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PAIN AND ACADEMIC PERFORMANCE IN YOUTH WITH SPINA BIFIDA: THE

MEDIATING ROLE OF NEUROPSYCHOLOGICAL FUNCTIONING

A THESIS SUBMITTED TO

THE FACULTY OF THE GRADUATE SCHOOL

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BY

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ABSTRACT

Objective: The current literature has identified few modifiable condition parameters associated with academic performance in youth with spina bifida (SB). Nevertheless, youth with SB are more likely to struggle academically than their typically developing (TD) peers. Therefore, identifying areas for clinical intervention is paramount. Pain, an understudied secondary condition in youth with SB, has been found to be associated with poorer academic performance in TD youth. Further, neuropsychological functioning has been found to be both negatively associated with pain and positively associated with academic outcomes. The aims of this study were to examine (1) the relationship between pain and academic functioning in youth with SB and (2) neuropsychological mechanisms that may explain the potential relationship between pain symptoms and academic performance. These aims were examined cross-sectionally and longitudinally. Methods: Participants were recruited as part of a larger ongoing longitudinal study (Devine et al., 2012). The current study included parent and teacher report of attention, executive functioning (working memory, cognitive flexibility, inhibition), and academic competence, as well as teacher report of academic motivation and academic record. Moreover, this study included neuropsychological performance measures given to youth to examine working memory, attention, and academic achievement. Finally, this study used child self-report of three pain symptoms (frequency, intensity, duration). Analyses controlled for SES, age, and illness severity. Results: no significant associations were found between pain and academic constructs as well as pain and neuropsychological functioning, cross-sectionally and

longitudinally. Attention and working memory were both found to be strongly associated with all academic outcomes. Inhibition was only significantly associated with academic motivation and cognitive flexibility was not found to be associated with any academic outcomes. Conclusions: Pain does not appear to be significantly associated with academic outcomes for youth with SB. Working memory and attention are strongly associated with academic outcomes over time. Results have clinical implications for developing a clinical intervention for academic success in this population.

CHAPTER ONE

INTRODUCTION

Research has shown that youth with spina bifida (SB) are more academically challenged than are typically developing youth (Holmbeck et al., 2003; Holmbeck et al., 2010). The current literature has identified several factors that are associated with poorer academic performance in this population, including the unique cognitive profile in SB (Dennis, Landry, Barnes, & Fletcher, 2006) and several demographic factors (i.e., SES, shunt-status, cognitive functioning, lesion level, seizure status; Holmbeck et al., 2003; Hommeyer, Holmbeck, Wills, & Coers, 1999; Lomax-Bream, Barnes, Copeland, Taylor, & Landry, 2007; Swartwout, Garnaat, Myszka, Fletcher, & Dennis, 2010; Wasserman, 2014). However, only a few studies have identified modifiable factors associated with academic outcomes in this population (Barnes et al., 2014; Holmbeck et al., 2003; Murray, 2017). Recent advances in medicine have increased life expectancy for individuals with spina bifida (Oakeshott, Hunt, Poulton, & Reid, 2010), encouraging researchers to adopt a more future oriented research agenda. Therefore, further examination of factors associated with academic performance in this population is needed. Current research has demonstrated that education is critical for the future independence for individuals with spina bifida (van Melchelen, Verhoef, van Asbeck, & Post, 2008). Moreover, research has shown that educational attainment predicts better physical and mental health in typically developing individuals, including lower rates of depression, lower rates of drug use, and better cardiovascular health (Molla, Madans, & Wagener, 2004; Topitzkes, Godes, Mersky,

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Ceglarek, & Reynolds, 2009; Winkleby, Jatulis, Frank & Frotmann, 1992). To develop clinical

interventions for academic performance in youth with SB, research must examine other

modifiable condition parameters.

One such condition parameter is pain. In addition to managing multiple illness-related

challenges, youth with SB frequently experience pain symptoms (Clancy, McGrath, & Oddson,

2005; Oddson, Clancy & McGrath, 2006; Wagner et al., 2015). Despite recent studies that have

confirmed the impact and prevalence of pain in SB, pain is an understudied secondary condition

in this population (Clancy et al., 2005, Essner, Murray, & Holmbeck, 2014). There is currently

limited research on the psychosocial outcomes of pain in SB. Existing research has found that

pain in SB is associated with poorer quality of life (Bellin et al., 2013), increased depressive

symptoms (Oddson et al., 2006), and a reduction in social activity involvement and social

competence (Essner et al., 2014).

While pain remains an understudied area in spina bifida research, there is a great deal of

research on the impact of pain on multiple domains of functioning across multiple pediatric

conditions. Chronic pain in youth has been found to negatively impact psychosocial functioning,

family functioning, and school outcomes. Poor academic performance has been found in multiple

pediatric pain populations, including chronic headache, musculoskeletal pain, and abdominal

pain (Abu-Arefeh & Russell, 1994; Claar, Walker, & Smith, 1999; Logan, Simons, Stein, &

Chastain, 2009). Research has found that pediatric pain is associated with declining grades,

incomplete homework, and self-perception of low academic competence (Arruda & Bigal, 2012;

Bennett et al., 2000; Campo, Comer, Jansen-McWilliams, Gardner, & Kelleher, 2002; Claar et

al., 1999; Rocha-Filho & Santos, 2014; Voerman et al., 2017). Moreover, chronic pain has been

associated with poor neurocognitive functioning, including executive dysfunction and inattention (Cruz, O'Reilly, Slomine, & Saolorio, 2011; Mifflin, Chronig, & Dick, 2016). This latter association is important to note given extensive research demonstrating significant relations between attention/executive functioning and academic performance (Alloway, Gathercole, Kirkwood, & Elliot, 2009; Bull, Espy, & Wiebe, 2008; Gathercole, Pickering, Knight, & Stegmann, 2004).

Youth with spina bifida are also at risk for inattention and executive dysfunction (Rose & Holmbeck, 2007). Indeed, research has shown that there are significantly higher rates of ADHD, inattention subtype, in youth with spina bifida compared to TD youth (Burmeister et al., 2005). Moreover, youth with spina bifida have difficulties with higher order processes, which require the use of executive functions (Burmeister et al., 2005; Fletcher et al., 1996; Hampton et al., 2011; Rose & Holmbeck, 2007; Tuminello, Holmbeck, & Olson, 2012). Research has found that these deficits are associated with lower levels of intrinsic motivation in school for youth with SB (Tuminello et al., 2012). Therefore, given the high prevalence of pain symptoms, neurocognitive dysfunction, and academic difficulties in this population, it is crucial to examine these inter-related factors in one model.

A review of the current literature reveals a lack of understanding of how pain symptoms may impact neurocognitive functioning and academic performance in youth with SB. The current study sought to address these gaps by testing longitudinal, multi-method, and multi-informant models of these individual factors. The following sections provide an overview of the current research on academic performance in youth with SB and pain in youth with SB as well as an overview of the current research on academic performance in pediatric pain populations.

Moreover, this review suggests that neurocognitive functioning may mediate the relationship between pain and academic performance. This review also suggests a theoretical framework with which we may understand this potential mediation, cognitive load theory (Sweller, 1988). Weaknesses and gaps in the current literature are identified. Finally, a detailed description of the current study is provided, along with the aims and hypotheses of this research.

Time 1	*Time 2*	*Time 3*
<u>Pain</u>	<u>Youth Neurocognitive Functioning</u>	<u>Academic Performance</u>
Pain (Y)	Attention (P)	Academic Performance (T)
Pain (P)	Executive functioning (P)	Academic Competence (P)
	Working Memory	Academic Motivation (T)
	Cognitive Flexibility	Academic Competence (T)
	Inhibition	Academic Record (T)
	Attention (T)	Achievement performance measure (Y)
	Executive Functioning (T)	
	Working Memory	
	Cognitive Flexibility	
	Inhibition	
	Neuropsychological performance measures (Y)	
	Attention	
	Working Memory	
	Cognitive Flexibility	

Note. P=Parent report, T=Teacher report, Y=Youth report.

Figure 1. Meditational Model of Pain, Neurocognitive Functioning, and Academic Performance

CHAPTER TWO

REVIEW OF THE RELEVANT LITERATURE

Spina bifida (SB) is a relatively common congenital birth defect that occurs in roughly 3 out of every 10,000 births in the United States (Centers for Disease Control and Prevention [CDC], 2011). SB occurs in the first month of pregnancy when the embryonic neural tube fails to close completely (Copp et al., 2015). SB is associated with a number of complications including bowel and bladder incontinence, varying degrees of paralysis of the lower extremities, clubfoot and other orthopedic conditions, hydrocephalus, increased risk of neurocognitive issues, and increased risk of learning disabilities (Kelly, Zebracki, Holmbeck, & Gershenson, 2008). The severity of SB varies, partly due to the individual's spinal lesion level and neurological complications, such as the number of shunt infections and shunt revisions (Copp et al., 2015). Therefore, to manage the aforementioned complications, individuals with SB are required to follow a demanding medical regimen, including medications, catheterization, bowel programs, skin checks, and shunt monitoring (Zukerman, Devine, & Holmbeck, 2011). Moreover, youth with SB often contend with poor psychosocial functioning and academic difficulties (Holmbeck & Devine, 2010; Holmbeck et al., 2003; Holmbeck et al., 2010). Research has shown that youth with SB have more academic struggles than TD youth, and that these difficulties are maintained overtime (Holmbeck et al., 2010).

Academic Outcomes in Spina Bifida

Research on school functioning in youth with spina bifida has almost exclusively focused

on the cognitive profile of this population and how this profile manifests itself academically.

Youth with spina bifida are not globally impaired but instead show specific strengths and

weaknesses across different academic domains (Dennis et al., 2006). Youth with spina bifida

show relative strengths in certain types of verbal processing but perform poorly in nonverbal

processing. This pattern is not commonly found in typically developing youth (without

neurological impairment) for whom there is usually a greater correspondence between nonverbal

and verbal skills (Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2005; Shalev, Auerbach,

Manor, & Gross-Tsur, 2000). Dennis and colleagues (2006) concluded that this unique pattern is

due to the fact that individuals with spina bifida have relative strengths in associative processing

but relative deficits in assembled processing. Dennis and colleagues define associative

processing as, "data driven and based on the formation of associations, enhancement,

engagement and categorization" (p. 289). Examples of associative processing include

recognizing faces or decoding familiar words. On the other hand, assembled processing is "based

on dissociation, suppression, disengagement, and contingent relations" (p. 289). Assembled

processing requires one to use several cognitive domains at once rather than focusing on one

stimulus. Examples of assembled processing include performing mental rotations and applying

real world knowledge to oral conversations or during tasks of reading comprehension (Dennis et

al., 2006). The cognitive profile in SB results in children performing better on basic academic

skills (e.g., grammar and vocabulary, word recognition, and math facts; Dennis et al., 2006) that

tap associative processing skills and struggling with more complex academic skills (e.g., reading

comprehension, text-based inferences, and complex math operations; Dennis et al., 2006) that necessitate assembled processing.

As noted, individuals with spina bifida perform better on tasks of verbal achievement, showing higher levels of verbal IQ versus nonverbal IQ (Dennis et al., 2006). More specifically, research has shown that youth with SB perform well on tasks that involve word-level processing such as single-word reading, word recognition, word decoding, word meaning, and understanding common idioms. Moreover, youth with SB also perform comparably to TD peers on tasks that involve sentence level processing or deriving meaning from syntax (Barnes & Dennis, 1992; Barnes et al., 2014; Dennis & Barnes, 2010; Dennis et al., 2006). Youth with SB also show relative strengths in vocabulary development (Dennis et al., 2006).

However, youth with SB often struggle with more complex verbal skills that involve assembled processing such as fluency and comprehension of text (Dennis & Barnes, 2010; Dennis et al., 2006; English et al., 2010). In a study comparing reading comprehension ability between youth with SB and TD youth, English and colleagues found that the best reading comprehension performance for an adolescent with SB was similar to that of the lowest reading comprehension performance of a TD adolescent.

Youth with SB have also been found to struggle with nonverbal tasks, particularly those that involve assembled processing. Indeed, one study found that 50% of children with SBM who were not intellectually disabled have a math disability (Fletcher et al., 2005). Specifically, youth with SB have been found to struggle with complex mathematical operations that involve manipulation of numbers, fluency, and concept formation (Barnes et al., 2014; Dennis & Barnes, 2010). This set of relative weaknesses emerges because children with SB have been found to use

fewer mature math strategies than their TD peers (adding or multiplying rather than counting; Dennis et al., 2006). Nevertheless, youth with SB performed well on mathematical tasks that tap into their associative processing skills. Research has shown that math retrieval or numeration remains intact for individuals with SB (Barnes, Dennis, & Hetherington, 2004; Dennis & Barnes, 2010). Moreover, youth with SB also have relative strengths in performing exact calculations (Dennis et al., 2006).

A few studies have examined other areas of school functioning. Some studies have found that youth with SB perceive themselves as less academically competent than their same aged-peers (Appleton et al., 1994; Shields, Taylor & Dodd, 2008). This may be why one study found that youth with SB do not actively participate in the classroom as much as their same-aged peers (Peny-Dahlstrand, Krumline-Sundholm, & Gosman-Hedstrom, 2013). Nevertheless this negative self-perception may abate as youth with SB grow into adolescence (Holmbeck et al., 2010).

While youth with SB typically graduate high school (85%), they have lower rates college attendance (14.6%) than their typically developing peers (Dicianno et al., 2008). Holbein and colleagues (2016) also found than when comparing emerging adults with SB to their same aged peers, youth with SB were significantly less likely to have achieved the milestones of attending college or obtaining a full time job. The discrepancy in higher education is important to note because one study found that education was the best predictor of work participation in youth with SB, better than level of lesion, hydrocephalus, IQ, functional independence, and ambulation (van Melchelen et al., 2008).

The current literature has highlighted several factors that predict academic achievement in youth with SB. These include shunt status (Hommeyer et al., 1999), lesion level (Hetherington et al., 2006), socioeconomic status (Holmbeck et al., 2003; Lomax-Bream et al., 2007; Swartwout et al., 2010), cognitive functioning, and seizure status (Wasserman, 2014). Healthcare professionals, however, cannot intervene on the aforementioned factors. On other hand, current research has also highlighted areas in which intervention is possible. These areas include fatigue (Murray, 2017), attention (Holmbeck et al., 2003), executive functioning (Barnes et al., 2014), and parental educational aspirations for their child (Holmbeck et al., 2003). Nevertheless, another important secondary condition parameter, pain in SB, has yet to be explored, despite its prevalence, potential for negative impact, and potential for clinical intervention.

Pain in Spina Bifida

Recently research has begun to recognize the impact and prevalence of pain in SB (Clancy et al., 2005; Essner et al., 2014; Wagner et al., 2015). One study of children and adolescents with SB (ages 8 to 19 years) found that over half of their sample experienced pain at least once per week (Clancy et al., 2005), which is significantly higher than prevalence rates found in TD youth (Stanford, Chambers, Biesanz, & Chen, 2008). Moreover, youth with SB may be at risk for untreated pain because parents often underestimate their child's pain (Clancy et al., 2005).

Youth with SB typically experience musculoskeletal pain, headache, abdominal pain, and joint pain. Headache was found to be the most common form of pain in children with SB, with an incidence rate of chronic headache being more than twice the rate in the general population (8.5% vs. 4%; Stellman-Ward, Bannister, Lewis, & Shaw, 1997). Research regarding the

etiology of headaches in SB has been mixed; some suggest headaches are a result of shunt malfunction or infection (Stellman-Ward et al., 1997), while others have shown that chronic headaches often do not subside after shunt revisions (Edwards, Witchell, & Pople, 2003). Ambulation method may also cause pain symptoms for youth with SB; overuse of certain muscles necessary for using wheelchairs or crutches can cause significant pain (e.g. shoulder pain; Marge, 1994). Other common forms of pain include lower body pain due to tethered cord, a common problem for children with SB (Rimmer, Rowland, & Yamaki, 2007) and abdominal pain due to constipation (Sobus, 2008). Moreover, individuals with SB have been found to have spasticity (Sobus, 2008), neuropathy (Werhagen, Hultling, & Borg, 2010), and scoliosis (Roehrig, 2008), all of which are associated with pain symptoms. Finally, recent research has also found that lumbrosacral malformations that involve the 5th lumbar vertebra, a condition common to spina bifida, increases the risk of chronic lower back pain and disability (Kurt, Turkyilmaz, Dadali, Erdem, & Tuncay, 2016).

There is currently limited research on the psychosocial outcomes of pain in SB. Existing research has found that pain in SB is associated with quality of life (Bellin et al., 2013; Wood, Watts, Hauser, Rouhani, & Frias, 2009), depressive symptoms (Oddson et al., 2006) and social activity involvement and social competence (Essner et al., 2014). Although there is limited research on pain's association with psychosocial outcomes in SB, there is an extensive literature on pain's impact on psychosocial outcomes in typically developing youth.

<div align="center">**Pain and Academic Outcomes in Typically Developing Youth**</div>

Chronic pain is a common occurrence in children and adolescents. Conservative estimates of the prevalence of chronic pain in youth ranges from 20% to 35% (King et al., 2011;

Stanford et al., 2008). Moreover, research suggests that the prevalence of chronic pain in children is increasing (Bandell-Hoekstra et al., 2001; Sillanpää & Anttila, 1996). Common chronic pain conditions in youth include musculoskeletal pain, headaches, and abdominal pain (American Pain Society, 2012). Headache is the most common pain type, with an estimated prevalence rate of 23% (King et al., 2011). Chronic pain has been found to negatively affect multiple aspects of functioning, including school outcomes.

Research has demonstrated that youth with chronic pain experience high rates of absenteeism (Campo et al., 2002; Saps et al., 2009; Logan et al., 2008), have poorer grades (Arruda & Bigal, 2012; Campo et al., 2002; Rocha-Filho & Santos, 2014; Voerman et al., 2017), fail to complete school assignments (Bennett et al., 2000), and perceive themselves as less academically competent than their TD peers (Claar et al., 1999). Arruda and Bigal (2012) found that children with migraine were significantly more likely to perform below average than their TD peers. Rocha-Filho and colleagues (2014) also found that headache severity was associated with poor academic performance. Campo and colleagues (2002) too found that children (4 to 15 years old) who complained of recurrent pain had worse grades than children without pain. Parents of children with chronic pain have also reported that, after the onset of pain, their child's performance in school worsened (Logan et al., 2008). However, other studies have found that there is no association between pain and academic outcomes (Ho, Bennett, Cox, & Poole, 2009). Moreover, another study found that the association between pain and poor academic outcomes is only significant when self-perception of academic competence in low (Claar et al., 1999). Still, another study found that while adolescents and their parents believed that pain was interfering with youth school performance, this impression did not negatively affect their perceived

academic competence (Logan et al., 2008). I will now discuss cognitive load theory, the theoretical framework that underlies this as well as the following potential mediators of the association between pain and academic outcomes: attention and executive functioning.

Cognitive Load Theory: Pain as Extraneous Load

In 1988, John Sweller and colleagues proposed a learning-based theory called cognitive load theory (CLT). The basic premise of this theory is that humans have limited cognitive capacity and our ability to learn suffers when our cognitive capacity is overloaded. Therefore, learning is most successful when we use our cognitive capacity efficiently. This theory was meant to inform instructional design (Chandler & Sweller, 1991). CLT states that learning involves two primary mechanisms: selective attention and cognitive processing capacity. When one learns, one must both attend to specific stimuli and have space for those stimuli to reside before learning can move to long-term memory. Cognitive processing capacity can be overwhelmed when one is learning something that involves a high cognitive load or, in other words, something that requires a lot of material to be held in working memory at one time.

In this theory, cognitive load is determined by the task's intrinsic load, extraneous load, and germane load (Sweller, 1988). Intrinsic load refers to the nature of the task itself. Intrinsic load or how much material is involved in learning a particular task cannot be altered. Extraneous load refers to cognitive resources devoted to elements that do not contribute to learning (Debue & van de Leemput, 2014). Originally extraneous load was conceived of as the way in which material is presented to the learner, which could overwhelm their cognitive capacity without enhancing learning (Debue & van de Leemput, 2014). Finally, germane load refers to mental resources used to move information from short-term memory to long-term memory (Debue &

van de Leemput, 2014). Germane load adds to cognitive load and is not necessarily intrinsic to learning the task but enhances the learning process (Paas, Renkel, & Sweller, 2004). Intrinsic, extraneous, and germane load are additive, therefore, if intrinsic load is high, extraneous load must be lower to learn the material. However, if intrinsic load is low and extraneous load is high learning may not suffer because one's cognitive processing capacity is not yet being overwhelmed (Debue & van de Leemput, 2014).

Cognitive load theory has been successfully applied to several populations. These include nursing students (Fraser et al., 2012), professional development students (Naismith et al., 2015), multimedia education (Mayer & Moreno, 2003), and middle school geometry students (Mousavi, Low, & Sweller, 1995). Moreover, one study offered preliminary evidence, using fMRI data that suggests that areas of brain typically associated with working memory and attention, or the frontoparietal network, are activated more during higher load tasks (Howard et al., 2015). However, to date, only two studies have examined pain's impact on cognitive load (Moore, Eccleston, & Keogh, 2017; Seminowicz & Davis, 2007). These studies produced contradictory results, one suggesting that pain does not exert an influence on cognitive load (Seminowicz & Davis, 2007), while another suggests that it does exert influence but only for specific tasks (Moore et al., 2017). No studies to date have examined cognitive load in spina bifida. Nevertheless, there is extensive literature on the components of cognitive load theory, attention and executive functions, in both the pain and spina bifida literatures. Therefore, this study will expand the framework of the cognitive load theory by examining pain as a form of extraneous load in youth with spina bifida. This study proposed that pain overpowers attentional abilities and executive functions, thereby impeding academic performance. This proposed model is

rooted both in the cognitive load theory and was developed in light of current literature regarding

attention and executive functioning in youth with SB and in typically developing youth with

chronic pain.

Attention and Spina Bifida

Youth with spina bifida often have neurological deficits including inattention and

executive dysfunction (Rose & Holmbeck, 2007). Burmeister and colleagues (2005) found the

incidence rate of ADHD to be significantly higher in youth with SB than their TD peers (31% vs.

17%). However, this study also found that inattention problems are manifested differently for

youth SB. Contrary to the typical clinical manifestation of ADHD, youth with SB struggle with

focusing and shifting attention rather than sustaining attention (Burmeister et al., 2005).

Research has shown that youth with SB have a difficult time orienting toward the most important

information (Dennis et al., 2006; Brewer, Fletcher, Hiscock, & Davidson, 2001; Rose &

Holmbeck, 2007). This attentional profile reflects deficits in the posterior attention system or the

"bottom-up" attention network, which is responsible for orienting, focusing, disengaging, and

shifting attention (Swartout et al., 2008). However, the anterior attention system or "top down"

attention network that is responsible for sustaining attention remains relatively intact in youth

with SB (Rose & Holmbeck, 2007; Swartout et al., 2008), but is much more problematic in youth

with ADHD.

Research regarding the etiology of inattention in spina bifida has pointed to disease

specific and demographic factors. Midbrain malformations, such as tectal beaking and small

posterior volume, have been found to be associated with the attentional deficits found in spina

bifida (Dennis et al., 2006). The Chiari II malformation, which is found in most individuals with

spina bifida, has been linked to problems in orienting one's attention (Kulesz et al., 2015).

Research has also suggested that hydrocephalus and shunt-related surgeries may be responsible

for attentional deficits. Moreover, inattention in SB is also associated with higher lesion level

(Fletcher et al., 2005). With regard to demographic factors, Loss, Yeates, and Enrile (1998)

found that socioeconomic status accounted for a significant amount of the variance in attention in

a sample of children with and without spina bifida. These researchers also found that attentional

ability predicted academic achievement for youth with SB and in the control sample.

Executive Functioning in Spina Bifida

Relatedly, youth with SB have also been found to have deficits in executive functioning.

Specifically, research has shown that youth with SB have problems with cognitive flexibility,

abstract reasoning, visual planning, sequencing, and switching (Burmeister et al., 2005; Fletcher

et al., 1996; Hampton et al., 2011; Rose & Holmbeck, 2007; Tuminello et al., 2012). Youth with

SB also appear to struggle with metacognitive tasks or tasks that involve working memory, task

initiation, planning, organizing, and self-monitoring (Brown et al., 2008; Zabel et al., 2011).

Possible causes for executive dysfunction in spina bifida include parietal cortical anomalies,

decreased overall cortical surface areas, and reduction in cerebral white matter (Juranek et al.,

2008; Kulesz et al., 2015). Moreover, shunt related surgeries and a history of seizures have been

found to be associated with poor metacognition (Brown et al., 2008). In a longitudinal study

comparing youth with SB to a group of TD children, Tuminello et al. (2012) found that executive

dysfunction in youth with SB was associated with lower levels of autonomy and lower levels of

intrinsic motivation in school over time. Moreover, multiple studies have found attention and

executive functioning deficits to be a significant predictor of academic achievement in TD

children (Breslau et al., 2009; Pingault et al., 2011; Sasser, Beekman, & Bierman, 2015). Nevertheless, despite the links between inattention, executive dysfunction, and negative school outcomes, the current literature has not isolated precipitant or causal factors that would constitute potential areas for clinical intervention for youth with SB. Pain, a potential area for clinical intervention in this population, has also been implicated in research exploring causes of deficits in attention and executive functioning difficulties.

Pain in Relation to Attention and Executive Functioning in Typically Developing Youth

Humans are biologically and culturally hardwired to interpret pain as threatening and to prioritize escaping this threat. Therefore, pain is thought to monopolize limited cognitive resources, disrupting one's ability to attend to other stimuli (Eccleston & Crombez, 1999). Indeed, fMRI studies have demonstrated that regions of the brain involved in pain modulation are the same regions involved in decision-making, executive functioning, and selective attention and memory (Apkarian et al., 2009; Miller & Cohen, 2001; Seminowicz & Davis, 2007). Therefore, it is no surprise that chronic pain has been found to be associated with cognitive deficits, including deficits in attention and executive functioning. The current literature has found evidence for psychological and physiological differences between individuals with and without chronic pain regarding their attentional and executive functioning abilities (Moriarty, McGuire, & Finn, 2011).

While the literature on chronic pain and attention focuses primarily on adult populations, there is increasing interest in attention in children and adolescents with chronic pain conditions. One study, using event-related brain potentials (ERP), found that youth with chronic migraine have altered attentional processing in which pain related stimuli were processed more

readily than non-pain related stimuli (Zohsel, Hohmeister, Flor, & Hermann, 2008). Moreover, other studies have found both attentional and memory biases toward pain related words (Boyer et al., 2006; Koutantji, Pearce, Oakley, & Feinmann, 1999). Studies that have examined performance on measures of attention have suggested that pain, like spina bifida, may only affect certain types of attention. However, there is not as clear of a consensus as to which type of attention is most impacted by pain. Villa and colleagues (2009) found that children with migraine performed significantly worse on tests of visual attention compared to their same aged peers, suggesting that selective attention is affected by pain. These findings have been echoed by Mifflin and colleagues (2016) who found that adolescents with chronic pain differ from their TD peers on tasks of selective attention but do not differ on tasks of sustained attention. On the other hand, Riva et al. (2012) found that youth with migraine exhibited deficits in sustained attention but did not exhibit deficits in selective attention. There is currently not enough literature to support a claim that one type of attention is uniquely disrupted by pain for children and adolescents.

Research on attentional deficits in adults with chronic pain has been conducted in numerous pain populations including fibromyalgia, musculoskeletal pain, arthritis, and diabetic neuropathy (Dick, Eccleston & Crombez, 2002; Moriarty et al., 2011). This primarily adult literature has also not concluded that one type of attention is most affected by pain. Some studies did not differentiate the types of attention but concluded that pain generally disrupts attentional abilities (Calandre, Bembibre, Arnedo, & Becerra, 2002). Other studies have found that both selective and sustained attention are affected by pain (Dick et al., 2002). However, Oosterman and colleagues (2012) only found evidence for sustained attention deficits in adult chronic pain

patients. Others found that while chronic pain patients frequently report cognitive failure, objective assessment of attention did not indicate that pain was related to inattention (Dufton, 1989).

Research has suggested that higher order attentional processes or executive functions may be the most affected by chronic pain in adults (Moriarty et al., 2011). Eccleston (1994) found that pain only impeded adult performance on cognitive tasks when the tasks were very difficult. These tasks were thought to require higher order functions of executive functioning. These findings were replicated in other studies that found that pain only affected executive functions (Apkarian et al., 2004; Bosma & Kessles, 2002). Pain has been found to be negatively associated with inhibitory control (i.e., the ability to control one's attention, behavior, thoughts and/or emotions to override internal predisposition; Diamond, 2013; Legrain et al., 2009) and working memory (Berryman et al., 2013; Moriarty et al., 2011). Moreover, a recent meta-analysis of executive functioning and pain found that pain is negatively associated with attention-related shifting abilities, or the ability to move back and forth between tasks, an ability that is often used as a measure of cognitive flexibility (Berryman et al., 2014). There are overlapping neuroanatomical pathways between nociceptive and cognitive systems, thereby suggesting that executive functions and pain processes occur in the same neurological location (Abeare et al., 2010; Moriarty et al., 2011). Still, others have found no deficits in executive functioning for chronic pain patients (Mongini, Keller, Deregibus, Barbalonga, & Mongini, 2005; Scherder et al., 2008; Suhr, 2003).

There is comparably less literature on the effect of pain on executive functioning in children and adolescents. However, several studies have found associations between pain and

poor executive functioning in youth with chronic pain (Cruz, O'Reilly, Slomine, & Salorio, 2011; Mifflin, Chorney, & Dick, 2016; Weiss et al., 2017). Similar to findings in adult populations, these studies found that working memory is often negatively impacted by pain. This finding is important to note because a great deal of research suggests that poor working memory is associated with poor academic achievement (Bourke & Adams, 2003; Bull et al., 2008; Loosli, Buschkuehl, Perrig, & Jaeggi, 2012). Working memory has been found to predict specific areas of achievement such as mathematics (Bull et al., 2008), science (Gathercole et al., 2004), and reading (Loosli et al., 2012), as well as academic performance generally (Alloway et al., 2009; Bourke & Adams, 2003).

Other studies have found that youth with better executive functioning abilities have better pain-related coping skills (Hocking et al., 2011). Compas and Boyer (2001) suggested that children who have poor attentional control will have a harder time disengaging from their condition symptoms, thereby leading to poorer outcomes. Indeed, research has found that if one successfully employs executive functions while experiencing pain, the pain will be less distressing (Verhoeven et al., 2014). This suggests that when one uses one's attentional control abilities to focus elsewhere and disengage from the pain, the experience of the pain will be less bothersome. It is therefore not surprising that distraction has been found to be an effective therapy method for treating pain in youth (Chambers, Taddio, Uman, & McMurtry, 2009; Kleiber & Harper, 1999; Walker et al., 2006). On the other hand, attention to pain or the inability to disengage from pain has been found to increase the potency of pain symptoms and the degree to which pain results in functional disability in youth (Manimala, Blount, & Cohen, 2000;

Walker et al., 2006). Therefore, pain and attention to pain may be important modifiable condition parameters to consider when addressing cognitive functioning and academic outcomes.

<div align="center">**General Issues with Current Research**</div>

While the significance of pain in youth with spina bifida has recently garnered attention, research on the nature of pain's impact remains sparse. The current literature has not explored multiple domains that pain may affect, such as academic performance (e.g., Arruda & Bigal, 2012; Campo et al., 2002; Dick & Riddell, 2010; Gorodinzky, Hainsworth, & Weisman, 2011; Rocha-Filho & Santos, 2014; Voerman et al., 2017). Moreover, while research has demonstrated that youth with spina bifida often struggle academically, there have been few studies that have identified modifiable condition parameters that affect school functioning. Therefore, determining whether there is a relationship between pain symptoms and academic performance in youth with SB has significant clinical implications.

Further, research should also consider mediating factors that could explain this relationship. Two such factors, inattention and executive dysfunction, are often present in both spina bifida and pain populations. Moreover, attention and executive functioning have been linked to academic performance (Frazier, Youngstrom, Glutting, & Watkins, 2007; Massetti et al., 2008; Salla et al., 2016; Sheehan & Larocci, 2015). However, these factors have yet to be explored in the context of pain in spina bifida and have not been tested as possible mediating factors in the previously described pathway between pain and academic outcomes in pediatric pain populations. Furthermore, there is comparably less literature on pain's impact on attention and executive functioning in youth than in adults (Cruz et al., 2011; Dick & Riddell, 2010). Therefore, there are critical gaps in the literature on academic performance in youth with SB,

pain in youth with SB, and the impact of pain on cognitive functioning in youth with pain generally.

Finally, with regard to methodological concerns, there are no studies to date that examine pain's impact on academic performance longitudinally. Considering the potential for identifying predictive factors and potential long-term effects, research on pediatric pain and academic outcomes would benefit from using longitudinal designs (Holmbeck, Franks Bruno, & Jandasek, 2006).

The Current Study

The present study aimed to expand the current knowledge on academic performance in youth with spina bifida. Specifically, this study aimed to examine pain's potential to negatively affect academic performance in this population. This study also aimed to expand the framework of cognitive load theory by identifying pain as a type of "extraneous load" (Sweller, 1988). Moreover, this study aimed to increase awareness of the potential for pain to negatively impact the psychosocial functioning of youth with SB by adding to the limited literature on pain in SB. It is believed that the findings from this study will inform future research, as well as the development of evidence-based pain interventions aimed at improving school outcomes in this population.

The current study also aimed to address methodological issues that exist in studies to date using a multi-method, multi-informant, longitudinal research design. The use of a longitudinal design allows the present study to be grounded in a developmental framework, which is critical when examining chronic conditions (Holmbeck et al., 2006). Moreover, by using three time points the present study can examine more complex models, thereby increasing the potential

knowledge gleaned from this study. Finally, this longitudinal design allows for an examination of how academic performance in youth with SB changes overtime.

Study Hypotheses

The present study had two objectives. The first objective was to examine the relationship between pain and academic functioning in youth with spina bifida. It was hypothesized that greater pain symptoms would be associated with poorer academic performance (Hypothesis 1). This objective was examined cross-sectionally and longitudinally, with pain variables at Time 1 predicting academic performance at Time 1, Time 2, and Time 3 (see Figure 2).

The second objective of this study was to examine neurocognitive mechanisms that may explain the potential relationship between pain and poorer academic performance. It was hypothesized that attention would mediate the relationship between pain symptoms and academic performance (Hypothesis 2a). It was also hypothesized that certain executive functions (working memory, inhibition, cognitive flexibility) would mediate the relationship between pain symptoms and academic performance (Hypothesis 2b). Thus, increased pain would be associated with inattention and/or executive dysfunction that would, in turn, be associated with poor academic performance (see Figure 3).
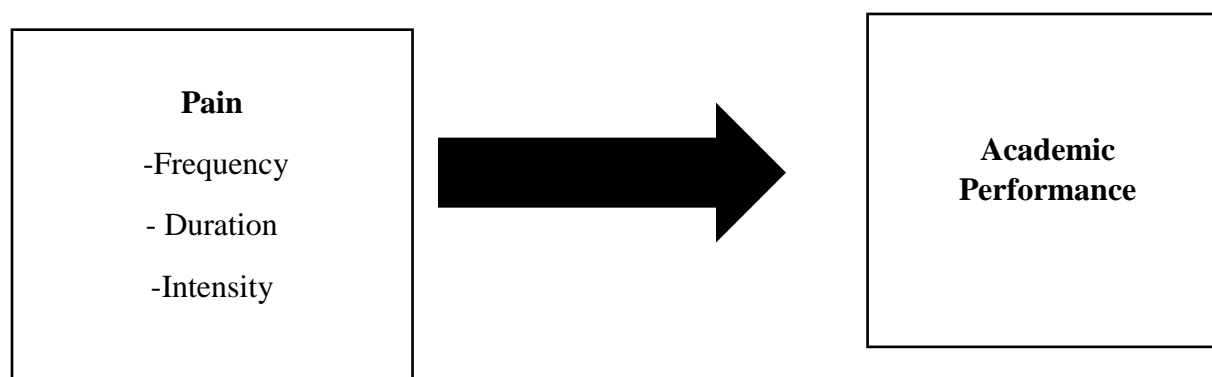
Figure 2. Model for Objective 1: The Association between Pain and Academic Performance
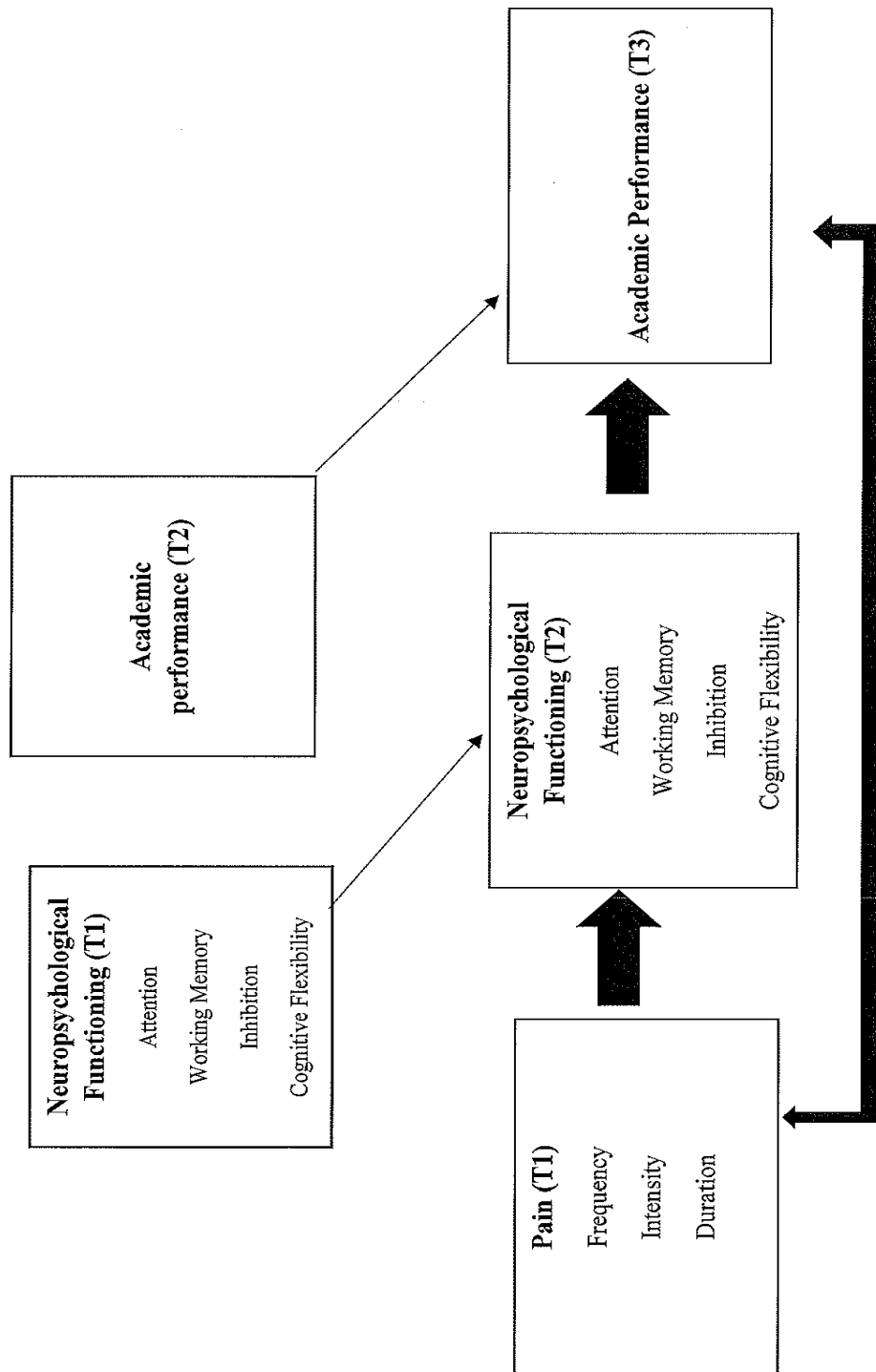
Figure 3. Model for Objective 2: Neuropsychological Functioning as Mediators of the Association between Pain and Academic Performance in Youth with Spina Bifida

CHAPTER THREE

METHODS

Participants

This study used archival data from an ongoing longitudinal study examining family and peer relationships, neuropsychological functioning, and psychological adjustment (see Devine, Holbein, et al., 2012; Devine, Holmbeck, et al., 2012; Psihogios & Holmbeck, 2013). The current study examined psychosocial functioning and neuropsychological functioning during the first three time points of this longitudinal study, with each time point spaced two years apart. Families of youth with SB were recruited from four hospitals and a statewide SB association in the Midwest. Families were recruited in person at regularly scheduled clinic visits or through recruitment letters. Interested families were screened by phone or in person by a trained member of the research team to determine if their child met the following inclusion criteria: (1) a diagnosis of SB (types included myelomeningocele, lipomeningocele, and myelocystocele); (2) age 8-15 years; (3) proficiency in English or Spanish; (4) involvement of at least one primary caregiver; and (5) residence within 300 miles of the laboratory (to allow for data collection at participants' homes).

During recruitment a total of 246 families were approached, of which 163 agreed to participate. However, 21 of the 163 families could not be contacted or later declined to participate, and two families did not meet inclusion criteria. The final sample included 140 families of children with SB (at Time 1, 53.6% female, $M_{age} = 11.40$; see Table 1).

Table 1. Youth Demographic and Spina Bifida Information at Time 1

	Total M (SD) or N (%)
Participants	140 (100%)
Age	11.32 (2.44)
Gender: male	64 (45.7%)
Spina bifida type	
Myelomeningocele	102 (72.9%)
Lipomeningocele	9 (6.4%)
Other	7 (6.2%)
Unknown/not reported	19 (13.6%)
Lesion level	
Thoracic	23 (16.4%)
Lumbar	72 (51.4%)
Sacral	43 (30.7%)
Unknown/not reported	2 (1.4%)
Shunt present	94 (75.2%)
IQ	85.68 (19.68)
Special education classroom	48 (34.3%)
Family SES	39.44 (15.90)

Procedure

The current study was approved by university and hospital Institutional Review Boards. Data were collected by trained undergraduate and graduate student research assistants during home visits that lasted approximately three hours. At Time 1, two separate three-hour home visits were conducted. For both Time 2 and Time 3, only one three hour home visit was conducted. For home visits with families who primarily spoke Spanish, at least one research assistant was bilingual. Prior to each home visit, informed consent from parents and assent from children were obtained. Parents also completed releases of information to obtain data from medical charts, health professionals, and teachers. During data collection, family members

completed questionnaires independently and participated in videotaped interaction tasks. The questionnaires were offered in both English and Spanish. Questionnaires that were only available in English were translated into Spanish by members of the research team who were native Spanish speakers. The questionnaires were counterbalanced to avoid order effects. Research assistants read questionnaires aloud to participants when requested or when the youth appeared to be having reading difficulties. Research assistants also completed neuropsychological testing of the child. The current study used youth-, parent-, and teacher -reported questionnaire data and neuropsychological performance data. Families received $150 and small gifts (e.g., logo t-shirts, pens, water bottles) as compensation for participation at each time point.

Measures

Covariates

  Demographics. At Time 1, parents completed a questionnaire reporting on family and youth demographic information. This questionnaire includes information on age, gender, race/ethnicity, income, education, and employment. The Hollingshead Four Factor Index of socioeconomic status was computed using parent's education and occupation, with higher scores indicating higher SES (Hollingshead, 1975).

  Youth illness severity. At Time 1, parents completed the Medical History Questionnaire (MHQ; Holmbeck et al., 2003), which asks questions about youth's disease-specific medical information including bowel and bladder functioning, ambulation method (i.e., ankle-foot orthoses (AFOs), knee-ankle-foot orthoses (KAFOs), hip-knee-ankle-foot orthoses (HKAFOs), wheelchair, or no assistance), medications, frequency of medical care, and surgery history. In addition to the MHQ, data were collected from medical charts to assess type of SB (i.e.,

lipomeningocele, meningocele, or myelomeningocele), shunt status, and lesion level (i.e., sacral, lumbar, or thoracic). These variables were used to compute an illness severity index based on membership in a specific group: shunt status (no = 1, yes = 2), myelomeningocele (no = 1, yes = 2), lesion level (sacral = 1, lumbar = 2, thoracic = 3), and ambulation status (no assistance/AFOs = 1, KAFOs/HKAFOs = 2, wheelchair = 3). Illness severity scores range from 4 to 10, with higher scores indicating higher levels of severity (see Hommeyer et al., 1999).

Youth Psychosocial Functioning

This study aimed to evaluate different domains of attention and executive functioning that might be affected by pain symptoms. In accordance with both the reviewed literature and the cognitive load theory (Sweller, 1988), the following areas were examined: (1) attention, (2) working memory, (3) cognitive flexibility, (4) inhibition. Youth attention and executive functioning was evaluated using questionnaires (parent and teacher report) and performance-based measures.

Attention. Parents and teachers completed the Swanson, Nolan, and Pelham Teacher and Parent Rating Scale version IV (SNAP-IV; Swanson et al., 2001). This is an 18-item measure of youth inattention, impulsivity, and hyperactivity. The items are from the DSM-IV (American Psychiatric Association, 1994) criteria for Attention-Deficit/ Hyperactivity Disorder (ADHD). The SNAP-IV is based on a 0 to 3 rating scale: Not at All = 0, Just A Little = 1, Quite A Bit = 2, and Very Much = 3. This measure yields two subscales: inattention and hyperactivity/ impulsivity. The *inattention* subscale was used for this study. This subscale demonstrated good internal consistency across reporters (mother, father teacher; T1: $\alpha = .73$; T2: $\alpha = .95$)

Executive functioning. Parents and teachers completed the Behavior Rating Inventory of Executive Functioning (BRIEF, Gioia, Isquith, Guy, & Kenworthy, 2000). This is a valid measures of executive functioning that yields eight sub-domains of executive function: Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor. This study used the *Working Memory Index, Shift Index,* and *Inhibition Index*. The Shift Index was used as a measure of cognitive flexibility and demonstrated adequate internal consistency. The Inhibition index was used as a measure of attention-inhibition. All indices used in this study demonstrated adequate internal consistency across reporters (mother, father, teacher): Working Memory (T1: α = .74; T2: α = .89); Shift (T1: α = .56; T2: α = .60); Inhibition (T1: α=.62; T2 α=.59). Higher scores indicate greater executive dysfunction.

Parents completed the Child Behavior Checklist and teachers completed the teacher version (Teacher Report Form, TRF; Achenbach & Rescorla, 2001). The CBCL is comprised of 118 items that describe behavioral and emotional problems, rated on a 0-2 Likert type scale (0= "not true" and 2= "very true"). The CBCL yields T-scores and percentiles for eight problem subscales (Anxious/Depressed, Withdrawn/Depressed, Somatic Complaints, Social Problems, Thought Problems, Attention Problems, Rule-Breaking Behavior, and Aggressive Behavior). The CBCL also yields DSM-oriented scales, including Affective Problems, Anxiety Problems, Somatic Problems, Attention Deficit/Hyperactivity Problems, Oppositional Defiant Problems, Conduct Problems, Sluggish Cognitive Tempo, Obsessive-Compulsive Problems, and Post-traumatic Stress Problems. This study used the *Attention problems* subscale from both the parent and teacher report. This subscale demonstrated adequate internal consistency across reporters for this study (mother, father, teacher; T1: α = .71; T2: α = .81).

Neuropsychological Performance Measures: Attention and Executive Functioning

During home visits, trained research assistants administered two subtests from the Cognitive Assessment System (CAS): Planned Connections and Number Detection. The CAS is an assessment battery designed to evaluate cognitive processing in children 5 through 17 years of age. The *Number Detection* (ND) subtest was used to assess attentional ability. Number Detection requires examinees to locate and underline specific numbers on a page containing distractor numbers (i.e., the same number in a different font.) Each item in Number Detection is scored for accuracy and total time. The raw score for Number Detection is the ratio of accuracy and total time, summed across all items. Raw scores were converted into age scaled scores. Higher scores indicate greater attentional abilities. Each subtest yields a scaled score with a mean of 10 and a standard deviation of 3. Number Detection has high internal reliability ($\alpha = .77$) and test-rest reliability ($r = .77$) across age groups (Naglieri & Das, 1997).

The Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003) was also administered during home visits to assess the cognitive ability of participants. This clinical instrument is used for children ages 6 years to 16 years and 11 months. Participants were administered the Digit Span and Symbol search subtests. This study used the *Digit Span* subtest to measure working memory. Digit Span includes two separate tasks: Digit Span Forward and Digit Span Backward. In Digit Span Forward the child repeats numbers aloud as they have been presented orally by the examiner. In Digit Span Backward the child repeats numbers in the reverse order of how they were presented orally by the examiner. Raw scores were converted into age scaled scores, with higher scores indicating greater working memory function. The Digit

Span subtest has good internal consistency ($r = .87$) and test-retest reliability ($r = .83$; Williams, Weiss, & Rolfhus, 2003).

Pain Symptoms

Youth reported on pain symptoms (e.g.. intensity, frequency, and duration) over the last three months on the Spina Bifida Pain questionnaire. Pain intensity is rated on a visual analogue scale with a 10 cm line ranging from 'no pain' to 'worst pain ever' (see Klepper, 1999; Palermo, Zebracki, Newman, & Singer, 2004). Pain frequency is measured on a 6-point Likert-type scale, ranging from '0-less than once a month' to '5-daily' (Palermo, Valenzuela, & Stork, 2004). Pain duration is measured on a 4-point Likert-type scale, ranging from '0- less than 1 hour' to '3 -all day' (Palermo, Valenzuela, et al., 2004).

Parents completed the Child Activity Limitations Interview (CALI; Palermo, Witherspoon, Valenzuela, & Drotar, 2004). This validated measure consists of questions about their child's functional impairment due to pain in the past three months. This survey asks about non-disease specific activities such as bathing, schoolwork, and riding in a car. Parents are asked to identify whether an activity is "difficult or bothersome because of discomfort/pain" (Yes, No N/A). If they respond "yes," the reporter ranks how difficult or bothersome the activity is on a five-point Likert scale, and how important the activity is for the child on a 5-point Likert scale. Internal consistency of this measure was excellent for this study (T1 mother report: α =0.97; T1 father report: α =0.96). This interview yields a composite score that represents parental perception of the impact of pain severity on their child's life.

Youth Academic Performance

  Academic competence. Teachers and parents completed the Parent/Teacher Rating Scale of Child's Actual Behavior (PRSCAB/TRSCAB) from the Harter SPPC Scale (Harter, 1985). This measure yields six subscales: Scholastic Competence, Social Acceptance, Athletic Competence, Physical Appearance, and Behavioral Conduct. This study used the *scholastic competence subscale* from teacher and parent report. This PRSCAB/TRSCAB asks the respondent to identify which of two statements best describes the youth (e.g., "My child is really good at his/her school work," or "My child can't do the work assigned"), and then to decide whether the statement is "really true" or "sort of true." Both the teacher and parent versions have shown adequate psychometric properties (Cole, Gondoli, & Peeke, 1998).

  In addition to the PRSCAB/TRSCAB this study also used the *school competence* subscale of the previously described CBCL from the parent report. This subscale consists of seven items in which a parent is asked to rate his/her child's performance in different subject areas (i.e., Reading, History, Arithmetic, Science, and three other categories) as "Failing," "Below Average," "Average," or "Above Average." The academic competence subscale composite (mother, father, and teacher report) demonstrated adequate internal consistency for this study (T1: $\alpha = .76$; T2: $\alpha = .85$).

  Academic achievement. The Wide Range Achievement Test 3 (WRAT3; Wilkinson, 1993) was administered to participants to measure basic skills of reading, spelling and arithmetic. The reading subtest requires examinees to recognize and name letters, and pronounce words out of context. In the spelling subtest, the examinee is asked to write his or her own name, and then to write letters and words dictated by the examiner. The Arithmetic involves counting,

reading number symbols, solving oral problems, and written computations. The WRAT3 yields

standard scores with a mean of 100 and a standard deviation of 15. The mean of the standard

scores for spelling, reading, and arithmetic was calculated for this study. The WRAT mean score

demonstrated excellent internal consistency for this study (T1: α =.92; T3: α =.91).

Academic performance. The Teacher Report Form (TRF; Achenbach & Rescorla, 2001)

from the CBCL also yields adaptive functioning subscales; the *academic performance* subscale

was used in this study. This subscale includes six items in which the teacher reports on

performance of the student in different subject areas. The teacher is asked to list the subject and

then rate the student's performance in that subject on a scale from 1 to 5 (1=far below grade

level, 3=at grade level, and 5=far above grade level.) For this study raw scores were used as

opposed to T-scores in order to more precisely characterize differences in academic performance

in this sample. The academic performance subscale demonstrated excellent internal consistency

(T1: α =.97; T2: α =.98; T3: α =.96).

Academic record. Teachers and parents completed the Grade Form in which they

reported on the youth's grades from his/her most recent report card. A mean score of grades in

science, social studies, English, and math was calculated for this study; mean scores for the grade

form demonstrated excellent internal consistency in this study (T1: α =.97; T2: α =.80; T3: α

=.91).

Academic motivation. Teachers reported on the Child Behavior Questionnaire (CBQ), a

measure developed for the CHATS study. This is a 67-item measure that assesses "emotional

health" and "social competence." Teachers rate the child's academic motivation, social skills,

peer acceptance, compliance, and disruptive behavior. This study used the 6-item *academic*

motivation subscale. This subscale asks teachers to rate how true certain statements are for the child (i.e., "this student is curious about things around him/her," "this student is motivated to do well in school") on a 5-point scale (1=never true for the child, 3=sometimes true for the child, 5=always true for the child). A composite score was calculated in which higher scores indicate higher academic motivation. The academic motivation subscale demonstrated good reliability for this study (T1: α =.80; T2: α =.80; T3: α =.80).

Statistical Treatment

Preliminary Analyses

Prior to testing the hypotheses, the psychometric properties of all measures were evaluated. Descriptive statistics were computed for all measures to examine basic distributional properties (see Table 2) and to assess for skewness and outliers, and to evaluate assumptions and missing data. To conserve power and reduce the potential number of analyses, data transformation and imputation techniques were used when appropriate. Associations between measures in which there were two reporters (e.g., mother-report, father-report) or methodologies (e.g., BRIEF Working Memory Index and WISC-Digit Span) were calculated using Pearson correlation coefficients. A criterion of $r \geq .40$ was used to determine which measures were be collapsed across reporters (Holmbeck, Li, Schurman, Friedman, & Coakley, 2002). If data were not significantly correlated, analyses were conducted separately. Cronbach's alpha coefficients were computed to measure associations between three or more informants (e.g., youth, mother, father, teacher) or methodologies (e.g. the CBCL for attention, the SNAP-IV, and the Number Detection from the CAS). If data had adequate internal consistency ($\alpha > .6$), composite scores

were created. However, if there was not significant agreement, analyses were be conducted

separately.

Table 2. Means and Standard Deviations of Pain, Neuropsychological, and Academic Variables

		Time 1		Time 2		Time 3	
	Variable	M	SD	M	SD	M	SD
Pain	Frequency	1.10	1.70	1.01	1.63	.88	1.45
	Intensity	2.93	3.13	2.22	2.54	2.67	2.39
	Duration	.49	.88	.58	.95	.57	.92
Working Memory	BRIEF (M)	1.81	.48	1.80	.53	1.75	.56
	BRIEF (F)	1.81	.47	1.81	.47	1.74	.55
	BRIEF (T)	1.87	.62	1.82	.58	1.82	.73
	WISC: DS	7.35	3.22	7.77	3.46	--	
Inhibition	BRIEF (M)	1.45	.44	1.32	.37	1.31	.34
	BRIEF (F)	1.42	.36	1.38	.42	1.31	.34
	BRIEF (T)	1.32	.45	1.30	.41	1.29	1.10
Cognitive Flexibility	BRIEF (M)	1.68	.44	1.60	.44	1.59	.56
	BRIEF (F)	1.63	.35	1.64	.39	1.56	.40
	BRIEF (T)	1.43	.48	1.40	.45	1.47	.46
Attention	SNAP (M)	2.06	.70	2.04	.73	1.99	.76
	SNAP (F)	1.99	.58	1.97	.64	1.95	.59
	SNAP (T)	2.22	.78	2.16	.83	2.11	.87
	CBCL (M)	5.23	3.91	4.77	3.88	4.63	4.52
	CBCL (F)	4.70	4.01	4.68	4.19	4.67	4.86
	CBCL (T)	6.54	4.76	5.80	5.22	5.80	5.42
	CAS: ND	6.13	3.37	5.88	3.03	--	
Academic	CBCL (T)	10.91	6.28	10.26	6.33	12.65	7.50
	WRAT	91.66	19.39	--		89.61	18.68
	Harter (M)	2.65	.70	2.71	.71	2.80	.73
	Harter (F)	2.75	.70	2.77	.66	2.44	.39
	Harter (T)	2.45	.89	2.56	.92	2.65	.88
	CBQ (T)	3.10	.78	3.16	.79	3.19	.77
	Record (T)	4.53	1.17	4.68	.96	4.60	1.07

Note. BRIEF=Behavior Rating Inventory of Executive Functioning; WISC: DS=Wechsler Intelligence Scale for Children-Fourth Edition: Digit Span; SNAP= Swanson, Nolan, and Pelham Teacher and Parent Rating Scale-IV; CAS: ND=Cognitive Assessment System: Number Detection; CBCL=Child Behavior Checklist; WRAT=Wide Range Achievement Test; CBQ=Child Behavior Questionnaire; M=mother-report; F=father-report; T=teacher-report

Primary Analyses

Youth age, SB disease severity, and SES was controlled for in all analyses, as all of these factors may impact neurocognitive functioning and academic performance.

Analytic plan for objective 1. A series of hierarchical multiple regressions were conducted to examine associations between pain symptoms at Time 1 and academic performance at Times 1, 2, and 3. Variables were entered in the following order: (Step 1) covariates-illness severity, age, SES; (Step 2) individual predictor (pain intensity, pain frequency, and pain duration). When running longitudinal regression analyses, independent variables were entered in the following order: (Step 1) Academic performance at Time 1 (for Time 2 outcome) or Academic Performance at Time 2 (for Time 3 outcome); (Step 2) covariates- illness severity, age, SES; (Step 3) individual predictor. Separate regressions were conducted for each predictor variable and outcome variable.

Analytic plan for objective 2. Preacher and Hayes' (2008) bootstrapping methods were used to determine the impact of pain symptoms at Time 1 on youth academic performance at Time 3, as mediated by attention and executive functioning at Time 2. Bootstrapping is currently the method of choice and is preferred over other methods such as the Sobel Test (Sobel, 1982), as bootstrapping is less conservative and reduces the possibility of Type II errors. This procedure produces an empirical approximation of the product of the estimated coefficients' sampling distribution constituting the direct path and percentile-based bootstrap confidence intervals (CIs and bootstrap measures of standard errors using 5000 resamples, with replacement, from the dataset [Preacher & Hayes, 2008]). When zero is not between the upper and lower bounds of the

confidence interval, it can be claimed, with 95% confidence, that the indirect effect is not zero, indicating a significant indirect effect.

For mediation models using bootstrapping methods, assuming a power of .80, and an alpha of .05, a sample size of 36 is required to detect large effect sizes, a sample size of 78 is required to detect medium effect sizes, and a sample of 558 is required to detect small effect sizes (Fritz & MacKinnon, 2007). Thus, the current study had enough power to detect medium or large effect sizes.

CHAPTER FOUR

RESULTS

Preliminary Analysis

All variables were examined for outliers, but none were identified. Moreover, all

variables were examined for skewness. A conservative approach was adopted in which variables

were considered skewed and were transformed if their skew was above 1.0. All pain variables at

all time points were transformed using square root transformations. Mother, father, and teacher

report on the BRIEF subscales of inhibition and cognitive flexibility were all skewed at all three

time points. Square root transformations were initially used to reduce skewness, however, these

variables remained significantly skewed, and therefore, natural log transformations were then

utilized. It should be noted that this study was unable to use the Child Activity Limitations

Interview (CALI) in analyses due both to a large amount of missing data and invalid responses,

which according to the scoring guidelines of the CALI would render the scores invalid. On the

CALI, parents answer three questions about 22 activities: (1) Is this activity difficult or

bothersome because of discomfort/pain (possible answers include: yes, no, N/A), (2) If yes, how

difficult or bothersome? (respondents answer on a 1-5 likert scale), 3) If yes, how important is

this activity for your child? (respondents answer on a 1-5 likert scale). Many parents circled

"N/A" but proceeded to then rate how difficult or bothersome the task was and how important it

was to their child. This response style could indicate that they misunderstood how to fill out the

questionnaire or that they believed that the listed activities were difficult for their child but not

due to pain. In either case, this study was unable to use these scores due to the N/A response to the first question. Further, according to Palermo, Witherspoon, et al. (2004) scores may be invalid if five or more responses are left blank. This was the case for the many of respondents, further complicating the use of this instrument in this study. Therefore, this study was unable to use parent report of youth pain on the CALI in the analyses, and consequently all of the analyses described below only used youth self-report of pain symptoms.

Attrition Analyses

The majority of families participated at all three time points ($N = 92$; 65.7%). However, some families who participated at Time 1 did not participate at subsequent time points ($N_{Time\ 1\ only} = 18$, 12.9%; $N_{Time\ 1\ \&\ Time\ 2} = 19$, 13.6%; $N_{Time\ 1\ \&\ Time3} = 11$, 7.9%). Youth who did not participate at Time 2 or Time 3 ($N=37$, 33%) did not significantly differ from youth who did with respect to gender, IQ, SES, illness severity, or youth reported pain symptoms. Further, there were no differences with respect to teacher, mother, or father reported inattention, attention problems (CBCL), inhibition (BRIEF), cognitive flexibility (BRIEF), or working memory (BRIEF). Moreover, no significant differences were found for teacher reported grades, academic performance (CBCL), and academic motivation (CBQ), as well as father and mother reported academic competence (Harter). Moreover, no significant differences were found with respect to youth performance on the CAS, WISC, or WRAT. However, youth who did not participate at Time 2 or 3 were significantly older at Time 1 compared to those who participated at all three time points ($M = 12.63$ [2.34] compared to 10.93 [2.35]). Youth who participated only at Times 1 and 3 (M=1.95, 0.46) also differed from youth who participated at all three time points (M=2.67, 0.68) on teacher reported academic competence.

Associations among multiple reporters of measures, and among multiple measures of a single construct were examined in order to determine whether composite scores could be created. Three or more reporters/scales were entered into reliability analyses as if they were single items (e.g., the "Attention Scale" included the mother, father, and teacher report on the CBCL and the SNAP, and the Number Detection subtest of the CAS). Results indicated that the following variables demonstrated adequate internal consistency at each time point, and therefore were averaged to create composite scores: mother, father, and teacher report of working memory as well as youth performance on Digit Span of the WISC (T1: $\alpha=.69$; T2: $\alpha=.76$) were averaged to create the composite working memory variable, mother, father, and teacher report of inhibition (T1: $\alpha=.62$; T2 $\alpha=.59$) and cognitive flexibility (T1: $\alpha=.56$; T2: $\alpha=.60$) were averaged to create the inhibition and cognitive flexibility composite variables, respectively, mother, father and teacher report of inattention (SNAP-IV), attention problems (CBCL), and youth performance on the number detection subtest on the CAS (T1: $\alpha=.78$; T2: $\alpha=.89$) were averaged to create the composite attention variable, and finally mother, father, and teacher report of academic competence (T1: $\alpha=.76$; T2: $\alpha=85$; T3: $\alpha=.73$) were averaged to create the composite academic competence variable.

Correlation Matrix

Prior to hypothesis testing, Pearson correlations were performed to examine relationships among pain, neuropsychological and academic variables, both cross-sectionally and longitudinally. No significant correlations were found between pain and neuropsychological variables, and pain and academic variables (see Table 3 and Table 4).

Table 3. Correlation Matrix of Independent Variables, Mediators, and Dependent Variables at Time 1

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Pain frequency	1											
2. Pain intensity	.59**	1										
	113											
3. Pain duration	.48**	.51**	1									
	119	112										
4. Working memory	.13	0	-.06	1								
	123	113	119									
5. Attention	.10	-.03	-.14	.82**	1							
	119	110	116	139								
6. Inhibition	.06	.02	.03	.53**	.51**	1						
	122	112	118	136	136							
7. Cognitive Flexibility	.17	.05	-.10	.34**	.33**	.47**	1					
	122	112	118	136	136	136						
8. Academic Performance	.06	.06	.19	-.38**	-.37**	-.11	.04	1				
	106	98	102	117	117	117	117					
9. Academic Achievement	-.05	-.01	.11	-.49**	-.44**	-.16	-.05	.62**	1			
	115	106	112	124	124	124	124	108				
10. Academic Motivation	-.08	.10	.15	-.65**	-.66**	-.28**	-.28**	42**	.31**	1		
	109	101	105	122	122	122	122	117	111			
11. Academic Competence	-.14	-.02	.15	-.68**	.62**	-.18*	-.14	.41**	.37**	.61**	1	
	121	111	117	135	135	135	135	117	123	122		
12. Academic Record	-.11	-.10	-.04	-.12	-.16	-.02	0	-.03	.16	-.10	-.03	1
	85	79	82	92	92	92	92	91	87	92	92	

Note. *p < .05, ** p < .01, ***p <.001.

Table 4. Correlation Matrix of Independent Variables (Time 1), Mediators (Time 2), and Dependent Variables (Time 3)

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Pain frequency	1											
2. Pain intensity	.59**	1										
	113											
3. Pain duration	.48**	.51**	1									
	119	112										
4. Working memory	.12	-.03	-.08	1								
(T2)	97	89	94									
5. Attention (T2)	.01	-.03	-.13	.87**	1							
	119	110	116	110								
6. Inhibition (T2)	.12	.01	.05	.55**	.57**	1						
	97	110	94	110	110							
7. Cognitive	.06	.07	.08	.27**	.35**	.33**	1					
Flexibility (T2)	97	89	110	110	110	110						
8. Academic	.08	-.05	.06	-.61**	-.52**	-.19	-.14	1				
Performance (T3)	57	50	55	59	62	59	59					
9. Academic	-.13	-.04	.13	-.65**	-.47**	.24**	-.03	.57**	1			
Achievement (T3)	86	78	83	86	95	86	86	58				
10. Academic	-.10	-.12	-.01	-.56**	-.47**	-.30*	-.08	.55**	.51*	1		
Motivation (T3)	64	57	62	66	71	66	66	62	67			
11. Academic	-.14	-.19	-.15	-.61**	-.49**	-.22	-.20	.43**	.36**	.61**	1	
Competence (T3)	81	72	78	80	89	80	80	62	76	71		
12. Academic Record	.23	.01	.14	-.24	-.27*	-.10	.05	.27*	.48**	.33*	.12	1
(T3)	54	47	52	55	58	55	55	57	54	58	58	

Note. *$p < .05$, ** $p < .01$, ***$p < .001$.

As expected, most neuropsychological variables were correlated with academic outcomes both cross-sectionally and longitudinally. Moreover, most neuropsychological constructs were significantly correlated with each other and most academic constructs were significantly correlated with each other (see Table 3 and Table 4).

Hypothesis Testing

Objective 1

A series of hierarchical multiple regressions were conducted to examine associations between pain symptoms at Time 1 and academic performance at Times 1, 2, and 3.

Time 1. Hierarchical multiple regressions were conducted to examine associations between youth reported pain variables at Time 1 and academic variables at Time 1 (reported by mother, father, and teacher, and assessed with youth performance on a test of academic achievement). For each analysis, SES, and illness severity were entered simultaneously as covariates in the first step. For analyses with academic record as the dependent variable, special education status at Time 1 (from mother report) was also included as a covariate in the first step. Pain variables were entered in the second step, with each predictor (pain frequency, intensity, and duration) run in separate regressions. At Time 1, pain frequency was not a significant predictor of academic performance (β=-.03, p=.80), academic motivation (β=.01, p=.94), academic competence (β=-.09, p=.40), academic achievement (β=-.09, p=.41), or academic record (β=-.18, p=.38). At Time 1, pain intensity also did not significantly predict academic performance (β=-.04, p=.73), academic motivation (β=.12, p=.31), academic competence (β=.01, p=.94), academic achievement (β=-.02, p=.83), or academic record (β=-.01, p=.96). Finally, at Time 1 pain duration also did not significantly predict academic performance (β=.19, p=.10),

academic motivation (β=.13, p=.25), academic achievement (β=.16, p=.13), or academic record (β=-.02, p=.87). However, pain duration at Time 1 was found to be significantly associated with academic competence at Time 1 in an unanticipated direction (β=.21, p=.04), such that greater pain duration was associated with greater academic competence. However, this finding is likely the result of suppression effect (i.e. one of the variables in the regression increased the predictive validity of another variable, thereby creating a statistical artifact; MacKinnon, Krull, & Lockwood, 2010) because the correlation between these two variables was not significant (r=.15, Table 3), therefore this result will not be interpreted further (see Table 5 for Time 1 results).

Time 2. Hierarchical multiple regressions were conducted to examine associations between youth reported pain variables at Time 1 and academic variables at Time 2. Variables were entered in the following order: one of the five academic outcomes at Time 1 was entered in Step 1, the covariates of age, SES, and illness severity were entered at Step 2, and one of the three pain predictors was entered in Step 3. For analyses with academic record as the dependent variable, special education status at Time 2 (from mother report) was also included as a covariate in the second step. Each predictor and outcome was run in separate regressions. Pain frequency at Time 1 did not significantly predict academic performance (β=.01, p=.92), academic motivation (β=.01, p=.93), academic competence (β=.05, p=.51), or academic record (β=-.11, p=.52) at Time 2. Pain intensity at Time 1 also did not significantly predict academic performance (β=-.21, p=.15), academic motivation (β=-.06, p=.68), academic competence (β= -.05, p=.54), or academic record (β=-.15, p=.54) at Time 2. Finally, pain duration was also not found to significantly predict academic performance (β=-.11, p=.38), academic motivation (β=

-.01, *p*=.92), academic competence (β=.00, *p*=.97), or academic record (β=-.27, *p*=.10; see Table

6 for Time 2 results).

Table 5. Summary of Regression Analyses for Pain Variables Predicting Academic Outcomes at Time 1 (Objective 1)

Variable	Step	*N*	*b*	β	*t*	*p*
Academic performance						
Pain Frequency	2	106	-.24	-.030	-.26	.80
Pain Intensity	2	98	-.27	-.04	-.34	.73
Pain duration	2	102	1.97	.19	1.67	.10
Academic Motivation						
Pain Frequency	2	109	.01	.01	.07	.94
Pain Intensity	2	101	.09	.12	1.02	.31
Pain duration	2	105	.15	.13	1.15	.25
Academic Competence						
Pain Frequency	2	121	-.08	-.09	-.85	.40
Pain Intensity	2	111	.01	.01	.07	.94
Pain duration	2	117	.24	.21	2.09	.04*
Academic Achievement						
Pain Frequency	2	115	-2.15	-.09	-.84	.41
Pain Intensity	2	106	-.48	-.02	-.21	.83
Pain duration	2	112	5.13	.16	1.54	.13
Academic Record						
Pain Frequency	2	85	-.18	-.12	-.89	.38
Pain intensity	2	79	-.01	-.01	-.06	.96
Pain duration	2	82	-.04	-.02	-.16	.87

Note. All predictor variables are measured at Time 1, and separate regression were run for each predictor. For cross-sectional analyses, the covariates of age, SES, and illness severity were entered at Step 1. For analyses in which the grade form (academic record) was used special education status at Time 1 (mother report) was also included as a covariate.

Table 6. Summary of Regression Analyses for Pain Variables Predicting Academic Outcomes at Time 2 (Objective 1)

Variable	Step	*N*	*b*	β	*t*	*p*
Academic performance						
Pain Frequency	3	76	.10	.10	.10	.92
Pain Intensity	3	70	-1.38	-.21	-1.46	.15
Pain duration	3	74	-1.18	-.11	-.89	.38
Academic Motivation						
Pain Frequency	3	81	.01	.01	.09	.93
Pain Intensity	3	75	-.05	-.06	-.42	.68
Pain duration	3	79	-.02	-.01	-.10	.92
Academic Competence						
Pain Frequency	3	97	.40	.05	.66	.51
Pain Intensity	3	89	-.03	-.05	-.61	.54
Pain duration	3	94	.00	.00	-.04	.07
Academic Record						
Pain Frequency	3	68	.13	.11	.65	.52
Pain intensity	3	62	-.14	-.15	-.63	.54
Pain duration	3	66	-.38	-.27	-.17	.10

Note. All predictor variables are measured at Time 1, and separate regression were run for each predictor. For longitudinal analyses, the academic outcome from the previous time point was entered at Step 1, the covariates of age, SES, and illness severity were entered at Step 2, and the predictor variable was entered in at Step 3. For analyses in which the grade form (academic record) was used special education status (mother report) at the time point of the dependent variable was also included as a covariate.

Time 3. Hierarchical multiple regressions were also conducted to examine associations between youth reported pain variables at Time 1 and academic outcomes at Time 3. Variables were entered in the following order: one of the five academic outcomes at Time 2 was entered in Step 1, the covariates of age, SES, and illness severity were entered at Step 2, and one of the three pain predictors was entered in Step 3. For analyses with academic record as the dependent variable, special education status at Time 3 (from mother report) was also included as a covariate in the second step. Each predictor and outcome was run in separate regressions. Pain frequency at Time 1 did not significantly predict academic performance (β=-.01, p=.95), academic motivation (β=-.14, p=.34), academic competence (β=-.05, p=.68), academic achievement (β= -.15, p=.22), or academic record (β=-.11, p=.60) at Time 3. Pain intensity also did not significantly predict academic performance (β=-.24, p=.30), academic motivation (β=-.26, p=.12), academic competence (β=-.10, p=.41), academic achievement (β=-.10, p=.43), or academic record (β=-.23, p=.37). Finally, pain duration was also not significantly associated with academic performance (β=.07, p=.70), academic motivation (β=.03, p=.84), academic competence (β=-.07, p=.54), academic achievement (β=.08, p=.53), or academic record (β=-.06, p=.78) at Time 3 (see Table 7 for Time 3 results).

Table 7. Summary of Regression Analyses for Pain Variables Predicting Academic Outcomes at Time 3 (Objective 1)

Variable	Step	N	b	β	t	p
Academic performance						
Pain Frequency	3	57	-.11	-.01	-.07	.95
Pain Intensity	3	50	-1.93	-.42	-1.07	.30
Pain duration	3	55	.95	.07	.39	.70
Academic Motivation						
Pain Frequency	3	64	-.13	-.14	-.97	.34
Pain Intensity	3	57	-.20	-.26	1.60	.12
Pain duration	3	62	.04	.03	.20	.84
Academic Competence						
Pain Frequency	3	81	-.03	-.05	-.41	.68
Pain Intensity	3	72	-.05	-.10	-.83	.41
Pain duration	3	78	-.06	-.07	-.62	.54
Academic Achievement						
Pain Frequency	3	86	-3.21	-.15	-1.18	.24
Pain Intensity	3	78	-1.03	-.10	-.42	.68
Pain duration	3	83	5.87	.20	1.65	.10
Academic Record						
Pain Frequency	3	54	-.78	-.11	-.53	.60
Pain intensity	3	47	-1.75	-.23	-.92	.37
Pain duration	3	52	-.62	-.06	-.28	.78

Note. All predictor variables are measured at Time 1, and separate regression were run for each predictor. For longitudinal analyses, the academic outcome from the previous time point was entered at Step 1, the covariates of age, SES, and illness severity were entered at Step 2, and the predictor variable was entered in at Step 3. For analyses in which the grade form (academic record) was used special education status (mother report) at the time point of the dependent variable was also included as a covariate.

Objective 2

Preacher and Hayes' (2008) bootstrapping methods were used to determine the impact of pain symptoms at Time 1 on youth academic performance at Time 3, as mediated by attention and executive functioning at Time 2. Results indicated no direct effects between the independent and dependent variables. However, consistent with cognitive load theory, attention and working memory were significantly associated with most academic outcomes longitudinally. Working memory deficits at Time 2 were significantly associated with academic outcomes at Time 3 including: academic performance (in a model with pain frequency: $N=54$, $b=-6.65$, $t=-5.61$, $p<.01$; in a model with pain intensity: $N=48$, $b=-6.30$, $t=-4.87$, $p<.01$; in a model with pain duration: $b=-6.56$, $t=-5.36$, $p<.01$), academic achievement (in a model with pain frequency: $N=78$, $b=-16.36$, $t=-7.24$, $p<.01$; in a model with pain intensity: $N=71$, $b=-16.69$, $t=-2.38$, $p<.01$; in a model with pain duration: $N=75$, $b=-16.61$, $t=-7.15$, $p<.01$), academic competence (in a model with pain frequency: $N=76$, $b=-.44$, $t=-5.42$, $p<.01$; in a model with pain intensity: $N=68$, $b=-.45$, $t=-5.42$, $p<.01$; in a model with pain duration: $N=73$, $b=-.45$, $t=-5.38$, $p<.01$), academic motivation (in a model with pain frequency: $N=60$, $b=-.55$, $t=-4.33$, $p<.01$; in a model with pain intensity: $N=54$, $b=-.56$, $t=-4.22$, $p<.01$; in a model with pain duration: $N=58$, $b=-.53$, $t=-4.10$, $p<.01$), and academic record (in a model with pain frequency: $N=51$, $b=-.53$, $t=-2.31$, $p=.03$; in a model with pain intensity: $N=45$, $b=-.51$, $t=-2.11$, $p=.04$; in a model with pain duration: $N=49$, $b=-.51$, $t=-2.19$, $p=.03$).

Attentional deficits at Time 2 were also significantly associated with academic outcomes at Time 3 including: academic performance (in a model with pain frequency: $N=54$, $b=-5.24$, $t=-4.38$, $p<.01$; in a model with pain intensity: $N=48$, $b=-5.14$, $t=-4.12$, $p<.01$; in a model with pain

duration: *N*=52*, b*=-5.33, *t*=-4.37, *p*<.01), academic achievement (in a model with pain

frequency: *N*=78, *b*=-14.53, *t*=-6.18, *p*<.01; in a model with pain intensity: *N*=71*, b*=-15.38,

t=5.94, *p*<.01; in a model with pain duration: *N*=75*, b*=-15.00, *t*=-6.07, *p*<.01). academic

competence (in a model with pain frequency: *N*=76, *b*=-.30, *t*=-3.81, *p*<.01; in a model with pain

intensity: *N*=68, *b*=-.33, *t*=-4.09, *p*<.01; in a model with pain duration: *N*=68*, b*=-.31, *t*=-3.87,

p<.01), academic motivation (in a model with pain frequency: *N*=60, *b*=-.36, *t*=-3.07, *p*<.01; in a

model with pain intensity: *N*=54*, b*=-.37, *t*=-3.08, *p*<.01; in a model with pain duration: *N*=58,

b=-.35, *t*=-2.97, *p*<.01), and academic record (in a model with pain frequency: *N*=51, *b*=-.52, *t*=

-2.42, *p*<.01; in a model with pain intensity: *N*=45, *b*=-.59, *t*=-2.65, *p*<.01; in a model with pain

duration: *N*=49, *b*=-.57, *t*=-2.57, *p*=.01).

Notably, inhibition deficits were only significantly associated with academic motivation

(in model with pain frequency as the predictor: *N*=60, *b*=-1.04, *t*=-2.13, *p*=.04; in model with

pain intensity as the predictor: *N*=54, *b*=-1.20, *t*=-2.40, *p*=.02; in model with pain duration as the

predictor: *N*=58, *b*=-1.24, *t*=-2.27, *p*=.03), such that greater deficits in inhibition were associated

with less academic motivation. Moreover, cognitive flexibility was not significantly associated

with any of the academic outcomes.

Exploratory Analyses

The cognitive load theory was originally created to inform instructional design for

teachers. Therefore, while this study conceptualized pain as a form of extraneous load that may

impact future performance in the classroom, this study's model may be best executed in a cross-

sectional design, rather than a longitudinal design. Therefore, certain meditational models were

run in which all variables were at Time 1. Variables chosen for these exploratory models were in

line with the cognitive load theory (attention and working memory). However, no model with pain frequency, intensity or duration demonstrated significant direct or indirect effects cross-sectionally.

As previously described, while research has not determined that one type of attention is most affected by pain, some of the literature regarding the relationship between pain and neuropsychological functioning has claimed that sustained attention may be the most important form of attention to examine (Oosterman et al., 2012; Riva et al., 2013). Moreover, the performance measures included in this study were measures of selective attention (CAS; Naglieri & Das, 1997) and working memory (WISC-IV; Wechsler, 1999). Therefore, this study added another neuropsychological performance measure, the Test of Every Day Attention for Children (Manly et al., 1999), a measure only given at Time 1 to examine potential cross-sectional mediations. The TEA-Ch is a standardized and normed clinical battery for children that assesses many forms of attention, including sustained attention. The TEA-Ch has two sustained attention subtests, *Score!* and *Score DT*. *Score!* requires a child to listen and count the number of "scoring sounds" on an audiotape. In *Score DT* a child is asked to listen for and count the number of "scoring sounds" on an audiotape while simultaneously listening for the name of an animal in a news broadcast. Pain frequency at Time 1 was found to be significantly correlated with *Score DT* (N=114, r=-.19, p=.05). However, Pain frequency was not significantly correlated with *Score!* (N=115, r=.05, p=.60). Nevertheless the two subtests are significantly correlated with each other (N=122, r=.47, p<.01). Therefore, meditational models were run using both a sustained attention composite score (*Score!* and *Score DT*) as the mediator and using just the score from the *Score DT* subset as the mediator. As expected, the mediations run with pain

frequency at Time 1, the sustained attention composite score at Time 1, and academic outcomes at Time 1 had no significant direct or indirect effects. Further, only one meditational model using just the *Score DT* subtest demonstrated a significant indirect effect; greater pain frequency was found to be associated with worse scores on this subtest, which in turn was associated with worse scores on the WRAT achievement test at Time 1 (*N*=110, *b*=-1.32, *se*=.67, *z*=-1.98 *p*=.05).

CHAPTER FIVE

DISCUSSION

Research has shown that youth with SB struggle more academically than TD youth
(Holmbeck et al., 2003; Holmbeck et al., 2010). However, few studies to date have identified
modifiable condition parameters associated with academic performance in this population. Due
to medical innovations, life expectancy in SB has increased (Bowman, McLone, Grant, Tomita,
& Ito, 2001). With this increased life expectancy, so too has there been an increase in research
that focuses on developing skills that are critical for fostering autonomy and increased quality of
life (e.g., Driscoll, Buscemi, & Holmbeck, 2018; Murray et al., 2015; Stern, Driscoll, Ohanian,
& Holmbeck, 2018). In recent years, pain has been increasingly recognized as an important
symptom to examine in youth with SB. It is associated with multiple psychosocial outcomes
(e.g., quality of life, Bellin et al., 2014; social competence, Essner et al., 2014; depressive
symptoms, Oddson et al., 2006), but has yet to be examined with regard to neuropsychological
functioning or academic performance. Therefore, this study sought to examine whether pain was
associated with poor neuropsychological functioning and/or academic performance in order to
inform future interventions. Due to research that has found significant associations between pain
and neuropsychological functioning (Cruz et al., 2011; Mifflin et al., 2016; Weiss et al., 2017),
as well as research that has found significant associations between neuropsychological
functioning and academic performance (Bourke & Adams, 2003; Bull et al., 2008; Loosli et al.,
2012), this study sought to test a meditational model that included all of those constructs.

Moreover, this meditational model was rooted in the cognitive load theory; a learning theory that hypothesizes that disruptive elements (e.g., extraneous load) can hinder the retention of information (i.e., neuropsychological functioning, namely working memory and attention), and consequently inhibit the learning process (Sweller, 1988). This study hypothesized that pain symptoms (e.g., frequency, intensity, duration) would interrupt one's ability to attend to information and reduce one's capacity to retain information before moving to long term memory (i.e., becoming material that is "learned"), resulting in poorer academic performance.

However, this study did not find any significant indirect effects for any of the three pain symptoms, four neuropsychological constructs, and five academic outcome variables in the proposed longitudinal mediation models. Further, this study only found one direct association between pain symptoms and academic performance, a cross-sectional relationship that was contrary to the hypotheses of the study (i.e., longer pain duration at Time 1 was associated with more academic competence at Time 1), which could be attributed to suppression effects. Exploratory analyses identified only one significant cross-sectional model with an indirect effect (i.e., the meditational model with pain frequency, the Score DT subtest of the TEA-Ch [sustained attention with a distractor], and Academic achievement all at Time 1). However, consistent with cognitive load theory, working memory and attention at Time 2 were negatively associated with all academic outcomes at Time 3, indicating that these two constructs may be best examined in an alternate meditational model in the future (e.g., a model with sleep as the independent variable). However, inhibition demonstrated only one association (academic motivation) and cognitive flexibility demonstrated no associations with academic outcomes, indicating that some executive functions may be more salient for academic success than other executive functions.

This finding may be useful to consider when developing an academic intervention for this population in the future.

These null findings were surprising given the reviewed literature that demonstrated significant associations between pain and academic performance (Arruda & Bigal, 2012; Campo et al., 2002; Rocha-Filho & Santos, 2014; Voerman et al., 2017) as well as pain and neuropsychological functioning (Cruz et al., 2011; Mifflin et al., 2016; Weiss et al., 2017). The results of the current study may imply: (1) Aggregating the performance and questionnaire measures of neuropsychological functioning as well as aggregating across reporters may have obscured some relationships between pain and neuropsychological functioning, (2) Due to the unique neuropsychological profile in this population, these results may indicate that, despite significant associations found between pain and executive functions chosen for this study (e.g., working memory, inhibition, cognitive flexibility) in other pediatric populations, these constructs may not be significantly associated with pain in this population, and/or (3) Other executive functions, such as planning or organizing, may be more strongly associated with pain symptoms in SB. Moreover, in light of the unusual finding with the TEA-Ch, in which one sustained attention subtest was significantly associated with pain frequency and the other was not, it may be important to consider the content of *Score!* vs. *Score DT*. Specifically, *Score!* requires that the listener identify a number of "scoring sounds" during a recording, tapping into sustained attention. *Score DT* requires the listener to not only count the number of "scoring sounds" but also listen for an animal name, thereby necessitating strategic sustained attention, and potentially higher order attentional processes such as planning. Therefore, given the increased complexity of *Score DT,* this result may echo Eccleston (1994) and Moore, Keogh, and Eccleston (2012),

which both found that pain only impeded performance on cognitive tasks that were considered very difficult.

With regard to the nonsignificant results found between pain and academic performance, it may be important to consider that one prior study found that pain was negatively associated with self-perception of academic competence but was not associated with actual performance (Claar et al., 1999). Therefore, it is possible that youth with SB who experience pain may perceive themselves as less academically competent; however, it was not possible to examine this potential relationship in this study because youth self-report measure of academic competence was not available.

The lack of significant results may also suggest that the measure used to assess youth pain did not truly capture this population's experience with pain symptoms. Moreover, these null results may indicate a lack of variability, lack of stability, or a floor effect for the pain variables. The psychometric properties of this measure indicated that the distribution was positively skewed; therefore, pain variables were transformed for analyses. Performing this transformation may have reduced the amount of variability and therefore reduced our ability to find significant associations. Also, we were unable to use the parent report of youth pain (CALI) due to a high rate of N/A responses. This is particularly problematic because the current literature recommends that the assessment of pediatric pain involve both youth and parent report (Cohen et al., 2008). Moreover, the lack of parent report made analyzing the effect of pain in this population challenging since parents of youth with cognitive deficits are usually included as respondents when assessing children's pain symptoms (Breau & Burkitt, 2009). Therefore, cognitive deficits

may have impaired the participant's ability to understand and report their pain, leading to an underestimation or underreporting of pain symptoms.

Moreover, while the Spina Bifida Pain Questionnaire (SBPQ) includes questions commonly found in validated pain measures (see Klepper, 1999; Palermo, Zebracki, et al., 2004), it has not been validated with youth with SB. Given the complexity of this condition, accurate assessment of pain in this population may necessitate developing a measure that is tailored to the experience of pain in SB, rather than using a measure that is based off of the experience of pain commonly observed across multiple pediatric populations. This measure might include questions that cue the participant's memory of SB specific pain such as pain associated with catheterization, pain associated with using crutches or braces, pain associated with using a wheelchair, and headaches associated with shunt malfunctions and hydrocephalus. Moreover, several questions on the SBPQ are worded in such a way that might have confused the participants or influenced their responses as the participant is asked to examine their experience of pain *due to spina bifida* (e.g., "How often do you experience pain due to spina bifida?"). The addition of the phrase "due to spina bifida" is important to note for two reasons: (1) this wording may have generally confused the respondent, and (2) this wording may have made the participant think about their pain symptoms in relation to all of their other secondary condition parameters, which may have led the respondent to report their symptoms as mild because they may consider their pain symptoms as less impactful compared to other difficulties they face (e.g., catheterization, bowel programs), which interrupt their daily activities in a significant manner. Pain, on the other hand, can function in an insidious manner, affecting one's

functioning subtly or compounding other issues that are already present (e.g., reducing social

activity [Essner et al., 2014], increasing in internalizing symptoms [Oddson et al., 2006], etc.).

However, these null findings may also indicate that pain symptoms are not the most

important factors to consider with regard to neuropsychological functioning or academic

performance in this population. Murray (2017) found that fatigue in youth with SB was

negatively associated with both neuropsychological functioning and grades. Therefore, given

these associations, it is possible that fatigue→neuropsychological functioning→academic

performance would prove to be a stronger meditational model than the model proposed in the

current study. Indeed, a future study could easily adopt the cognitive load theory with the

aforementioned model, identifying fatigue as "extraneous load." Another important construct to

consider with regard to neuropsychological functioning and academic performance is

internalizing symptoms. Indeed, research has shown that internalizing symptoms are strongly

associated with neuropsychological functioning (Han et al., 2016; Lennon et al., 2015; Stern et

al., 2018) and academic performance (Hishinuma, Chang, McArdle, & Hamagami, 2012;

Weidman, Augustine, Murayama, & Elliot, 2015). Therefore, given these associations, as well as

recent findings that internalizing symptoms mediate the relationship between executive

functioning and medical autonomy in youth with SB (Stern et al., 2018), one might consider

examining whether the association between executive functioning and academic performance is

also mediated by internalizing symptoms. Moreover, internalizing symptoms have found to be

associated with social competence in this population (Essner et al., 2014), a skill frequently

associated with academic success (Bagwell, Newcomb, & Bukowski, 2008; Birch & Ladd,

1996); therefore future research may also consider examining relations among internalizing

symptoms, social competence, and academic performance in this population.

Finally, these findings may have emerged as a consequence of this study's statistical

approach. In longitudinal analyses, the mediators and dependent variables from the previous time

point were included as covariates. This reduced some of the variability, thereby reducing our

ability to find significant associations. Moreover, multiple reporters and methodologies were

used to avoid common method variance; however, this too may have reduced this study's ability

to find significant associations. While the composite variables achieved appropriate internal

consistency, previous studies using this data set have found that teacher report often differs

significantly from mother and father report and that significant associations may only be found

with one or two of the possible reporters (e.g., Essner et al., 2014; Driscoll et al., 2018; Lennon

et al., 2015; Stern et al., 2018).

Strengths, Limitations, and Future Research

This study has several strengths. First, this study sought to expand the limited knowledge

on pain in youth with SB, the impact of pain on cognitive functioning (i.e., executive functioning

and attention) in youth generally, and on modifiable factors associated with academic

performance in this population. Second, this study used multiple reporters (i.e., youth, parent,

and teacher) and methodologies (i.e., questionnaire and performance measures). Third, this study

employed a longitudinal design, which allows one to identify predictive factors and associations

with potential long-term effects (Holmbeck et al., 2006), and allows for consideration of

developmental changes in childhood and adolescence (Kelly et al., 2008). Finally, this study was

rooted in a theoretical framework (cognitive load theory; Sweller, 1988).

However, there are several limitations of the current study, which should inform future research. First, in all longitudinal analyses the sample size was small due to the portion of the sample who were over 18 at Time 3 and not included in analyses because academic performance data were not collected for these participants. Second, this study relied heavily on teacher data, for which there was a significant amount of missing data. Third, this study did not include multiple reporters of youth pain, which runs contrary to both research and clinical recommendations (Breau & Burkitt, 2009; Cohen et al., 2008; Holmbeck et al., 2006). Fourth, attrition analyses revealed that youth who participated only at Time 1 and Time 3 had poorer academic competence (teacher report) compared to youth who participated at all three time points. While the attrition analyses revealed no other differences (apart from age), this may indicate that participants who were struggling more academically may not have participated at all three time points, thereby limiting this study's ability to draw conclusions. Fifth, this study was not able to examine one of the academic constructs fully, academic competence, because this study did not have youth self-report of academic competence. In light of previous research that identified associations between pain and youth perception of academic competence (Claar et al., 1999), this may be an important piece of the narrative for future research to explore. Finally, while there are many advantages to using a longitudinal design, future research should consider whether cognitive load theory might be best conceptualized using a shorter-term longitudinal design (i.e., data are gathered in increments that are shorter than two years apart), due to the more immediate nature of the mechanisms involved.

Conclusions and Clinical Implications

The results of the current study have important implications for clinical work with youth with SB. First, while youth with SB are at-risk for both poor academic performance and chronic pain, it appears that these two vulnerabilities may not be related. Therefore, given the importance of academic performance for future independence (van Melchelen et al., 2008), and physical and mental health (Molla et al., 2004; Topitzkes et al., 2009; Winkleby et al., 1992), it is crucial that research identify factors that impact academic performance for youth with SB. Moreover, it is also of the utmost importance that research continues to examine the potential long-term ramifications of pain in this population in order to improve quality of life for individuals with SB throughout adolescence and into adulthood. Second, while previous research has identified associations between executive functioning and academic performance in this population, the results of this study indicated that certain executive functions may be more closely related to academic performance than others (i.e., working memory and attention vs. inhibition and cognitive flexibility). This finding should direct clinicians to potentially prioritize providing supports for specific executive functioning deficits if their intervention is focused on academic performance. Further, this finding is in line with cognitive load theory, thereby encouraging future researchers to examine other potential factors that drive, moderate, or mediate (i.e., sleep, internalizing symptoms, social competence) this relationship to develop a clinical intervention. Finally, a SB-specific pain measure that focuses on pain common in this population should be developed and validated to fully assess the impact of pain for youth with SB.

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VITA

Diana Ohanian is a doctoral student at Loyola University Chicago studying clinical psychology with a specialty in child, adolescent, and family issues. She received her B.A. in history from The College of William and Mary in 2012, graduating magna cum laude. During her time as an undergraduate at William and Mary, she received a Dintersmith research award and the William Ebert Fraley Award. After graduating, Diana received her M.A. in French history at the University of Chicago where she received a Foreign Language and Area Studies Fellowship (Title VI). Diana's history master's thesis examined a French humanitarian organization that rescued and rehabilitated Jewish children during World War II. This project sparked her interest in power of early intervention and the importance of promoting self-efficacy in the face of extreme adversity. Subsequently, Diana transitioned to studying pediatric chronic fatigue syndrome as a research assistant at DePaul University's Center for Community Research. Through her work in this position, she developed a strong interest in pediatric psychology. In 2016, Diana happily joined the Chicago Healthy Adolescent Transition Study at Loyola University led by Dr. Grayson Holmbeck. As a part of this lab she has worked on projects related to pain, neuropsychological functioning, parenting, medical autonomy, self-management, and culture and religion in youth with spina bifida. Diana's master's thesis examined the relation between pain, neuropsychological functioning, and academic performance in youth with spina bifida.