIAG

Total Number of Forms Created: __________

Block Shapes Key:
1 = rectangle
2 = half-rectangle
3 = round column
4 = long roof plank
5 = medium roof plank
6 = arch
7 = quarter circle
8 = triangle
9 = square column
10 = square half-column

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BIOGRAPHICAL SKETCH

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