An Evaluation of Several Measures of Attention and Inhibition in Ten Year Old Children

by

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ABSTRACT

Due to numerous definitions for attention and inhibition, it is very difficult to operationalize and measure these constructs (Barkley, 1996). The primary purpose of this study was to determine whether there is evidence for independence between attention and inhibition constructs using measures from the TEA-ch, Gordon CPT, Stroop Task, WISC- Digit Span and Go-No-Go Tasks and tasks of inhibition. Each of 140 students were evaluated on all measures and scores were correlated. In addition, Teacher Ratings and scores from the OLSAT were also correlated with attention and inhibition scores. Gender differences between all scores were also examined.

Overall, measures did not correlate as expected. Results showed that there were significant but weak correlations among the sustained and selective attention variables. Similarly, when all inhibition variables were correlated only four significant but weak correlations were found. The lack of convergent validity and low correlations among these measures suggest that attention and inhibition constructs may be multi-dimensional. Intercorrelations between attention and inhibition variables were also weak.

Relationships between OLSAT scores, Teachers Ratings and attention and inhibition variables showed that as scores that reflect reasoning skills and Teacher Ratings increased, the ability to attend and inhibit also increased. Gender differences in attention and inhibition scores were also examined and showed that girls were better at paying attention to stimuli and inhibiting impulsive responses than boys.

Keywords: Attention, Inhibition, Attention Measures, Inhibition Measures.

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AN EVALUATION OF SEVERAL MEASURES OF ATTENTION AND INHIBITION IN TEN YEAR OLD CHILDREN

Attention and inhibition have been defined and classified in various and often overlapping ways (Barkley, 1996; Halperin, McKay, Matier & Sharma, 1994). Due to the lack of universally accepted definitions for attention and inhibition, it is often difficult to operationalize and measure these processes (Fletcher, 1998; Goldhammer, Moosbrugger & Schweizer, 2007; Halperin, 1996; Levin et al., 1996; Nigg, 2001, Wilding, 2005). The principal approaches for studying and identifying the constructs of attention and inhibition in children have been through the use of populations with Attention Deficit Hyperactivity Disorder (Alderson, Rapport, Sarver & Kofler, 2008; Alderson, Rapport & Kofler, 2007; Barkley, 2001; Wilding, 2005) and parent and teacher ratings (Bauermeister, Alegria, Bird, Rubio-Stipec & Canino, 1992; Dupaul, Anastapoulos, McGoey, Power, Redi & Ikeda, 1997; Floyd & Kirby, 2001; Wilding & Burke, 2006). In these clinical investigations, researchers have questioned whether problems with attention and inhibition deficits are unidimensional or multidimensional (Barkley, 2001; Bauermeister et al., 1992; Goldhammer et al., 2007; Hart, Lahey, Loeber, Applegate & Frick, 1995; Lahey et al., 1988; Nigg, 2000).

The third edition of the Diagnostic and Statistical Manual of Mental Disorders (DMS-III, APA, 1980) defined Attention Deficit Hyperactivity Disorder (ADHD) as three dimensional with symptom combinations of inattention, impulsivity and hyperactivity. In 1987, the DSM-III-R redefined ADHD as a unidimensional disorder manifested by inattentive, impulsive and hyperactive symptoms (APA, 1987). In 1994 the DSM-IV again redefined ADHD as a two dimensional disorder characterized by

symptoms of inattention and hyperactivity-impulsivity (APA, 1994). The DSM-V criteria for ADHD are similar to those in the DSM-IV. The same 18 symptoms are included and continue to be divided into two dimensions: inattention and hyperactivity/impulsivity (APA, 2013).

Barkley (2001) has discussed the controversy regarding the predominantly inattentive type (PIT) of ADHD as a distinct disorder and not as a subtype of ADHD. He cautions researchers that attention must be recognized as a construct that is multidimensional and that several distinct disorders of attention are likely to be identified in addition to ADHD. Barkley (2001); Goldhammer et al., (2007); Halperin et al., (1994); Nigg (2001) and Wilding (2005) have argued that these constructs are not unitary and further that a general consensus regarding definition was lacking. Fletcher (1998) and Wilding (2005) reported that attention was not a unitary construct, but a construct with multiple subtypes. They further argued that confusion and debate often arose because some of the multiple processes subsumed under the construct of attention, were often included or represented in other cognitive models. The construct of inhibition, for example, was often found in models of inattention (Barkley, 1997), thus adding to the perplexity of whether these constructs were independent. Barkley (1997) reviewed numerous studies, which employed subjective as well as objective measures of attention and inhibition and investigated the independence of these functions. Halperin et al., (1994) have argued that subjective behavioral observations do not differentiate between them. In addition, Barkley (1997) has reported that when more objective and standardized methods are used and subjected to data reduction methods such as factor analysis, caution must be exercised when reviewing the various labels given to similar

dimensions by researchers who attempt to differentiate attention and inhibition. Fletcher (1998) also agreed that differing definitions or labels were often given to the same cognitive processes. Many researchers have reported that attention and inhibitory abilities are also included in many definitions of executive function. (Brocki & Bohlin, 2004; Chan et al., 2008; Jurado & Roselli, 2007; Klernberg, Korkman & Lahti-Nuuttilla, 2001; Nigg, 2000; Wilding 2005).

The constructs of attention and inhibition have been intensely researched. However, due to questions concerning the independence between the two constructs, lack of all-encompassing definitions and measurement difficulties, further research in this area is needed. The design and the rationale for this investigation was to determine the relationship between attention and inhibition comparing newer and traditional measures. To begin this paper, literature is reviewed about the theories, definitions, as well as the developmental course of attention and inhibition. In addition, the various measures used to assess attention and inhibition are discussed.

Historical and Contemporary Theories of Attention

> Everyone knows what attention is. It is the taking possession of the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal more effectively with others and is a condition which has a real opposite in the confused, dazed, scatterbrained state .....”(James, 1890, pp. 403-404).

To William James (1890) attention was synonymous with active selection by the individual. In other words James believed that what one attended to was what one was captivated by or interested in. Out of several objects, one becomes central and it is that one to which the individual will attend. James also described *varieties* of attention. These

categories were objects of sense or sensorial attention and ideal/represented objects or intellectual attention. He further divided intellectual attention into immediate and derived subtypes. Attention is immediate when the topic or object is intrinsically interesting without being related to anything else. Attention is derived when the interest is due to an association or relation to another immediately interesting thing. James also described attention as being either passive (non-voluntary) or active and voluntary. He further discussed the immediate effects of attention as being able to make one perceive, conceive, distinguish, remember and shorten reaction time. James was central in the introduction of this field as he, unlike philosophers before him chose not to ignore the concept of attention or think of the individual as passive "clay" (p. 403). As described above, he asserted that individuals decide on their experience by attending to what is chosen by them.

There was subsequently little research on attention until the 1950's when attention became a central interest of researchers who were interested in the auditory aspect of focused selective attention and later, focused visual attention. This work began with Cherry (1953) who studied what he termed the "Cocktail Phenomenon". This refers to an individual's ability to attend to one conversation in the midst of many. Cherry discovered factors such as gender and location of speaker as well as intensity of voice affected the ability to selectively attend. In one experiment Cherry (1953) used one speaker to record two messages which were presented to both ears of the subjects simultaneously. The subjects had difficulty separating the messages. Cherry (1953) also conducted experiments in which one message was played into the left ear while a different message was played in the right ear. The subjects were required to repeat one of

the messages out loud (shadow) as they were listening to the second message. The subjects were able to do this with relative ease, however when prompted for information about the second message, very little information was extracted.

Broadbent (1958) built upon the shadowing experiments and formulated the Filter Theory regarding auditory selective attention. He argued that when two messages are presented at the same time as in the auditory experiments, the filter is a device that prevents overload of the limited capacity system and this filter admits one message to the exclusion of others based on its physical characteristics. The other message may remain in the buffer for later input. This *early* selection hypothesis was considered by Eysenck and Keene (1990) to be a rigid system that could not account for the variation in the amount of analysis of the rejected messages. Other researchers questioned whether some of the contents of the rejected message had been examined and processed. Treisman (1964) preferred a refined version of Broadbent's early selection theory. She believed that the rejected or unattended message was not entirely discarded but that analysis was reduced. Deutsch and Deutsch (1963) favored a *late selection* model in which they suggested that all incoming messages were fully analyzed and that selection of a particular message occurred after the information was processed.

These theories looked at the concept of selective attention from an auditory perspective. Researchers have also examined how visual selective attention works. Two popular concepts have been those of the zoom lens (Eriksen & St. James, 1986) and the spotlight (Laberge, 1983). In the zoom lens theory, visual attention is seen as a lens with different magnification capabilities. When the lens is at a low magnification level, the field of view is broad but there is no magnification of the objects within that field.

Although the whole field of view is available there is no discrimination of detail. When the magnification of the lens increases, the broad field of vision decreases and there is increasing discrimination of detail. In terms of processing, if the size of the attentional field increases, the concentration of processing resources decreases. In contrast, the spotlight theory of visual attention is described as a spotlight which is moving through space and illuminates particular objects. Everything within the lighted area can be seen clearly. Anything out of the range of the spotlight or falling outside of the beam is impossible to see. Spotlights are also believed to have adjustable beams which can be increased or decreased. Visual attention is believed to have these same properties. And like the zoom lens theory, since the size of the spotlight can vary, as the attentional spotlight increases in size the processing capacity also decreases.

The previous discussion has summarized the most historically influential theories which commenced a century long debate into the nature of attention. Unlike some of the first historical approaches, contemporary attention theories rely heavily on empirical evidence and less on subjective theoretical insights. However, one idea that still remains and fuels scientific inquiry after a century is William James' (1980) belief that attention is not a single entity. And thus, if attention is not a single entity then it, as well as its sub processes cannot be accurately defined until the nature of this multidimensional construct is clarified.

Russell Barkley (1996), a leading researcher in the area of attention discusses the universal problem of definition faced by many researchers of attention.

> Yet, while the concept of attention has died many deaths it continues to be cited again and again in our literature We are stuck with the notion, as Michael Gordon (personal communication, August 14, 1993) once said, that there

> is a glue that binds behavior to the environment: This glue we call attention. It is to be found in our responsiveness, broadly construed as both external and internal reactions, to our environment. And, perhaps, it is this general responsiveness or capacity to react that is the best agreement we can currently reach regarding the meaning of the term attention. (p. 48)

Most researchers agree that attention is not unidimensional (Barkley, 2001; Fletcher, 1998; Goldhammer et al., 2007; Mirsky, 1996; Robertson, Ward, Ridgeway & Nimmo-Smith, 1996) but there are theoretical and empirical problems in defining the dimensions (Barkley, 1996; Fletcher; 1998; Halperin, 1994; Schweizer, Mossbrugger, & Goldhammer, 2005) Empirically, attention is no longer viewed or described in global terms but rather as a set of processes or subtypes (Anderson, Fenwick, Manly, Robertson, 1998; Barkley, 2001; Das, 2002; Mirsky, 1996; Robertson, Ward, Ridgeway, Nimmo-Smith, 1996) therefore, it is important in any discussion of attention to begin with current definitions of the basic subtypes.

Definitions of Attention

The research suggests there are three main types of attention. Selective attention is defined as attending to specific stimuli while ignoring irrelevant stimuli (Bjorkland & Kipp, 1996; Milliken, Joordens, Merickle & Seiffert, 1998; Sharma et al., 1991). Manly, Robertson, Anderson, and Nimmo-Smith (1999) defined selective/focused attention as one's ability to resist distraction, sort information and discriminate between factors to determine which are important to the task at hand. Selective attention has the following two components: divided attention, defined as the ability to attend to two or more stimuli simultaneously (Halperin et al., 1994) and focused attention defined as attending to a single stimulus while ignoring all others. (Sharma et al., 1994). The second major

type of attention is sustained attention which is the ability to maintain vigilance over an extended period of time as well as the ability to prepare and maintain readiness for response (Schachar et al., 1988; Giambra, 1996). Sergeant (1996) defined sustained attention as one's ability to maintain performance over time. Manly et al. (1999) defined sustained attention as "The ability to keep one's mind on a job that may do very little to 'grab' attention itself, but is necessary to achieve a goal." The third major type of attention is attentional switching which is defined as the ability to switch attentional focus between one thing and another (Manly et al., 1999). Das (2002) defined attention as "A mental process by which a person selectively registers some stimuli and ignores others. Attention has at least two primary aspects; it can be focused and it is selective."

There have been many different definitions as well as theoretical models proposed in the study of attention. These have consisted of cognitive, neuropsychological and behavioral approaches (Chan, 2008; Christensen & Joschko, 2001; Sternberg, 1969; Schneider & Shiffrin, 1977; Mirsky, 1991; McIlvane, Dube & Callahan, 1996). These models will not be discussed here, but in their own manner, they have each added new insight to the study of this elusive construct and remain indispensable to the advancement of the field.

Development of Attention

The attention of children under five years of age is most likely to be seized by the most noticeable features in the environment (Nurcombe, 1991). Halperin (1994) reported that specific, preferred stimuli elicit the orienting response. Berger and Thompson (1998) reported that infants prefer to attend to novel stimuli, complex visual patterns and stimuli that include contrast and contour density. Halperin (1994) also reported that by four

years of age, novelty was not the primary factor in guiding visual attention, because the child was increasingly able to voluntarily direct attention independent of external stimuli. He proposed that this was the beginning of voluntary attention as described by Vygotsky and that this form of attention is well demonstrated by five or six year olds. Nurcombe (1991) also reported that between the ages of five and seven children were increasingly able to use selective search strategies.

In terms of development of selective attention, Halperin et al. (1994) reported inconsistencies in findings regarding selective attention abilities. They noted that a number of earlier studies had found that older children performed better than younger children on selective attention tasks but that other researchers believed that this was due to differences in perceptual abilities and not to increasing efficiency of selective attention. In terms of sustained attention, Nurcombe (1991) reported that reaction time, capacity for vigilance and sustained attention improved up to twelve years of age.

Halperin et al. (1991) administered the "A-X" version of the Continuous Performance Task (CPT) to 138 nonreferred boys between the ages of seven and eleven. In this twelve minute version of the task, 11 letters were presented on a computer screen at the rate of 1 per second. The stimuli remained on the screen for a duration of 200 ms with a 1.5 s interstimulus interval. A total of 400 letters were presented. Each block of 100 letters contained 10 targets, an A followed by an X. In addition 17 A's not followed by an X and 5 X's not preceded by an A were included. The child was told to press a button whenever the target, an A followed by an X appears. Results of their experiment showed that the number of correct hits, believed to represent sustained attention increased with age while the number of misses decreased with age. Overall inattention scores

(defined as equal number of misses + very late ‘correct’ responses + long latency false alarms which are those false alarms that have reaction times greater than hit reaction times) also decreased as a function of age.

McKay, Halperin, Schwartz and Sharma (1994) assessed the normal development of sustained attention, selective attention as well as response organization in 62 children aged 7 to 11 and sixteen adults, aged 21 to 48 years. To assess sustained attention they used the A-X version of the CPT and to assess selective attention they used the Visual Focused Attention Task (VFAT) in which subjects are required to respond to a target stimulus in the presence or absence of distracters. In this nine minute task, red, yellow and blue rectangles appear in the center of a video monitor, one at a time, for a duration of 2 s with an interstimulus interval of 2.5 s. In addition to the large boxes, smaller green squares sometimes appeared on the screen (distracters). Subjects were to ignore all distracters and only press the button when a blue box appeared in the middle. The score was the change in Reaction Time (RT) as a function of increasing number of distracters. Results for sustained attention showed that overall accuracy (hits) improved with age, but these gains were significant only for those between the ages of 11 and adulthood. There were no substantial gains in sustained attention for those between 7 and 11. In contrast, results for selective attention showed that reaction time increased as number of distracters increased and reaction time decreased as a function of age, however, these changes could not be attributed to changes in selective attention. Thus, there was no evidence of development in the age ranges studied. Levy (1980) also assessed the development of sustained attention using the CPT in 230 children aged 3 to 7. Results showed a marked development in the capacity for sustained attention between the ages of 4 and 6 years.

Kanaka, Matsuda, Tomimoto, Nota, Matsushima, Matsurra and Kojima (2008) assessed the development of cognitive as well as attention function in 541 girls using the CPT. Ages of the girls ranged from 5 to 12. They looked at cancellation for target or nontarget stimuli, omission scores, hit rate, commission errors, false alarms and mean reaction time. They grouped their scores into three types based on pattern of change. T-cancel, False and Commission are related to inhibition of response. N-cancel, Hit and omission are related to inattention of stimuli, and coefficient of variance of mean reaction time CVRT which is related to stability of processing time. The results indicated that inhibition function, inattention to stimuli and stability of processing time developed first and exhibited significant change at the ages of 5 to 6 years of age. The ability to discriminate between target and non-target exhibited significant change until 8 years of age. And reaction time exhibited significant change until 11 years of age.

Klernberg et al. (2001) assessed the development of selective, sustained and auditory attention as well as executive functions using the Nepsy Battery of tests. They administered the subtests to 400, 3 to 12 year olds. Their results suggest a staging of development that begins at 6 years of age with relative maturation of auditory and visual attention function by 11 years of age.

In a longitudinal study of 435 urban children, Rebok, Smith, Pascualavaca, Mirsky, Anthony and Kellam (1997) used various tasks to measure the normal development of sustained and focused attention, the ability to shift attentional focus and the ability to encode information. They used these four distinct elements of attention because of their prior work involving the factor analysis of a large battery of neuropsychological tests which yielded four factors. Overall, their results showed

improved performance from ages 8 to 10 on all but one measure of attention. Sustained attention improved over time, as the results from the CPT tests showed that number of hits and percent correct omissions improved from ages 8 to 13, however the improvement was more substantial for those children between the ages of 8 and 10 than those between 10 and 13. The ability to focus and execute responses as well as the capacity to shift attentional focus, all showed a significant improvement from ages 8 to 10. Rebok et al. (1997) concluded that the ability to focus and execute responses continued to improve with age, however the ability to shift attention remained relatively stable after 10 years of age. Thus, their research into various aspects of attention showed that the most significant developmental gains were found between the ages of 8 and 10.

While there is scant information regarding the development of divided attention, it is believed to improve with age (Halperin et al., 1994; Nurcombe 1991). However, Halperin (1996) notes that this increased ability may be due to an increase in memory capacity. In terms of attentional capacity, Weber and Segalowitz (1990) conducted a study in which they modified the Attentional Capacity Test (Weber, 1988) and administered it to seventy-two children between the ages of five and thirteen. Results showed that although there was individual variation at each age level performance increases with age. They also found that attentional capacity is fully developed by age thirteen. In reviewing the belief that child attentional as well as other functions improve with age, Morris (1996) questioned the validity of the findings . She questions whether these changes related to development are actually due to the development of attention or to higher order executive systems. Thus, measures must be developed that accurately measure and are sensitive to developmental changes in this domain.

Inhibition

Behavioral inhibition, like attention, is critical in everyday life. It allows us to control our thoughts and actions and prevents inappropriate responses. May and Hasher (1998) report that

> Inhibition holds candidate responses in abeyance until they can be evaluated for their appropriateness and suppresses those responses that are disconfirmed as undesirable. Inhibition is particularly important for controlling responses that are highly practiced and thus are likely to be emitted quickly and prior to careful evaluation.

Thus, inhibition enhances actions which may be socially desirable as well as keeping goals central to the individual. Barkley (1997) has reported that clinically, behavioral inhibition is significant in that a deficit in behavioral inhibition is the central impairment in ADHD. This deficit leads to secondary impairments in four executive functions: working memory, internalization of speech, self-regulation of affect, motivation and arousal, and reconstitution. Working memory is the capacity to hold information in mind that will be used to control future behavior. Internalization of speech involves rule governed behavior, problems solving, etc. The third function involves regulation of affect, emotions, ability for self-motivation and self-arousal to direct towards future goals. The fourth executive function of reconstitution refers to an individual's ability to take apart and recombine various types of information and use the information in a new way, much like problem solving.

Theories of Behavioral Inhibition

The concept of behavioral inhibition is central in many theories of child development as well as childhood psychopathology (Schachar & Logan, 1990). Logan's Race Model of Response Inhibition is such a model (Logan & Cowan, 1984). In this

model, response inhibition depends on a race between two processes: The primary task or the ‘Go’ processes and the inhibition or stopping processes. If the primary tasks or ‘Go’ processes win, a response occurs. If the stopping or inhibitory processes win, a response does not occur. Since the processes vary in terms of finishing time, the outcome is a question of probability. The dependent and independent variables in the model are the probability of inhibition and the interval between the stop signal and the primary task response, respectively (Schachar & Logan, 1990). The speed of one process does not affect the speed of the other process. Distribution of reaction times is an indicator of speed of the ‘go’ response. The proportion of the reaction times (RTs) that are greater than the time required by inhibition is indicated by the probability of inhibition. The Stop Signal Paradigm which is a widely used measure of inhibition (Alderson et al., 2008; Jennings, van der Molen, Pelham, Debsky & Hoza, 1997; Pliszka, Borcherding, Sprately, Leon & Irick, 1997;Schachar & Logan, 1990; Schachar, Tannock, Marriott & Logan, 1995) is based on this theory of inhibition. This task differentiates between stimuli that elicit and inhibit impulsive behaviors. In this task subjects are engaged in a primary task such as forced choice letter discrimination, for example, and are occasionally presented with a stop signal stimulus such as a tone which instructs them to inhibit their response to the primary task. As discussed before, a race is set up between the RT to the primary task and the inhibition process. An error of commission occurs if the inhibition process is too slow and is greater than the RT to the primary task. Conversely, if the inhibition process is shorter than the RT to the primary task, inhibition wins. Stop Signal Reaction Time (SSRT) scores are also calculated. Stop Signal Reaction

Time which is believed to be the primary measure of behavioral inhibition reflects the relative speed of the stop process relative to the go process (Alderson et al., 2007).

In an attempt to explain the lack of inhibition seen in children with ADHD, Quay (1997, 1988) made use of Gray's neuropsychological theory of an underactive behavioral inhibitory system (BIS). Quay described Gray's three interrelated systems in the brain. The first was a flight/fight system. The second was a reward or behavioral activation system. The third was the Behavioral Inhibition System (BIS). When this system detects conditioned punishment there is increased BIS activity which subsequently results in inhibition of behavior. In contrast, he also explains that if there is an underactive behavioral inhibition system that fails to produce sufficient fear and anxiety continuation or initiation of negative behavior will result. Thus, Quay believes that disinhibition in ADHD results from an under functioning behavioral inhibition system.

Another theory which implicates behavioral inhibition as the central feature of ADHD is by Russell Barkley(1997). Barkley presented a model which tries to relate a central feature of behavioral inhibition to four executive functions and the resulting self-control over behavior. Barkley borrowed many of his assumptions from Jacob Bronowski (1967/1977, as cited in Barkley, 1997). Bronowski believed that humans were distinguished from animals based on four unique properties of language which he termed, prolongation, separation of affect, internalization and reconstitution. Human language was not solely a means for communication but also for reflection where a course of action can be planned, performed and tested. Bronowski believed that in order for reflection to take place there must be a delay between the arrival and response of an

event. Thus, behavioral inhibition delays the response as well as the decision to respond so that information from the four unique properties can influence the decision to be made as well as the subsequent response. Bronowski stated that these functions and abilities were governed by the prefrontal cortex.

Barkley's (1997) theory is best understood in terms of a hierarchy, with behavioral inhibition at the top because it is the central feature and major impairment. Behavioral inhibition provides the critical support needed so that the executive functions can be used effectively. The four executive functions make up the second part of the hierarchy, directly below behavioral inhibition. These four functions, as previously discussed are working memory, internalization of speech, self- regulation of affect, motivation and arousal, and reconstitution. In short these executive functions manage our behavior or in other words our self-control. And this is where the problems associated with ADHD begin. ADHD is caused by an impairment in the central function of inhibition which leads to secondary impairments in the executive functions (Barkley, 1997). Thus, because the individual with ADHD cannot delay, the urge to act is immediate, there is a decrease in self-control and time and future no longer influence behavior. The ADHD child's difficulty is not being able to stop, look, listen and feel. Barkley's (1997) and Nigg's (2000) theories suggest that attention problems may be related to these response-inhibition abilities.

Although this present investigation is not focusing on clinical populations, these theories were presented to illustrate the central importance of behavioral inhibition or disinhibition and its effects on behavior.

Definition of Behavioral Inhibition

As with attention there is also no universally accepted definition for response inhibition (Halperin et al., 1994). Schachar, Mota, Logan, Tannock and Klim (2000) define behavioural inhibition as a psychological construct that underlies the ability to withhold or stop an ongoing response. Derefinko, Adams, Milich, Fillmore, Lorch and Lynam (2008) define inhibition as the process of suppressing an inappropriate response. Nigg (2001) describes how the construct of inhibition has been divided into components including executive inhibition and motivational inhibition. Executive inhibition involves the effortful suppression of a response in order to pursue a goal. Motivational Inhibition refers to the suppression of a response in the face of negative consequences or emotionally aversive feedback.

It is interesting to note that executive inhibition is defined in the same way as behavioral inhibition. Jennings et al. (1997) defined inhibition as stopping a motor response that has already begun. Schachar and Logan (1990) explained that lack of inhibitory control is actually revealed by impulsive behaviors such as responding to a task before it is understood, answering without sufficient information, allowing attention to be drawn by irrelevant stimuli and failing to correct responses that are evidently inappropriate. Halperin et al. (1994) discussed the problems inherent in the various definitions given for response inhibition. They explained that disinhibition may lead to impulsivity but that it can be exhibited in many other ways such as perserverative behavior which is the repetition or continuation of a behavior beyond an appropriate point. Also the ability to quickly stop goal-directed behavior once initiated can be considered another definition of inhibition. Following these various interpretations of

inhibition they argue that there is not a clear and precise definition of inhibition that can be considered independent from other constructs such as selective attention. Thus, Halperin et al. (1994) operationally defined inhibition as the ability to withhold a goal-directed and motivated response in order to enhance adaptive functioning. Perhaps the most elaborate definition of behavioral inhibition is provided by Barkley (1997). In his model, behavioral inhibition is comprised of three interrelated processes: the ability to inhibit a response, the ability to stop an ongoing response and protecting an initial period of delay from disruption or interference control. Thus, it is evident that some definitions given for inhibition are contradictory while others are relatively indistinguishable from other constructs. These problems will be discussed in the measurement section of this paper.

Development of Behavioral Inhibition

Halperin (1994) reported that the ability for self-regulation and the inhibition of inappropriate responses is considered of one of childhood's major developmental milestones. Barkley (1996) provided an interpretation of Bronowski's writings concerning the evolutionary emergence of executive functions. He suggested that because of the initial immaturity of the infant's prefrontal cortex, motor inhibition and delayed response are the primary functions to develop and it is these functions that lead to and provide the foundation for the four executive functions. These executive functions then emerge at relatively different points in development and at the same time the development of inhibitory and delaying capacities are ongoing.

Kopp (1982) described a developmental framework of self-regulation which argues that the ability to monitor and change ongoing behavior emerges between two and

three years of age. Vaughn, Kopp and Krakow (1984) measured the ability to exercise self-control in 72 children aged 18 to 30 months by assessing whether the children could inhibit their responses to an attractive stimulus such as a toy, food or a gift. Results showed that there was momentary evidence of inhibition in 18 month old children but that the abilities were variable across children and tasks. However, their results did show that as age increased so did the ability to inhibit and delay.

Brocki and Bohlin (2004) investigated the dimensionality and development of executive functioning including Inhibition in 6 to 13 year old children. They used measures such as the Go-No-Go Task, CPT and a Digit Span task. The reported that the most striking developmental advances occurred at ages 7.6 to 9.5 and again from 9.6 to 11.5. These results are very similar to those reported by Levin et al. (2001) below.

Schachar and Logan (1990) examined the development of impulsivity and inhibition in 36 children between the ages of 8 and 12 as well as twelve adults using the Stop Signal Paradigm Task. In this task, subjects are presented with a primary task in which they must respond to a forced-choice letter discrimination task. Intermittently, they are given a stop- signal tone or stimulus to inhibit responding to the primary task. Results for the normal group showed that older children and adults responded more quickly than younger children and with less variability of reaction time in the primary task. In terms of ability in inhibiting a motor response, results showed that younger children triggered the stopping response as often as older children and adults and the speed at which the stopping processes occurred also did not differ significantly. In other words young children were just as able to inhibit their response as older children. The authors further suggested that the mechanism of inhibitory control may be well developed by grade 2.

Williams, Ponesse, Schachar, Logan and Tannock (1999) conducted a similar study using the Stop Signal Task and also looked at the development of inhibitory control in individuals between the ages of 6 and 81 years of age. They found that older children (9-12 yrs) were significantly faster than younger (6-8 yrs) children in inhibiting their response. Overall they found that the ability to inhibit a response as well as execute one significantly improved throughout childhood. These findings are inconsistent with the former study conducted by Schachar and Logan (1990) which used the same methods and similar population but consistent with Levin et al. (1991) findings.

Levin, Culhane, Hartmann, Evankovich, Mattson, Harward, Ringholz, Cobbs and Fletcher (1991) looked at the development of executive functions in 183 children between the ages of seven and fifteen years of age. They used a go-no go computerized task in which the false alarms scores were believed to be a measure of inhibitory control. The go no-go task is a motor inhibition task which requires subjects to emit a motor response such as pressing a button or tapping a finger as fast as possible when given the cue to do so and then to inhibit the same response when cued to do so. Results showed that as age increased so did the ability to inhibit responses. The greatest decline in false alarm errors appeared between seven and eight year old children and again between nine and twelve year olds.

Grodzinsky and Diamond (1992) administered a battery of neuropsychological tests believed to assess frontal lobe functions to sixty-six ADHD boys and sixty-four controls between the ages of six and eleven. The tasks that were used to measure inhibition/impulsivity were the vigilance subtest of the Gordon Continuous Performance task (CPT) and the Stroop test. The scores used from the vigilance task were number

correct, commission (generally thought to assess inhibition) and omission (generally thought to assess sustained attention). Results showed that overall, for all three measures from the vigilance subtest, children's performance increased as age increased.

Halperin et al. (1991) in a similar study using the CPT with nonreferred seven to eleven year old boys found that the number of hits increased and reaction time decreased with age but no significant difference in age for false alarms or impulsivity scores. Halperin (1994) asserts that data such as that from his earlier study and that of Schachar and Logan (1990) may suggest that there is no sizable increase in the ability to inhibit responding during the early grade school years. There seems to be some lack of agreement between these studies as to when gains are made in the area of inhibition. Some studies report significant gains in early childhood while others report them in middle childhood. Schachar and Logan (1990) argued that these changes that are possibly seen in middle childhood may be more a factor of other developmental processes tapped by the measures used and not inhibition per say. Williams et al. (1999) reviewed similar studies which found no significant differences between younger and older children on the ability to inhibit a response and suggested that the small sample sizes and low statistical power in the previous studies would account for this.

While this current study does not focus on clinical populations or developmental differences, it was necessary to provide a summary of how attention and inhibition have been viewed historically. In addition, although fraught with conceptual and measurement difficulties, it was important to review how research has tried to outline and differentiate the developmental course of these two constructs. Although inconsistencies do exist, the general consensus that remains is that there is no universally accepted definition for

attention as well inhibition constructs. When considering the development of attention it is widely accepted that older children perform better than younger children on measures of selective, sustained, switching and divided attention. However, it is not clear whether the increase in attentional abilities is due to the development of other perceptual, memory or executive functions these abilities are often intertwined.

As with attention, the development of inhibition is ambiguous. The ability to inhibit does increase throughout childhood, but the timetable of the gains is not clear. Whether the gains are made in early childhood or late childhood is undetermined. As well, the gains in the ability to inhibit could be due to the development of other processes tapped by the measures used. As Lyon (1996) pointed out, a major reason for these problems is that researchers from different fields used different assumptions, vocabularies and use various tasks and methodologies. This leads to the final section of this introduction, the question of measurement.

Measurement of Attention and Inhibition

Weber and Segalowitz (1990) have argued that because attention problems have a negative impact on various aspects of children's functioning, appropriate measures of children's attentional functioning are needed that can properly assess and differentiate normal from abnormal functioning. This line of thinking would also hold true for inhibition. Christensen and Joschko (2001) agree that because attentional deficits are so clinically significant there is a need for practical tests of these abilities. As well, specific measures that can assess the various components of attention or inhibition are also needed. (Nigg, 2001; Riccio & Reynolds, 2003). Thus, the goals of measurement are many. A clinician needs to be able to make a correct diagnosis and implement correct

treatment A neuropsychologist needs to be able to clearly understand the relationship between brain structure/function and behavior and the behaviorist needs to understand the reasons for an individual's behavior and in general to ascertain whether the measure used is indeed valid.

General Assessment of Attention and Inhibition

In terms of general attentional assessment, there are many commonly used measures including behavior rating scales, reaction time tasks, paper and pencil cancellation tasks, continuous performance tests (CPT), subtests of intelligence tests, the Stroop test, maze completion tests as well as observation of attending behaviors in natural settings (Akshoomoff, 2002; Alderson et al., 2007; Barkley, 1996; Barkley, 1991; Brocki & Bohlin, 2004; Chan et al., 2008; Danis et al., 2008, Halperin, 1994 ; Kanaka et al., 2008; Loo et al., 2007; Muir-Braoddus, Rosenstein, Medina & Soderberg, 2002; Morris, 1996; Pasini et al., 2007). Halperin et al. (1994) divided psychometric tests used to assess attention into three categories. The first category included tests of attentional capacity. These would include tests such as digit span, letter span or visuospatial span. In tests such as letter or digit span, an individual is required to repeat a string of letters or words of increasing length verbatim. The second set of tests are those which measure sustained attention. These assessments generally consist of continuous performance tasks (errors of omission). The third group of tests measure an individual's ability to resist distracters, for example, in the Stroop test the individual is required to read a list of color names printed in black, then name the colors of X's and finally name the color of the ink when it conflicts with the color of the word. Divided attention is measured by tasks that require the subject to attend to multiple features of a stimulus or memory-recognition

search tasks. These different tests all measure single aspects of attention. In addition, Barkley (1996) argued that these types of laboratory tasks are limited in terms of how well they generalize or relate to attention in natural settings. He explains that measures of attention that make use of more natural tasks may be more ecologically valid and may produce greater generalizability of results.

The Test of Everyday Attention for Children (Manly et al., 1999) is such a test battery which uses game-like tasks to measure different aspects of attention, specifically, selective, divided and sustained attention as well as attentional control/switching. It has also included a measure of children's ability to inhibit motor responses. The TEA-ch presents several advantages when compared to other measures of attention. A distinct advantage of the TEA-ch is that it assesses multiple components of attention and uses various modalities such as visual and auditory.

As with attention there are numerous measures for inhibition (Alderson et al., 2008; Barkley, 1997; Christ, White, Mandernach & Keys, 2001; Halperin et al., 1994; Lansbergen et al., 2007; Pasini et al., 2007; Reynolds et al., 2008). These include, the Matching Familiar Figures Test, Porteus Mazes, Go-No-Go Tasks, errors of commission on Continuous Performance Tasks, Delay of Gratification Tasks as well as the Stroop. Alderson et al. (2008) explain that performance measures used for behavioral inhibition constructs usually involve dual task paradigms where children respond to a primary stimulus while withholding a response to a secondary stimulus such as the Go-No-Go task and the Stop Signal Task. Halperin et al. (1994) report that the many of these tasks such as the Porteus Mazes and the Matching Familiar Figures Test lack construct validity, depend on many other factors such as IQ and are too global to precisely measure the

construct of inhibition. Barkley (1997) reported that there is a need for tests that directly measure inhibition. Schachar and Logan (1990) as well as Barkley (1997) reported that the Go-No-Go Task, the Stop Signal Paradigm and the CPT are such tasks.

This section was intended to provide a brief summary of the numerous tools used to assess attention and inhibition. For interest purposes a summary chart of commonly used measures of attention and inhibition appear in Appendix A . The list also includes information from various attention and inhibition studies such as what the these measures have been used to specifically assess .

Problems with Subjective Measures

A primary reason for the problems in studying and trying to differentiate attention and inhibition come from the initial attention and inhibition/impulsivity studies that tried to determine whether the behavior problems underlying ADHD were unidimensional or multidimensional (Bauermeister et al., 1992; Lahey et al., 1994; Lahey et al., 1988; Mcgee et al., 1985; Nigg, 2001; Sherman et al., 1997). This problem in definition was seen in both the DSM-II and DSM-III-R (1980, 1987). Thus, if in clinical studies, ADHD is unidimensional, then there is a single dimension of maladaptive behavior that includes attention and inhibition as well as hyperactivity. But, if it is multidimensional then attention and inhibition are separate constructs. Much research has been conducted by obtaining teacher and/or parent ratings of behavior which were then factor analyzed. Using teacher and parent ratings in these analyses is controversial (Manly et al., 2001; Reynolds et al., 2008). In reviewing studies which included behavioral ratings, Halperin et al. (1994) reported that these studies which are supposed to describe hyperactivity, impulsivity and inattention yield a two factor solution with impulsivity being divided

across inattention and hyperactivity. Thus, Halperin interprets these findings as suggesting that impulse control may not be independent of attention and level of activity.

In terms of assessing attention, Halperin also believes that these types of subjective approaches such as asking teachers to rate various behaviours exhibit poor interrater reliability, over-rating of pervasiveness of symptoms and halo effects. Halperin continues to explain that halo effects occur when similar ratings across various behavioral domains are applied to a child. He asserts that while rating scales may be suitable for assessing problems in functioning, they are not suitable for assessing the construct of attention and further, rating scales may not be the appropriate instrument for trying to chart the developmental course of these constructs. Barkley (1991) also believes that factor analyses of rating scales are problematic in that they may produce a factor that is labeled as a specific construct but may be contaminated by an item that covaries with it.

Problems with Objective Measure

When more objective measures that assessed attention and inhibition were factor analyzed to determine the precise nature of the constructs, problems continued to exist. Barkley (1997) reviewed various studies and concluded that many factor analytic studies were limited because they were mainly exploratory, did not try to directly test whether there were separate dimensions and because of the nature and intended purpose of the instruments chosen. For example, Morris (1996) reports that many measures used by researchers to measure attention may be used by others as a measure of executive function. More specifically, tasks such as the Stroop, Trail Making Test and Digit Span, for example, which are used to assess attention were found by Morris to be also listed as measures of executive functions. Further, Friedman, Haberstick, Willcut, Miyake,

Young, Corley and Hewitt (2007) assert that attention problems are widely thought to reflect deficits in executive functions, but the question of whether attention problems are related to distinct EF's remains as of yet unresolved. Van der Sluis, de Jong and van der Leih (2006) argue that one of the fundamental problems in the measurement of executive functioning in which they include attention and inhibition function, is the task impurity problem. They further state that when a relationship is determined between performance on an executive task and performance on other cognitive measures, it is uncertain, whether the relationship is a reflection of the executive or non-executive parts of the task. Therefore, these become psychometric problems which make interpretation of the findings and hypothesis testing extremely difficult.

Barkley also cautioned against accepting the various labels given to the dimensions once measures were subjected to factor analysis. These problems arise because of the different assumptions made by the researchers in regard to what the test actually measures. For example, he compared three studies (Mirsky, 1996; Levin et al., 1996; Shute & Huertas, 1990) which referred to the Wisconsin Card Sorting Task as dimensions of attention labeled as 'shift", 'concept formation/problems solving' and 'formal operational thinking' respectively. Thus, confusion is bound to arise when researchers uncover similar dimensions but label and interpret them differently.

Gender Differences In Attention and Inhibition Measures

The majority of studies which incorporate the attention and inhibition measures used and discussed in this paper did not examine possible gender differences (Halperin et al., 1988; Muroi et al., 1997; Pliszka et al., 1997; Schachar et al., 1991; Schachar &

Logan, 1990; van der Meere & Sergeant, 1988) or used male only groups (Grodzinsky & Diamond, 1992; Halperin et al., 1991; Jennings et al, 1997; Schachar et al., 1995; Schachar et al., 1988). The majority of recent studies examined found inconsistent gender differences. For example, Brocki et al. (2004) administered various measures of executive functioning including measures of inhibition to children between the ages of 6 and 13 and reported that boys tend to be quicker than girls on Go- No –Go Reaction Time measures and that girls made more errors of omission that boys on a CPT task. Klernberg et al. (2001) administered the Nepsy battery to children between the ages of 3 and 13 and found that girls performed better than boys on the Visual Attention subtest. Manly et al. (2001) administered the Tea-ch as well as the WISC and the WRAT to 293 children between the ages of 6 and 16 and the Creature Counting (timing score)was the only significant sex difference where the boys performed better than the girls. When age ranges were examined they found that for the age groups 9 to 11, and 13 to 15, girls outperformed boys on the Sky Search visual measure.

Williams et al. (1999) administered the stop-signal task to 275 subjects between the ages of 6 and 81 years of age. They did not find significant sex differences for the stop-signal reaction time (measured in milliseconds) but did find a significant difference for go-signal reaction time. Females were initially slower to respond than males. Weber et al. (1990) administered the Attentional Capacity test to 72 children between the ages of 5 and 13. In this task, which has eight subtests, children must process and remember various sequences of aurally presented numbers. There were no significant differences reported for this task between males and females.

Levin et al. (1991) administered a battery of tests which included the Go/No-Go, Tower of London and the Wisconsin Card Sorting Task to 52 children between the ages of 7 and 15. No overall gender differences were reported. Rebok et al. (1997) also administered a battery of tests which, for example, included the Continuous Performance Task (CPT), Digit Span and the Wisconsin Card Sorting Task. Gender differences were found for reaction time on the CPT with boys outperforming girls at all age levels. Gender differences were also found for completion time in the Digit Cancellation Task. On this task males took longer to complete the task than girls. Significant gender differences were also found for omission errors on the CPT, which are a reflection of sustained attention, but only until 10 years of age, with males scoring higher than females.

Bjorkland and Kipp (1996) reviewed numerous studies which employed various measures of response inhibition including delay of gratification tasks, go/no-go tasks teacher ratings of impulsivity, and reported that the results were highly inconsistent with about half reporting gender differences. In those studies which did find gender differences, they reported that the majority of them favored girls in all inhibition tasks.

Relationship of Achievement to Attention and Inhibition Measures

Few researchers have investigated the relationship between attention and inhibition measures, and standardized achievement test scores to determine if these constructs are independent of other cognitive abilities. The majority of studies reviewed often examined the relationship between attention and inhibition measures and IQ (Block et al., 1986; Halperin et al., 1991; Manly et al., 1999; Oosterlaan & Sergeant, 1996; Schachar et al., 1995; Schachar & Logan, 1990; Schachar et al., 1990; Sharma et al.,

1991). Manly et al. (1999) examined the relationship between TEA-ch measures and the Wide Range Achievement Test (WRAT) - Revised (Justak & Wilkinson, 1984) composed of Writing, Reading and Arithmetic Scales. They found that the visual search subtests (Sky Search, Map Mission) that measured selective attention were not significantly related to academic achievement. For those subtests that measured attentional control/switching (Creature Counting Accuracy and Speed, Opposite worlds), they found that the Creature Counting accuracy score was significantly but weakly related to the WRAT arithmetic scale ($r = 40$, $p < .05$) and the Creature Counting Speed Score was significantly but also weakly related to the WRAT spelling scale ($r = .22$, $p < .05$) and the WRAT reading scale ($r = .17$, $p < .05$). Four of the subtests that measured sustained attention (Score, Sky Search DT, Walk Don't Walk and Code Transmission) were significantly related to all three scales from the WRAT with correlation coefficients ranging from .17 to .33 ($p < .05$). Manly et al. (2001) had 166 children complete four subtests of the WISC-III in addition to nine subtests of the Tea-ch. Only four showed significant correlations with IQ. They were Creature Counting Accuracy, Map Mission, Walk Don't Walk and Code Transmission ($r =.31$, .25, .21 and.17).

Halperin et al. (1991) also investigated the relationship between CPT measures and academic achievement. The CPT measure of false alarms which is an indicator of inhibitory ability was significantly ($r = -.23$) related to reading ability as measured by the WRAT-R as were the Reaction Time Standard Deviation ($r = -.31$) scores and the inattention scores ($r = -.23$, $p < .0055$). They also found that there were no significant relationships between all CPT scores and the Reading Comprehension subtest of the Peabody Individual Achievement Test - Revised (PIAT - R; Markwardt, 1989). Sharma

et al. (1991) examined the relationship between the Visual Focused Attention Test and various attention and inhibition measures as well as the Reading and Arithmetic subtests from the WRAT-R. The Visual Focused Attention score was not related to the measures of academic achievement. If achievement and intelligence measures correlate with measure of attention and inhibition, then, these constructs are not independent. To achieve convergent validity attention and inhibition constructs should be insensitive to differences in child reasoning and general cognitive abilities.

When studies which look at the constructs of attention and inhibition include teacher ratings these are often ratings of behavior not academic achievement. These teacher ratings are often correlated with various measures and are made up of likert-type scales which include, for example, ratings of aggression, hyperactivity, anxiety or variations of DSM criteria (Barkley et al., 1990; Das, 2002; Halperin et al., 1998; McGee et al., 1985; Sherman et al., 1997). With regards to the relationship between attention and inhibition measures and measures of academic achievement in this study an attempt was made to determine the relationship between and teacher ratings of academic achievement in addition to standardized achievement test scores with attention and inhibition measures.

Rationale and Hypotheses

Several conclusions can be drawn from the literature reviewed. First, there is no universally accepted definition for either attention or inhibition. Second, because definitions for the two constructs are often varied and overlapping, measures used to assess them may not be valid or may measure more than one construct and furthermore, because of these problematic definitions, the relationship between these constructs is

difficult to ascertain. Third, the actual developmental course of the constructs may be uncertain.

Thus, the primary purpose of this study was to determine whether there is evidence for independence between the constructs of attention and inhibition. Unlike most studies as reported by Barkley (1997), which in an exploratory sense have used various measures of attention and inhibition without directly testing the question of whether they are separate, this investigation will select a range of attention and inhibition which have been shown by leading researchers (Barkley, 1997; Manly et al., 1999) to be valid measures of these constructs and attempt to verify the relationships between them.

Christensen and Joschko (2001) explain that psychological measurement theory maintains that any test that purports to measure a particular construct should be highly correlated with other measures of the same construct (known as convergent validity), while it should not be too highly correlated with tests of different constructs (known as discriminant validity).

This study also examined whether there were gender differences on measures of attention, inhibition and achievement. To date, the various studies which have looked at gender differences on these variables have been inconclusive (Bjorkland & Kipp, 1996). In addition, possible relationships between achievement and attention and inhibition scores were investigated.

Using the Review of Attention and Inhibition Measures from Appendix A , a selection of tests that purport to measure either attention or inhibition constructs was selected from past research. The following hypotheses were formulated.

1) If Go-No-Go Omissions Scores, Gordon Vigilance Task Omission Scores,

TEA-ch Score and Teach Sky Search DT variables each measure the ability to sustain attention then these measures should be highly positively correlated and represent valid tasks for measuring sustained attention.

2) If TEA-ch Sky Search Score, TEA-ch Sky Search Attention Score, Creature Counting, WISC Digit Span and Go No Go Hits each measure the ability to selectively attend then these measures should be highly positively correlated.

3) If Go-No-Go False Alarms Scores, Gordon CPT Commission Scores, Gordon Delay Efficiency Ratio, Stroop Interference Score and the TEA-ch Walk Don't Walk all represent Behavioural Inhibition then these measures should be highly correlated.

In addition, a number of research questions were addressed.

4) This study attempted to ascertain whether there are gender differences and the nature of those differences on all measures of attention and inhibition. No predictions were made as past research is inconclusive.

5) Teacher Ratings were correlated with all attention and inhibition measures to determine relationships. Past research is inconclusive.(as it has solely focused on behavior ratings and not ratings of academic achievement in the classroom)

6) This study also tried to ascertain whether there is a relationship between academic achievement as measured by the OLSAT and measures of attention and inhibition.

Past research in this area has used other measures of achievement and is also inconclusive.

7) This study attempted to ascertain the possible relationship between Number of Siblings and attention and inhibition variables. This has not been investigated in the previous literature.

METHOD

Subjects

The subjects included one hundred and four 10 year old children, 39 boys and 65 girls. Six additional children were excluded because they had a formal diagnosis of ADHD and were not included in the analysis because previous research has shown that these children perform differently when compared to undiagnosed children on tasks of attention and inhibition (Barkley, 1997). This specific age was chosen because it is the approximate average age looked at in other studies of this kind (Alderson et al., 2007) and attentional and inhibitory processes are thought to be well developed by this age (Alderson et al., 2007; Akshoomoff, 2002). All participants were in good health and were not taking any prescription or over the counter medications.

Measures

Continuous Performance Test (CPT)

The CPT (Gordon, 1983) is used to assess sustained attention as well as the ability to inhibit responses. Scores derived from this task are number of hits (correctly pressing the button for an X that comes after an A), misses also known as omission errors (not pressing the button when an X appears after an A), false alarms also known as commission errors (pressing the button when an A is not followed by an X), correct rejections, very late correct responses and mean hit reaction time. Two out of ten subtests were administered from the CPT. Reliability for the subtests ranges from .66 to .80. The Delay task is an 8 minute task which requires the subject to wait a specific period of time

(Delay Interval) before pressing a Blue button at the bottom of a computer screen. If the subject has waited long enough before pressing the button the red light on the top of the screen will shine and the counter on the front screen will increment. If the child does not wait long enough and presses the button, no points are earned, the red light does not shine and the timer resets. Scores calculated for this subtest are Total Correct, Total Responses and Efficiency Ratio which is the Total Correct divided by the Total Responses. These scores reflect the subject's ability to delay or inhibit impulsive behavioral responses. The Vigilance subtests is a nine minute test in which subjects watch a screen where numbers are flashed at a rate of 1 per second. The subjects is required to press the blue button at the bottom of the screen only when a 9 flashes after a 1 has flashed. The scores derived from this test are number correct (hits), number of omissions (misses) and number of commissions (false alarms). Omission scores are thought to reflect inattention while commission scores are thought to reflect inability to inhibit inappropriate responses. (Barkley, 1997; Barkley, 1991; Kanaka et al., 2008, Reynolds et al., 2008)

Stroop

The Stroop (Golden, 1978) assesses the subject's ability to resist distracters and interference. This is a timed test with three parts. In the first part the subject has 45 seconds to read a list of repeating color names such as red, blue, green which are printed in black. The second part requires the subject to name the various colors which a series of X's are printed in. The subjects also had 45 seconds to complete this task. In the final test of the Stroop, the subject is required to name the color of the ink when it conflicts with the different color names printed. For example, if the word 'YELLOW' is printed in blue ink, the subject must say blue and not yellow. This measures the ease at which a person

can ignore distracters and make a correct response in a limited period of time. This last part is known as the interference task and is believed to assess selective attention (Halperin et al., 1994) but in other cases believed to measure the ability to inhibit responses (Enticott & Ogloff, 2006; Grodzinsky & Diamond, 1992; Lansbergen et al., 2007). Reliability for each of the three scores ranges from .71 to .88.

Digit Span from the Wechsler Intelligence Scale for Children- III (Wechsler, 1991)

In this subtest a series of number sequences are read aloud to the subject. For each of the items, the subject repeats the numbers in the same order as given. Each of the eight items consist of two trials. In Digits Backward a series of number sequences are also read aloud to the subjects. For each of the items the subjects must repeat the number in reverse order. The task is discontinued if both trials on any one item are failed. Scores derived from this subtest are total trials correct. This task is thought to measure one's attentional capacity and sequential processing of auditory information (Halperin et al., 1994) as well as the ability to focus and select target information from an array of information (Mirsky et al., 1991). This subtest has a mean of 10 and a standard deviation of 3. The reliability coefficient for this subtest is .84.

Test of Everyday Attention for Children (TEA-ch)

The TEA-ch (Manly, Robertson, Anderson, Nimmo-Smith, 1998) is a functional test of attention that assesses different attentional capacities. This test has been standardized and normed for children and adolescents between the ages of 6 and 16. Reliability for each of the subtests ranges from .57 to .87 and standard scores from all the subtests have a mean of 10 and a standard deviation of 3. This test requires children

to complete various life like tasks that simulate everyday attentional abilities while minimizing the demands of other skills such as memory, language and comprehension. There are nine subtests which provide separate measures of selective attention (focused attention, sustained attention, attentional control/switching as well as response inhibition). Each of the four attentional factors can be screened using the first four subtests and were used in this study as well as the subtest measuring response inhibition because of the inclusion of other tasks previously described as well as time constraints. Each of the five subtests will be described below.

Sky Search: In this timed test, subjects are required to find as many target spaceships as they could on a sheet filled with similar distracter spaceships. Score derived from this task were the number of correctly circled spaceships and time taken. This is a measure of selective/focused attention. In the second part of the task which controls for the effect of motor speed on visual selection the subjects must again circle the target spaceships but there are no distracters on the page. Scores derived from this are number correct and time taken. When Score 2 is subtracted from Score 1, a measure of the subject's ability to select targets free from the influence of motor control is available. Time for this subtest is approximately 5 minutes.

Score : In this task, subjects are required to listen to a tape which contained ten trials of variously numbered scoring sounds. The subjects had to report the number of scoring sounds they heard in each trial. The time gaps between the sounds are irregular and do not really seize the subject’s attention. It is for this reason that the test assesses the

ability to sustain attention. Score derived are number correct out of ten. Time for this subtest is approximately 8 minutes.

Creature Counting: In this paper task, a variable number of creatures are shown in their dens. Children are required to count aliens in their burrows and must switch between counting upwards (1-2-3-for example) and counting downwards (3-2-1) . The subjects must always start with the number one when counting the aliens and only the occasional arrows tell them when to change the direction they are counting in. This is a measure of attentional control/switching. Scores derived from this test are time taken and number correct. Time for this subtest is approximately 10 minutes.

Sky Search DT :In this task, the Sky Search Task and the Score task are combined. Subjects are required to combine the two tasks of searching for target spaceships among similar distracter ships while keeping count of scoring sounds. The scores derived from this task is the dual task decrement score. This task measures sustained/divided attention. Time for this subtest is approximately 5 minutes.

Walk Don't Walk : In this task, subjects are required to take one step at a time on a paper path, with a marker, after a tone is played on a tape recorder. There are two separate tones in this task. One tone means it is safe to take a step, the other tone means do not take a step. These two tones occur unpredictably. This is believed to be a measure of sustained attention/response inhibition. The score derived from this task is number correct. Time for this subtest is approximately 7 minutes.

Delay Of Gratification Task

Bjorkland and Kipp (1996) reviewed many studies which used delay of gratification tasks where participants were asked to choose between receiving a small reward immediately or waiting for a more attractive one. In this task subjects were also given the choice of receiving a small reward at the end of the session or a larger reward the next session. A smaller reward consisted of one card of their choice while a larger reward consisted of two cards of their choice. The rewards used were World Wrestling Federation Cards for Boys and Spice Girl Cards for girls. This task is considered to assess the ability to inhibit and delay (Barkley, 1997; Bjorkland & Kipp, 1996).

Go No-Go Task (Barkley, 1997; Valenstein & Nadeau, 1997

This simple task (Barkley, 1997; Valenstein & Nadeau, 1997) which measures the ability to inhibit a prepotent response as defined by Barkley (1997) requires the subjects to hold up one finger when the experimenter holds up two. When the experimenter holds up two fingers the subjects should not hold up any. Stimuli were presented at the rate of one per second. The session consisted of 50 trials, 25 go responses and 25 no-go responses and their orders were randomly assigned. The commission score reflects the ability to inhibit a response (Barkley, 1997; Derefinko et al., 2008; Muroi et al., 1997). Scores derived from this task were number of hits, correct rejections, commission and omission scores.

Otis Lennon School Achievement

Otis Lennon School Achievement Test scores (OLSAT) were retrieved from the Rainbow District School Board for each participating subject. This is a measure of

educational achievement and yields three scores: Verbal, Non-verbal and Total test scores with a mean of 100 and a standard deviation of 15. The reliability coefficients for the Total, verbal and non-verbal scores are, .89 to .90 and .81 to .90. The OLSAT Total score combines the child`s performance on the verbal and non-verbal sections of the Test. The Verbal score is based on comprehension and reasoning. It measures the child`s ability to manipulate or respond to information by using language and solving language problems. The Non-Verbal score is based on figural and quantitative reasoning that does not include language such as pattern and relationships and similarities and differences which includes use of numbers.

Each teacher was asked to assign the child a rank of 1 to 4 where 1 indicated academic performance in the top quarter and 4 indicated academic performance in the lowest quarter. In addition, each child was asked about the number of siblings. It is important to mention that these former variables were chosen to be used as exploratory variables to determine the relationship between these and the attention and Inhibition measures/variables.

Procedure

After the proposal was accepted by the Laurentian University ethical committee and the Rainbow District School Board, principals from twenty elementary schools within the Rainbow District School Board were contacted by telephone in order to recruit subjects. Seven principals and grade five teachers agreed to allow the experimenter into the classroom to talk to the prospective subjects and hand out consent forms and letters. The seven schools came from various locales within the city of Sudbury, Ontario. Parental consent forms and letter were then given out to those students who wanted to

participate and who were ten years old. The testing took place over a period of four months. Subjects were tested twice, each session lasting one-half hour with a time lapse of two weeks between the first and second testing session. The first half hour testing session included the TEA-ch as well as the Digit Span subtest from the WISC. The second half hour testing session included the Go No-Go task, The CPT, the Stroop and the Delay of Gratification Task. All subjects were given a brief summary, of the fact that the study was looking at attention and inhibition measures and that these game like tasks were not overly difficult and that they could not fail them. Teacher questionnaires were given to all teachers and they were asked to have it completed by the end of the day.

Statistical Analysis

Preliminary examination indicated that some variables were both positively and negatively skewed which violated assumptions for parametric analyses. Out of thirty measures thirteen measures were skewed towards lower performance. These measures were Teacher Rating, Scaled Sky Search Score, Scaled Sky Search DT, Go-No-Go Correct Rejections, Go-No-Go False Alarms, Go-No-Go Misses, Gordon Delay Task Total Correct, Gordon Delay Task Total Responses, Gordon Vigilance Task Total Correct, Gordon Vigilance Task Omission Score, Gordon Vigilance Task Commission Score, T Stroop Color Word Score and OLSAT Verbal Score. T Stroop Interference Score was the only variable skewed towards higher performance. The remaining measures were normally distributed. Criterion was skew greater than two. Therefore, because the data was very skewed and multiple transformation on each variable were not desirable, non-parametric statistics which do not have assumptions of normality were employed. Factor Analysis was initially used to answer the above hypotheses. However,

the degree of skewness found and difficulties with transformation did not allow for it. The statistics used were Spearman Correlation and Mann-Whitney tests. Scaled scores were used when available. When measures did not have scaled scores, raw scores were used. All scores were used in the correlation matrix.

RESULTS

The most significant research question of this investigation was whether or not attention and inhibition were independent constructs and this project was designed to establish the relationship between them. Gender differences for each variable were examined. In addition, the relationships between the OLSAT Total, Verbal and Nonverbal scores with the attention and inhibition measures were analyzed. Relationship between Number of Siblings and all variables was also explored as were relationships between Teacher ratings and all remaining variables. The Delay of Gratification variable was not sensitive to any transformation. The Descriptive Variable Delay of Gratification failed to reach significance in all parametric and non-parametric analyses. Because this variable was not related to any other variable, it is not discussed further.

Descriptive Statistics

Means and Standard Deviations for all exploratory, attention and inhibition measures are presented in Table 1. Norms for OLSAT scores, Digit Span scores, TEA-ch Scores, Stroop Scores and Gordon CPT scores are listed in Appendix B. Appendix C describes the meaning of the measurement scores. Overall, the participant scores in the study were in the normal range for all tests. Overall mean scores were not more than one Standard deviation from the test mean. Sky Search DT scores were one standard deviation below the subtest mean. This test combines two different tests from the TEA-ch and assesses two different modalities, visual and auditory. It is possible that when this particular subset of children were tested their combined abilities were weaker when the two tests were combined. Walk Don't Walk mean scores were

Table 1.

Descriptive Variables, Means and Standard Deviations of Attention and Inhibition Test Scores.*

Measure	Mean	SD
Descriptive Variables		
Teacher Rating(TR)	2.2	.94
Number of Siblings(SIB)	1.5	1.1
OLSAT Total #(OLSTOT)	102.1	14.8
OLSAT Verbal #(OLSVER)	99.4	16.3
OLSAT Nonverbal #(OLSNV)	103.5	14.2
Attention Test Scores		
Sky Search(SSSS)	18.1 (9.9)	2.3(2.7)
Search Timing Score(SSSTS)	3.7 (11.5)	.88 (2.3)
Sky Search Attention(SSSAS)	2.9 (11.2)	.80 (2.4)
Score(SSS)	9.0 (11.0)	.98(2.7)
Sky Search DT(SSSDT)	1.8 (7.0)	3.1(2.3)
Creature Counting(SCCA)	5.4 (9.6)	1.2 (2.7)
Creature Counting Timing(SCCTS)	4.2 (9.6)	.86 (2.4)
Digit Span (SDS)	13.9 (10.5)	2.7 (2.7)
Go/No-Go Hits(GNGHIT)	24.1	1.1
Go/No-Go Correct Rejections(GNGCR)	21.8	2.2
Go/No-Go Misses(GNGMISS)	.83	1.0
Gordon Vigilance Task Total Correct(GVTTC)	42.4	2.6
Gordon Vigilance Task Omissions(GVTOS)	2.6	2.6
Stroop Word Score(TSWS)	110.6(51.3)	10.89(5.4)
Stroop Color Score(TSCS)	77.75	8.46(5.7)
Stroop Color Word(TSCWS)	46.4 (51.4)	5.9 (5.9)
Stroop Predicted Color Word Score(RSPCWS)	45.1	5.0
Stroop Interference Score(TSIS)	1.15(51.5)	5.6(5.5)
Inhibition Test Scores		
Delay of Gratification(GRAT)	1.8	.39
Walk Don't Walk(WDW)	14.7 (8.4)	3.4 (3.5)
Go/No-Go False Alarms(GNGFA)	3.2	2.2
Gordon Delay Task Efficiency Ratio(GDER)	.82	.10
Gordon Vigilance Task Commissions(GVTCOM)	4.1	4.8
Gordon Delay Task Total Correct(GDTTC)	50	10.7
Gordon Delay Task Total Responses(GDTTR)	61	13.7

*Original Means and Standard Deviations reported/Scaled or T- scores in brackets.
Standardized scores.

** Stroop scores were also used as inhibition measures for interest purposes as literature has previously shown. As well Creature counting was also used as a measure of inhibition for interest purposes.

half a standard deviation below the test mean. These were the most extreme scores below the mean.

Relationships Among Attention Variables

It was predicted that certain measures of attention would correlate strongly with one another. More specifically, Go-No-Go Omission scores, Gordon Vigilance Task Omission scores, TEA-ch Score and TEA-ch Sky Search DT should be correlated with each other as they represent the ability to sustain attention (Hypothesis 1). It was further predicted that TEA-ch Sky Search, Sky Search Attention, Creature Counting, WISC Digit Span and Go-No-Go Hits would show a significant relationship with each other as they are all measures of selective attention (Hypothesis 2).

When all attention variables were intercorrelated (Appendix D) more than half of the relationships (65 of 91) failed to reach significance. Nineteen correlations that fell in the range between .16 and .25 were significant but weak. Two correlations were found to be above .80, but these were due to scores from the same subtest, such as the timing score used to calculate the total score from the same Sky Search subtest (Sky Search Attention and Sky Search timing score). The only three significant correlations found in support of the first hypothesis were between the Gordon Vigilance Omission Scores with TEA-ch Sky Search DT (r = -.17) and TEA-ch Score (r = -. 18) and TEA-ch Score with TEA-ch Sky Search DT (r = -.10). These findings were very weak.

Only two significant relationships were found among attention variables in support of the second hypothesis. Scaled Sky Search was significantly related to Creature Counting (r =.19) and Sky Search Attention Score which was related to WISC Digit Span (r = .17). Interestingly, the highest correlation was between a measure of selective

attention and sustained attention from the same test: Go No Go Hit was inversely related to Go-No-Go Miss (r = -.96). Although there were significant correlations found in support of each hypothesis, the correlations were very low. Based on these low correlations, hypotheses one and two were not supported. The measures chosen to represent selective and sustained attention do not seem to show convergent validity.

Relationships Among Inhibition Variables

It was hypothesized that Go-No-Go False Alarms, Gordon CPT Commission Scores, Gordon Delay Efficiency Ratio, Stroop Interference Score, TEA-ch Walk Don't Walk and Creature Counting, all measures of behavioral Inhibition would be intercorrelated (Hypothesis 3).

When all inhibition variables were correlated (Table 2), twelve of twenty-one correlations were not significant. Six significant correlations were in the range of .16 to .25. There were no significant correlations above .40. When considering the third hypothesis, the only four significant but weak correlations supporting it were between The Gordon Vigilance Commission Scores and Go-No-Go False Alarms (r = .25), Gordon Delay Efficiency Ratio (r = -.17), Creature Counting (r = -. 23) and TEA-ch Walk Don't Walk. (r = -.23). The Gordon Delay Efficiency Ratio was also correlated with the Stroop Interference Score (r = .18). Again, although some of these inhibition variables were significantly interrelated, the correlations are too weak to provide proof of convergent validity. This pattern of results also suggests that Inhibition may be multi-dimensional.

Relationships Among Attention and Inhibition Variables

To further explore any existing relationship between attention and inhibition measures, and to check for divergent validity, relationships among the two sets of variables were examined (Appendix E). If attention and inhibition are different constructs, there should be few significant relationships. Out of 247 correlations 169 were not significant. Forty-seven correlations fell in the range of .16 and .25, so there were some weak relationships between these constructs.

Go-No- Go False Alarms were significantly and inversely correlated to the attention scores from WISC Digit Span (r = -.18) and Go No Go Correct Rejections (r = -.99). Gordon Vigilance Commission Scores were significantly inversely correlated with attention scores from Sky Search DT (r = -.25), Digit Span (r = -.21) and Go-No-Go Correct Rejection (r = -.25). The Gordon Delay Efficiency Ratio was significantly correlated to the attention scores from Sky Search (r = .17), Score (r =.18), Creature Counting Timing Score (r = .19) and Go- No-Go Misses (r = .17) The Stoop Interference Score was not significantly related to any attention variables. The Teach Walk Don't Walk was only significantly related to one attention variable, the Go-No-Go Omission Score (r = -.26). In general, these patterns of interrelationships suggest that as the ability to pay attention increased, disinhibitory behavior decreased. Because relationships were as strong as those among tests designed to measure the same construct, divergent validity cannot be supported as there is overlap in these constructs.

TABLE 2

Relationship (Spearman Rho) Among Inhibition Measures.

	GVTCOM	GNGFA	TSIS	SCCA	SWDW	GDER
GNGFA	.25 (104) p=.005					
TSIS	-.06 (104) p=.24	.05 (104) p=.28				
SCCA	-.23 (104) p=.01	-.04 (104) p=.33	.04 (104) p=.37			
SWDW	-.20 (104) p=.01	-.08 (104) p=.13	-.01 (104) p=.47	.05 (104) p=.28		
GDER	-.17 (104) p=.03	.05 (104) p=.27	.18 (104) p=.03	-.09 (104) p=.15	-.05 (104) p=.27	
SCCTS	-.36 (104) p=.00	-.13 (104) p=.09	.11 (104) p=.12	.17 (104) p=.03	.17 (104) p=.04	.19 (104) p=.02

Legend

GNGFA- Go-No-Go False Alarm
TSIS- Stroop Interference T Score
SCCA-Scaled Creature Counting Accuracy Score
SWDW-Scaled Walk Don't Walk
GDER- Gordon Delay Efficiency Ratio
SCCTS-Scaled Creature Counting Timing Score
GVTCOM- Gordon Vigilance Task Commission

Significant Relationships Between Number Of Siblings and Attention and Inhibition

When the exploratory descriptive variable Number of Siblings was correlated with all of the attention and inhibition variables, only three significant relationships emerged. Number of Siblings was positively correlated with Gordon Vigilance Task Commission Score (r = .19) and negatively correlated with TEA-ch Sky Search (r = -.18) and TEA-ch Score (r = -.16). As number of siblings increased, so did number of commissions. Also, as number of siblings increased, the ability to sustain attention and selectively attend decreased as reflected by the TEA-ch Sky Search and Score scores. These weak relationships which indicate that family size is negatively related to task focus, but this result may be mediated by other factors such a SES.

Relationships Between Teacher Rating, and Attention and Inhibition

Past research on the relationship between teacher ratings of behavior, and attention and inhibition measures has been inconclusive. For the present study Teacher rating described academic performance in the classroom where 1 was defined as performance in the top quarter of the class and 4 was defined as academic performance in the bottom quarter.

All attention variables were correlated with the descriptive variable Teacher Rating (Table 3). The analysis revealed 6 of the 14 correlations to be significant. Five correlations that fell in the range between .16 and.25 were weak, but significant. The highest correlation was between Teacher Rating and Digit Span (r = -.28). In general the correlations displayed weak inverse relationships. As teacher rating increased, indicating poorer performance, the ability to selectively attend and to sustain attention decreased.

All inhibition variables were correlated with the Descriptive Variable Teacher Rating (Table 4). Four of eight correlations were weak, but significant. Three of these correlations fell in the range between .16 and .20. The strongest relationship was between Teacher Rating and Creature counting timing score (r = -.32) In general, the relationships conveyed by these correlations was that that as teacher rating increased, indicating poorer academic performance, the ability to inhibit an impulsive response decreased.

Results from Teacher Ratings are weak in suggesting that children who are not doing well academically, are not paying attention and are not able to inhibit inappropriate responses.

Relationship Between OLSAT Scores, and Attention and Inhibition Variables.

OLSAT Total, Verbal and Non-Verbal Scores were correlated with all attention measures (Table 5). Thirty three of forty-two correlations were not significant. Six correlations fell in the range of .17 and .20. The strongest correlations in this subset were between OLSAT Total, Verbal and Nonverbal with Digit span, (r = .27, r = .26, r= .26). The general relationship between these variables can be described in the following way: as the ability to selectively attend and to sustain attention increases so do the scores that reflect verbal and nonverbal reasoning skills. OLSAT Total, Verbal and Non-verbal Scores were correlated with all Inhibition measures. (Table 6). Eighteen of twenty-four correlations were not significant. Six correlations that fell between the range of .19 and .29 were weak. Gordon Vigilance Commission Scores were significantly related to all Olsat test Scores (r = -.25, r = -.29, r = -.27) as was Creature Counting Timing Scores(r = .23, r =.25, r = .19).

TABLE 3

Relationship (Spearman Rho) between Teacher Rating and All Attention Variables. (N=104)

SSSS	-.17 p=.03	GNGHIT	-.07 p=.23
SSSTS	-.15 p=.05	GNGCR	-.15 p=.06
SSSAS	-.10 p=.15	GNGMISS	.04 p=.33
SSS	-.21 p=.01		
SSSDT	-.08 p=.19		
SDS	-.28 p=.002		
TSIS	.14 p=.07		
TSCWS	-.18 p=.03		
GDER	.05 p=.30		
GVTOS	.20 p=.02		
GVTTC	-.15 p=.06		
TR	1.00		
	TR		TR

LEGEND

SSSS-Scaled Sky Search Score
SSSTS-Scaled Sky Search Timing Score
SSSAS-Scaled Sky Search Attention Score
SSS-Scaled Score Score
SSSDT-Scaled Sky Search DT
SDS- Scaled Digit Span
TSIS-Stroop Interference T-Score
TSCWS-Stroop Color Word T-Score
GDER-Gordon Delay Efficiency Ratio
GVTOS-Gordon Vigilance Omissions
GVTTC-Gordon Vigilance Total Correct
GNGHIT-Go No-Go Hits

TABLE 4

Relationship (Spearman Rho) Between Teacher Rating and all Inhibition Variables.

	TR
SCCTS	-.32 (104) p=.00
SCCA	-.09 (104) p=.17
SWDW	-.01 (104) p=.45
TSCWS	-.17 (104) p=.03
GNGFA	.15 (104) p=.04
GVTCOM	.16 (104) p=.04
GDER	.05 (104) p=.30
TSIS	.14 (104)

Legend

SCCTS- Scaled Creature Counting Timing Score
SCCA-Scaled Creature Counting Accuracy Score
SWDW-Scaled Walk Don't Walk
TCWS-Stroop Color Word T-Score
GNGFA-Go-No-Go False Alarms
GVTCOM-Gordon Vigilance Task Commission Score
GDER-Gordon Delay Efficiency Ratio
TSIS-Stroop Interference T-Score
TR-Teacher Rating

TABLE 5

Relationship Between OLSAT Scores and Attention Variables.

	OLSTOT	OLSVER	OLSNV
SSSS	.14 (104) p=.09	.03 (104) p=.35	.10 (104) p=.15
SSSTS	.17 (104) p=.05	.17 (104) p=.05	.16 (104) p=.06
SSSAS	.17 (104) p=.05	.14 (104) p=.08	.18 (104) p=.04
SSS	.14 (104) p=.09	.04 (104) p=.35	.11 (104) p=.15
SSSDT	.06 (104) p=.27	-.02 (104) p=.41	.13 (104) p=.10
SDS	.27 (104) p=.01	.26 (104) p=.01	.26 (104) p=.01
TSCWS	.10 (104) p=.15	.12 (104) p=.13	.09 (104) p=.18
TSIS	-.10 (104) p=.16	-.06 (104) p=.25	-.04 (104) p=.33

LEGEND

SSSS-Scaled Sky Search Score
SSSTS-Scaled Sky Search Timing Score
SSSAS-Scaled Sky Search Attention Score
SSS-Scaled Score Score
SSSDT- Scaled Sky Search DT Score
SDS-Scaled Digit Span
TSCWS-Stroop Color Word T-Score
TSIS-Stroop Interference T-Score

OLSTOT- Olsat Total Score
OLSVER-Olsat Verbal Score
OLSNV- Olsat Non-Verbal Score

TABLE 5

Relationship (Spearman Rho) Between OLSAT Scores and Attention Variables. Con't

GDER	.01 (104) p=.45	-.06 (104) p=.26	.03 (104) p=.35
GVTOS	-.17 (104) p=.05	-.11 (104) p=.15	.16 (104) p=.06
GNGHIT	-.01 (104) p=.44	-.01 (104) p=.45	-.06 (104) p=.27
GNGMISS	-.00 (104) p=.48	-.01 (104) p=.46	.05 (104) p=.31
GNGCR	.02 (104) p=.39	.11 (104) p=.13	-.01 (104) p=.43
GVTTC	.17 (104) p=.05	.10 (104) p=.15	.16 (104) p=.16
	OLSTOT	OLSVER	OLSNV

LEGEND

GDER-Gordon Delay Efficiency Ratio
GNGHIT-Go –No-Go Hit
GNGCR-Go-No-Go Correct Rejections
OLSTOT-Olsat Total Score
OLSNV-Olsat Nonverbal Score
GVTOS-Gordon Vigilance Task Omission Score
GNGMISS-Go-No-Misses
GVTTC-Gordon Vigilance Task Total Correct
OLSVER-Olsat Verbal Score

This would indicate that as verbal and non-verbal reasoning skill scores increased the ability to inhibit impulsive responses also increased. Although there is a relationship between OLSAT scores, and the Attention and Inhibition Variables, the relationship suggests that the variables have a minimal contribution (predicting less than five percent of variation) to OLSAT performance.

Relationship Between OLSAT Scores and Teacher Ratings

All OLSAT scores were correlated with Teacher Rating. OLSAT Total, Verbal and Non-verbal scores were significantly related to Teacher Rating ($r = -.42$, $r = -.31$, $r = -.35$). These relationships suggest that as scores that reflect verbal and non-verbal reasoning skills increase so does teacher rating which reflects greater academic performance.

Gender Differences For Attention and Inhibition Variables

Mann-Whitney U tests were performed to test for gender differences on attention variables. For the TEA-ch variables Score, Creature Counting Accuracy and Creature Counting Timing Score, the test showed that there was a significant difference between boys and girls, ($U=942.5$, $p< .05$; $U=945.5$, $p<.05$; $U=977.5$, $p<.05$) . The mean rank for girls was higher than the mean rank for boys, so girls had a higher performance on these three subtests.

Mann-Whitney U tests were also performed to test for sex differences on inhibition variables. For the inhibition variable Gordon Vigilance Task Commission Score, the Mann Whitney showed a significant gender difference, ($U=909.0$, $p<.05$). Boys had a higher mean rank than girls which means that boys had a higher performance

TABLE 6

Relationship (Spearman Rho) Between OLSAT Scores and All Inhibition Variables(N=104).

	OLSTOT	OLSVER	OLSNV
SCCA	.00 p=.48	.10 p=.16	.05 p=.33
SCCTS	.23 p=.01	.25 p=.01	.19 p=.04
SWDW	.15 p=.08	.08 p=.23	.14 p=.09
TSCWS	.10 p=.16	.12 p=.13	.09 p=.18
TSIS	-.10 p=.16	-.06 p=.25	-.04 p=33
GVTCOM	-.25 p=.01	-.29 p=.003	-.27 p=.01
GDER	.01 p=.45	- .07 p=.26	.04 p=.36
GNGFA	-.04 p=.37	-.13 p=.12	.01 p=.46

LEGEND

SCCA-Scaled Creature Counting Accuracy Score
SCCTS-Scaled Creature Counting Timing Score
SWDW-Scaled Walk Don't Walk Score
TSCWS-Stroop Color Word T-Score
TSIS-Stroop Interference T-Score
GVTCOM-Gordon Vigilance Task Commissions
GDER-Gordon Delay Efficiency Ratio
GNGFA-Go-No-Go False Alarms
OLSTOT-Olsat Total Score
OLSVER-Olsat Verbal Score
OLSNV-Olsat Nonverbal Score

score than girls. For the inhibition variable, Gordon Delay Efficiency Ratio, girls had a higher mean score for the efficiency ratio than did boys, ($U=856.5$, $p<.01$). The remainder of the Attention, Inhibition and descriptive variables had no significant gender differences. In general, these results show that girls were better at paying attention to stimuli and were also better at inhibiting an impulsive response than boys.

DISCUSSION

Although the research on attention and inhibition has been extensive, there still remains much theoretical confusion concerning the structure, definitions and relationships of these constructs. This issue has been approached in this study by comparing newer and commonly used measures that are purported to measure attention and inhibition. These measures were specifically used to answer theoretically and clinically relevant questions. This discussion begins by briefly examining the results in the context of existing research. Secondly the characteristics and confusion surrounding the constructs and measures used in this study will be reviewed. Finally, limitations will be explored and suggestions for future research will be discussed.

SUMMARY AND INTEGRATION OF FINDINGS

Specifically, it was hypothesized that measures representing sustained attention would be significantly correlated with each other. More than half of the correlations failed to reach significance. Only three significant correlations were found to support the first hypothesis. The Gordon Vigilance Omission Scores were associated with Teach-Sky Search DT and also with Teach-Score. The pattern of these scores suggest that as the ability to sustain attention increases, omission scores decrease. Teach Sky Search DT also correlated with Teach Score which would be expected because Teach Score is a component of Teach Sky Search DT. The correlations found however in these analyses were very weak.

It was also hypothesized that measures representing selective attention would be significantly interrelated. Only two significant relationships were found between all the selective attention measures. Scaled Sky Search scores were associated with Creature Counting scores. These may be measuring a similar construct as the scores produced by both are simply number correct and time taken. Sky Search Attention Score was also related to WISC-III Digit Span scores. These correlations were again very weak. The strongest relationship ($r = -.96$) was an inverse correlation found between Go-No-Go Hits which is a measure of selective attention and Go-No-Go Miss which is a measure of sustained attention. This can be interpreted as meaning that as number of correct hits increases, the number of misses decreases. This may also suggest that sustained and selective attention are not discrete constructs but related in an inverse manner.

In summary, contrary to expectation, convergent validity could not be established for measures of sustained or selective attention. Although there were significant correlations found, they were too few and weak to allow for the conclusion that the measures represent one construct. Based on these low correlations, hypotheses one and two were not supported. This pattern of interrelationships suggests that attention is multidimensional and that different tests may measure different facets of attention. The studies summarized below concur with the results of this study.

Manly et al. (2001) conducted a study in which they examined the performance of 293 children on the TEA-ch battery. They also looked at the relationship of the TEA-ch to other measures of attention such as the Stroop, Trails Test, Matching Familiar Figures test, WRAT and subtests from the WISC-III. Of interest here is the fact that the Sky Search and Creature Counting Accuracy Subtest which are both attention measures

correlated with the Stroop. (r = .40, r = .31), which was used in this study as a measure of inhibition. This thesis did not find any significant relations between these three measures. When Manly and colleagues correlated the remaining attention subtests, 18 out of 22 correlations were under .40. TEA-ch subtests also correlated with scores from the WRAT but these relationships were also very weak. Correlations ranged from .17 to .40. The TEA-ch manual does not provide correlations among TEA-ch subtests, so those correlations could not be directly compared to the findings of this thesis. However, the present study encountered many of the same issues concerning lack of significance and low correlations between the various subtests of attention. Manly and colleagues concluded their study by arguing that the subtests of the TEA-ch are not measures of attention but of auditory and visual detection, counting, response speed, etc. But, they explained that they simplified many of the tasks so as to minimize other confounding factors.

In her PhD Dissertation Belloni (2011) tested six age groups to ascertain the factor structure of the TEA-ch. She also looked at the correlations among the TEA-ch subtests using Factor Analysis and Pearson Correlation coefficients. Factor analysis is a statistical procedure that determines which variables in a set of data form distinct factors that are independent of one another and represent underlying processes. Belloni correlated all nine subtests. Out of nine significant correlations, six were less than .30. This study found similar results with 23 correlations below .30 for all the attention variables. Belloni also found that the Walk Don’t Walk subtest did not load on the sustained attention factor as Manly (1999) had previously shown. The Walk Don’t Walk was used as a measure of inhibition in the present study and was weakly but positively

correlated with the Gordon Vigilance Commission Score which was also used as a measure of inhibition. Belloni did find that the Walk Don't Walk subtest was significantly, but weakly (r =.19) related to Score which was not found in this study. She also found that Score was significantly but weakly related to Sky Search DT (r =.22) as this present study also found (r =.16). She reports that not all of the subtests for each factor correlated. Specifically she found that the selective attention TEA-ch subtests correlated together as suspected. However, she found no support for an attentional control switching factor as Manly (1999) did. The sustained attention subtests were mixed with only some correlation. She explained that these results show that the subtests may not be measuring similar constructs as intended.

Another objective of this research was to determine whether measures that historically represent inhibition as well as newer measures that represent inhibition would correlate with one other. Six variables that are believed to measure inhibition were intercorrelated. More than half of these correlations failed to reach significance. Five significant, but weak correlations were found. Gordon Vigilance Commission Scores were positively associated with Go-No-Go False Alarms which may suggest that both these tests measure the ability to inhibit a response and they are simple counted scores. The Gordon Vigilance Commission Score was also inversely related to Gordon Delay Efficiency Ratio, Creature Counting and TEA-ch Walk Don't Walk. The Gordon Delay Efficiency Ratio was also related to the Stroop. These relationships may suggest that as the ability to inhibit a response decreases, commission scores increase. Although some of these inhibition variables were interrelated, they were too weak to support convergent validity between the inhibition measures. This suggests that inhibition may also be

multidimensional. The studies discussed below also indicated that correlations found between inhibition measures were consistently weak.

Wu et al. (2011) used the TEA-ch and examined developmental differences, components and factor structure of Executive Functions in children. They used Creature Counting, Opposite Worlds, Sky Search and Code Transmission subtests from the TEA-ch. They used Stroop and Sky Search as measures of inhibition and as well as other Executive Function tests. When they intercorrelated attention tasks that they had named as EF tasks , they reported that correlations between most were moderate and significant. ($r = .27$ to $.54$, $p < .01$) and interestingly the inhibition measure Stroop was significantly related to the inhibition measure Sky Search but was weak ($r = -.22$, $p = .05$). The present study as well as those of Manly et al. (2001) and Belloni (2011) used Sky Search as an attention measure. The present study also used the Stoop as a measure of inhibition but it was not significantly related to Sky Search.

This study as well as the studies reviewed thus far in this paper have tried to determine the relationship between attention and inhibition subtypes and measures. If, as previously discussed, attention and inhibition are distinct processes then attention measures should not correlate with measures that represent other constructs but should correlate robustly with measures also representing attention. Any relationship found between attention measures were very weak and convergent validity among tasks could not be shown. Therefore the first two hypotheses could not be supported. This was evident with inhibition measures as well. The construct or constructs measured by these tasks remain uncertain.

Manly et al. (2001) have stated that because children vary in abilities such as motor skill, task comprehension, language, memory demands, etc, skills which may be also needed in these tasks, this task impurity has been thought to be the cause of low correlations that have been observed . Even though Manly et al. (2001) attempted to create a battery that minimizes these demands, these confounds could still be present in other tasks.

As an exploratory measure in the present study all inhibition variables were correlated with all attention variables. Measures that underlie one specific construct should not be strongly related to measures from a separate apparently unrelated construct. In other words, attention measures should not correlate with inhibition measures. In support of that hypothesis, more than half of the correlations were not significant. However, five of the Inhibition measures, Go-No-Go False Alarms, Gordon Vigilance Commission scores, Gordon Delay Efficiency Ratio and TEA-ch Walk Don't Walk were related to attention measures such as Digit Span, Sky Search DT, Sky Search, Score Go-No Go Misses. Interestingly, the Stroop interference score was not related to any attention measure which may suggest that it may not be a measure of attention, but possibly a valid measure of inhibition. In general, these relationship patterns suggest that as ability to pay attention increased, the disinhibited behavior decreased. But, because the relationships here were as strong as the relationships among the tests that were designed to measure the same construct, divergent validity cannot be supported. There is some degree of relationship among certain attention and inhibition variables.

In summary, although the measures chosen in this study were all purported measures of attention and inhibition these measures may be tapping into different

processes and skills as revealed by low correlations and perhaps should not be regarded as measuring the same construct. This could also be due to construct validity of tasks. No task can be a pure measure of a construct. There may be some minor relationship between the tasks but the demands of the task differ so these tests may also be measuring different processes (Barkley, 2001). Some tasks must involve memory, motivation alertness, and motor control and possibly other EF functions (Manly et al., 2001). Intercorrelations found between attention, inhibition and constructs termed as Executive Functions provide evidence for interdependence among constructs as revealed by this study as well as previous ones. Weak correlations also suggest considerable non-overlapping variance between measures. The question of construct validity remains important. This study as well as the previous studies discussed show the difficulties in trying to ascertain relationships among measures. Many of them do not find the relationships expected and if they do the correlations are often too weak to prove convergent or divergent validity. Many studies which look at correlations among attention measures as well as correlations among inhibition measures also find low correlations (Shuster & Tolpak, 2009).

Comparison of Siblings, OLSAT, Teacher Ratings and Gender Differences

As previously stated, the possible relationship between number of siblings and attention and inhibition variables has not been investigated in previous literature. To explore the possible nature of this relationship all variables were correlated. Interestingly, the Number of Siblings variable correlated positively with Gordon Vigilance Commission Score and displayed a negative relationship with Sky Search and Score from the TEA-ch. Subjects who had a greater number of siblings also had a higher number of commission scores which means they were possibly less able to inhibit a response.

Studies in the past have looked at Teacher Ratings and their relationship with attention and inhibition as well as academic achievement (Barkley, 1997; Barkley et al., 1990; Halperin et al., 1994). Most of these studies looked at the relationship between attention and inhibition variables and IQ (Manly et al., 1999), or correlated teacher ratings with other ratings and tests of anxiety, aggression and hyperactivity (Barkley et al., 1990; Cornish et al., 2008; Floyd & Kirby, 2001). This study attempted to discern the relationship between attention and inhibition variables and teacher ratings of academic achievement. Teacher rating was scored from 1 to 4 with 1 meaning academic performance in the top quarter and 4 meaning academic performance in the bottom quarter. Teacher Rating has a positive relationship with the Gordon Vigilance Omission Score. As Teacher Rating increased and children scored more poorly in academic performance omission scores also increased. It may be possible that because omission scores reflect sustained attention, the children who score higher on the scale reflecting poor performance may not be paying attention in class. So their learning may be compromised by possible attention problems or they may have motivational issues. Teacher rating was inversely related to the attention variables Score, Digit Span, and Creature Counting Timing Score. This may suggest that as Teacher Ratings increased, attention scores decreased, implying that the ability to sustain attention and perform in the classroom decreases.

The positive relationship between Teacher rating and the inhibition variables Go-No-Go False Alarms and Gordon Vigilance Commission Score is also very important as it relates to academic ability. Children with poorer academic ratings may also have more trouble inhibiting or delaying an impulsive response. It is important however to mention

that these correlations for teacher rating were very weak in suggesting that kids who are not paying attention or able to inhibit are doing poorly in school.

Use of teacher and parent ratings is not without drawbacks. Often different ratings from different informants can be discrepant. This study used only one teacher rating. The rating seemed to discriminate good academic performers from poorer academic performers in terms of attention and inhibitory performance. Although this study used both performance based measures of attention and inhibition as well as teacher report measures of academic achievement, when using both measures together, discrepancies may often arise. However, in this situation, teacher ratings did weakly predict poorer performance on measure of attention and inhibition.

Relationships between OLSAT, Teacher Ratings and attention and inhibition variable were also determined in this study. The OLSAT standardized achievement test is a measure of higher order reasoning skills. These are skills that are important for successful learning. Three OLSAT scores were used in this study, Total Score, Verbal and Non-Verbal with higher scores indicating higher order reasoning skills. All three OLSAT scores were moderately yet negatively correlated with teacher ratings. This is interpreted as meaning as OLSAT scores increase meaning higher reasoning skills, teacher ratings decreased meaning higher academic performance. Teacher ratings and OLSAT scores are in agreement. Children with more advanced reasoning skills perform better in the classroom. Although these types of teacher ratings are subjective, in this study they do concur with objective measures of academic performance.

In terms of attention variables, the OLSAT Total Score was positively correlated with Sky Search Attention Score and Digit Span. This suggests that increased higher

order reasoning skills are associated with the ability to selectively attend and a greater attentional capacity. The OLSAT Total Score was inversely related to the Gordon Vigilance Omission Score which may mean that increased higher order reasoning skills are associated with the increased ability to sustain attention as evidenced by the relationship to lower omission scores. OLSAT Non Verbal Score was positively related to Sky Search Attention Score which suggests that children with better non Nonverbal reasoning abilities are better able to selectively attend to important stimuli.

The OLSAT Total, Verbal and Nonverbal Scores were both positively associated with Digit Span. These were the strongest correlations for this subset of tests. These results suggest that higher Verbal and Non Verbal reasoning abilities were associated with increased ability to selectively attend or a greater attentional capacity.

In terms of inhibition variables, all OLSAT Scores were also positively correlated with Creature Counting Timing Score. It seems that children with increased abilities to switch their attention also do better on tasks that utilize higher order reasoning skills. All OLSAT scores were also inversely related to Gordon Vigilance Commission Score. This would suggest that children with higher reasoning skills are better able to inhibit a response. Overall the pattern of these findings suggest that children with higher order reasoning skills are also better able to sustain and focus their attention on relevant stimuli while also being able to inhibit inappropriate responses.

Regarding gender differences in attention and inhibition variables, previous research has proved inconclusive (Bjorklin & Kipp, 1996; Brocki & Bohlin, 2004; Klernberg et al., 2001; Levin et al., 1991; Manly et al., 2001). In general the results from this study showed that in ten year old children, females were better able to pay attention

to stimuli and also were better able to inhibit an impulsive response. Chan et al. (2008) found no gender differences with the exception of Creature Counting on the Teach. Boys performed better than girls. In this study the opposite was found; girls performed better on the Creature Counting task than boys. Manly et al. (2001) also found that boys performed better than girls on creature counting. Wu et al. (2011) also found significant gender differences for the Sky Search Attention Score and the Creature Counting Timing Score. They found that boys scored higher than girls on Sky Search and girls scored higher than boys on Creature Counting. They concluded that boys may be better than girls on tasks that involve motor responses that are timed and girls may be better at tasks that involve rapid verbal counting. The results of the current study found that girls scored better on both measures.

CRITICAL EVALUATION OF CONSTRUCTS

Problems in measuring attention and inhibition constructs exist because there are no universally accepted definitions for these constructs (Barkley, 1996; Halperin et al., 1994; Nigg, 2001). In order to determine relationship or lack thereof in attentional and inhibitory constructs, the constructs themselves must be first agreed upon and defined. In addition, as many different subtypes as possible need to be labeled appropriately. Also, their relationship to Executive Functions, intelligence and other functions must be determined (Barkely, 2001). As stated previously, there are numerous definitions of attention, inhibition and executive functioning in the literature (Barkley, 1996; Barkley, 2001; Chan et al., 2008; Nigg, 2000). But, these numerous definitions have various levels of overlap with attention and inhibition as well as various subdomains. Attention and inhibition may be thought of as distinct constructs but they may very well be intertwined

as was shown in this study when certain attention variables correlated with inhibition variables. However, researchers do agree that these constructs are multidimensional. There are numerous attention and inhibition theories such as Barkley's (1997) Behavioral Inhibiton Theory; Nigg's (2000) Inhibitory Processes Theory which explain inhibition in six parts; Posner's Attention Theory (1990); Murray's Effortful Control (2002) which is similar to Barkley's Theory, and Endicott and Ogloff (2006) who discuss and assess the construct of impulsivity using measures that are currently used to examine inhibition. All of these various theories will not be expanded upon here but show that the definitions or descriptions of these constructs are vague as well as broadly defined and most often overlap with each other causing much confusion as to what is actually being measured or described.

Researchers try to explain and disentangle these constructs but there is still much disagreement on the nature of these constructs. Executive Functions and Working Memory seem to be included in many of these studies, even though the structure of Executive Functions also remain elusive (Brocki & Bohlin, 2004; Friedman et al., 2007). What is agreed upon is that Executive Functions are also a set of complex constructs (Jurado & Rosselli,2007).

CRITICAL EVALUATION OF MEASURES

It is very difficult to compare different studies that examine the same construct because these studies use different definitions, tasks and scoring measures resulting in different findings, correlations and relationships. As such, it is then difficult to ascertain the construct validity of a test or a group of tests when the constructs are not well defined. An additional assessment problem is that many of these measures may tap into other

functions, abilities or skills, as is evident in this study when measures that purport to assess the same construct are entirely unrelated.

In addition to examining the correlations between numerous measures of attention and inhibition, it is important to understand the elements of the individual tests used, what they purport to measure as well as what is measured in terms of scoring and possible confounding abilities. Problems with attention and inhibition measures will be reviewed.

Attention Tasks

In discussing TEA-ch tasks from the TEA-ch manual, there seems to be the obvious possibility of performance confounds. For the Sky Search subtest, information needs to be filtered to detect relevant information from irrelevant information. Since it is a paper and marker test, style of performing in terms of how targets are found could be a confound. Strategy differences such as column by column or row by row or all over search can make a difference in the score that does not reflect attentional ability. Sky Search DT has similar confounds but the addition of the auditory component makes it even more difficult. In this subtest the subject must now attend to two different modalities.

The Score subtest is considered boring as it does little to engage attention. This auditory task requires keeping count, so memory is obviously a factor and a confound as is motivation. These scores could also be offset by problems in ability to count. It is also important to note that the selective attention tasks are speed measures and the sustained attention tasks are accuracy measures. The nature of these scores differ. Wilding (2005) discusses that accuracy and speed within a test are related so the correlation may be

negative caused by a speed/accuracy trade-off or positive because difficult trials may yield slower or more accurate responses.

The Creature Counting Task from the TEA-ch is supposed to be a measure of attentional switching. But upon closer inspection this subtest would require coordination and planning. A subject must switch from counting upwards to counting downwards and vice versa. Working memory may be a confound as the subject must be able to work out a rule and then remember the response and switch. Creature Counting also shows a strong relationship to working memory.

Researchers have differing opinions as to what Digit Span measures. It is often considered to be a task of short term, auditory memory, sequencing and verbal expression (Muir-Broaddus et al., 2002; Rosenthal et al., 2006).

Inhibition Tasks

Wright et al. (2003) report that tasks like Walk Don't Walk , Go-No-Go and Stop Task are often used to measure inhibition in children because they seem like simple tasks. They further explain that these types of tasks establish or assume an established simple motor response to an auditory or visual signal. After a number of correct responses have occurred, after a certain period of time, a stop signal is presented or a change in response is needed. Inhibitory ability is measured by the extent to which the child continues to execute the original response to the signal. So these types of tasks depend on establishing a learned response before inhibiting that response. It is undetermined if these tasks are actually well-learned and if they are not, they may not make demands on inhibition to stop the response. These are also measures of motor responses so inhibition is inferred from these tasks.

Wright et al. (2003) explained that the Stroop task is widely used as a measure of inhibition but it is also used as a measure of attention. It requires a subject to suppress an automatic prepotent reponse to perform a less automatic one. For the easier word task, the response is quicker because reading is a well practiced process. There is less of a demand on other processes so it is considered automatic. The ink naming task, however, is new, weak and susceptible to interference from other conflicting tasks. So this process will require more resources and be susceptible to interference.. It requires shifting to and generating another response as well as reading ability.

The Gordon CPT is an instrument that assesses impulsivity and sustained attention (Gordon, 1987) The Delay Task requires a child to wait a set period of time before pressing a button. It is a measure of sustained attention. The manual does state however that this task includes other complex cognitive, motivational and behavioural processes. In cognitive terms, the subject must develop a strategy to determine when to press and to use that feedback for timing. This can be considered working memory because the subject must retain a mental representation of the marker that must be responded to. In behavioural terms, the subject must wait and delay a response. Also, motivation is needed to complete the task. The delay Task can be considered to be self-paced. For the Vigilance subtest omission and commission are scored. Subject must be able to focus attention but also inhibit a response. This task is instrument paced so the subject does not need to develop strategies .

In reviewing these tasks, it is evident that some tests require speed, others accuracy, some both. In addition, some of these tasks may also rely on memory, sequencing, verbal expression and auditory as well as visual modalities. The measures

may tap into these other skills and not a specific construct as intended. The TEA-ch manual states that the subtests minimize the need for other skills such as memory, language and comprehension. However, the need for motor control as well as auditory and visual modalities are evident. So threats to TEA-ch performance would be hearing, vision or motor problems however slight. Working memory may also be a confound in these tasks For example, key factors in these scenarios may be reaction time or processing speed which would mean that subjects with faster processing speeds and quick reaction times do not need to hold items in mind as long, therefore reducing demand on working memory.

In summary, because of the weak correlations found in this study, when trying to assess attention and inhibition, it remains difficult to determine if poor performance on one of the tasks is indeed due to a deficit in the construct being assessed or another skill that may be involved in the task. There are always concerns regarding task impurity and confounding processes. Many tasks involve perceptual (verbal, spatial), cognitive (memory) and output systems (motor). Manly et al. (2001) conclude that

> "The fundamental problem with measuring attention is that, as a postulated central process, it is at once everywhere and nowhere. The influence of attention cannot be measured unless a person is asked to do something. That something will inevitable involve many other perceptual, cognitive and output systems that may be as or more influential on performance than attention." (p. 1066).

In addition, no task is a pure measure of a construct. As well, low correlations do not mean the tasks are unrelated because other task commands may mask the commonalities. Because children display variability in their developmen, this is also a

problem. Statistical results can be the result of pooled outcomes of unnamed underlying processes and correlation among tasks will likely change across developmental levels.

CLINICAL IMPLICATIONS

The main goal of this study was to ascertain whether commonly used tasks of attention and inhibition would correlate with each other (convergent validity) and whether there was evidence for independence between these constructs (discriminant validity). The results of this investigation showed no support for either convergent or discriminant validity. This is problematic because it is evident that at least some of these measures are not actually measuring what they are purported to. The exact nature of what is being measured is still elusive.

Attention and inhibition affect many cognitive and behavioural processes. Attention processing problems can greatly impact a child's life. Barkley (1997) reports that clinically significant attention problems are associated with a greater risk for low academic achievement, poor school performance, retention in grade, school suspensions and expulsions, and poor school performance. Inhibition is also important as it allows children to control their thoughts and actions and act in socially desirable ways (Barkley, 1997) Subsequently, because attention and inhibition problems can have a negative impact on children's functioning, it is imperative that appropriate and valid measures exist to properly assess normal from abnormal functioning. Specific measures that can assess various components of attention and inhibition are crucial. Unfortunately, this study has clarified that some of the instruments used in clinical practice today may not be measuring what the clinician believes they are measuring. None of the attention or inhibition measures used correlated strongly with each other. So, researchers and

clinicians must err on the side of caution until more specific and valid measures are developed and perhaps use many objective as well as subjective measures before coming to a clinical conclusion that may affect the treatment of a child.

LIMITATIONS OF STUDY AND FUTURE DIRECTIONS

Several limitations of the study need to be addressed. While the current sample did result in some interesting and novel findings, the sample size may be at issue. The results of the present study are also dependent on the measures that have been employed. Most of these measures have been shown in the past to be good indicators of the constructs measured. Of course measures only reflect all underlying processes that are needed to execute them. Even though the measures chosen have in the past been heavily researched in terms of validity, the true nature of attention and inhibition functions remain largely unknown. It is also important to address the fact that although this study has tried to establish the relationship between types of attentions and inhibition, it was not able to ascertain definitely whether or not certain test of attentions and inhibition do indeed measure the construct they are supposed to be measuring. Counterbalancing was not used in the present study. Although counterbalancing would have been ideal, overall, when compared to norms, performance on the second day was not of poorer quality than the first day.The Sky Search DT measure which had scores that were furthest from the norm was administered on the first day. Comparison of Table 1 with Appendix B leads to the conclusion that for this thesis, lack of counterbalancing did not make any difference.

Many other factors may affect the results of this study. For example, measurement error, student fatigue, distractions, motivation, weakness in any of the aforementioned functions, misinterpretations of the tests or test instructions can also affect the outcome.

This new domain definitely warrants further study. Inhibition measures from this study that were found to not tap into any attentional measures can be used in future research. Futures studies should include a larger number of tests that encompass all empirical definitions and subsets of attention, inhibition and executive function.

A possible way to disentangle all of these interrelated and overlapping constructs is to perhaps look at past and present research and see which brain regions account for each construct. Using neuroimaging at the same time as performing attention or inhibition tasks will add to the validity of the tests being measured and will also try to ascertain which regions highlighted corresponds to specific tests of these constructs. MRI and functional MRI as well as cat scans could be used to help identify areas of the brain responsible for attentive and inhibitory functioning Koschack, Kunert, Derichs, Weniger and Irle (2003) explain that there is an increasing amount of evidence that suggests that attention is achieved by the interaction of many different subcomponents and an interplay of various neuroanatomical networks. To fully understand the constructs of attention and inhibition, the cognitive and behavioral operations must be recognized as must the underlying neuroanatomical activity.

In addition to the aforementioned suggestions, researchers need to examine practical definitions versus theoretical definitions as well as real-world implications versus theoretical constructs . These are areas which need to be elaborated upon. This study does contribute to the literature on measurement of attention and inhibition as well

as their subtypes by describing the inherent problems in definition and measurement. It is likely that with advancements in the study of attention, inhibition and EF's, more distinctions in these constructs will be defined.

Once researchers arrive at one agreed upon definition for each of these variable using methods described above, strong psychometric performance based measures of these constructs will help identify problems in the area and intervention can occur much earlier. Attention and inhibition skills are essential to learning and development. It is important that we are able to assess these constructs accurately in children.

A number of factors have hindered this type of investigation. First, these constructs have been difficult to define. There is a tendency in the literature to use these constructs interchangeably with other Executive Functions. Another important clinical implication is the ecological validity of these tests. When researchers are trying to validate criteria for certain diagnoses such as ADHD, and are looking or deficits in sustained or selective attention, there must be valid assessment tools. If the construct cannot be measured effectively then the criteria cannot be validated or is incorrectly validated.

Attention difficulties impact a student's ability to learn in an academic setting. Proper assessment and identification of attention problems is vital to the implementation of intervention in schools. Proper identification and assessment of inhibition is important because disinhibition is linked with numerous difficulties in academic as well as social life. It is also important to have convergent validity among tests when trying to differentiate subtypes of certain disorders such as ADHD.

The present study was undertaken in order to explore the relationships between attention and inhibition constructs. The uncertainty regarding the independence of attention and inhibition as well as Executive Function is hotly debated. In reviewing past studies concerning construct independence, substantial evidence has accrued to argue for the position that attention and inhibition are not unitary constructs (Barkley, 1996; Halperin et al., 1994; Nigg, 2001; Wilding, 2008). As well, proper definition and distinct subtypes have yet to be clearly defined. The present study utilized tasks that were designed to measure attention and inhibition and to distinguish among various subtypes, however the hypotheses were not supported.

In summary, research on attention and inhibition constructs has been extensive and exhaustive. Yet, there remains theoretical confusion concerning the definition, structure and interrelationships of these constructs. A fundamental question when studying attention and inhibition constructs is: What are the tests we are using actually measuring? It is imperative that research in this domain continue to reach theoretical and practical clarity. This study has attempted to approach the issue from a very basic standpoint. To use extensively researched measures to disentangle the most simplest of relationships which as of yet remain elusive.

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APPENDIX A

Review of Attention and Inhibition Measures

Measures	Attention	Inhibition	Descriptions
Stop Signal Task(Paradigm)		13 Studies(Alderson et al, 2008; Reynolds et al, 2008; Tilman et al, 2008; Alderson et al, 2007; Cheung, 2004; Christ et al, 2001, May& Hasher, 1998, Barkley, 1997, Jennings et al, 1997; Plizska et al, 1997; Quay, 1997; Oosterlan & Sargeant, 1996; Schachar et al, 1995.)	Used mostly in ADHD and inhibition studies with children aged 6-14.
Kagan's Matching Familiar Figures Test.		7 Studies(Barkley, 1997; Bjorklin and Kipp, 1996; Halperin et al, 1996; Pennington, 1993, Grodinsky & Diamond, 1992.)	Usually used in ADHD studies with children aged 6-12.
Wisconsin Card Sorting Task		4 Studies(Barkley, 1997; Bjorkland & Kipp, 1996; Pennington 1993; Grodinsky & Diamond, 1992.)	Usually used for ADHD comparison
Go-No-Go Task		12 studies(Derefinko et al, 2008; Kanaka et al, 2008; Reynolds et al, 2008;Berlin, 2004; Brocki & Bohlin, 2004; Cheung , 2004; Floyd & Kirby, 2001; Barkley, 1997; Levin et al, 1997; Levin et al, 1996; Muroi et al, 1997; Levin et al, 1991.	Mostly ADHD comparison studies.
CPT	15 Studies (Kanaka et al, 2008; Kilic et al, 2007; Loo et al, 2007 Muir-Braoddus 2002; Ho et al, 1996; Halperin et al, 1994; Pennington, 1993; Matie et al, 1992; Barkley, 1991; Halperin et al, 1991; Sharma et al, 1991; Halperin et al, 1998; Barkley,	11 Studies(Reynolds et al, 2008; Lansbergen et al, 2007; Pasini et al, 2007; Christ et al, 2001; Barkley, 1997; Halperin et al, 1996; Grodinsky & Diamond, 1992; Métier et al, 1992; Halperin et al, 1998; Schachar et al, 1998.)	For attention- mostly comparison studies of ADHD sustained attention task. For Inhibition:

	1990; Shachar et al, 1988; Werry et al, 1987.)		Mostly comparison studies of ADHD
Stroop	5 Studies (Chan et al, 2008; Dos Sanots-Assef et al, 2007; Passini et al, 2007; Halperin et al, 1994; Robertson et al, 1994.)	10 Studies (Lansbergen et al, 2007; Antrop et al, 2006; Enticott, 2006; Cherry, 2004; Floyd & Kirby, 2001; May & Hasher, 1998; Barkley, 1997; Bjorkland & Kipp, 1996; Halperin et al, 1996; Grodinsky & Diamond, 1992.)	Interference control- may be measure of selective attention or inhibition.
Resistance To Temptation Tasks.		2 Studies(Enticott, 2006, Bjorklin & Kipp, 1996)	Measure of inhibition/ Impulsivity.
Teach	4 Studies(Savage et al. 2006; West et al, 2002	Savage et al, 2006 West et al, 2002.	
WISC-Digit Span	5 Studies(Brocki & Bolin, 2004; Muir-Braoddus, 2002; Halperin et al, 1994.)		Test of attention Capacity or working memory.

APPENDIX B

Norms for the OLSAT, TEA-ch, Digit Span, Stroop and Gordon CPT.

Measure	Mean	SD
OLSAT Total	100	16
OLSAT Verbal	100	16
OLSAT Nonverbal	100	16
All TEACH Subtests	10	3
WISC Digit Span	10	3
Gordon Vigilance Task Total Correct	42.75	2.1
Gordon Vigilance Task Commission Scores	3.7	4.7
Gordon Delay Task Total Correct	50	9.4
Gordon Delay Task Total Responses	61	12.8
Gordon Delay Task Efficiency ratio	.83	.12
Stroop Word T Score	50	10
Stroop Colour Word T Score	50	10
Stroop Interference T Score	50	10

APPENDIX C

MEANING OF MEASUREMENT SCORES

Teacher Rating- Ratings from 1-4. 1 means academic performance in the top quarter and 4 means academic performance in the bottom quarter. So the lower the rating the better the student in terms of academic achievement.

Number of Siblings- How many siblings a subject has.

OLSAT Total, Non-Verbal and Verbal Scores- Higher scores mean higher order reasoning skills. Skills that are important for successful learning.

Teach Scores:

Sky Search Score- number of correctly circled spaceships. Higher score = better performance.

Sky Search Timing Score- Time taken to find all spaceships. Lower score means more efficient.

Sky Search Attention Score- Calculated using the two preceding scores and then controlled for motor responses. This is the key score from this subtest and measures Selective Attention. The higher the score the better one is at selectively attending.

Score-Subject score out of ten. Measures sustained attention, the higher the score the better able one is to sustain attention

Sky Search DT- Combines Sky Search and Score. Reported as a measure of Divided/sustained attention. The higher the score the better able you are to divide or sustain attention.

Creature Counting Accuracy - number of trials correct. The higher the score the better one is at selectively attending.

Creature Counting Timing Score- The Accuracy score used to find the timing score. Possible measure of attentional control/switching or Behavioural Inhibition. A higher score would mean that you are either better at switching your attention or controlling your response.

Walk Don't Walk- scored as number correct out of 20. Used here as a measure of Inhibition. The higher the score the better able one is to inhibit impulsive responses.

WISC-Digit Span-Scored as total trials correct. Used as a measure of selective attention or of attentional capacity. The higher the score the better able you are to selectively attend or the greater the attentional capacity.

Go-No-Go Hits-measures number of correct responses. The higher the score the better able one is to selectively attend.

Go-No-Go Correct Rejections-measure of sustained attention. The higher the score the better able one is to sustain attention.

Go-No-Go Omission Scores-measure of sustained attention. Higher scores reflect poor ability to sustain attention. Number of missed responses.

Go-No-Go False Alarms-Measure of Inhibition. A higher scores reflect poor ability to inhibit inappropriate responses.

Gordon Vigilance Task Total Correct(CPT)- total correct responses. Higher score means better able to selectively attend.

Gordon Vigilance Task Omissions- -Number of missed responses. The higher the score, less able to sustain attention.

Stroop Word Score- How many color names you can read in 45 sec.

Stroop Color Score- How many colors you can name in 45 Seconds.

Stroop Interference Score- This is the main score for interpreting the Stroop. Uses Word and Color score to calculate this score. This tests whether you can resist distractors and interference. So is used both as a measure of attention and inhibition. The higher the score the better able one is to resist distractors or inhibit a response.

Gordon Vigilance Task Commission Scores- measure of inhibition. The higher the score the less able one is to inhibit a response.

Gordon Delay Total Correct and Total responses are used to Calculate the Gordon Delay Efficiency Ratio- This ratio is used to measure behavioral inhibition. The higher the score the better able one is to inhibit an inappropriate response.

Delay of Gratification- used to measure the ability to inhibit or delay. Scored as 1 or 2. 1 was defined as receiving a reward now and 2 was defined as receiving a bigger reward in one week.

APPENDIX D

Relationship (Spearman Rho) Between All Attention Scores. (N=104)

SSSTS	-.04 p=.34					
SSSAS	-.11 p=.11	.80 p=.00				
SSS	.17 p=.04	-.05 p=.29	-.004 p=.48			
SSSDT	.16 p=.04	-.24 p=.00	-.21 p=.01	-.09 p=.16		
SDS	.05 p=.29	.23 p=.01	.17 p=.04	.12 p=.09	-.04 p=.31	
TSIS	-.13 p=.08	.10 p=.15	.02 p=.41	-.04 p=.34	-.01 p=.46	.05 p=.30
TSCWS	-.03 p=.38	.32 p=.00	.16 p=.04	.13 p=.08	.05 p=.30	.13 p=.08
GDER	-.09 p=.16	.04 p=.30	.08 p=.20	.17 p=.04	.08 p=.18	.03 p=..36
GVTOS	-.16 p=.04	-.12 p=.11	-.15 p=.06	-.18 p=.02	-.17 p=.03	-.02 p=.40
GNGHIT	-.11 p=.12	.16 p=.04	.04 p=.31	-.04 p=.31	-.02 p=.39	.02 p=.40
GNGMISS	.14 p=.06	-.20 p=.02	-.09 p=.18	.05 p=.27	.07 p=.23	.003 p=.48
GNGCR	.02 p=.39	.04 p=.34	.02 p=.40	.11 p=.12	.03 p=.35	.17 p=.03
GVTTC	.16 p=.04	.11 p=.11	.15 p=.06	.18 p=.02	.17 p=.03	.02 p=.40
	SSSS	SSSTS	SSSAS	SSS	SSSDT	SDS

SSSTS-Scaled Sky Search Timing Score
SSSAS-Scaled Sky Search Attention Score
SSS-Scaled Score Score
SSSDT-Scaled Shy Search DT Score
SDS-Scaled Digit Span
TSIS-T Stroop Interference Score
TSCWS-T Stroop Color-word Score
GDER- Gordon Delay Efficiency Ratio
GVTOS-Gordon Vigilance Omissions
GNGHIT-Go-No-Go Hit
GNGMISS-Go-No-Go Misses
GNGCR-Go-No-Go Correct Rejections
GVTTC-Gordon Vigilance Task Total Correct
SSSS-Scaled Sky Search Score

APPENDIX D

Relationships (Spearman Rho) Among Attention Scores (N=104). Con't

	TSIS	TSCWS	GDER	GVTOS	GNGHIT	GNGMISS	GNGCR
TSCWS	.60 p=.00						
GDER	.18 p=.03	.15 p=.058					
GVTOS	.01 p=.44	-.26 p=.003	-.10 p=.14				
GNGHIT	.02 p=.38	.01 p=.42	-.15 p=.058	.001 p=.49			
GNGMISS	-.02 p=.39	-.02 p=.40	.17 p=.04	.03 p=.34	-.96 p=.00		
GNGCR	-.06 p=.27	.10 p=.13	-.06 p=.27	-.10 p=.15	.09 p=.15	.07 p=.21	
GVTTC	-.01 p=.44	.26 p=.003	.10 p=.14	1.0 p=.00	-.00 p=.49	.03 p=.34	.10 p=.15

LEGEND

TSCWS-Stroop Color Word T-Score
GDER-Gordon Delay Efficiency Ratio
GVTTC-Gordon Vigilance Total Correct
GNGMISS-Go-No-Go Misses

TSIS-Stroop Interference T-Score
GVTOS-Gordon Vigilance Omission Score
GNGHIT-Go-No-Go Hit
GNGCR-Go-No-Go Correct Rejections

APPENDIX E

Relationships (Spearman Rho) Among Attention and Inhibition Variables (N=104)

	SSSS	SSSTS	SSSAS	SSS	SSSDT	SCCA
SSSTS	.05 p=.29					
SSSAS	-.04 p=.48	.86 p=.00				
SSS	1.00 p=.00	.05 p=.29	-.004 p=.48			
SSSDT	.09 p=.16	-.24 p=.01	-.21 p=.01	.09 p=.16		
SCCA	.19 p=.02	-.09 p=.17	-.12 p=.09	.19 p=.02	.26 p=.003	
SCCTS	.06 p=.24	.34 p=.00	.18 p=.02	.06 p=.24	.20 p=.02	.17 p=.03
SWDW	-.02 p=.38	.10 p=.13	.13 p=.08	-.02 p=.38	.06 p=.26	.05 p=.28
SDS	.12 p=.09	.23 p=.01	.17 p=.04	.12 p=.09	.04 p=.31	.12 p=.10
GNGHIT	-.04 p=.31	.16 p=.04	.04 p=.31	-.04 p=.31	-.02 p=.39	-.01 p=.45
GNGCR	.11 p=.12	.04 p=.34	.02 p=.40	.11 p=.12	.03 p=.35	.04 p=.32
GNGFA	-11 p=.12	-.04 p=.33	-.02 p=.39	-.11 p=.11	-.03 p=.35	-.04 p=.33

LEGEND

SSSTS- Scaled Sky Search Timing Score
SSS-Scaled Score Score
SCCA-Scaled creature Counting Accuracy
SWDW-Scaled Walk Don't Walk Score
GNGHIT- Go-No-Go Hit Score
GNGFA-Go-No-Go False Alarm

Scaled Sky Search Attention Score
SSSDT-Scaled Sky Search DT Score
SCCTS-Scaled creature Counting Timing Score
SDS-Scaled Digit Span
GNGCR-Go-No-Go Correct Rejection

APPENDIX E

Relationships Among Attention and Inhibition Variables (N=104) Con't.

	SSSS	SSSTS	SSSAS	SSS	SSSDT	SCCA
GNGMISS	.05 p=.27	-.20 p=.02	-.09 p=.18	.05 p=.27	.07 p=.23	.03 p=.38
GDTTC	.06 p=.25	.11 p=.12	.11 p=.12	.06 p=.25	.03 p=.36	.11 p=.12
GDTTR	-.06 p=.24	.02 p=.39	-.01 p=.44	-.06 p=.24	-.07 p=.23	.15 p=.06
GDER	.17 p=.04	.04 p=.30	.08 p=.20	.17 p=.04	.08 p=.18	-.09 p=.15
GVTTC	.18 p=.03	.11 p=.11	.15 p=.06	.18 p=.03	.17 p=.04	.14 p=.06
GVTOS	-.18 p=.02	-.11 p=.11	-.15 p=.06	-.18 p=.02	-.17 p=.03	-.14 p=.06
GVTCOM	-.11 p= .12	-.04 p=.31	-.009 p=.46	-.11 p=.12	-.25 p=.00	-.23 p=.01
TSWS	.28 p=.00	.18 p=.03	.03 p=.39	.28 p=.00	.02 p=.43	.004 p=.48
TSCS	.14 p=.07	.41 p=.00	.30 p=.001	.14 p=.07	.03 p=.37	.04 p=.37
TSCWS	.13 p=.08	.32 p=.00	.16 p=.04	.13 p=.08	.05 p=.30	.14 p=.06
TSIS	-.04 p=.34	.10 p=.15	.02 p=.41	-.04 p=.34	.01 p=.46	.04 p=.31

GDTTC-Gordon Delay Total Correct GDTTR-Gordon Delay Total Responses GDER-Gordon Delay Efficiency Ratio
GNGMISS-GO-No-Go Misses GVTTC-Gordon Vigilance Total Correct GVTOS-Gordon Vigilance Omission score
GVTCOM-Gordon Vigilance Commission TSWS-Stroop Word T-Score TSCS-Stroop Color T-Score
TSCWS-Stroop Color- Word T-Score TSIS-Stroop Interference T-Score SSSS-Scaled Sky Search Score
SSSTS-Scaled Sky Search Timing SSSAS-Scaled Sky Search Attention Score SSS-Scaled Score Scores
SSSDT-Scaled Sky Search DT SCCA-Scaled creature Counting Accuracy

APPENDIX E

Relationships Among Attention and Inhibition Measures (N=104) Con't

SWDW	.17 p=.04					
SDS	.23 p=.01	.03 p=.35				
GNGHIT	.08 p=.19	-.10 p=.15	.02 p=.40			
GNGCR	.12 p=.09	.09 p=.16	.17 p=.03	.09 p=.15		
GNGFA	-.13 p=.09	-.08 p=.18	-.18 p=.03	-.10 p=.14	-.99 p=00	
GNGMISS	-.05 p=.27	.11 p=.12	.003 p=.48	-.96 p=.000	-.07 p=.21	.08 p=.19
GDTTC	.12 p=.10	-.02 p=.40	.01 p=.43	-.15 p=.06	-.04 p=.31	.05 p=.29
GDTTR	.001 p=.49	.04 p=.33	-.08 p=.19	-.03 p=.37	.01 p=.46	-.004 p=.48
GDER	.19 p=.02	-.05 p=.27	.03 p=.36	-.15 p=.058	-.06 p=.27	.05 p=.27
GVTTC	.11 p=.12	.26 p=.004	.02 p=.40	-.001 p=.49	.10 p=.15	-.10 p=.14
GVTOS	-.11 p=.12	-.26 p=.004	-.02 p=.40	.001 p=.49	-.10 p=.15	.10 p=.14
GVTCOM	-.36 p=.000	-.20 p=.02	-.21 p=.01	.01 p=.46	-.24 p=.006	.25 p=.005
TSWS	.35 p=000	.18 p=.02	.14 p=.07	.008 p=.46	.18 p=.03	-.18 p=.03
TSCWS	.34 p=.000	.16 p=.04	.13 p=.08	.02 p=.42	.10 p=.13	-.11 p=.12
TSIS	.11 p=.12	-.01 p= .47	.05 p= .30	.03 p= .38	-.06 p= .27	.05 p= .28
	SCCTS	SWDW	SDS	GNGHIT	GNGCR	GNGFA

APPENDIX E

Relationships Among Attention and Inhibition Measures (N=104) Con't

GDTTC	.12 p=.09					
GDTTR	.003 p=.48	.61 p=000				
GDER	.17 p=.04	.18 p=.03	-.53 p=.00			
GVTTC	.04 p=.34	.06 p=.26	-.01 p=.42	.10 p=.14		
GVTOS	-.03 p=.34	-.06 p=.26	.02 p=.42	-.10 p=.14	1.00 p=.000	
GVTCOM	-.05 p=.29	.02 p=.40	.14 p=.07	-.17 p=.03	-.47 p=.00	.47 p=.00
TSWS	-.01 p=.46	.09 p=.17	.07 p=.23	.12 p=.10	.19 p=.02	-.19 p=.02
TSCS	-.05 p=.29	.18 p=.02	.18 p=.03	-.03 p=.37	.32 p=000	-.32 p=.00
TSCWS	-.02 p=.40	.07 p=.23	.00 p=.48	.15 p=.058	.26 p=.003	-.26 p=.003
TSIS	-.02 p=.39	-.01 p=.46	-.07 p=.23	.18 p=.03	-.01 p=.44	.01 p=.44
	GNGMISS	GDTTC	GDTTR	GDER	GVTTC	GVTOS

LEGEND

GDTTC- Gordon delay Task Total Correct
GDTTR-Gordon Delay Task Total Responses
GDER-Gordon Delay Efficiency Ratio
GVTTC-Gordon Vigilance Total Correct
GVTOS-Gordon Vigilance Omission Score
GVTCOM-Gordon Vigilance Commission Score
TSWS-Stroop Word T-Score
TSCS-Stroop Color T-Score
TSCWS-Stroop Color Word T-Score
TSIS-Stroop Interference T-Score
GNGMISS- Go-No-Go-Misses

APPENDIX E

Relationship Among Attention and Inhibition Measures (N=104) Con't

	GVTCOM	TSWS	TSCWS	TSIS
TSWS	-.24 P=.006			
TSCS	-.23 p=.01	.61 p=.000		
TSCWS	-.27 p=.002	.44 p=.000	.55 p=.000	
TSIS	-06 p=.24	-.20 p=.01	-.14 p=.06	.60 p=.000

LEGEND

TSWS-Stroop Word T-Score
TSCS-Stroop Color T-Score
TSCWS-Stroop Color Word T-Score
TSIS-Stroop Interference T-Score
GVTCOM- Gordon Vigilance Commission Score

APPENDIX F

Laurentian University
Ramsey Lake Road
Sudbury, Ontario
Canada P3E 2C6
(705) 675-1151
FAX (705) 675-4889

Université Laurentienne
Chemin du lac Ramsey
Sudbury (Ontario)
Canada P3E 2C6
(705) 675-1151
Télécopieur (705) 675-4889

Department of Psychology
Département de psychologie

Dear Parent(s):

I am a master's student in the Human Development Program at Laurentian University and I am required to complete a research study. Previous research has indicated that attention and inhibition have been defined and characterized in a number of different and overlapping ways. I am interested in examining whether there is evidence for independence between attention and inhibition. More specifically, I am interested in investigating the relationship of new and commonly used measures of attention and inhibition in 10 year olds. Your co-operation in permitting your child to participate in this research would be greatly appreciated.

Each participant will be asked to complete various brief game-like tasks in which they will search for hidden spaceships and aliens, read different colored words, count computer scoring sounds and letters, monitor computer screens for targets and tap fingers or buttons when cued. As part of the procedure small gift tokens will be given which will consist of various trading cards such as sports, music or comic figures. Young people tend to find these types of tasks novel and interesting.

If you give your permission you will be asked to answer a few screening questions(included) about your child regarding existence of medical problems, disabilities and usage of medication. In addition, each participant will be asked questions regarding their language of origin and number of siblings . The entire process should take about one hour, divided into two sessions of one half hour each and will be done during regular classroom hours.

Permission is also requested for the release of your child's OLSAT scores which were administered within the last two years. I am interested in the relationship between these questions, the OLSAT measure and the attention and inhibition measures.

The final decision regarding the participation of each child must be made by the child and the parent. You are under no obligation to participate in this study and you may withdraw at any time without consequence. The results of this study will not affect your child's grades. Personal information gathered as part of this study will remain private and confidential. Names of children and schools will be coded into numerical form so as not to identify the child or school in any way. The information pertaining to names of the subjects and corresponding schools will be kept in strictest confidence and locked in filing cabinets until end of all testing sessions at which point all identifying information will be destroyed. This project has been approved by the Rainbow District School Board and the Human Development Program at Laurentian University.

Please complete the enclosed parental consent form and brief questionnaire and return it to the school **AS SOON AS POSSIBLE.** We would appreciate receiving an answer even if you do not want your child to participate. If you have any questions regarding this research investigation, please call my supervisor, Dr. Elizabeth Levin at 675-1151, ext.4242. A copy of the complete study results will be provided to the school at the end of August. A summary sheet will also be made available to the parents through the school office.

Sincerely,

E. Levin
Supervisor

Bernadette Pasquali
Student Researcher

APPENDIX G

CHILD CONSENT FORM

I hereby grant permission for my child to participate in the research examining the relationship of new and commonly used measures of attention and inhibition in ten year old children which is being conducted by Bernadette Pasquali, Human Development student at Laurentian University, supervised by Dr. Elizabeth Levin.

I understand that my child will be completing various game like tasks and answering brief questions. I also understand that the Rainbow District School Board will, upon my approval of this research, release my child's OLSAT scores for use in this research project. I have been informed that the entire testing procedure will be completed on two separate sessions during regular classroom hours.

I understand that my child is under no obligation to participate in this study and that he/she may withdraw at any time without consequence. Furthermore, I understand that my child has the right to refuse to answer any special question(s) and that the results of this study will not affect my child's grades.

I understand that all material collected will be used for research purposes only and that my child's anonymity will be protected. Any personal information gathered as part of this study will remain private and confidential.

I have been informed that a copy of the complete study results will be made available to the school at the end of August, and that a summary sheet will also be made available through the school office at that time. I understand that the long-term goals of this research are first, to determine whether attention and inhibition are separate constructs and second, to determine the relationship between various measures of attention and inhibition which will lead to a clearer definition of these concepts for various types of future research.

If I have any questions , I have been invited to speak to Dr. Elizabeth Levin at 675-1151, Ext. 4242.

I give permission for my child to participate. _____

I do not give permission for my child to participate. _____

NAME OF CHILD: _____

PARENT/GUARDIAN: _____
(Signature)

CHILD: _____
(Signature)

DATE: _____

PLEASE RETURN CONSENT FORM TO SCHOOL BY _____

(IF GIVING CONSENT, PLEASE TURN OVER AND ANSWER QUESTIONS)

Appendix H

SCREENING QUESTIONS

1. Some medications may affect attention, therefore, we would like to know if your child is taking any prescription medications prescribed by a doctor.

   Yes _____ No_____

If yes, please list any prescription medication your child is currently taking.

_____.

2. Is your child taking any over the counter medication?

   Yes _____ No _____

If yes, please list.

_____

3. Does your child have any disabilities or medical problems(e.g. - Hearing loss, Vision Problems, Learning disorders, Behavioral Disorders, etc.)?

   Yes _____ No_____

If yes, please describe?

_____.

APPENDIX I

Laurentian University – Human Development Programme
RESEARCH ETHICS APPROVAL

☞ Major Supervisor, student, and Ethics Committee must sign this form. Append all comments and **a copy of the written proposal** and leave with the Secretary of the Centre for Research in Human Development.

STUDENT: Bernadette Pasquali

THESIS SUPERVISOR: DR. ELIZABETH LEVIN

PROPOSAL TITLE: RELATIONSHIP OF NEW AND COMMONLY USED MEASURES OF ATTENTION AND INHIBITION IN 10 YEAR OLDS.

STUDENT -EXPERIMENTER AGREEMENT

Bernadette Pasquali, as a student-experimenter and
(Signature of student)

E. Levin, as major supervisor, agree to be guided
(Signature of major supervisor)

in our conduct by ethical principles associated with research using human participants.

DATE: Jan 5/99.

↔ ↔ ↔ ↔ ↔ ↔ ↔ ↔ ↔ ↔ ↔

THE PROPOSAL WAS JUDGED BY THE DEVE ETHICS COMMITTEE TO BE:

☒ Acceptable

☑ Acceptable, subject to modifications appended to this form (see consent form)

☐ Not yet acceptable; and a new proposal should be presented

☐ Not acceptable; the student should abandon this topic.

SIGNATURES:

Lynette Norman	Alan Salmoni
[print name]	[print name]
M. HEAMAN	Coordinator of DEVE
[print title]	[print title]
Associate Prof. Psyc	
[signature]	[signature]
JAN 11 1999	Jan. 12/99
[date]	[date]