NOISE SENSITIVITY AND DISTRACTION IN YOUTH WITH ADHD: 
THE ROLE OF INDIVIDUAL DIFFERENCE FACTORS AND NOISE TYPES

By

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Abstract

Noise is a prevalent feature of many academic environments. Research examining the impact of noise on the cognitive performance of children with Attention-Deficit/Hyperactivity Disorder (ADHD) has demonstrated a positive effect of white noise and an adverse effect of silence/speech. These results are consistent with the Moderate Brain Arousal (MBA) model of ADHD, in which stimuli that evoke moderate arousal lead to improved performance over noises that are under- or over-stimulating. The present dissertation aims to investigate the noise sensitivity and preferences of adolescents with \((n = 52)\) and without ADHD \((n = 51)\), and the impact of noise on the academic performance of youth with ADHD.

First, participants completed a questionnaire examining their levels of noise sensitivity. Youth with ADHD reported higher levels of noise sensitivity than their peers without ADHD, and noise sensitivity was significantly associated with gender and youth-reported inattention and hyperactivity/impulsivity. Second, a subset of participants \((n = 16, \text{half with ADHD})\) completed an interview examining their noise preferences while studying. The responses of youth with ADHD indicated a preference for some noise versus no noise during studying, and difficulties studying in the presence of conversation. In contrast, youth without ADHD did not report a consistent preference for background noise.

The third study examined the effects of two noises (babble and white noise) relative to a no noise condition on reading and writing tasks for youth with ADHD. Youth were also asked to rate the perceived difficulty of each task. Planned contrasts revealed that participants in the
white noise condition read the passage in less time and wrote more words in their composition compared to participants in the other conditions, though white noise did not improve reading and writing accuracy. The contrasts also revealed that the participants in the babble condition rated the tasks as more difficult than those in the no noise condition.

Overall, the findings provided some support for past research and the MBA model. The results also highlight the need for further investigations of noise sensitivity and the effects of noise on academic measures in youth with ADHD. Educational and clinical implications are discussed.
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List of Abbreviations

ADHD=Attention-Deficit/Hyperactivity Disorder
ANOVA=Analysis of variance
APA=American Psychiatric Association
CELF=Clinical Evaluation of Language Fundamentals
CFA=Confirmatory factor analysis
CFI=Comparative fit index
CHADD=Children and Adults with Attention Deficit Disorder
CIHR=Canadian Institutes of Health Research
CPT=Continuous Performance Task
CTOPP=Comprehensive Test of Phonological Processing
CWS=Correct writing sequences
DSM=Diagnostic and Statistical Manual of Mental Disorders
EF=Executive functioning
ICC=Intraclass correlation coefficient
IEP=Individual Education Plan
IQ=Intelligence quotient
ISE=Irrelevant speech effect
LD=Learning disability
LDAO=Learning Disabilities Association of Ontario
MBA=Moderate Brain Arousal
OWLS=Oral and Written Language Scales
PAL=Process Assessment of the Learner
PCWS=Proportion of correct writing sequences
REB=Research ethics board
RMSEA=Root mean square error of approximation
QRI=Qualitative Reading Inventory
SART=Sustained Attention to Response Task
SRMR=Standardized root mean-square residual
SR=Stochastic resonance
TOMAL=Test of Memory and Learning
TORC=Test of Reading Comprehension
TOWRE=Test of Word Reading Efficiency
VR=Virtual reality
WASI=Wechsler Abbreviated Scale of Intelligence
WISC=Wechsler Intelligence Scale for Children
WJ-III ACH=Woodcock Johnson Tests of Achievement
WM=Working memory
WMTB-C=Working Memory Test Battery for Children
CHAPTER ONE

Introduction and Literature Review
1.1 Introduction

Noise is a prevalent feature in many academic learning environments despite efforts to control noise levels by school staff and administration (Enmarker & Boman, 2004). As students often add selected background noises to the mix (e.g., television, music) while undertaking academic tasks such as homework completion and studying at home (Patton, Stinard, & Routh, 1983), it is evident that a considerable amount of academic work is completed in the presence of background noise. This may not be an optimal choice as background noise may have a negative impact on cognitive and academic functioning by causing distraction from the task at hand.

Given that youth with high levels of inattention report more problems with distraction and concentration than their typically developing peers (Connors, Connolly, & Toplak, 2012), it is possible that noise may be even more bothersome to students with Attention-Deficit/Hyperactivity Disorder (ADHD). ADHD is a behaviour disorder consisting of three presentations: predominantly inattentive, predominantly hyperactive-impulsive, and combined (American Psychiatric Association [APA], 2013). A specific ADHD diagnosis is given based on whether criteria are met for the inattentive symptom list, the hyperactive/impulsive symptom list, or both symptom lists in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; APA, 2013). For example, in order to receive a diagnosis of ADHD-predominantly inattentive presentation, a child or youth (under the age of 17) needs to demonstrate six or more of the symptoms listed for inattention. These symptoms include: failing to give close attention to detail or making careless mistakes in work, difficulty sustaining attention in tasks, not listening when spoken to directly, not finishing work or following directions, difficulty with organization, avoiding tasks that require sustained mental effort, losing things, being easily distracted or having unrelated thoughts, and being forgetful. To receive a diagnosis of ADHD, several of these symptoms must be present before the age of twelve and they must be present in more than
one setting, such as at home and at school. Accordingly, distractions from environmental stimulation, and the accompanying difficulties with sustaining focus, are key diagnostic features of ADHD.

Prevalence estimates indicate that approximately 6 to 7% of children and adolescents meet criteria for ADHD (Willcutt, 2012), with a lifetime prevalence rate of about 9% for adolescents in one study (Merikangas et al., 2010). It has also been estimated that the number of ADHD symptoms declines with age, such that the disorder remits in some adolescents who were previously diagnosed; on the other hand, impairment appears to remain stable or even increase into adolescence for youth who still exhibit some symptoms of ADHD (Sibley et al., 2012), suggesting that even those adolescents with a sub-threshold symptom level would experience significant difficulties in many domains, including academic, cognitive, and social functioning. Further, more recent research within a developmental perspective suggests that ADHD often persists into adulthood for many children diagnosed with ADHD, though the clinical presentation may vary over time, from the preschool years (e.g., extreme hyperactivity), to the school-age years (e.g., diminishing hyperactivity with impairments in attention and goal-directed behaviour), to later adolescence and adulthood (e.g., disorganization and forgetfulness; Halperin, Bedard, & Berwid, 2010). Such changes in symptom expression are related to both cognitive and brain maturation in the individual, as well as changes in social and cognitive demands in the environment, across the lifespan (Campbell, Halperin, & Sonuga-Barke, 2014). Thus, even though they may experience greater development of cognitive processes (e.g., executive functioning skills) that would help ameliorate attention difficulties, adults with ADHD would still exhibit difficulties with functioning in social and occupational domains due to increased demands for independent functioning later in life. For example, adults with ADHD may be even more likely to experience detrimental effects of communication noise in open-plan
offices than adults without inattention, as well as other negative effects of noise observed with adults in general (e.g., increased risk of accidents/injuries in noisy occupational environments, increased aggression after exposure to loud noises at bars and nightclubs; Banbury, Macken, Tremblay, & Jones, 2001). Given the nature of the diagnostic criteria and the negative outcomes frequently evident in later adolescent and adulthood ADHD, youth with the disorder are a particularly important group to study when examining the impact of noise on academic performance and outcomes.

The main goal of this dissertation was to increase understanding of the relationship between noise and academic performance for adolescents with ADHD, including their self-reported sensitivity to and preferences for noise and the impact of different background noises during complex academic tasks. This current dissertation is noteworthy as it focuses on adolescents with ADHD, who have been underrepresented in research examining the impact of noise on academic and cognitive functioning. Given that distraction from background noise could be related to developmental level (e.g., Elliott, 2002) and age (e.g., Bell, Buchner, & Mund, 2008), it is important to conduct research that examines the impact of noise on adolescents, to add to what is already known about the impact of noise on children and adults. In addition, examining academic performance of youth who also have clinical levels of inattention is important as poor attentional control has been hypothesized to be related to greater distraction from noise (Elliott, 2002).

Considering that youth with ADHD are at greater risk for significant academic underachievement (especially as they are required to complete complex school tasks more independently in the upper-elementary and high school grades), it is important to expand our knowledge about the optimal learning environment for those youth. Youth with ADHD often also have various other co-morbid psychiatric disorders that could impact their academic
functioning, including oppositional defiant disorder and learning disorders, than youth without ADHD (Spencer, Biederman, & Mick, 2007). Furthermore, as mentioned earlier, symptoms of inattention generally remain relatively stable as children move into adolescence, whereas hyperactive and impulsive symptoms tend to decline rapidly as children age (Spencer et al., 2007); thus, adolescents with ADHD may be just as inattentive and distractible as children with the disorder, though they would likely appear to be less impaired due to the reduction of the more overt symptoms of hyperactivity and impulsivity. Through greater understanding of the impact of environmental noise on academic and cognitive performance, we can better develop interventions that result in improved academic achievement for all students, and especially those with ADHD.

This dissertation is presented in manuscript format over four chapters. The present chapter provides a brief overview of the existing research on the impact of noise on academic and cognitive performance, as well as related topics. The areas discussed include: theoretical models to understand the impact of background noise on students with ADHD; distraction by and sensitivity to noise in general; the impact of noise for individuals with and without ADHD on cognitive, academic, and self-report measures; and other factors that may impact academic performance for youth with ADHD. In order to provide a developmental framework for understanding distraction, research completed with children and adults will be reviewed as well as the research completed with adolescents. In addition, reviewing research involving participants without ADHD is helpful for making comparisons between individuals with and without clinical levels of inattention. Another reason for including the research completed with different age groups and those without ADHD is that there is a scarcity of extant research examining the impact of noise on adolescents with ADHD. Research examining other factors that may impact academic performance for youth with ADHD is reviewed to identify variables
unrelated to noise that may impact performance on the academic measures in the current study. Those factors were included as supplementary variables in this dissertation so that they could be examined and controlled for in the statistical analyses as necessary. Taken together, this review of the literature emphasizes the issues related to noise effects that are most relevant to adolescents with ADHD, as well as areas that require further investigation in future research. At the conclusion of the current chapter, the rationale, primary objectives (including research questions), and literature-based hypotheses of this dissertation are presented.

Chapter 2 (Study 1 and Study 2) examines whether adolescents with ADHD report being more distracted by noise in academic environments than youth without ADHD using both a questionnaire and an interview. More specifically, the questionnaire investigated whether youth with ADHD report being more annoyed by and sensitive to noise in the classroom than adolescents without ADHD and the interview investigated subjective background noise preferences during studying in youth with and without ADHD. Chapter 3 (Study 3) is an experimental study that investigated the impact of background noise (white noise, classroom babble, or no noise) on the reading comprehension and written expression of adolescents with ADHD. The final chapter, Chapter 4, discusses overarching conclusions and implications by integrating the results from the three studies. Implications for research, theory, assessment, and intervention with adolescents with ADHD are also reviewed. Because of the overlap of subject matter in the various chapters, there will be some reiteration in the discussion of certain topics throughout the dissertation.

1.2 Literature Review

1.2.1 Theoretical Frameworks for Predicting Noise Effects

Optimal Stimulation theory. For human beings, optimal stimulation refers to the tendency “to acquire those reactions which, when over-all stimulation is low, are accompanied
by increasing stimulation; and when over-all stimulation is high, those which are accompanied by decreasing stimulation” (Leuba, 1955, p. 29). Research results that show a facilitative effect of background noise on performance for individuals with ADHD provide support for the Optimal Stimulation theory (Leuba, 1955) which suggests that individuals with ADHD are under-aroused, and therefore environmental stimulation in the form of noise would lead to improved attention, behaviour, and performance. Using such a theory, the distractibility of children with ADHD could be explained by their attempts to regulate their under-arousal by looking for increased levels of stimulation or novelty. The theory of Optimal Stimulation has received more empirical support than other theories of noise effects for individuals with ADHD (e.g., Abikoff, Courtney, Szeibel, & Koplewicz, 1996; Pelham et al., 2011; Söderlund, Sikström, & Smart, 2007; Uno et al., 2006), and has implications for research design studies involving children who are inattentive. Based on the Optimal Stimulation theory, performance may be most efficient when a task is novel, providing more stimulation for students with ADHD; accordingly, it is imperative to counterbalance conditions across participants, as well as provide short tasks, to prevent habituation to the tasks.

**Stimulus Reduction theory.** In contrast to the Optimal Stimulation theory, the Stimulus Reduction theory argues that children with ADHD are unable to filter out irrelevant stimuli, resulting in hyperactivity and distractibility (Strauss & Lehtinen, 1947). As implied by this theory, a proposed treatment for ADHD involves a reduction of environmental stimuli, including background noise, to promote academic performance. Overall, however, there has been very little empirical evidence supporting the Stimulus Reduction theory, though many educators have attempted to use stimulus reduction in their classrooms (Sneddon, 2004).

**Moderate Brain Arousal model.** A third theoretical model, which is the core model used in the present dissertation, is the Moderate Brain Arousal (MBA) model of ADHD
(Söderlund et al., 2007), which takes aspects from both the Stimulus Reduction theory and the Optimal Stimulation theory into account. The MBA model suggests that children with ADHD are under-aroused, and seek environmental stimulation to improve their levels of attention (i.e., the theory of Optimal Stimulation); however, in contrast to the theory of Optimal Stimulation, it also hypothesizes that too much stimulation has a negative impact on performance, similar to what is hypothesized by the Stimulus Reduction theory.

The MBA model is different from the other models of distraction for individuals with ADHD in that it uses Stochastic Resonance (SR) to account for cognitive performance (Sikström & Söderlund, 2007). SR refers to the phenomenon that an optimal amount of noise may be beneficial for cognitive performance in some situations. This phenomenon has been found with animals and humans, and in different modalities (including auditory; Rausch, Bauch, & Bunzeck, 2014). Additionally, in individuals with ADHD, evidence indicates that cognitive and behavioural deficits could be caused by a hypo-functioning dopamine system (Sikström & Söderlund, 2007). Dopamine has an inhibitory action, in which too little or too much dopamine attenuates performance. The Moderate Brain Arousal (MBA) model implies that noise in the external environment introduces internal noise into the neural systems of children with ADHD through the perceptual system (Söderlund et al., 2007). This external noise induces SR, compensating for the reduced neural activity found in children with ADHD due to their hypo-functioning dopamine systems.

Past research also suggests that noise has to be continuous and at a high energy level at all frequencies (i.e., white or pink noise) to induce the SR effect. For example, Söderlund et al. (2007) found a positive effect of white noise on memory performance for children with ADHD, for both medicated and non-medicated children, supporting the MBA model. Furthermore, beneficial noise levels may vary between groups, as children with ADHD required more noise
for optimal performance than children without ADHD in that study. Similar results have been found with inattentive children who have not been diagnosed with ADHD (Söderlund, Sikström, Loftesnes & Sonuga-Barke, 2010). An improvement in memory performance was found for children rated as inattentive by their teachers as white noise levels increased, indicating that higher levels of white noise can also improve cognitive performance in children with non-clinical levels of inattention. Sikström and Söderlund (2007) note that, whereas moderate levels of arousing stimuli in the environment may be beneficial for children with ADHD, powerful and irrelevant stimuli may interrupt concentration, and an impoverished environment may be compensated for by hyperactivity.

In past research, the MBA model has not been specifically tested with either academic outcomes (as opposed to cognitive performance) or youth with ADHD (as opposed to children with ADHD). The current dissertation is novel in that it will examine the impact of noise thought to provide the optimal environment (i.e., white noise) compared to the impact of noises that are either under-stimulating (i.e., silence) or over-stimulating (i.e., babble) on the academic performance of adolescents with a diagnosis of ADHD.

1.2.2 Noise and Distraction

Noise is a prevalent feature of many locations, including the classroom, the home environment, and the workplace. When attempting to focus in those environments, sounds and noises often draw attention away from the task at hand, resulting in a decrement in performance (Banbury et al., 2001). Biologically and evolutionarily speaking, the ability to attend to sounds unrelated to current responsibilities is helpful for detecting immediate danger in the environment and responding accordingly, or in more recent times, responding to significant sounds such as alarms; however, as stated by Banbury et al. (2001), our ability to attend to background noise also has “the disadvantage that our attention will be captured by sounds with no relevance or
significance, even when we are intent on concentrating on something else” (p. 13). Thus, while some noise is important and helpful to attend to, other noise is just plain distracting.

The distracting impact of noise in general has been studied extensively in research on adults (for an overview see Banbury et al., 2001, and Szalma & Hancock, 2011), though less so on children, and especially, adolescents (for an overview see Clark & Sörqvist, 2012, and Klatte, Berström, & Lachmann, 2013). As Klatte et al. (2013) suggest, children may be more vulnerable to the disruption to their cognitive functioning caused by noise because their cognitive abilities, including attentional control, are less well developed than that of adults. Due to a lack of research with adolescent participants, it is unclear if the noise effect with youth would be similar to that seen in children (because of underdeveloped cognitive control) or more comparable to that seen in adults. For example, children’s performance on speech perception tasks is often more impaired than adults’ in noisy environments, though improvements lead to adult-like performance by early adolescence; however, even with improvements, older children with attention disorders still show more impairment from background noise on speech perception tasks than their normally-developing peers (Klatte et al., 2013). Thus, as adolescents with ADHD exhibit more poorly developed attentional control than their peers, they may show more difficulty on tasks in the presence of noise than youth without ADHD.

Results of studies conducted with adults and children indicate that both characteristics of the task and characteristics of the noise can influence the amount of disruption on task performance. Related to the characteristics of the task, seriation tasks, or those that require that items be remembered in order (e.g., mental arithmetic, serial recall), are more disrupted by noise than tasks that do not require seriation (e.g., Perham & Vizard, 2001). The timing of the noise presentation during a task does not seem to influence the magnitude of the noise effect as sounds can be detrimental for performance whether they are presented during learning trials and/or
during recall (Banbury et al., 2001). Tasks that are related to semantic understanding, such as reading comprehension, story writing, and proofreading tasks, appear to have a greater amount of distraction from certain types of noises that have more apparent meaning (e.g., recognizable speech, lyrical music; Banbury et al., 2001; Klatte et al., 2013). Additionally, more cognitively demanding tasks and tasks that measure accuracy (as opposed to speed) have been shown to have larger adverse noise effects (Szalma & Hancock, 2011), at least with adults.

Studies of noise effects also suggest that characteristics of the noise, in addition to characteristics of the required task, contribute to the effect of noise on performance for children, youth, and adults. Noise intensity is not of primary importance for the magnitude of the noise effect. For example, Banbury et al. (2001) found that negative effects of noise on performance occur regardless of the sound pressure level of the noise (measured in decibels), even for noises that are presented at very low levels. The most disruptive type of noise appears to be speech and other linguistic noises for all age groups, including children, adolescents, and adults (Klatte et al., 2013; Szalma & Hancock, 2011). A robust finding with every age group is that intermittent noise (e.g., conversation, varying tones) has been shown to be more impairing for performance than noise that is more continuous (e.g., white noise; Klatte et al., 2013; Szalma & Hancock, 2011). The results are consistent with the Changing-State Hypothesis, a component of the Object-Oriented Episodic Record model proposed by Jones, Macken, and Murray (1993), which states that when auditory distractors change in state (i.e., vary over time), they are more disruptive on performance than auditory distractors that remain the same. This could be due to the fact that “changes in sounds produce discrepancies from the existing mental model of the sounds, interfering more than sounds without changes” (Elliott, 2002, p. 480). For example, Batho (2008) examined the impact of background speech on serial recall and found that performance was better in both the silent and steady-state speech conditions when compared to
performance in the changing-state speech condition for all children, regardless of their levels of attention.

A common changing-state noise condition encountered in learning environments is irrelevant speech, which is considered to be one of the most impairing types of noises. As defined by Salamé and Baddeley (1982), the impaired serial recall performance of visually presented stimuli in the presence of irrelevant speech backgrounds is known as the Irrelevant Speech Effect (ISE). There are two general groups of theories that have been put forth to account for the ISE. One group of theories implicates automatic access of irrelevant speech without a specific role for attention, indicating that the irrelevant speech enters the participants’ processing systems beyond their control, whereas the second group of theories includes a role for attention (Elliott, 2002). According to the first group of theories, instructing participants to ignore irrelevant speech is ineffective in preventing the ISE. In contrast, the second group of theories suggests that participants would differ in their ability to ignore background speech depending on their attentional control. Recent evidence tends to support the second group of theories that include a role for attention (Cowan, 1995; Elliott, 2002; Elliott, Barrilleaux, & Cowan, 2006). For instance, according to Cowan’s (1995) theory of attentional control, the irrelevant speech draws attention away from the relevant items that need to be recalled, preventing them from being kept active in memory by attention and rehearsal. Thus, it is possible that individual differences in attentional abilities may be associated with the magnitude of the ISE for adolescents. That is, youth with inattention may have more difficulty ignoring irrelevant speech than youth with good attention abilities.

Due to the fact that the majority, if not all, of speech distractors encountered in the classroom are changing-state, it is important to examine youth’s academic and cognitive performance in changing-state speech conditions as well as steady state-noise conditions. For
the current study, the changing-state noise will be linguistic babble, typical of what is heard in a classroom, and the steady-state noise will be white noise.

Noise, or unwanted sound, also creates problems in school environments because it annoys students in addition to interfering with communication and learning within the classroom (Enmarker & Boman, 2004). Annoyance is a vague concept in the literature, referring to “feelings of irritation, discomfort, distress, frustration, or offence when noise interferes with one’s thoughts, feelings, or ongoing activities” (Boman & Enmarker, 2004, p. 208). As such, annoyance is a subjective experience and the level of annoyance is likely to vary for each individual, resulting in varying levels of disturbance on performance and distraction from the task at hand. Research suggests that much of the variation in noise annoyance levels is related to the individual characteristic of noise sensitivity, or how susceptible a person is to the negative consequences of noise (i.e., disturbance and distraction; Enmarker & Boman, 2004). Although research on noise annoyance and sensitivity is often completed with adults (e.g., see Kjellberg, Landström, Tesarz, Söderberg, & Åkerlund, 1996, who examined noise in the workplace), several studies have examined sensitivity to noise in regular noise backgrounds for typically-developing children, adolescents, and college students (e.g., Connolly, Dockrell, Shield, Conetta, & Cox, 2013; Enmarker & Boman, 2004; Waye, 2008; Weinstein, 1978).

1.2.3 The Effects of Noise for Typically-Developing Children

Cognitive task performance. In previous studies various types of background noise were examined as possible influential variables on the cognitive functioning of typically-developing children (e.g., Batho, 2008; Cohen, Evans, Krantz & Stokols, 1980; Elliott, 2002); in general, findings suggest that speech impairs performance on working memory, serial recall, episodic memory, semantic memory, and other cognitive tasks. Background noises that vary over time, such as tones (e.g., Elliott & Cowan, 2005) and traffic and aircraft noise (e.g., Cohen et al.,
1980), have also been found to impair performance on cognitive tasks for typically-developing children though there are some inconsistencies in the literature. In addition to negative effects on cognitive outcomes, various noises have also been shown to affect other areas of functioning that may impact cognitive performance for children. For instance, in the study by Cohen et al. (1980), children from schools exposed to frequent aircraft noise were not only more likely to fail on a cognitive task, but they were also more likely to give up before the time to complete the task had elapsed than children from quiet schools. In this study, it was also revealed that there were physiological effects (e.g., higher blood pressure) of background auditory noise.

**Academic task performance.** Impairment from background noise on academic tasks has also been noted in previous research with typically-developing children. Specifically, speech backgrounds (though not necessarily other noise backgrounds such as traffic noise) have been shown to have a detrimental effect on reading, spelling, and mathematics tasks for typically-developing children (Klatte et al., 2013). For instance, in a study that examined the impact of classroom babble, as well as babble in combination with environmental noise, it was found that children in the combined condition performed significantly worse on speed of processing tasks when compared to the babble only condition (Dockrell & Shield, 2006). In that same study, however, performance on the verbal tasks was significantly worse in the babble only condition when compared to the combined condition.

**Self-report measures.** Studies on noise annoyance and sensitivity in academic settings for typically-developing children have generally shown that not all background noises are perceived as annoying or bothersome. Two studies looked at responses to classroom noise reported by elementary students using both a questionnaire (Enmarker & Boman, 2004) and an interview (Boman & Enmarker; 2004) approach. Both studies found that chatter and other sounds created by people (e.g., scraping chairs/tables, sounds from the hallway), described as
“activity noise”, were the most disturbing. Chatter was also related to increased stress and difficulty maintaining concentration, though general sensitivity to noise strongly predicted the level of annoyance, mediated by the ability to adapt to different sounds. In another example, pre-schoolers who were interviewed in a study by Waye (2008) described both physical and emotional discomfort when exposed to threatening (e.g., screaming, crying) and high-frequency (e.g., squeaking, scratching) noises in their classroom, though they did not appear to notice constant background noises such as fans and computers.

1.2.4 The Effects of Noise for Typically Developing Adolescents and Adults

Cognitive task performance. The impact of background noise on normally-developing adolescents’ cognitive functioning is examined much less frequently in the literature, making it difficult to determine whether the results described above with children also apply to adolescents. In one study, Hygge, Boman and Enmarker (2003) demonstrated that both road traffic noise and irrelevant speech resulted in similar impairment on an episodic memory task, a semantic memory task, and overall levels of attention for upper-level (aged 18 to 20 years old) high school students. Another study revealed that irrelevant speech, but not road traffic noise, resulted in impairment in semantic memory for 13- and 14-year-old young adolescents (Boman, 2004). Thus, it would appear that speech is detrimental for the cognitive performance of typically-developing youth, though the impact of other types of noises (e.g., tones, traffic sounds) remains unclear.

Research has also been conducted with college students (e.g., Alley & Greene, 2008; Buchner, Rothermund, Wentura & Mehl, 2004; Elliott et al., 2006), and adults (Bell et al., 2008; Elliott & Cowan, 2005; Kjellberg, Ljung, & Hallman, 2008; Meijer, de Groot, Van Boxtel, Van Gerven, & Jolles, 2006) to examine the effects of noise on cognitive performance. In general noises such as music (e.g., Alley & Greene, 2008), speech (e.g., Bell et al., 2008; Meijer et al.,
2006), and general background noise (Kjellberg et al., 2008) have been found to impair performance on cognitive tasks for college students and adults. In addition, adults have rated a word recall task as being more difficult in the presence of background noise compared to silence (Kjellberg et al., 2008), suggesting that noise may also increase task demand.

**Academic task performance.** Once again, there are limited studies on the impact of noise on adolescents’ academic functioning. In one study, Anderson and Fuller (2010) found that reading comprehension performance worsened when listening to music for a group of young adolescents in Grades 7 and 8. Furnham and Strbac (2002) also found that students performed worse on a reading comprehension task, a prose recall task, and a mental arithmetic task when in the presence of lyrical music or office noise as compared to their performance in silence. Thus, the limited research on the impact of noise on the academic performance of typically-developing youth suggests that music and background noise impairs performance on academic tasks.

Similar results have been found with adults. For example, one study revealed an impact of background music on text memory (recognizing sentences from the text) but not text comprehension (recognizing paraphrased sentences from the text), when graduate students were asked to read paragraphs in silence or in the presence of music, either instrumental or with lyrics (Takahashi, 2006). Other studies have found a specific adverse effect of background irrelevant speech for college students on reading comprehension (Martin, Wogalter, & Forlano, 1988; Oswald, Tremblay, & Jones, 2000), writing fluency (Ransdell, Levy, & Kellogg, 2002), and length and quality of written essays (Ransdell & Gilroy, 2001). Oswald et al. (2000) suggest that meaningful irrelevant speech backgrounds are more disruptive than meaningless speech for academic tasks that require participants to process meaning, such as with reading comprehension and written expression. Thus, it appears that for college-age students without
inattention, irrelevant background noise (e.g., music, speech) impairs academic performance on tasks with a linguistic component.

*Self-report measures.* One strength of the two studies described above that investigated the impact of noise on the academic performance of adolescents (Anderson & Fuller, 2010; Furnham & Strbac, 2002) is that both studies also included surveys of the participants’ perceptions of and preferences for background noise while completing academic tasks, in addition to the experimental measures. Anderson and Fuller (2010) found that students who had a stronger preference for music experienced a greater adverse impact on their reading comprehension in the presence of music than those who reported less fondness for music while studying. Furthermore, students who reported a stronger preference for music performed more poorly in general, regardless of whether they were working while listening to music or in silence (Anderson & Fuller, 2010), suggesting that an individual preference for music while completing academic work appears to be related to difficulties with learning in general. In contrast, Furnham and Strbac (2002) found that the adverse noise effect in their study was less pronounced for extroverts, who were also more likely to study with music and to report being less distracted by music, than for introverts. Another study found that adolescents who had additional learning needs were more sensitive to noise and more negatively affected by a poor acoustic environment (Connolly et al., 2013). Taken together, there may be some individual characteristics that influence the magnitude of the noise effect on adolescents, including, but not limited to, preference for music while studying, level of extroversion versus introversion, and learning difficulties in general.

Similar effects of noise have also been found with young adults. Weinstein (1978) looked at individual differences in reactions to noise for college freshmen living in a dormitory. He divided the students into two groups based on self-report measures, those who were highly
sensitive to noise and those who were insensitive to noise. His findings revealed that those who were sensitive to noise were more bothered by dormitory noise than those who were insensitive to noise. In addition, noise-sensitive students became increasingly more disturbed by the dormitory noise over the year, whereas noise-insensitive students showed no change. Of particular interest to the present study was the finding that those students who were noise-sensitive had lower levels of academic achievement, perhaps because they had difficulties ignoring noise while working and were more negatively affected by noise than those who were noise-insensitive. Similarly, Kjellberg et al. (1996) found that noise sensitivity was related to both annoyance and distraction for adults in an office environment.

1.2.5 The Effects of Noise for Children with ADHD

**Cognitive task performance.** Generally, it is thought that noise impairs cognitive processing because auditory distractors remove attention from the task. As children with ADHD struggle with focus, it would seem appropriate that noise would be particularly detrimental to this group of students; however, despite being a key criterion of ADHD, studies that have examined the impact of different types of noise on the cognitive performance of children with ADHD have revealed inconsistencies. In addition, many studies with children with ADHD have shown results that conflict with the research on noise effects on cognitive performance for typically-developing children.

In contrast to research with typically developing children, there is some evidence that children with ADHD actually perform better on tasks during noise relative to silence (e.g., Söderlund et al., 2007). Söderlund et al. (2007) found that auditory white noise had a positive effect on memory performance for children with ADHD compared to their performance in silence. Improvements on a verbal recall task for inattentive children without a formal diagnosis of ADHD have also been found (Söderlund et al., 2010), indicating that inattentive students do
not need to meet criteria for ADHD to benefit from background white noise on memory tasks. Improved performance during noise exposure for children with ADHD was also found with general background noise on a Continuous Performance Task (CPT; Uno et al., 2006), with alerting tones on a Sustained Attention to Response Task (SART; O’Connell, Bellgrove, Dockree, & Robertson, 2006), and with novel sounds on a two-choice reaction time task (van Mourik, Oosterlaan, Heslenfeld, Konig, & Sergeant, 2007). van Mourik et al. (2007) concluded that sounds that are normally considered “distracting” may not be so for children with ADHD, and that some distraction may have beneficial effects on cognitive performance, perhaps by increasing the arousal of children with ADHD to an optimal level. These results are consistent with both the Optimal Stimulation theory and the MBA model.

Not all studies, however, demonstrate that noise has a facilitative effect on cognitive performance (e.g., Adams, Finn, Moes, Flannery, & Rizzo, 2009; Cassuto, Ben-Simon, & Berger, 2013). Several studies examining the clinical utility of adding auditory (classroom noise) and visual distractors to a CPT for identifying children with ADHD have found that distraction appears to be a key marker of ADHD (Adams et al., 2009; Cassuto et al., 2013). In those studies, children who had a diagnosis of ADHD had more difficulty sustaining attention in the presence of environmental distraction (auditory and visual) than their normally-developing peers, as evidenced by an increase in omission errors in the presence of distracting stimuli. These results provide support for the Stimulus Reduction theory, as well as for the MBA model in that the visual and auditory distractors used in the study could be considered over-stimulating, resulting in an adverse impact on performance.

**Academic task performance.** Noise has also been found to have both beneficial and adverse impacts on the academic performance of children with ADHD. For example, Abikoff et al. (1996) found that children with ADHD had more correct answers on an arithmetic task in a
music condition when compared to silent and speech conditions, which had similar numbers of correct responses. In another study, the academic performance and behaviour of children with ADHD was not reduced by background music in the classroom; however, there were individual differences in response to the background music, in that some of the boys with ADHD had improved behaviour and classwork completion in the presence of music whereas others were adversely impacted (Pelham et al., 2011). In contrast to these two studies, adverse effects of noise on academics have also been found for children with ADHD. Specifically, classroom noise, speech, and music with lyrics have been found to impair performance on arithmetic (Sneddon, 2004), reading (Zentall & Shaw, 1980), and writing tasks (Whalen, Henker, Collins, Finck, & Dotemoto, 1979) compared to performance in silence. Furthermore, Whalen et al. (1979) also found that high levels of ambient environmental noise reduced attention on academic tasks and increased the rates of distracting and off-task behaviour for children who are hyperactive.

**Self-report measures.** No studies were found that examined the perceived impact of noise on the academic performance of children with ADHD, including their self-reported noise sensitivity and their preferences for background noise during academic tasks.

### 1.2.6 The Effects of Noise for Adolescents and Adults with ADHD

**Cognitive task performance.** Only two studies were found that examined the impact of background noise on the functioning of either adolescents (Berger & Cassuto, 2014) or young adults (Linewaver et al., 2012) with ADHD. The results of the study by Berger and Cassuto (2014) were similar to comparable studies with children (e.g., Cassuto et al., 2013); however, Berger and Cassuto (2014) found that only visual and combined auditory-visual distractors, and not purely auditory distractors, resulted in an increase in omission errors for youth on a CPT, whereas Cassuto et al. (2013) found that all three types of distractors increased the error rate for
children with ADHD. In contrast, Lineweaver et al. (2012) found that auditory distraction (conversation) impacted performance on visual working memory tasks for college students with ADHD. Thus, it would appear that for youth and young adults with ADHD, visual, combined auditory-visual, and speech distractors adversely impact cognitive performance, though more research is needed in this area.

**Academic task performance & self-report measures.** No studies were found that examined either the impact of noise on academic performance or the self-reported noise sensitivity and preferences of youth and adults with ADHD. Thus, it is unclear if similar results to those found with inattentive individuals would also be found with youth and adults who have been diagnosed with ADHD.

1.2.7 Other Factors that may Influence Academic Performance for Youth with ADHD

**Academic impairments in youth with ADHD.** Children with ADHD usually have tremendous difficulties with both their academic performance (i.e., their productivity in the classroom) and their level of achievement in all academic areas (Frazier, Youngstrom, Glutting, & Watkins, 2007). This poorer performance and achievement when compared to typically developing children is believed to be related to the inattentive, impulsive, and restless behaviour of children with ADHD in the classroom. Stimulant medication has been shown to improve many of these behaviours in the short-term, including attention to a task, gross motor movement, verbalizations, noise-making, disruption, and inappropriate activity (Whalen et al., 1979). Medication that serves to reduce the off-task and disruptive behaviours of children with ADHD can also improve academic productivity, and sometimes accuracy, for these children (Barkley, DuPaul, & Connor, 1999; Famularo & Fenton, 1987); however, even with improvements, children with ADHD still demonstrate impairments in their academic
performance on standardized measures of reading, writing, spelling, and math achievement (DeBono et al., 2012; Frazier et al., 2007; Mayes & Calhoun, 2006; Yoshimasu et al., 2011).

According to Sibley et al. (2012), adolescents with ADHD may be even more impaired than children with the disorder as they display the impairments seen in children with ADHD (e.g., academic difficulties) as well as begin to show impairments that are evident in adulthood-ADHD (e.g., substance use, driving problems). In addition, adolescents with ADHD may also be impaired in ways that are unique for their developmental stage, including increased high school drop-out and delinquency (Sibley et al., 2012). Although the overall number of ADHD symptoms experienced by youth with the disorder declines from childhood into adolescence, it is evident that the symptoms that remain constant for youth with ADHD lead to a high level of impairment (Sibley et al., 2012). Longitudinal studies that have followed children with ADHD into adolescence have demonstrated that students with ADHD in high school fail more classes, achieve lower report-card grades, and have poorer performance on standardized achievement tests than their normally-developing peers, in addition to being more likely to develop co-morbid psychiatric conditions such as mood, anxiety, and substance-use disorders that could influence academic achievement (e.g., Loe & Feldman, 2007; Spencer et al., 2007). Similar to what has been observed with childhood-ADHD, Langberg et al. (2011) found that adolescents with ADHD have poor academic outcomes that are associated with their inattentive symptoms. Moreover, they reported that medication use was not significantly related to an improvement in grades for youth with ADHD. They suggested that early clinical inattention negatively impacts the development of academic skills (e.g., classroom performance, homework management) that results in persistent difficulties with academic functioning (Langberg et al., 2011). This would suggest that youth with ADHD struggle to develop the necessary learning skills and habits for
academic success in their early school years, resulting in sustained academic difficulties in the upper elementary and high school grades.

**Study habits in youth with ADHD.** As asserted by Zimmerman (2002), many students have not been taught to use self-regulation skills (e.g., goal setting, time management, seeking help, and evaluating one’s work) while studying and completing homework, though such skills may compensate for individual learning differences. He states that self-regulation on academic tasks is especially important for present-day students who are constantly inundated with electronic distractions such as cell phones, music players, computers, and televisions (Zimmerman, 2002). Such self-regulation skills and strategies may be even more important for students with ADHD who often have academic difficulties and are possibly more distractible than students without attention impairments.

Research specifically on the study habits of typically-developing children and youth has confirmed that students often choose to listen to certain background noises (e.g., television, music) while completing academic tasks such as studying (Patton et al., 1983; Kotsopoulou & Hallam, 2010). For instance, using a questionnaire to examine the study environments of typically-developing children in grades 5 through 9, Patton et al. (1983) found that students often changed from quiet settings for reading tasks to non-quiet settings for writing and math tasks. They concluded that although music and other environmental distractors may have a negative impact on academic performance overall, they may also have benefits, such as increasing the amount of time a student devotes to an academic task. A similar study found that students between the ages of 12 and 21 rarely play music when studying though they were more likely to play music when thinking or writing (Kotsopoulou & Hallam, 2010). In that study, the beneficial impact of music was related to an increased ability to relax, alleviate boredom, and concentrate on their tasks according the questionnaire responses of the students. An awareness
of the impact of background noise on academic performance was noted, as most students reported that they would turn off music if it interfered with their work, especially for the older students (Kotsopoulou & Hallam, 2010).

Research on the study habits of high school students with ADHD is limited, with most studies focusing on the study strategies of either elementary school-aged children or college students. Studies conducted with elementary school students with ADHD using teacher ratings of academic enablers such as motivation and study skills show that more proficient study skills are positively related to stronger academic achievement and motivation (DuPaul et al., 2004; DuPaul et al., 2006; Volpe et al., 2006). For instance, Volpe et al. (2006) found that the impact of ADHD on academic achievement was mediated by motivation, which influenced study skills, especially for reading achievement. Similarly, DuPaul et al. (2004) found that academic achievement for students with ADHD was predicted both by academic skills and academic enablers, including study skills, as perceived by the classroom teacher. With regard to gender differences, DuPaul et al. (2006) found that girls with ADHD may be less impaired than boys with ADHD on academic enablers, especially related to motivation levels and study skills.

The study habits of college students with ADHD have been the focus of three recent studies (Advokat, Lane, & Luo, 2011; Reaser, Prevatt, Petscher, & Proctor, 2007; Weyandt et al., 2013). In the study by Advokat et al. (2011), college students with ADHD reported similar study habits to students without ADHD, though they had significantly lower grades and were more likely to withdraw from a course. In contrast, other studies have found that college students with ADHD had lower scores than a group without any diagnoses on measures of study skills (e.g., organization, time management, concentration, test strategies) and learning styles (e.g., motivation, information processing; Reaser et al., 2007; Weyandt et al., 2013). In general,
research examining the study habits of children and young adults with inattention suggest that students with ADHD have underdeveloped study skills compared to students without ADHD.

Knowing how students with ADHD study and whether their study strategies are different from those of students without ADHD is important when working with inattentive students, especially considering that students with ADHD are at greater risk for significant academic underachievement (e.g., Frazier et al., 2007). Interestingly, Advokat et al. (2011) found that college students with ADHD were able to attain similar grade-point averages to students without ADHD by simply studying ahead of time for an exam. Further knowledge of the study skills and preferences of adolescents with ADHD is needed in order to assist youth in developing their study habits to improve academic achievement.

Information processing weaknesses. Children and youth with inattention often underperform on information processing measures when compared to their normally-developing peers, including measures of working memory (WM) and processing speed (e.g., Carte, Nigg, & Hinshaw, 1996; Jarrold, Mackett, & Hall, 2013; Martinussen & Tannock, 2006). WM is related to an ability to store information in one’s memory while manipulating it and producing a result, whereas processing speed is related to the ability to complete simple tasks quickly and efficiently. In the past, performance on subtests that measure working memory and processing speed has been used as an indicator of attention and distractibility in children, and has been shown to correlate with other measures of attention (Barkley, 2006).

More generally, difficulties with executive functioning (EF) are often cited as a central deficit in individuals with ADHD, particularly with respect to inhibitory control (Barkley, 1997). EF encompasses a wide range of abilities, including goal setting and planning, organization of behaviour, cognitive flexibility, attention and memory systems (including WM), and self-regulatory processes (e.g., self-monitoring; Barkley, 2006). A specific deficit in
inhibition was proposed by Barkley (1997), in which difficulties with behavioural inhibition lead to problems with WM (both verbal and nonverbal), self-regulation, and reconstitution (e.g., fluency, rule creativity) that impact speed of processing and the motor control system, thus leading to the behaviours observed in individuals with ADHD. In later publications, however, Barkley (2006) noted that it is possible that ADHD is not only related to a primary deficit in inhibition, but also related to a primary deficit in other areas of cognitive functioning, such as WM. In the case of working memory, a meta-analysis of studies that examined working memory in children with ADHD (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005) demonstrated evidence of WM impairments for those children, supporting theoretical models that associate working memory processes with ADHD. Poorer performance on WM tasks has also been associated with inattention in community samples of children (Gathercole et al., 2008; Jarrold et al., 2013; Lui & Tannock, 2007), indicating that the association between working memory and inattentive behaviour is not restricted to clinical populations.

Numerous studies have demonstrated that these cognitive processing difficulties can negatively impact academic skill development and achievement (e.g., Aronen, Vuontela, Steenari, Salmi, & Carlson, 2005; Gathercole et al., 2008; Preston, Heaton, McCann, Watson, & Selke, 2009). For example, in the study by Aronen et al. (2005) that examined the association between visuospatial memory, a component of working memory, and attention, low working memory performance was associated with attentional problems and poor academic achievement at school. Weaknesses with information processing have also been linked to distraction (e.g., Jarrold et al., 2013; Clark & Sörqvist, 2012). For instance, Jarrold et al. (2013) found a significant link between working memory, especially speed of processing, and poor concentration (i.e., higher levels of distraction), resulting in limited learning ability in the classroom. Clark and Sörqvist (2012) also found that individuals with low working memory
capacity are more vulnerable to auditory distraction than those with high working memory capacity. Thus, information processing deficits, such as weakness with WM and processing speed, are likely related to both behavioural inattention and individual sensitivity to noise.

It is important to consider difficulties in executive functioning (including information processing weaknesses such as working memory and processing speed) in the current study because of the negative implications of poor EF on academic achievement. Adequate reading comprehension has been linked to cognitive skills beyond word decoding and reading fluency, including higher level skills that are related to EF such as working memory, planning, organizing, and monitoring (Sesma, Mahone, Levine, Eason, & Cutting, 2009). As such, effective reading comprehension requires individuals to hold and manipulate information in working memory, planning/sequencing multi-step tasks, and establishing the “big picture” from a set of details (Sesma et al., 2009). In addition, weak working memory is associated with poor inference making and ineffective comprehension monitoring, resulting in poorer comprehension of what is being read for children with ADHD (Berthiaume, Lorch, & Milich, 2009).

Working memory is also related to written expression performance. Writing a composition requires coordination of working memory processes, planning (which involves memory retrieval, problem solving, and decision making), language generation, and reviewing written output (Olive & Kellogg, 2002). These higher-level processes are activated concurrently with motor transcription during written tasks, placing high demands on EF. Related to writing, children with ADHD have been shown to have difficulties with the legibility of their writing when compared to children without ADHD (Brossard Racine, Majnemer, Shevell, & Snider, 2008). Fewer studies have investigated higher-level writing processes, such as writing a composition or an essay. In a study of the expressive writing abilities of children with ADHD, however, it was shown that the ADHD group had lower scores than children without ADHD,
whether they were asked to write a description of an image, respond to a verbal description, or write a narrative text (Re, Pedron, & Cornoldi, 2007). The lower scores for children with ADHD were related to poorer quality (including structure, grammar, and spelling), shorter length, and more errors in their writing.

Because executive functioning is highly related to performance on both reading comprehension and written expression tasks, it is important to ensure that experimental groups are comparable on measures of EF (e.g., working memory, processing speed) in the current study; thus, measures of working memory and processing speed were administered to all participants. If preliminary analyses indicated that the experimental groups were not matched on working memory or processing speed performance in the current study, then those abilities were controlled for in the analyses.

**Intellectual ability.** Children with ADHD often obtain lower estimates of intellectual ability (or IQ) on standardized intelligence tests than community comparison groups (Barkley, 2006). On average, their scores are often 7 to 10 points (or 0.61 standard deviations) below the mean of a normally-developing comparison group. Children with ADHD specifically under-perform on certain subtests of the Wechsler Intelligence Scale for Children (WISC-IV), namely those that measure working memory and processing speed (Barkley, 2006), consistent with the information processing literature described above. An abbreviated measure of IQ was also used in the current study to examine and control for the intellectual ability of all participants.

**Task demand.** Task difficulty, and the resulting demand on working memory, has been hypothesized to influence the amount of impact that background noise has on task performance. For instance, on a task that was considered novel and more challenging for hyperactive children (an alphabet cancellation task), both noise low in linguistic content and noise high in linguistic content was shown to be detrimental for performance, as compared to poor performance in only
the high linguistic noise for a mathematics task (Zentall & Shaw, 1980). As well, Furnham and Strbac (2002) hypothesized that music and noise are similar in their distracting effects on complex cognitive tasks, but that music may be beneficial on simpler tasks. It is not clear from the research, however, what impact cognitive demand has on performance of academic tasks in the presence of background noise and speech.

In terms of task demand, when examining reading comprehension proficiency, research has shown that questions that measure explicit or factual understanding of a text are easier to answer and less cognitively demanding than those that measure implicit or implied understanding of a text. For instance, Flick and Anderson (1980) found that for both native English speakers and speakers who were learning English as their second language, implicit definitions were more difficult to understand than explicit definitions. They concluded that difficulty in comprehending implicitly stated information is a general problem that affects all readers, regardless of proficiency with English. A related finding demonstrates that it is more difficult to process inferential causal statements (e.g., “Because most distinguished students got bad grades, the teacher made some mistakes in evaluating his students’ papers”) than it is to process factual causal statements (e.g., “Because he got tired after a long semester, the teacher made some mistakes in evaluating his students’ papers”; Mohamed & Clifton, 2008), especially for students with ADHD (Berthiaume et al., 2009). Thus, cognitive demand increases when participants are required to answer questions that measure inferential understanding, as opposed to factual understanding, during reading comprehension tasks.

Research has also demonstrated that merely copying a written passage is less cognitively demanding than asking individuals to compose their own written passage (Olive & Kellogg, 2002). High-level processes such as planning, language generation, and reviewing, are needed when a person is asked to generate a text. For example, Olive and Kellogg (2002) found that
when adults are required to transcribe and compose their own passages, high-level processes are activated concurrently with motor output, resulting in higher attentional demands. Thus, for individuals who have automatized fine motor skills, tasks that require composition of a passage are more cognitively demanding than those that simply require transcription (e.g., copying).

In the current study, participants were asked to complete academic tasks that require high cognitive demand. We are most interested in the effects of auditory noise on the ability to accomplish more demanding academic tasks (i.e., comprehend text and generate written text) because being able to comprehend content and clearly communicate ideas is important to school outcomes (Graham & Perin, 2007; Knighton & Bussière, 2006). Also, cognitively demanding tasks are more likely to be negatively affected by background auditory stimulation, and thus, are interesting to study from a theoretical point of view (Klatte et al., 2013). We assessed the effect of white noise and linguistic babble on the ability of youth with ADHD to comprehend expository text and generate a brief composition. Comprehension was assessed with an oral retell of the expository passage they read. Performance on the writing task was assessed with total words written (an indicator of writing fluency) and the percentage of correct word sequences. This latter measure captures accuracy in spelling, mechanics, and grammar.

1.3 The Current Dissertation

1.3.1 Rationale

The literature review presented above summarizes research examining the impact of noise on distraction levels and academic performance in children, adolescents, and adults with and without ADHD. On the whole, most research has focussed on the impact of noise on either children or adults, leaving the study of noise effects on adolescents largely uninvestigated. In addition, there is a scarcity of research examining the impact of noise on the particular subset of adolescents who have been diagnosed with ADHD. Indeed, only one study was found that
examined noise effects on adolescents with ADHD; that study focussed on the utility of adding noise to a sustained attention task for purposes of diagnosis (Berger & Cassuto, 2014). The extremely limited evidence that exists suggests that adolescents with ADHD may be distracted by visual and combined visual-auditory distractors on cognitive tasks, though not by purely auditory distractors (e.g., music). Related to academic performance, it is possible that adolescents would experience improvement on academic tasks in the presence of some noises (e.g., music, tones, white noise) and decrements in the presence of other noises (e.g., speech), as has been demonstrated for children with ADHD. Altogether, however, more research is needed to clarify the relationship between background noise and academic performance for youth with ADHD, as academic work increases in both demand and complexity for youth once they enter the upper-elementary and high school years. Research in this area will lead to important implications for assessment and treatment, especially related to optimal school environments for improved academic outcomes. Accordingly, the overarching goal of this dissertation was to better understand the relationship between background noise and academic performance for adolescents with ADHD.

1.3.2 Objectives, Research Questions, and Hypotheses

With the intention of addressing gaps from the previous literature related to noise effects for youth with ADHD, three primary research objectives were examined for this dissertation.

The objective of the first study (Chapter 2) was to investigate whether adolescents with ADHD report being more sensitive to noise in the classroom than a matched sample of adolescents without ADHD. Adolescents with ADHD ($n = 52$) and without ADHD ($n = 51$), ages 14 to 16, completed a noise questionnaire that examined noise sensitivity (i.e., susceptibility to negative effects of noise) through questions related to annoyance, disturbance, distraction, and control over noise. The specific research question was: Are adolescents with
ADHD more sensitive to noise than adolescents without ADHD? Given the diagnostic criteria and the evidence of academic impairments for youth with ADHD, it was assumed that they would report being more sensitive to noise in the classroom than youth without ADHD.

A related objective in the second study was to help understand the self-reported background noise preferences of youth with and without ADHD using an interview approach (see Chapter 2). The participants included youth with \( n = 8 \) and without \( n = 8 \) ADHD. Each completed a brief semi-structured interview that provided information regarding their noise preferences during studying. Specifically, the research questions were related to what types of noises youth find particularly helpful or annoying during academically-oriented activities (i.e., studying) and why they find those noises helpful or annoying. Responses to the interview were summarized and placed into categories to help with description of the results.

Finally, the objective of the third study (Chapter 3) was to investigate the impact of background noise on the academic performance of adolescents with ADHD. Adolescents with ADHD between the ages of 14 and 16 \( n = 52 \) completed reading comprehension and writing tasks in one of three randomly assigned background noise conditions: no noise, white noise, and linguistic classroom babble. The specific research question was: What are the effects of different noise conditions on reading comprehension and written expression performance for adolescents with ADHD? Based on the MBA model, it was expected that there would be a significant impact of background noise, such that the participants with ADHD would perform best in the white noise condition, compared to their performance in the no noise or classroom babble condition. Furthermore, based on the research examining the effects of linguistic noise on academic performance, it was also expected that participants would perform worse in the classroom babble condition, compared to their performance in the no noise condition.
CHAPTER TWO

Noise Sensitivity and Distraction in Adolescents

with and without ADHD
2.1 Study 1 & Study 2 – Noise Sensitivity and Distraction

2.1.1 Abstract

The current two studies were conducted to explore noise sensitivity and distraction in adolescents with Attention-Deficit/Hyperactivity Disorder (ADHD). First, participants with \( n = 52 \) and without \( n = 51 \) ADHD completed a questionnaire assessing noise sensitivity as well as performance-based assessments of working memory, processing speed, and oral language proficiency. Second, a subset of participants (ADHD, \( n = 8 \); comparison, \( n = 8 \)) completed a brief semi-structured interview regarding their noise preferences during studying. Youth with ADHD reported significantly higher levels of noise sensitivity than their peers, as did females in general. Noise sensitivity was significantly associated with gender and youth reports of inattention and hyperactivity/impulsivity independent of parent-reported inattention. The interview responses revealed a preference for some noise versus no noise during studying with the majority of respondents with ADHD reporting that they enjoy listening to music while studying. Youth with ADHD also tended to report difficulties studying in the presence of conversation. In contrast, youth without ADHD did not report a consistent preference for background noise overall, although the majority reported that they found music to be distracting during studying. Educational implications will be discussed.

2.1.2 Introduction

The purpose of this paper is to investigate self-reported noise sensitivity and preferences of adolescents with ADHD in relation to performing academic work in the classroom and at home. Noise is a prevalent feature in many academic learning environments despite efforts to control noise levels by school staff and administration (Enmarker & Boman, 2004). As students often add selected background noises such as television and music while completing academic tasks (Patton, Stinard, & Routh, 1983), a considerable amount of academic work is completed in
the presence of background noise. This may not be an optimal choice as background noise (e.g., music, activity noise, irrelevant speech) has been shown to have a negative impact on student’s reading comprehension (Anderson & Fuller, 2010), text memory (Takahashi, 2006), mental arithmetic (Furnham & Strbac, 2002), writing fluency (Ransdell, Levy, & Kellogg, 2002), and length and quality of written essays (Ransdell & Gilroy, 2001).

Distractions from environmental stimulation, and the accompanying difficulties with sustaining focus, are key diagnostic features of Attention-Deficit/Hyperactivity Disorder (ADHD; American Psychiatric Association [APA], 2013). Furthermore, youth with high levels of inattention report more problems with distraction and concentration than their typically developing peers (Connors, Connolly, & Toplak, 2012). Although it would therefore seem likely that background noise would be particularly bothersome to students with ADHD, data does not clearly support this hypothesis (van Mourik, Oosterlaan, Heslenfeld, Konig, & Sergeant, 2007; Söderlund, Sikström, & Smart, 2007). Furthermore, only one study has been conducted on the effects of noise on performance of adolescents with ADHD, and this study examined performance on a continuous performance task rather than an academic task (Berger & Cassuto, 2014). Therefore, it is important to explore noise sensitivity of adolescents with ADHD in relation to academic performance.

The goal of the present study is to investigate the self-reported noise sensitivity and preferences of adolescents diagnosed with ADHD when they are completing academic tasks such as studying. As there are no other existing studies examining the self-reported noise sensitivity and preferences of youth with ADHD, particularly related to academic work, the current research is novel and will help clarify the relationship between background noise and academic performance for those individuals. In addition, research in this area will lead to
important educational implications, especially related to optimal school environments for improved academic outcomes for youth with ADHD.

2.1.2.1 Noise and Distraction in Children and Youth with ADHD

There are two theoretical models that provide some insight into the potential impact of background noise on youth with ADHD: the theory of Optimal Stimulation and the Stimulus Reduction theory. The theory of Optimal Stimulation hypothesizes that the distractibility of children with ADHD is the result of their attempts to regulate their under-arousal by looking for increased levels of stimulation or novelty (Leuba, 1955). In contrast, the Stimulus Reduction theory hypothesizes that children with ADHD are unable to filter out irrelevant stimuli, resulting in hyperactivity and distractibility (Strauss & Lehtinen, 1947).

Previous research findings are mixed in terms of their support for these models. There is some evidence supporting the theory that children with ADHD are under-aroused and therefore environmental stimulation in the form of noise would lead to improved attention, behavior, and performance (e.g., Abikoff, Courtney, Szeibel, & Koplewicz, 1996; Pelham et al., 2011; Söderlund et al., 2007). For instance, Söderlund et al. (2007) found that auditory white noise had a positive effect on memory performance for children with ADHD compared to their performance in silence. In addition, Abikoff et al. (1996) found that children with ADHD performed better on an arithmetic task in a music condition when compared to a silent condition or a speech condition and van Mourik et al. (2007) found that, for children with ADHD, potentially distracting novel sounds reduced the omission rate during a two-choice reaction time task. As van Mourik et al. (2007) indicated, it is possible that sounds that are normally considered “distracting” may not be so for children with ADHD, and that some distraction may have positive effects perhaps by increasing the arousal of children with ADHD to an optimal level.
In contrast, other studies report a detrimental effect of background noise on cognitive or academic performance (e.g., Adams, Finn, Moes, Flannery, & Rizzo, 2009; Zentall & Shaw, 1980). For example, Adams et al. (2009) found that children with ADHD were more adversely impacted by auditory distractors than typically developing children on a Continuous Performance Task. Zentall and Shaw (1980) demonstrated that hyperactive children were most active and performed worse on math and alphabet tasks in the presence of high linguistic noise, as compared to performance in low linguistic noise; however, they also found that students with more severe levels of hyperactivity and inattention reported a greater preference for background noise during math problem-solving and computation than the comparison group.

In general, there is a lack of research overall examining noise effects for youth with ADHD, as only one study was found examining the effects of noise on performance for adolescents with the disorder (e.g., Berger & Cassuto, 2014). The results of that study differed from a comparable study with children (Cassuto, Ben-Simon, & Berger, 2013). Whereas Berger and Cassuto (2014) found that only visual and combined auditory-visual distractors, and not purely auditory distractors, resulted in an increase in omission errors for youth on a Continuous Performance Task, Cassuto et al. (2013) found that all three types of distractors increased the error rate for children with ADHD. In both studies, it was concluded that individuals with ADHD have difficulty with sustaining attention in the presence of distractors; however, it is possible that various types of background stimuli (particularly noise) may have a differential impact on the distraction levels of children and youth with ADHD.

Thus, research suggests that noise can result in both beneficial (consistent with the Optimal Stimulation theory) and adverse (consistent with the Stimulus Reduction theory) effects on academic and cognitive performance for individuals with ADHD. Instead of considering these two theories, research results are more consistent with a recent theoretical framework, the
Moderate Brain Arousal (MBA) model, in which stimuli that evoke moderate brain arousal in the dopamine system lead to improved memory performance for children with ADHD, whereas too little or too much stimuli lead to reduced performance (Sikström & Söderlund, 2007). The MBA model could also be used to describe noise sensitivity or annoyance; for instance, stimuli that evoke moderate arousal not only lead to improved performance, but are also likely to result in lower levels of annoyance. As noise sensitivity has not yet been studied among children with ADHD, it is not known whether the MBA model has implications for noise annoyance and sensitivity levels in addition to memory performance.

2.1.2.2 Cognitive Correlates of Inattention and Distraction

Children and youth displaying inattentive behavior often under-perform on information processing measures when compared to their normally-developing peers, including measures of working memory, processing speed, and language processing (e.g., Carte, Nigg, & Hinshaw, 1996; Jarrold, Mackett, & Hall, 2013; Martinussen & Tannock, 2006). These processing difficulties can negatively impact academic skill development and achievement (Preston, Heaton, McCann, Watson, & Selke, 2009) and are often linked to distraction (Clark & Sörqvist, 2012). For instance, Jarrold et al. (2013) found a significant link between working memory and processing speed with concentration; lower working memory scores and a slower speed of processing were associated with greater distraction, resulting in limited learning ability in the classroom. Clark and Sörqvist (2012) also found that individuals with low working memory capacity are more vulnerable to auditory distraction than those with high working memory capacity. Thus, deficits in processing speed and working memory are likely related to both behavioral inattention and individual sensitivity to noise. Furthermore, there may be a subgroup of youth with ADHD, quite possibly those that have information processing weaknesses, who are more likely to be distracted by background noises while completing academic work (for
discussion of possible subgroups, see Pelham et al., 2011). More research is needed to clarify the links between measures of information processing, behavioral inattention, and sensitivity to noise, and how those factors are related to actual distraction in an academic environment.

2.2 Study 1

Given this lack of clarity regarding noise sensitivity and distraction in adolescents with ADHD, the primary objective of this study was to better understand adolescents’ subjective experiences with background noise in academic environments; that is, are adolescents with ADHD more sensitive to noise than adolescents without ADHD? Stimulus Reduction theory would suggest that youth with ADHD would report more noise sensitivity than the comparison group (consistent with the diagnostic criteria of the disorder), whereas the Optimal Stimulation theory would suggest that they would report less sensitivity than the comparison group. We also investigated other possible predictors of noise sensitivity by examining the association between noise sensitivity and parent- and youth-reported ADHD symptom severity, in addition to demographic variables (i.e., age, medication status) and cognitive variables that are commonly associated with distraction levels (i.e., working memory, processing speed, language processing, cognitive ability; Carte et al., 1996; Clark & Sörqvist, 2012; Jarrold et al., 2013; Martinussen & Tannock, 2006; Shanahan et al., 2006). This latter analysis was completed to examine the correlates of self-reported noise sensitivity, as well as possible individual difference variables that could help predict noise sensitivity levels in students with and without ADHD.

2.2.1 Method

2.2.1.1 Participants

Fifty-two secondary school students with a parent-reported diagnosis of ADHD from a physician or clinical psychologist and a comparison sample of 51 typically developing adolescents without ADHD participated in the current study, for a total sample of 103
participants (ages 14 to 16). A childhood diagnosis of ADHD was accepted for the current study as research has demonstrated that symptoms of ADHD are reasonably stable from early childhood to late adolescence, especially for inattentive symptoms (Holbrook et al., 2014).

Participants were primarily recruited through local newspaper advertising. Parents who contacted the lab completed an intake interview and the Conners-3 Parent Rating Scales, Long Form (Conners 3-P; Conners, 2008) over the phone to screen potential participants for the study. A participant needed to obtain a T-score of at least 70 on one or more of the central ADHD indices (i.e., DSM-IV Hyperactive Impulsive, DSM-IV Inattentive, and DSM-IV Global) from the Conners 3-P, in addition to having a previous diagnosis of ADHD, to be included in the ADHD group. Participants in the non-ADHD group needed to obtain T-scores less than 65 on all of the central ADHD indices of the Conners 3-P to be included in the study. In addition, both groups could not have a prior diagnosis of a genetic or neurological disorder (e.g., Tourette’s syndrome, autism spectrum disorder, psychotic disorder) according to parental report. Participants were also only included in the present study if their estimated IQ was at a standard score of 70 or greater, or if they had a standard score of 70 or more on at least one of the subscales (i.e., verbal or non-verbal reasoning) measuring IQ\(^1\), as research has suggested that excluding children with ADHD who have standard scores in the borderline range (IQ 70 to 79) unnecessarily truncates the sample (Antshel, Phillips, Gordon, Barkley, & Faraone, 2006).

Demographic features for the participants are summarized in Table 2.1. T-tests or chi-square tests, as appropriate, were used to compare the ADHD group and the non-ADHD group on background variables to determine if the groups had any significant differences in their composition. The two groups did not differ significantly from each other on grade, parent

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\(^1\) Students who did not have an estimated IQ score available were still included in the study if they performed in the average range on the remaining cognitive measures (e.g., working memory, processing speed) and if their parent did not report that they were identified with an intellectual disability.
education level, parent marital status, and estimated intelligence level. The groups did have significant differences with respect to their sex composition, such that there were more males in the ADHD group and more females in the non-ADHD group, and whether or not they have an individual education plan, with more ADHD participants having an IEP (not including gifted IEPs) than comparison participants. Youth in the comparison group were also more likely to speak a language other than English at home and to be born outside of Canada than youth in the ADHD group. Finally, as expected, the two groups differed on their parent- and self-ratings of DSM-IV inattention and hyperactivity/impulsivity. Of the participants with ADHD, 69% were taking medication for the disorder, though they were asked to refrain from taking their medication on the day of testing as medication has been shown to improve academic and cognitive performance for children with ADHD in the presence of auditory distractors (Pelham et al., 2011).

2.2.1.2 Materials

Noise sensitivity. Participants completed an adapted and revised version of a Swedish noise questionnaire (Kjellberg, Landström, Tesarz, Söderberg, & Åkerlund, 1996) to examine the noise sensitivity (i.e., susceptibility to negative effects of noise) of students in a classroom setting. The noise questionnaire specifically asked about disturbance and distraction from classroom noise, perceived control over noise, and ability to become accustomed to background noises (available in Appendix A). It includes 7 items that are each rated on a scale ranging from 1 (not at all/never/very easy) to 5 (very much/very often/very hard).

The internal consistency of the noise questionnaire for the sample in the present study was high (Cronbach’s alpha = .90). A confirmatory factor analysis (using Mplus) indicated that the 7 items adequately load onto a single factor, which will be referred to as general noise sensitivity, with acceptable goodness of fit measures (RMSEA = .091, CFI = .970, and SRMR =
.043). Inter-item correlations were all significant and ranged from $r = .39$ to $r = .80$. Due to the high level of internal consistency and the single factor structure of the questionnaire, general noise sensitivity was calculated by summing the responses to the 7 items and dividing by the number of items ($M = 2.82; SD = .93; \text{range} = 1.00 \text{ to } 5.00$). For the average sensitivity score, histograms, normal probability plots, and skewness and kurtosis statistics revealed a normal distribution.

**Estimated IQ.** The Matrix Reasoning and Vocabulary subtests from the *Wechsler Abbreviated Scale of Intelligence* (WASI; Wechsler, 1999) were administered to obtain an estimated full-scale IQ. Raw scores were converted to age-based T-scores (with a mean of 50 and a standard deviation of 10) and these latter scores were used in the analyses.

**Working memory.** To assess working memory abilities, the digits backward task from the *Test of Memory and Learning-Second Edition* (TOMAL-II) and the Listening Recall subtest from the *Working Memory Test Battery for Children* (WMTB-C; Pickering & Gathercole, 2001) were administered to all participants. The listening recall subtest is a measure of verbal working memory, requiring the youth to listen to a series of short sentences, determine the truth of the statements by responding ‘true’ or ‘false’ aloud, and then recall the final word of each sentence in the correct sequence. Raw scores from the digits backwards task were converted to age-based scaled scores (with a mean of 10 and a standard deviation of 3) and the results from the listening recall task were converted to age-based standard scores (with a mean of 100 and a standard deviation of 15), and these latter scores were used in the analyses.

**Processing speed.** To measure processing speed, participants were given a rapid digit naming task from the *Comprehensive Test of Phonological Processing* (CTOPP). Raw scores were converted to age-based scaled scores and these latter scores were used in the analyses.
A rapid naming task was used to index processing speed in the current study as past research has demonstrated that there is a high correlation between measures of rapid naming and other measures of processing speed, such as coding and Stroop tasks (e.g., Arnett et al., 2012; Shanahan et al., 2006). Rapid naming is related to both reading difficulties and ADHD, which may explain some of the comorbidity between the disorders (Shanahan et al., 2006). Thus, it is possible that the rapid naming measure used in the current study represents a possible confound for those with comorbid ADHD and reading disability; however, it also appears that naming speed is a reliable predictor of inattentive symptom severity independent of phonological awareness ability (Arnett et al., 2012) and that students with a reading disability only show larger processing speed deficits on both naming speed tasks and speeded motor tasks than those students with either ADHD only or both disorders (Shanahan et al., 2006).

Expressive and receptive language. Two measures of language functioning (recalling sentences and formulating sentences) from the Clinical Evaluation of Language Fundamentals (CELF) were given to participants. Raw scores were converted to age-based scaled scores and these latter scores were used in the analyses.

Self-reported ADHD symptoms. All participants also completed the Conners 3 Self-Report Rating Scale, Long Form (Conners 3-SR) to examine their self-reported inattention and hyperactivity/impulsivity symptoms. Raw scores were converted to T-scores based on gender (male or female) and age.

2.2.1.3 Procedure

Parents provided their verbal consent to complete the Conners rating scale and background interview questions over the phone before their youth visited the lab to determine whether they met the inclusion criteria for the study. Parents of participants were sent consent, information, and demographic forms to complete prior to the visit to the lab. When the
participants arrived at the lab, they first completed a set of academic and experimental measures from a related study focusing on text comprehension in youth with ADHD, followed by the noise questionnaire. Ethical approval was obtained from the University of Toronto’s Social Sciences and Humanities Research Ethics Board (REB) and informed consent/assent was obtained from all participants and their parents before participating in the study.

2.2.1.4 Data Analysis Plan

First, a 2 (ADHD versus comparison) by 2 (male versus female) analysis of variance (ANOVA) was conducted to assess the effects of ADHD status and gender, and the interaction between those two variables, on noise sensitivity. Correlations between overall noise sensitivity and cognitive, language, behavioral, and demographic measures were also examined before a multiple regression analysis was conducted to examine the unique predictors of noise sensitivity. Gender was included in the ANOVA and the regression analysis because it was significantly related to both noise sensitivity (such that females were more sensitive to noise than males) and parent-reported inattention (such that males were more inattentive than females). Individual analyses sometimes used fewer participants than the full sample due to missing data on some of the dependent measures.

2.2.2 Results

Group Differences on Noise Questionnaire. Participants with ADHD, regardless of gender, reported more noise sensitivity \((M = 3.01, SD = 1.00)\) than their peers without ADHD \((M = 2.63, SD = .82)\), \(F(1, 99) = 9.33, p = .003\), partial \(\eta^2 = .09\). Girls reported more noise sensitivity \((M = 3.05, SD = .84)\) than boys \((M = 2.60, SD = .96)\), \(F(1, 99) = 11.70, p = .001\), partial \(\eta^2 = .11\). There was no significant interaction, \(F(1, 99) = .48, p = .49\).

Correlations between Noise Questionnaire and Other Measures. Table 2.2 presents the correlations between overall noise sensitivity (average score on the noise questionnaire) and the
remaining measures, including age, medication status, estimated IQ, working memory, processing speed, expressive and receptive language, and parent and youth ratings of inattention and hyperactivity for the full sample. Higher levels of noise sensitivity were significantly correlated with higher scores on the Conners parent inattention subscale and the self-reported inattention and hyperactivity-impulsivity subscales. Self-reported noise sensitivity was not significantly related to age, medication status, the cognitive variables (including intelligence, working memory, and processing speed), the language measures, or parent-reported hyperactivity/impulsivity. All of the scores on the ADHD rating scales were associated with each other. Parent inattention ratings were also significantly associated with processing speed, intelligence, and working memory. These results indicate that cognitive factors such as processing speed and working memory, in addition to individual noise sensitivity, are associated with behavioral inattention.

**Standard multiple regression.** A preliminary hierarchical regression was completed with all of the significant correlates of noise sensitivity (gender, parent- and self-reported inattention, self-reported hyperactivity/impulsivity) entered in the first block and the interaction between gender and parent-reported inattention entered in the second block. The interaction between parent-reported inattention and gender was not significant for predicting self-reported noise sensitivity, $p = .25$, so a standard multiple regression with all of the significant correlates entered in the equation at one time was used as the main analysis.

The results of the standard multiple regression are presented in Table 2.3. The regression model using parent-reported inattention, self-reported inattention and hyperactivity/impulsivity, and gender to predict noise sensitivity was significant, $F(4,98) = 14.78$, $p < .001$. Approximately 38% of the variance in noise sensitivity ratings in this sample can be accounted for by the variables included; however, only gender and self-reported inattention and hyperactivity/
impulsivity ratings had a unique significant contribution to the prediction equation for noise sensitivity. Parent-reported inattention did not significantly predict noise sensitivity scores after taking into account the contributions made by gender and self-reported symptoms.

2.2.3 Discussion

As distraction and problems with focusing are key features of ADHD, it is important to understand whether noise, an environmental variable that is often viewed as annoying and distracting to children and adults, is also perceived to be problematic for youth with ADHD. Consistent with the Stimulus Reduction theory and diagnostic criteria for ADHD, individuals with ADHD reported being more sensitive to background noises than individuals without ADHD, with a medium effect size for the difference between the two groups.

Noise sensitivity was also significantly related to gender (with girls reporting higher levels of noise sensitivity than boys) and self-reported inattention and hyperactivity-impulsivity; however, noise sensitivity was not independently associated with parent-rated inattention or hyperactivity-impulsivity. Gender differences have also been reported in past studies, in the same direction as the current results (i.e., females reporting higher levels) though it is often unclear why such differences exist. For instance, females reported higher levels of noise annoyance, but not overall noise sensitivity, in the study by Kjellberg et al. (1996). Enmarker and Boman (2004) also found that females rated two items on a noise questionnaire higher than males; specifically, the females reported that they were more irritated by noise and thought about other things more often when reading than males. They also found that females perceived themselves as having more stress symptoms due to noise than males (Enmarker & Boman, 2004), perhaps indicating that they are more physically reactive to noise. Physical and stress reactions that females experience in noise may also lead them to perceive themselves as also being more sensitive to and annoyed by background noises during academic work than males.
Finally, contrary to expectations, noise sensitivity was not associated with cognitive measures of working memory and processing speed. The lack of a significant correlation between self-reported noise sensitivity and working memory ability in the present study is not consistent with some evidence showing that measures of cognitive control (e.g., working memory) are linked to auditory distraction (Clark & Sörqvist, 2012). One reason why working memory may not be related to distraction is that the level of distraction may be more related to the nature of the distractor rather than an individual’s working memory capacity (Sörqvist, Marsh, & Nöstl, 2013). Specifically, Sörqvist et al. (2013) suggest that working memory capacity may only be related to the amount of distraction from sounds with one abrupt change in a sequence (e.g., a single word within an instrumental song) but not to sounds that are constantly varying (e.g., a conversation, classroom noise).

Overall, the results of Study 1 provide greater insight into those factors that contribute to individual differences in noise sensitivity. The results also provide further support for the literature that proposes that individual noise sensitivity is impacted by characteristics of the listener, including their learning needs (e.g., Connolly, Dockrell, Shield, Conetta, & Cox, 2013) and their ability to adapt to different sounds (e.g., Enmarker & Boman, 2004). In general, this suggests that individual noise sensitivity may be an individual characteristic to consider when trying to understand variation in behavioral inattention.

2.3 Study 2

The goal of Study 2 was to understand the types of noises that adolescents with and without ADHD find particularly helpful or annoying during academically-oriented activities (i.e., studying) and why they find those noises helpful or annoying. An interview approach was utilized in this study as most previous studies examining the noise preferences of youth with ADHD employed a questionnaire design; therefore, students were not able to explain why they
prefer a noisy over a quiet setting (e.g., Advokat, Lane, & Luo, 2011; Zentall & Smith, 1992). It was expected that adolescents’ self-reported preferences for background noise would be related to research on auditory distraction and the MBA model; that is, their preferences would be related to the levels of stimulation that the auditory backgrounds provide. For instance, adolescents with ADHD may report preferring background noise with a moderate level of stimulation (e.g., white noise, music) over background noise that is either too stimulating (e.g., chatter) or too under-stimulating (e.g., silence), whereas normally developing adolescents may report preferring silent backgrounds, while completing academic tasks.

2.3.1 Method

2.3.1.1 Participants

A subset of participants (n = 16) from the first part of the study was invited to return to the lab to complete a brief interview examining their study preferences, including what noises they find helpful or distracting while studying and how difficult it is for them to complete academic work when music is playing or people are talking around them. Purposeful sampling was used to obtain participants who varied in ADHD status and sex (8 from the ADHD group, 50% male; 8 from the non-ADHD group, 50% male). In addition, participants were chosen to ensure a wide range of responses to the questionnaire item that asked about their perceived sensitivity to noise (“How sensitive to noise to you think you are, compared to others your age?”). Participants also had to agree in advance to be contacted for future studies and then agree to return to the lab after obtaining information about the interview study. As participant selection was not fully random, there may be some bias in the results; for example, it may be that participants who were more aware of their difficulties and would like to understand them more fully agreed to participate in the interview study.
Demographic features for each group are summarized in Table 2.4. Group comparisons revealed that parents of participants with ADHD reported that their children had significantly higher levels of inattention and were more academically impaired than the youth without ADHD. Additionally, all participants with ADHD, but none without ADHD, had an Individual Education Plan (IEP) and 75% of the participants with ADHD were taking medication for the disorder.

2.3.1.2 Materials

The interview examined noise preferences during studying (see Appendix B). Following an open-ended question about study habits, several probes were used depending on the first response. Specifically, probes asked about what noises are helpful and distracting during studying, including music and chatter, and why those noises were considered either helpful or distracting. A focused and open-ended interview format was chosen to help discover what the students think about background noises while they are studying. According to Thorne (2000), information obtained from interviews is especially helpful in exploratory analyses, particularly when attempting to gain insight into participants’ subjective experiences.

2.3.1.3 Procedure

Participants were interviewed individually by the same doctoral-level student using a standard interview, which was audio-recorded and transcribed to facilitate coding responses. Interview responses were also manually recorded on an interview protocol. Each participant completed all questions from the noise interview in a single session. The format of the interview was semi-structured, with a standard set of questions for each participant and prompts that depended on previous responses. Ethical approval was obtained from the University of Toronto’s Social Sciences and Humanities Research Ethics Board (REB) and informed
consent/assent was obtained from all participants and their parents before participating in the study.

2.3.1.4 Analysis

Responses to the noise interview were transcribed, explored, and summarized using quasi-qualitative methods. In particular, interview responses were first compared and then coded for adolescents with and without ADHD using a process termed “constant comparative analysis” (Thorne, 2000, p. 69), in which one interview transcript was compared with all others to identify similarities and differences and to help understand the possible relations between each interview until all interviews were compared with one another. Then, using the data-driven approach to coding (DeCuir-Gunby, Marshall, & McCulloch, 2011), specific categories were created for each question so that data could be reduced and key findings could be summarized. Categories were determined by looking at major themes that emerged and these categories were then used to code the transcripts. Coding was completed at the “level of meaning” (DeCuir-Gunby et al., 2011), in which the transcripts were split into codes based on their fundamental meaning, as opposed to coding by sentence or paragraph. Categories identified for each question are presented below, along with illustrative quotes from participants in the ADHD group (see Appendix C to Appendix G for full listings of the identified categories, with participant tallies and illustrative quotes, for each interview question).

2.3.2 Results

Study habits and preferences. Thematic analysis of the responses to the initial open-ended question, “Tell me how you study,” resulted in six key concepts being identified, including academic strategies, memory strategies, background sounds/noises, breaks/scheduling, aspects of the physical environment, and turning off electronics. Only four participants (one
with ADHD) referred to noise or music in their initial response, including listening to music and studying in quiet (e.g., “With music in the background”).

**Helpful noises while studying.** Next, participants were asked about specific noises that they find helpful during studying. Coding revealed four categories of responses, including music, no noises, environmental noises, and other noises. Nine responses referred to music (e.g., “Music that I like”), with a similar number of ADHD and non-ADHD participants responding that they find music helpful. Four participants indicated that they do not find any noises helpful while studying (e.g., “None,” “I don’t really find any noises helpful”). Three participants each reported finding environmental noises (e.g., “I like it when I’m in the kitchen and my parents are watching T.V. in the other room”) and other noises (e.g., “My own voice reading out loud”) helpful while studying.

**Distracting noises while studying.** Participants were also asked about specific noises that they find distracting during studying. Nine respondents identified music as being distracting (6 with ADHD, 3 without ADHD), and tended to comment on the genre or volume of the music (e.g., “Music I don’t like”). Seven participants mentioned that people talking around them was a distraction, especially if the conversation could be heard clearly or was directed to them (e.g., “A lot of other people if I can actually hear their conversation”). Four of the sixteen youth (3 comparison, 1 with ADHD) commented that the presence of background noises was distracting (e.g., “Cars going by”). Three participants each stated that electronics (e.g., “The T.V. or something on like electronics playing”), loud noises, and repetitive noises (e.g., “If there’s a ticking clock or something repetitive”) were distracting during studying.

**Listening to music while studying.** Participants were then asked if they like to listen to music while they work and to explain their rationale for their response. Ten respondents indicated that they like to listen to music while studying (6 with ADHD and 4 without ADHD).
When asked why, five categories of responses were identified including that music calms them, improves focus, prevents boredom, blocks out other noise, or some other reason. Four respondents each found music calming (e.g., “Calm music usually calms you down so you can do it”), indicated that music improved their focus (e.g., “It just kinda helps me concentrate”), or identified some other reason (e.g., “It’s kinda just background noise”; “I just like it”). Three participants indicated that music prevented boredom (e.g., “It prevents me from getting too bored of studying”) and two participants (both with ADHD) responded that music blocks out other noises from their environment while studying (e.g., “It cuts all the other noises out”; “It blocks the noise from my room or my house”).

Six participants (2 with ADHD and 4 without ADHD) mentioned that they do not like to listen to music while studying. When asked for their reasons, three categories of responses were observed, namely that music impairs focus, music distracts, or some other reason. Four youth (3 comparison, 1 with ADHD) indicated that music impairs their focus (e.g., “I just can’t focus on what I’m reading or I can’t take in information”) and two participants indicated that music is distracting in general (e.g., “It distracts me”). One youth without ADHD referred to a specific genre of music (e.g., rock) as being distracting.

**Listening to talking while studying.** Lastly, participants were asked if they can study when people are talking around them and to explain their rationale for their response. When the six participants who indicated that they can work in the presence of conversations were asked for their rationale, only one category was identified. They indicated that talking does not impair their focus (e.g., “’Cause I can focus in on what I’m doing”; “It doesn’t really bother me”). Ten participants responded that they are unable to work if people are talking around them (6 with ADHD and 4 without ADHD). When asked why they cannot work in the presence of conversation, the youths’ responses were coded into three categories, including that talking is
distracting, impairs focus, or another reason. Six participants mentioned that talking is distracting and that they often listen to others’ conversations (e.g., “If I don’t take my pill I’ll focus on a bunch of things, so if people are talking, it’s like I’ll focus on that as well”). Impaired focus on work in the presence of talking was identified by three participants (e.g., “It’s harder for me to focus on what I’m doing and get my thoughts together when other people are talking”). Finally, one participant mentioned that they do not know the reason why they are unable to work if people are talking around them (e.g., “I don’t know the background reason for it, I just can’t”).

2.3.3 Discussion

Summary and description of the participants’ interview responses indicated that youth with and without ADHD generally responded in a similar manner when asked about helpful noises and noises that are distracting. When asked specifically about whether they can work in the presence of music or conversation, some differences also emerged. Participants with ADHD generally reported that, whereas chatter is distracting when completing work, music is calming, prevents boredom, blocks out others noises, and improves focus. In contrast, the majority of youth without ADHD reported that they found music to be distracting during studying. Thus, results are somewhat consistent with what would be expected by the MBA model, in that many of the youth with ADHD prefer working in music (which is likely optimally stimulating), compared to working in silence (which is likely under-stimulating) or conversation (which is likely over-stimulating). The responses of youth without ADHD were more mixed; generally, these youth reported less of a preference for background noise overall.

These results are also consistent with those of Pelham et al. (2011) where most, but not all, participants with ADHD reported that they are able to work in the presence of music. In the current study, some participants hinted at the differential impact of various types of music and
noise suggesting that future research into the effect of type of noise during academic tasks is needed, including music genre, lyrical versus instrumental music, and steady environmental noises (e.g., white noise) versus changing background noises (e.g., cars honking). It is also important to consider ADHD students’ noise preferences for studying. In the current study, many participants responded that they preferred certain background noises (e.g., music, environmental noise) to others because those noises facilitated focus and concentration on the material they were studying. On the other hand, many respondents found certain background noises (e.g., chatter) distracting because they impaired focus or concentration. These preferences are consistent with the broader research on the impact of noise on learning and performance (e.g., Abikoff et al., 1996; Söderlund et al., 2007; Zentall & Smith, 1992).

2.4 General Discussion

Despite the fact that distractibility is a key diagnostic criterion for ADHD, a clear pattern of findings regarding distraction and noise has not emerged (e.g., Abikoff et al., 1996; Pelham et al., 2011). The present study extends current research on distraction in individuals with ADHD by focusing on the self-reported noise sensitivity and preferences for youth with ADHD when they are completing academic tasks, which has not been examined in past research.

Four key findings emerged from the results of Study 1. First, supporting the Stimulus Reduction Theory, adolescents with ADHD reported significantly higher levels of noise sensitivity than adolescents without ADHD. Second, girls reported higher levels of noise sensitivity than boys. Third, noise sensitivity was associated with self-reported inattention and hyperactivity-impulsivity, but was not independently associated with parent-rated inattention or hyperactivity-impulsivity. Fourth, contrary to expectations, noise sensitivity was not associated with cognitive measures of working memory and processing speed. Although the results of Study 1 appear to support the Stimulus Reduction theory, the results of Study 2 (where 6 of 8
adolescents with ADHD reported that they prefer to study while listening to music) suggest that may be an oversimplification. More specifically, contrary to what would be expected by the Stimulus Reduction theory, the responses to the noise interview revealed that youth with ADHD do not overwhelmingly report preferring a silent or quiet environment when studying at home. The majority of youth with ADHD in this study noted that they found music and some background noise as helpful when studying, perhaps because they provide an optimal level of stimulation, whereas silence and chatter are reported as over-stimulating. Collectively, these findings provide support for the MBA model. Whereas youth with ADHD perceive themselves to be more sensitive to general classroom noise (which is likely over-stimulating), they also tend to prefer some amount of background noise (e.g., music) over silence (which is likely under-stimulating) when studying in the home environment. Results also suggest a need for continued exploration of the link between noise preferences/sensitivity and performance in adolescents with and without ADHD, particularly as this is the first study to examine noise sensitivity in relation to academic work for that group of students. Thus, it is important for the MBA model to be considered and investigated further in future research.

The present findings are consistent with some but not all of the prior research on the effects of noise on attention in children or youth with ADHD. For example, our findings support recent data showing that children with attention difficulties are more impaired by noise on speech perception tasks than their typically developing peers (Klatte, Bergström, & Lachmann, 2013), showing more omission errors when presented with distractors (auditory, visual, and combined). In contrast, Berger and Cassuto (2014) reported that adolescents with ADHD showed no change on a sustained attention task in the presence of purely auditory distractors. Discrepancies in findings may be related to developmental differences in noise sensitivity between children and adolescents. In addition, it is possible that subgroups of youth
with ADHD may be more likely to be distracted by background noises than other subgroups, perhaps related to individual arousal levels (Pelham et al., 2011). As the current study was designed to explore the self-reported noise sensitivity and preferences of youth with ADHD, an area that is lacking in past research, the results of this study cannot clarify whether such individual or developmental differences exist.

2.4.1 Limitations

The strengths of the present study include the investigation of noise preferences and sensitivity for youth with ADHD, which has not been examined in past research, and the inclusion of a broad range of correlates (e.g., cognitive, oral language, and demographic) of noise sensitivity. However, there are several limitations to consider. The questionnaire and the interview both focused on the impact of noise in general on academic work and did not address how different noises may impact different academic tasks. It is possible that background noise may not impact academic performance in various domains, such as reading, written language, or mathematics, in the same manner. Boman and Enmarker (2004) found that students believed their performance in mathematics was most sensitive to noise interference, followed by their performance in language-based subjects. Also, participants’ perceptions of noise sensitivity and its impact on academic performance were only obtained through self-report. The impact of certain types of noises and noise preferences on actual academic achievement was not measured. As demonstrated by past research, the impact of noise on academic performance is not always straightforward (e.g., Anderson & Fuller, 2010; Boman, 2004; Ransdell et al., 2002; Takahashi, 2006). For the interview study, due to a lack of previous research on the perceptions of youth with ADHD on background noise while studying, a small sample was used to explore the possible areas to be examined in future research through a semi-structured interview instead of employing a full qualitative study design. The majority of the youth with ADHD in the
interview study sample were also being treated with medication and thus different patterns of responses may be found in youth with ADHD who are not receiving pharmacological treatment. Thus, the results are preliminary and cannot be generalized to other youth with ADHD.

2.4.2 Educational Implications

Some researchers advocate a quiet work environment for all students, regardless of their levels of attention. As an example, Boman and Enmarker (2004) state that providing students “with good conditions for learning requires lowering noise levels” (p. 208). Based on the results of these two studies, it does not appear that a quiet environment would be perceived by all students as beneficial. This finding is consistent with those of Smith and Riccomini (2013) who reported that not all students with learning difficulties benefitted from noise-reducing headphones during a reading task. Understanding how background noises impact academic performance on an individual basis is important in developing recommendations for optimal environments for both the classroom and home study space. Accommodations related to the physical environment of the classroom, including changes in background noise, are easily implemented and require little effort and time for the teacher (Carbone, 2001).

2.4.3 Directions for Future Research

Overall, the results highlight the need for further investigation into the perceptions of children and youth with ADHD regarding their level of distraction, noise sensitivity, and noise preferences while completing academic work in the presence of background noise. In particular, future research could continue to investigate whether the MBA model can help explain variations in noise sensitivity levels and noise preferences for youth with ADHD while they are completing academic tasks, to expand on research that has demonstrated a positive effect of noise on the cognitive performance of children with ADHD (Söderlund et al., 2007). Various factors may impact the level of distraction, including the nature of the distractors (e.g., music
versus conversation), individual differences (e.g., noise sensitivity), and environmental factors (e.g., home versus classroom setting). It is also important to examine the relations between self-reported noise sensitivity and performance-based indicators of performance (e.g., measures of reading comprehension or math problem solving) during distraction. As more becomes known about distraction for students, especially those with inattention and academic difficulties, future research can examine whether changes in actual classroom and study space environments are needed to facilitate attention (and improve performance) on academic tasks.
Table 2.1
Demographic features of the noise questionnaire participants

<table>
<thead>
<tr>
<th></th>
<th>ADHD Group (n = 52)</th>
<th>Comparison Group (n = 51)</th>
<th>Difference Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>χ</td>
</tr>
<tr>
<td>Gender (% male)</td>
<td>34 (65.38)</td>
<td>19 (37.25)</td>
<td>8.16**</td>
</tr>
<tr>
<td>Speaks Language other than English at Home (% yes)</td>
<td>13 (25.00)</td>
<td>25 (49.02)</td>
<td>8.30**</td>
</tr>
<tr>
<td>Born in Canada (% yes)</td>
<td>47 (90.38)</td>
<td>32 (62.75)</td>
<td>7.62**</td>
</tr>
<tr>
<td>Has an IEP (% yes)</td>
<td>41 (78.85)</td>
<td>3 (5.88)</td>
<td>61.27***</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>t</td>
</tr>
<tr>
<td>Parent-reported inattention¹</td>
<td>81.67 (8.49)</td>
<td>50.88 (6.24)</td>
<td>-20.93***</td>
</tr>
<tr>
<td>Parent-reported hyperactivity/impulsivity¹</td>
<td>82.15 (10.31)</td>
<td>50.12 (7.34)</td>
<td>-18.14***</td>
</tr>
<tr>
<td>Self-reported inattention¹</td>
<td>62.69 (12.03)</td>
<td>53.63 (8.40)</td>
<td>-4.43***</td>
</tr>
<tr>
<td>Self-reported hyperactivity/impulsivity¹</td>
<td>64.50 (13.98)</td>
<td>52.59 (9.41)</td>
<td>-5.06***</td>
</tr>
<tr>
<td>Estimated IQ²</td>
<td>105.08 (14.03)</td>
<td>109.86 (11.58)</td>
<td>1.88</td>
</tr>
</tbody>
</table>

Note. ¹Parent-reported inattention and hyperactivity/impulsivity are T-scores based on the DSM-IV inattention and hyperactivity/impulsivity scales from the Conners-3 parent report, and self-reported inattention and hyperactivity/impulsivity are T-scores based on the DSM-IV inattention and hyperactivity/impulsivity scales from the Conners-3 self report. ²Estimated IQ is a standard score obtained from the Matrix Reasoning and Vocabulary subtests of the Wechsler Abbreviated Scale of Intelligence (WASI).

* p < .05; ** p < .01; *** p < .001.
Table 2.2
Correlations between the noise questionnaire average score and demographic, cognitive, and oral language measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Noise Sensitivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2. Age</td>
<td>.004</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Medication Status</td>
<td>.004</td>
<td>.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Estimated IQ</td>
<td>-.10</td>
<td>-.10</td>
<td>.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Working Memory: Digit Span Backwards</td>
<td>-.04</td>
<td>.03</td>
<td>.14</td>
<td>-.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Working Memory: Listening Recall</td>
<td>-.12</td>
<td>-.03</td>
<td>.09</td>
<td>.08</td>
<td>.39**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Language: Formulating Sentences</td>
<td>-.08</td>
<td>-.21*</td>
<td>-.16</td>
<td>-.02</td>
<td>.23*</td>
<td>.22*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Language: Recalling Sentences</td>
<td>-.17</td>
<td>-.11</td>
<td>.13</td>
<td>.05</td>
<td>.35**</td>
<td>.47**</td>
<td>.48**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Processing Speed: Rapid Digit Naming</td>
<td>-.07</td>
<td>.02</td>
<td>.17</td>
<td>.25*</td>
<td>.45**</td>
<td>.22</td>
<td>-.03</td>
<td>.26*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Parent DSM-IV Inattention subscale</td>
<td>.22*</td>
<td>.11</td>
<td>.03</td>
<td>-.20*</td>
<td>-.21*</td>
<td>-.22*</td>
<td>-.11</td>
<td>-.12</td>
<td>-.40**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Parent DSM-IV Hyperactivity/Impulsivity subscale</td>
<td>.12</td>
<td>.05</td>
<td>.03</td>
<td>-.14</td>
<td>-.16</td>
<td>-.21*</td>
<td>-.19</td>
<td>-.18</td>
<td>-.27*</td>
<td>.82**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Youth report DSM-IV Inattention subscale</td>
<td>.53**</td>
<td>-.07</td>
<td>.20</td>
<td>.01</td>
<td>-.09</td>
<td>-.23*</td>
<td>-.07</td>
<td>-.11</td>
<td>-.15</td>
<td>.42**</td>
<td>.35**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Youth report DSM-IV Hyperactivity/Impulsivity subscale</td>
<td>.26**</td>
<td>-.03</td>
<td>.17</td>
<td>.08</td>
<td>-.09</td>
<td>-.08</td>
<td>-.06</td>
<td>.05</td>
<td>-.10</td>
<td>.44**</td>
<td>.47**</td>
<td>.76**</td>
<td></td>
</tr>
</tbody>
</table>

Note. For all variables, total $n = 103$, except for Estimated IQ and Formulating Sentences ($n = 102$), and Rapid Digit Naming ($n = 79$).

*p < .05, **p < .01
Table 2.3
Results of multiple regression analyses predicting self-reported noise sensitivity

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model Predicting Noise Sensitivity$^2$</th>
<th>$B$</th>
<th>$SE\ B$</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent-reported inattention$^1$</td>
<td></td>
<td>.01</td>
<td>.01</td>
<td>.10</td>
</tr>
<tr>
<td>Self-reported inattention$^1$</td>
<td></td>
<td>.06</td>
<td>.01</td>
<td>.71***</td>
</tr>
<tr>
<td>Self-reported hyperactivity/impulsivity$^1$</td>
<td></td>
<td>-.02</td>
<td>.01</td>
<td>-.29*</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td>.44</td>
<td>.15</td>
<td>.24**</td>
</tr>
<tr>
<td>$R^2$</td>
<td></td>
<td>.44</td>
<td>.38</td>
<td></td>
</tr>
<tr>
<td>$F$</td>
<td></td>
<td></td>
<td></td>
<td>14.78***</td>
</tr>
</tbody>
</table>

Note. $^1$Parent-reported inattention and self-reported inattention and hyperactivity/impulsivity are T-scores based on the DSM-IV inattention and hyperactivity/impulsivity scales from the Conners-3. $^2$Noise sensitivity is the average score from the noise questionnaire. *$p < .05$, **$p < .01$, ***$p < .001$
Table 2.4
Demographic features of the noise interview participants

<table>
<thead>
<tr>
<th></th>
<th>ADHD Group</th>
<th>Comparison Group</th>
<th>Difference Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 8)</td>
<td>(n = 8)</td>
<td></td>
</tr>
<tr>
<td>Parent reported inattention$^1$</td>
<td>81.13 (8.51)</td>
<td>56.88 (8.59)</td>
<td>-5.67***</td>
</tr>
<tr>
<td>Youth self-reported inattention$^1$</td>
<td>62.25 (11.50)</td>
<td>57.38 (6.61)</td>
<td>-1.04</td>
</tr>
<tr>
<td>Sensitivity to noise</td>
<td>2.88 (1.36)</td>
<td>2.38 (0.92)</td>
<td>-.86</td>
</tr>
<tr>
<td>Estimated IQ</td>
<td>104.63 (17.17)</td>
<td>113.00 (6.89)</td>
<td>1.28</td>
</tr>
<tr>
<td>Parent rating of academic impairment$^2$</td>
<td>2.13 (.64)</td>
<td>.63 (1.19)</td>
<td>-3.14**</td>
</tr>
</tbody>
</table>

Note. $^1$Parent-report inattention and self-reported inattention are T-scores based on the DSM-IV inattention scales from the Conners-3.

$^2$Parent-reported impairment is based on the response to “Your child's problems seriously affect schoolwork or grades” on the Conners-3P, with 0 = not true at all, 1 = just a little true, 2 = pretty much true, and 3 = very much true.

**$p < .01$, ***$p < .001$
CHAPTER THREE

The Effects of Background Noise on Academic Performance

for Adolescents with ADHD
3.1 Study 3 – Background Noise and Academic Performance

3.1.1 Abstract

This study examined the effects of two types of environmental noises (irrelevant speech and white noise) relative to a no noise control condition on the performance of youth with Attention-Deficit/Hyperactivity Disorder (ADHD) on reading comprehension and written expression tasks. Youth were also asked to rate the level of difficulty of each task. Fifty-two youth with ADHD participated. Performance on the reading task was measured by an oral retell (reading accuracy) and time spent reading the passage. Performance on the writing task was measured through the proportion of correct writing sequences (writing accuracy) and the total words written on the essay (writing fluency). Participants in the white noise condition took less time to read the passage and wrote more words overall when completing the writing task compared to participants in the other conditions, though white noise did not improve academic accuracy. The participants also rated the tasks as most difficult in the presence of babble. Educational implications are discussed.

3.1.2 Introduction

The impact of auditory environmental stimulation on the academic and cognitive functioning of children, youth, and adults has been the focus of a number of investigations (Batho, 2008; Boman, 2004; Buchner, Rothermund, Wentura & Mehl, 2004; Cohen, Evans, Krantz & Stokols, 1980; Elliott, 2002; Furnham & Strbac, 2002; Hygge, Boman & Enmarker, 2003; Martin, Wogalter, & Forlano, 1988; Ransdell & Gilroy, 2001). In general, findings suggest that background speech impairs performance on memory, reading comprehension, writing, and mathematics tasks for typically developing children, adolescents, and college students, as does background noise that varies over time (e.g., traffic noise, classroom noise). For instance, Elliott (2002) found that irrelevant background speech had an adverse impact on
children’s serial recall as compared to silent and tone conditions. In general, tones (e.g., Elliott & Cowan, 2005), traffic noise (e.g., Hygge et al., 2003), and music (e.g., Alley & Greene, 2008; Furnham & Strbac, 2002) have been found to impair performance on memory and academic tasks, though findings are not always consistent.

Research findings on the impact of environmental auditory stimuli on children with Attention-Deficit/Hyperactivity Disorder (ADHD) are also generally inconsistent (Abikoff, Courtney, Szeibel & Koplewicz, 1996; O’Connell, Bellgrove, Dockree, & Robertson, 2006; Sneddon, 2004; Söderlund, Sikström, & Smart, 2007; Uno et al., 2006; Zentall & Shaw, 1980). On the one hand, it has been argued that noise would be problematic for students with inattention because they are more vulnerable to distraction (Connors, Connolly, & Toplak, 2012), and noise is thought to impair cognitive processing and remove attention from the task (Elliott, 2002). A few studies, however, have shown a beneficial impact of background noise for children with ADHD (e.g., Abikoff et al., 1996; O’Connell et al., 2006; Söderlund et al., 2007; Uno et al., 2006; van Mourik, Oosterlaan, Heslenfeld, Konig, & Sergeant, 2007). For instance, white noise (Söderlund et al., 2007), vocal music (Abikoff et al., 1996), and novel sounds (van Mourik et al., 2007) have been shown to improve performance on cognitive (e.g., memory, reaction time) and academic (e.g., arithmetic) tasks. As van Mourik et al. (2007) indicated, it is possible that sounds that are normally considered “distracting” may not be so for children with ADHD, and that some background noise may have beneficial effects perhaps by increasing the arousal of children with ADHD to an optimal level. These results are consistent with the Moderate Brain Arousal (MBA) model in which stimuli that evoke moderate brain arousal in the dopamine system lead to improved performance for children with ADHD, whereas too little or too much stimuli lead to reduced performance (Sikström & Söderlund, 2007).
The primary objective of this study was to examine the effects of different background noises on academic performance in adolescents with ADHD. Students with ADHD often exhibit academic difficulties (Frazier, Youngstrom, Glutting, & Watkins, 2007) and are at higher risk for school drop-out (Fried et al., 2013), in addition to showing weaknesses in processing speed, working memory, and inhibitory control (Carte, Nigg, & Hinshaw, 1996; Shanahan et al., 2006). Given that youth with high levels of inattention often report more problems with distraction and concentration than their typically developing peers (see Chapter 2), it is possible that noise may be even more bothersome to students with ADHD. In fact, it is often assumed that students with learning and/or attention problems benefit from accommodations that limit background noise (e.g., writing tests in a separate room); however, as outlined above, there is little actual data from past research supporting this assumption.

This current exploratory study is noteworthy as it focuses on adolescents with ADHD, who have been underrepresented in research examining the impact of noise on academic and cognitive functioning. Given that distraction from background noise could be related to developmental level (e.g., Elliott, 2002) and age (e.g., Bell, Buchner, & Mund, 2008), it is important to also have existing research that examines the impact of noise on adolescents, to add to what is already known about the impact of noise on children and adults. In addition, examining academic performance of youth who also have clinical levels of inattention is important as poor attentional control has been hypothesized to be related to greater distraction from noise (Elliott, 2002). To our knowledge, there have not been any prior studies that have examined the impact of different types of noise on the academic performance of youth with ADHD, and only one study (i.e., Berger & Cassuto, 2014) that examined the impact of noise on cognitive performance for that group of individuals. Further research in this area is essential as
the results have important educational implications, especially related to optimal school environments for improved academic outcomes for youth with ADHD.

3.1.3 Factors Influencing Background Noise Effects in Children and Youth with and without ADHD

Research suggests that distraction from background noise is likely related to individual characteristics, including age, developmental level, and attention abilities (Bell et al., 2008; Elliott, 2002); specifically, younger individuals and those with inattention are more vulnerable to distraction than older individuals and those with good attentional control. Other factors that have been hypothesized to influence the effects of auditory stimuli on academic performance and behaviour include the characteristics of the auditory stimulation and the characteristics of the task (Klatte, Berström, & Lachmann, 2013), in addition to individual characteristics of the listener. For example, in the study by Söderlund et al. (2007), there was a positive effect of white noise on performance for children with ADHD, for both medicated and non-medicated children, supporting the MBA model. This is also consistent with other research that suggests that noise has to be continuous and at a high energy level at all frequencies (i.e., white or pink noise) to be beneficial, as intermittent noise is most disruptive to performance (Szalma & Hancock, 2011).

Results of other past studies also provide support for the MBA model for children and youth with ADHD. For example, white noise and music, which seem to provide moderate brain arousal, often enhance performance (e.g., Abikoff et al., 1996; Pelham et al., 2011; Söderlund et al., 2007). In contrast, auditory irrelevant speech likely provides too much arousal (e.g., Elliott, 2002) and no noise likely provides too little arousal (e.g., Söderlund, Sikström, Loftesnes & Sonuga-Barke, 2010; Uno et al., 2006), thereby resulting in poorer performance on tasks in speech and silent conditions. In the current study, performance in noise hypothesized to provide
an optimal level of stimulation (i.e., white noise) will be compared to performance in noises that are hypothesized to be either under- (i.e., silence) or over-stimulating (i.e., babble) for youth with ADHD.

Task characteristics, such as the requirements and difficulty level, also likely influence the impact of background noise on performance. Academic tasks such as reading comprehension and written generation tasks are likely to be the most strongly affected by noise because of their linguistic content (Klatte et al., 2013). It has been suggested that meaningful irrelevant speech backgrounds are more disruptive than meaningless speech for academic tasks that require participants to process meaning (Oswald, Tremblay, & Jones, 2000). As an example, one study found a specific adverse effect of background irrelevant speech on reading comprehension, especially for meaningful speech (Oswald et al., 2000). In studies on writing, background music, whether vocal or instrumental, has been shown to impair the length and quality of written essays (Ransdell & Gilroy, 2001). Thus, it appears that the characteristics of the academic task and specifically whether or not there is a linguistic component, will also affect the amount of disruption from background noise.

Relatedly, task difficulty, and the resulting demand on working memory, has also been hypothesized to influence the amount of impact that background noise has on task performance (Szalma & Hancock, 2011). For example, Furnham and Strbac (2002) hypothesized that music and noise are similar in their distracting effects on complex cognitive tasks, but that music may be beneficial on simpler tasks. Thus, academic tasks that require reading comprehension and composition (e.g., essay writing) are likely to be more strongly affected by noise than simpler tasks such as copying a text or reading single words. Reading comprehension requires higher-level processes, such as integrating ideas into a text to form a coherent mental model. In turn,
high-level processes such as planning, language generation, and reviewing, are needed when a person is asked to generate text (Olive & Kellogg, 2002).

3.1.4 Study Objectives and Hypotheses

The current study investigated the effects of two different types of environmental noise on academic performance in adolescents with ADHD. Participants were asked to complete academic tasks that require high cognitive demand. We are most interested in the effects of auditory noise on the ability to accomplish more demanding academic tasks (i.e., comprehend written text and generate written text) because being able to comprehend content and clearly communicate ideas is important to school outcomes (Graham & Perin, 2007; Knighton & Bussière, 2006). Also, tasks that require semantic understanding and those that are cognitively demanding are more likely to be affected by background auditory stimulation, and thus, are interesting to study theoretically (Klatte et al., 2013).

Academic performance measures focused on reading comprehension and written expression and included measures of performance accuracy, as well as performance speed and fluency. Perceived difficulty of the task, or cognitive load, was also measured as perceptions of task difficulty may affect learning ability and performance (e.g., Paas, Renkl, & Sweller, 2004). Furthermore, Choi, van Merriënboer, and Paas (2014) state that it is likely that aspects of the physical environment, including background noise, are separate factors that influence cognitive load in addition to individual characteristics of the student and features of the task. Perceptions of task difficulty may also affect task persistence (e.g., Sideridis & Kaplan, 2011), which has been linked to educational outcomes for adolescents, with higher levels of persistence leading to greater educational attainment ( Andersson & Bergman, 2011). Given that youth with ADHD tend to exhibit maladaptive task persistence and motivation compared to their normally-
developing peers (e.g., Hoza, Pelham, Waschbusch, Kipp, & Owens, 2001), increases in difficulty may especially reduce perseverance on complex tasks for that group of students.

Task performance on the reading comprehension task was measured with an oral retell of the passage (reading accuracy) and time to silently read the passage for each participant. Task performance on the written expression task was measured by the proportion of correct writing sequences (correct writing sequences divided by the total number of possible writing sequences, measuring writing accuracy) and total words written (writing fluency) for each participant. Finally, participants were also asked to rate the perceived level of difficulty of both tasks after their completion in their assigned noise condition.

The specific research question examined by this study was: What are the effects of different noise conditions (no noise, classroom babble, and white noise) on reading comprehension and written expression performance for adolescents with ADHD? Classroom babble was chosen as a noise condition because it is a typical auditory background for students when they are completing academic tasks, and past research has demonstrated that linguistic noise (e.g., speech, lyrical music) is often detrimental to performance. Conversely, white noise was chosen as a background condition because there is limited research on the impact of that particular type of noise on academic tasks, though preliminary findings suggest that white noise can improve memory performance for children with ADHD. Based on the MBA model, it was expected that there would be a significant impact of background condition, such that the participants with ADHD would perform best in the white noise condition on all outcomes, compared to their performance in the no noise or classroom babble condition. In addition, based on research on general noise effects, it was also expected that participants would exhibit the poorest performance in the classroom babble condition compared to the no noise condition, as
reading comprehension and written generation tasks are likely to be more strongly affected by semantic noise because of their linguistic content (Klatte et al., 2013).

3.2 Method

3.2.1 Participants

A sample of 52 adolescents (65% male) with a parent-reported diagnosis of ADHD (either inattentive-type or combined-type) were included in the present study which was part of a larger study examining oral and written comprehension in youth with and without ADHD. Participants who were between the ages of 14 and 16 were recruited from newspaper and community advertisements, contacts with organizations like the Learning Disabilities Association of Ontario (LDAO) and Children and Adults with Attention Deficit Disorder (CHADD), and local school boards. Parents who contacted the lab completed an intake interview and the *Conners-3 Parent Rating Scales, Long Form* (Conners 3-P; Conners, 2008) over the phone to screen potential participants for the study. A participant needed to obtain a T-score of at least 70 on one or more of the central ADHD indices (i.e., DSM-IV Hyperactive Impulsive, DSM-IV Inattentive, and DSM-IV Global) from the Conners 3-P, in addition to having a previous clinical diagnosis of ADHD, to be included in the ADHD group.

Youth were excluded from participation in the study if they had a prior diagnosis of a genetic or neurological disorder (e.g., Tourette’s syndrome, autism spectrum disorder, psychotic disorder) according to parental report. Adolescents with both ADHD and a learning disability (LD) and/or other diagnoses (e.g., oppositional defiant disorder, conduct disorder, anxiety or mood disorders) were not excluded from the study. Participants were also only included in the present study if their estimated IQ was at a standard score of 70 or greater, or if they had a standard score of 70 or more on at least one of the subscales (i.e., verbal or non-verbal
reasoning) measuring IQ\(^2\), as research has suggested that excluding children with ADHD who have standard scores in the borderline range (IQ 70 to 79) unnecessarily truncates the sample (Antshel, Phillips, Gordon, Barkley, & Faraone, 2006). Parents of participants were asked if their child has sufficient understanding of the English language and if they have any hearing difficulties. In total, 69\% of the adolescents with ADHD were taking medication for the disorder, though they were asked to withhold taking their ADHD medication on the day of the testing, as medication has been shown to improve academic and cognitive performance for children with ADHD in the presence of auditory distractors (Pelham et al., 2011). Participants were randomly assigned to each noise condition, including no noise (\(n = 16\)), white noise (\(n = 16\)), and classroom babble (\(n = 20\)).

3.2.2 Materials

**Reading task.** For the reading comprehension task, participants each read a short information text about immigration from the *Qualitative Reading Inventory-Third Edition* (QRI-3; Leslie & Caldwell, 2001) in their assigned background noise condition. Previous knowledge of the topic of the text was assessed before reading, using 4 questions each scored from 0 to 2 for a total possible score of 8, to measure differences in previous knowledge of the text among the 3 conditions. The academic accuracy outcome variable on the reading comprehension task was the number of elements (main ideas and details) correctly recalled in an oral retell of the passage. Oral retell responses were double-scored for 15 of the participants with and without ADHD with high inter-rater reliability based on the Intraclass Correlation Coefficient (ICC = .93). Time to silently read the QRI passage was also recorded for each participant (presented in seconds), as a measure of time spent on the task.

\(^2\) Students who did not have an estimated IQ score available were still included in the study if they performed in the average range on the remaining cognitive measures (e.g., working memory, processing speed) and if their parent did not report that they were identified with an intellectual disability.
**Writing task.** Participants also completed a text generation (writing) task. They wrote a persuasive essay in response to a given probe (e.g., “Should cell phones be allowed in school?”). They were given 2 minutes to plan their response and 5 minutes to complete the essay, and completion time was noted if participants finished before the time limit. The academic accuracy variable on the writing task was the proportion of correct writing sequences (PCWS, which was calculated by dividing the number of correct writing sequences by the number of total possible word sequences), and the academic fluency variable was the total words written (TWW). PCWS is a measure of correct writing mechanics, taking into account spelling, punctuation, and grammar, independent of how much was written. Such measures of written expression performance have been found to be both valid and reliable for examining writing ability in adolescents (Espin et al., 2000). All writing samples were double-scored by two different raters, with rater 1 double-scoring the writing samples for the first 34 participants and rater 2 double-scoring the writing samples for the remaining participants. The inter-rater reliability for the TWW with both raters was extremely high (ICC = .99). The inter-rater reliability for the PCWS was also high for both rater 1 (ICC = .93) and rater 2 (ICC = .90). TWW and PCWS were also significantly correlated with other measures of writing in the current study, including writing fluency (r = .47 and r = .50, respectively) and a standardized measure of writing ability (Woodcock Johnson Third Edition, Writing Samples subtest; r = .44 and r = .48, respectively), indicating that they are valid measures of written expression performance.

**Difficulty rating.** After completion of both the reading comprehension task and the writing task, participants were asked to rate the perceived level of difficulty of the experimental tasks in response to a probe (“Please rate how difficult this task was for you by circling one of the numbers below. A rating of 1 indicates that you felt the task was extremely easy whereas a rating of 9 indicates that you felt the task was extremely difficult”). This task difficulty
assessment has been used in prior research as an indicator of cognitive load when completing tasks (e.g., DeLeeuw & Mayer, 2008).

**Background noise.** The background noise was continuously played in the lab during completion of the reading and writing experimental tasks. Noise was played over a speaker placed behind and to the right of participants. On traditional dichotic listening tasks, speaker placement has been related to a right-ear advantage for most individuals (i.e., participants are better able to attend to auditory information presented to the right ear over auditory information that is presented to the left ear); however, for students with inattention a left-ear advantage has been found (Schmithorst, Farah, & Keith, 2013). Thus, differing impacts of the background noise could be expected for participants based on a possible right- or left-ear advantage; however, the current study differs from traditional dichotic listening tasks as participants were instructed to ignore all irrelevant noise as opposed to instructions to specifically pay attention to information from one ear or the other. As such, it is not expected that any possible confounds would result from the speaker placement, which was the same for all participants.

Participants were randomly assigned to one background noise condition only (i.e., silence, classroom babble, or white noise), and they read a passage or completed a writing task in their assigned noise condition. An independent groups design was employed as opposed to a repeated measures design due to limited time (the experimental measures were administered at the end of a 6-hour testing battery) and the difficulty of creating reading and writing measures that would be similar enough to use in each background condition (e.g., measures would vary in difficulty, interest level, prior knowledge of the topic). Both the classroom babble and the white noise were presented at a level of about 70 decibels, as Sikström and Söderlund (2008) indicate that noise levels need to be within 70 to 80 decibels to show a beneficial effect; levels of noise that are too low show weaker or absent effects, whereas higher levels are universally detrimental.
for performance. Decibel levels were measured with a portable decibel meter to ensure similar conditions across participants.

**Other Measures.**

*Estimated IQ.* Intellectual ability in general was assessed using the *Wechsler Abbreviated Scale of Intelligence* (WASI). Raw scores were converted to T-scores (with a mean of 50 and a standard deviation of 10) based on age and these latter scores were used in the analyses.

*Working memory.* To assess working memory abilities, the listening recall subtest from the *Working Memory Test Battery for Children* (WMTB-C; Pickering & Gathercole, 2001) was administered to all participants. Raw scores from the listening recall task were converted to age-based standard scores (with a mean of 100 and a standard deviation of 15), and these latter scores were used in the analyses.

*Processing speed.* To measure processing speed, participants were given a rapid digit naming task from the *Comprehensive Test of Phonological Processing* (CTOPP). Raw scores were converted to age-based scaled scores and these latter scores were used in the analyses.

A rapid naming task was used to index processing speed in the current study as research has demonstrated that there is a high correlation between measures of rapid naming and other measures of processing speed, such as coding and Stroop tasks (e.g., Shanahan et al., 2006). Rapid naming is related to both reading difficulties and ADHD, which may explain some of the comorbidity between the disorders (Shanahan et al., 2006). Thus, it is possible that the rapid naming measure used in the current study represents a possible confound for those with comorbid ADHD and reading disability; however, it also appears that naming speed is a reliable predictor of inattention symptom severity independent of phonological awareness ability (Arnett et al., 2012) and that students with reading disability only show larger processing speed deficits
on both naming speed tasks and speeded motor tasks than those students with either ADHD only or both disorders (Shanahan et al., 2006).

Receptive language. The listening comprehension subtest of the *Oral and Written Language Scales* (OWLS) was administered to measure receptive language. Raw scores were converted to age-based standard scores, which were used in the analyses.

Academic measures. The *Test of Word Reading Efficiency* (TOWRE) was used to assess reading fluency and the *Woodcock Johnson Tests of Achievement* (WJ-III ACH) was used to assess general writing ability. For both tasks, raw scores were converted to age-based standard scores, which were used in the analyses. A standardized measure of writing fluency from the *Process Assessment of the Learner* (PAL-RW) was also administered, with raw scores (total number of letters written within the time limit) being used in the analyses.

Self-reported ADHD symptoms. Finally, all participants also completed the *Conners 3 Self-Report Rating Scale, Long Form* (Conners 3-SR) to examine their self-reported inattention and hyperactivity/impulsivity symptoms. Raw scores were converted to T-scores based on gender (male or female) and age.

3.2.3 Procedure

General intake procedures are described in the previous study on noise sensitivity (Chapter 2). Youth came to the University of Toronto and were individually tested in a lab for one session by trained graduate students. The data for this present study were collected in the context of data collection for other studies, and near the end of the 6-hour session. Ethical approval from the University of Toronto’s ethics board was obtained before beginning recruitment and data collection.

For the present study, youth with and without ADHD were randomly assigned to one of three noise conditions (no noise, white noise, and linguistic classroom babble). Each participant
completed academic tasks, measuring reading comprehension and writing, in the presence of their assigned noise, and then rated the perceived difficulty of each task. For the reading comprehension task, which was completed first for all participants, noise was only presented when the participants read the text and not during the comprehension outcome measure (i.e., oral retell) whereas noise was presented during the entire writing task (i.e., planning and composing).

3.2.4 Data Analysis Plan

Preliminary analyses (one-way ANOVAs or chi-square tests, as appropriate) were conducted to examine whether the participants with ADHD in each experimental condition were similar on the demographic and screening measures, so that significant differences between groups in each condition could be controlled for in the analyses. Then, the effects of background noise condition (no noise, white noise, or classroom babble) on performance for the ADHD participants on each outcome variable were examined using orthogonal planned contrasts based on both the MBA model and research on the impact of linguistic noise on academic performance.

The two sets of contrasts were chosen to investigate the impact on academic work of the two background noise conditions employed in this study: a noise condition expected to provide optimal stimulation but that is rarely used in practice (i.e., white noise) and a typical classroom condition that has been shown to be detrimental for academic performance (i.e., babble). Specifically, the first set of planned contrasts specifically examined whether reading comprehension performance (including reading accuracy, measured by an oral retell of the passage, and time spent reading) and written expression performance (including writing accuracy, measured by PCWS, and writing fluency, measured by TWW) were best in the white noise condition compared to the average performance in the no noise and babble conditions, as
would be predicted by the MBA model. A second set of planned contrasts examined whether performance in the no noise condition was significantly better than performance in the babble condition on each of the reading comprehension and writing outcome measures. Past research would predict that participants would demonstrate worse performance in the babble condition compared to the no noise condition, based on the evidence that suggests that linguistic noise is detrimental to performance. As both sets of contrasts specify a directional relationship between group performance in the different conditions (i.e., predicting that one group would perform better than another group in a different noise condition), one-tailed significance tests were employed. The magnitude of differences in performance between the conditions was assessed using Cohen’s d. In addition, the Binomial Effect Size Display (BESD) calculation was used to examine the actual differences in performance between the conditions (Rosenthal, Rosnow, & Rubin, 2000).

One of the outcome variables (PCWS) was transformed for analysis using an arcsine transformation to account for a negatively skewed distribution which is often seen with proportional data. Additionally, individual analyses sometimes did not include the entire sample due to missing data on some of the dependent measures.

3.3 Results

3.3.1 Preliminary Analyses

Results of the preliminary analyses comparing the youth with ADHD in each background noise condition are summarized in Table 3.1. A significant difference was found only for medication status. Examination of the cross-tabulation table revealed that participants with ADHD in the no noise condition were more likely to be taking medication than participants in the white noise or classroom babble conditions; however, as none of the participants took their medication on the day of testing, medication status did not need to be controlled for in the
analyses. There were no significant differences on any of the other demographic, cognitive, or academic variables.

One-way ANOVAs were also conducted to examine whether the participants with ADHD in each experimental condition were similar on the supplementary experimental measures, including previous knowledge of the reading comprehension passage (i.e., knowledge of concepts related to immigration) and time spent planning and writing the essay\(^3\). There were no significant differences between the groups in each experimental condition on those three measures; thus, they were not included in the analyses as control variables.

### 3.3.2 Effects of Noise on Academic Task Performance

The means and standard errors for the groups in each of the background noise conditions on the experimental measures are presented in Figure 3.1 (for the reading task) and Figure 3.2 (for the writing task).

**Reading comprehension accuracy.** Background noise condition did not appear to influence the accuracy of reading comprehension performance. On the oral retell task, the planned contrast comparing the white noise group to the average of the no noise and babble conditions was not significant, \( p = .13 \), nor was the planned contrast comparing the no noise group to the babble group, \( p = .15 \). Students in the no noise were able to recall about 8 ideas from the text in total, whereas the white noise group and babble group could only recall 5 and 6 ideas, respectively. Effect sizes were in the small to medium range (\( d = .34 \) and \( d = .37 \), respectively). Using the BESD calculation as another way of evaluating the degree of change between groups in different conditions (Rosenthal et al., 2000), the babble group exhibited a 15% decrease in the number of correct ideas in their oral retell relative to the no noise group. In

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\(^3\) Whereas time spent reading the passage is a main outcome variable, time spent writing the essay is considered a supplementary measure as there was a set time limit for the writing task. Most participants wrote for the entire 5 minute period and many would have continued writing if they were not told to stop; thus, time spent writing is not an accurate measure of how long participants may have written for without a limit (as with the reading task).
addition, the white noise group experienced a 17% decrease in their oral retell ideas relative to participants in the babble and no noise conditions combined.

**Time spent reading.** Using time spent reading on the reading comprehension task as the dependent variable, the planned contrast comparing the white noise group to the average of the no noise and babble conditions was not significant \( (p = .13, d = .40) \) nor was the planned contrast comparing the no noise group to the babble group \( (p = .41, d = .06) \). Nonetheless, results of the first contrast were consistent with what was predicted by the MBA model, as according to the BESD calculation, the white noise group experienced a 17% improvement in their reading time (i.e., they read the passage in 35 fewer seconds with a reading time of 169 seconds) compared to the average reading time of the other two groups. Examination of the bar graph for time spent reading (see Figure 3.1) indicates that the expected pattern of results (i.e., better performance in white noise) was evident in the data. In contrast, the no noise group had a reading time that was very similar to the babble group, with a mere 3% increase in the time spent reading for the no noise group (208 seconds) over the babble group (201 seconds).

**Writing accuracy.** On the measure of writing accuracy (PCWS), the planned contrast comparing the white noise group (PCWS = .85) to the average of the no noise and babble conditions was not significant \( (p = .35, d = .09) \) nor was the planned contrast comparing the no noise group (PCWS = .88) to the babble group (PCWS = .84; \( p = .19, d = .35 \)). Using the BESD calculation, the white noise group experienced a 5% decrease in writing accuracy compared to performance in the other two groups, and the no noise group experienced a 13% improvement in their performance compared to the babble group. In general, however, participants from each background noise condition wrote a proportionately similar number of correct and incorrect writing sequences irrespective of the background noise present while completing the writing task.
**Writing fluency.** For the outcome variable examining writing fluency (TWW), the planned contrast comparing the white noise group (TWW = 92) to the average of the no noise and babble conditions was significant, $p = .047$, with a medium effect size, $d = .53$. In contrast, the planned contrast comparing the no noise group to the babble group was not significant ($p = .39, d = .09$). Thus, results of the first contrast were consistent with what was predicted by the MBA model. In addition, according to the BESD calculation, the white noise group experienced a 24% improvement in their writing fluency, writing about 14 more words than the other two groups. Examination of the bar graph for writing fluency (see Figure 3.2) confirms that the expected pattern of results (i.e., better performance in white noise) was evident in the data. In contrast, the no noise group (TWW = 80) demonstrated similar writing fluency to the babble group (TWW = 78), with only a 4% increase in their TWW over that of the babble group.

**Self-reported task difficulty.** Differences between the groups for task difficulty on the reading task were found using the planned contrasts. Whereas there was no significant difference between the white noise group and the average of the other two groups ($p = .46, d = .004$), participants in the no noise condition rated the task as being significantly easier than the participants in the babble condition ($p = .02$), with a medium effect size, $d = .74$. In addition, according to the BESD calculation, the ratings of the youth in the babble group were 30% greater than that of the no noise group. In contrast, the white noise group demonstrated similar difficulty ratings to the average of the two other groups, with a mere 2% increase in their difficulty rating over that of the no noise and babble groups combined.

Similar results were found with the writing task. Whereas there was no significant difference between the white noise group and the average of the other two groups ($p = .47, d = .02$), participants in the no noise condition rated the task as being easier than the participants in the babble condition ($p = .02$), with a medium effect size, $d = .79$. In addition, according to the
BESD calculation, the ratings of the youth in the babble group were 31% greater than that of the no noise group. In contrast, the white noise group demonstrated similar difficulty ratings to the average of the two other groups, with a mere 1% decrease in their difficulty rating over that of the no noise and babble groups combined.

3.4 Discussion

The present study tested the effects of two different noise conditions hypothesized to either facilitate or hinder the ability of youth with ADHD to comprehend and compose written text (Söderlund et al., 2007), skills of importance to academic success in high school and beyond. Results showed that youth with ADHD in the white noise condition wrote more words and took less time to read the text relative to youth in the other two conditions. While only the group differences on TWW were statistically significant, an examination of the effect sizes for both TWW and reading time suggests a moderate difference between the noise conditions. Participants’ performance in the no noise and classroom babble conditions on writing fluency and time spent reading were not significantly different (nor practically different in magnitude according to the effect sizes) suggesting that both too little (e.g., no noise) and too much (e.g., babble) background stimulation can similarly attenuate academic response time/fluency performance.

While there appears to be a benefit of white noise for reading time and writing fluency, the pattern of findings on the academic accuracy measures (i.e., oral retell, PCWS) suggests that white noise does not result in an improvement in performance accuracy. For oral retell, measuring reading comprehension accuracy, the results imply that a no noise condition may be the most advantageous for comprehension based on the fact that the total number of ideas recalled in the oral retell was reduced in the white noise condition (by 17%) and the babble condition (by 15%) relative to the number of ideas recalled in the no noise condition. In
contrast, for the writing task, although the participants in the white noise condition had an increase in the total number of words written (by 24%), they did not have a significantly different writing accuracy score from the groups in the other two noise conditions (which were also very similar in terms of their PCWS). Thus, it is possible that no noise is the most advantageous for higher-level thinking (e.g., comprehension of ideas) while reading, though not necessarily while writing; however, as only correct writing mechanics was assessed by PCWS in the current study, it is possible that noise may have had a larger adverse effect on measures more related to higher-level thinking while writing (e.g., organization, creativity, coherence), which were not examined in the present study. Future research with larger sample sizes is needed to determine whether the possible advantage of white noise on reading time/writing fluency is offset by a potentially negative effect on higher-level academic processes.

Overall, these results partially support the hypotheses based on the MBA model, which states that an optimal level of noise would provide the optimal environment for students with ADHD when they are completing academic and cognitive tasks, whereas too little or too much auditory stimulation would result in a decrement in performance. This pattern of results was only found for the measure of writing fluency and time to read the text passage. In contrast, adolescents’ performance across the conditions on measures of accuracy (e.g., oral retell, PCWS) was not consistent with the MBA model as there were no significant improvements in the white noise condition compared to performance in the other two conditions for those measures. In addition, those measures had low effect sizes (according to Cohen’s d) or effect sizes in the opposite direction than expected (according to the BESD).

Thus, it seems there was a positive effect of background noise on the amount of time it took to read the passage with participants in the white noise condition completing the reading portion of the task more quickly, but just as accurately, than participants in the other noise
conditions. Conversely, this effect was not evident with reading comprehension accuracy. It is unclear from past research what effect noise might have on amount of time spent reading as no studies examining the impact of background stimulation on reading time were found. Consequently it is also uncertain if the white noise served to increase reading fluency for youth with ADHD, or if it impacted reading speed by some other means (e.g., by increasing focus so that the youth were able to read with fewer breaks in concentration and redirections back to the passage).

As well, the youth in the white noise group wrote 14 more words on average than the group mean of the youth in the no noise and babble conditions, suggesting an improvement while listening to white noise for youth with ADHD in the current study, with similar levels of performance found in the no noise and classroom babble conditions. These results are in contrast to those found by Ransdell, Levy, and Kellogg (2002), who found that background speech decreased compositional fluency, but not the quality, of an essay compared to a silent condition for university students. As they examined the writing performance of typically developing students, both results can still be considered consistent with the MBA model. In the current study, students with ADHD required an optimal level of background stimulation (i.e., that provided by white noise) for improved performance, and showed a relative decrement in performance in silence and babble. On the other hand, it would be expected that the typically developing students in the Ransdell et al. (2002) study would be negatively impacted by any type of noise and would perform best in a silent condition, as they would not require any amount of background noise for optimal stimulation.

Overall, the results of this study and results from past research suggest that background noise may impact the speed of a response (e.g., time spent reading, writing fluency) differently than it impacts the accuracy of a response. Previous research indicates that background noise,
especially speech, has a stronger negative impact on measures of response accuracy than on measures of response speed for cognitive and communication tasks, at least for healthy adults (Szalma & Hancock, 2011). Based on the results of the current study, it also seems that the converse may be true for youth with ADHD (i.e., that some noise may have a stronger beneficial impact on measures of response speed than response accuracy). As there are no previous studies on the academic performance of youth with ADHD in varying noise backgrounds, more research is needed to draw conclusions about the types of noise that may be most helpful (e.g., white noise, music) or detrimental (e.g., speech) for both performance speed and accuracy on academic tasks.

In addition to the type of background noise, task difficulty has also been linked to the amount of impairment resulting from background noise in research (e.g., Zentall & Shaw, 1980; Szalma & Hancock, 2011). Participants in the current study perceived the classroom babble condition to be the most difficult for reading and writing tasks, whereas the no noise condition was perceived to be the easiest. This is an interesting finding as the perceived difficulty of a task may affect the extent to which an individual with ADHD persists on the task (Hoza et al., 2001). Previous research has also found that participants do not always accurately perceive the improvement or decrement in performance in the presence of background noises. For example, in a study that examined working memory ability in the presence of vocal music, instrumental music, and irrelevant speech, Alley and Greene (2008) found that speech and vocal music degraded performance for college students, though participants were not able to accurately perceive the memory impairment that resulted from the noise. In contrast, in the current study, youth perceived a negative impact of babble on their reading and writing performance as evidenced by an increase in their difficulty ratings.
3.4.1 Limitations

The main strength of the present study is the investigation of noise effects (predicted to be either facilitative or adverse depending on the noise) for adolescents with ADHD on complex academic measures, which has not been examined in past research. However, there are several limitations of the current study. A between-subjects design was used, with a small number of youth with ADHD in each experimental condition, resulting in a decrease in power and cautious interpretation of the effects. With a larger sample size, of about 30 participants or greater in each condition, it is possible that more of the contrasts may be significant. Nevertheless, effect sizes and BESD calculations, as well as bar charts illustrating the trends in data, indicate support for future testing of the MBA model with larger sample sizes.

In addition, a within-subjects design would have been beneficial, not only for increasing sample size, but also for investigating possible order effects in the enhancement of academic performance. For example, in the study by Abikoff et al. (1996), academic performance was enhanced by music for only the children with ADHD who received music as their first condition. Abikoff et al. (1996) suggested that the beneficial impact of music seen initially with academic performance could not counter boredom for the entire duration of the task. Thus, it is possible that the beneficial effect of white noise on academic fluency in the current study may have diminished had participants received it as their second or third background condition.

The current study is similar to the study by Söderlund et al. (2010), in that noise was only presented while reading the passage (i.e., during encoding) but not while retelling the passage (i.e., during retrieval), so the effects of noise can only be attributed to the encoding condition for the reading comprehension task. Improvements from white noise were only found on the time spent reading the passage; it is possible that improvements in comprehension could have also been found had the white noise continued while the participants provided an oral retell
of the passage. On the other hand, improvements for writing fluency, and not for writing accuracy, were found on the text generation task, which had a continuous presentation of white noise for the entire planning and writing portions of the task.

In addition, only two background noise conditions (white noise and babble) were compared to a no noise condition in the current study. The beneficial or adverse impact of other noise conditions (e.g., music) on academic performance was not examined. Furthermore, the decibel level of the “quiet” condition was not measured in the current study, so we do not have knowledge of the natural noise intensity of the no noise condition. As noted by Szalma and Hancock (2011), even low-intensity noises or quiet conditions may have a negative impact on performance depending on their decibel level. They recommend that the decibel level (i.e., noise intensity) of the quiet condition also be measured and reported in all research studies examining noise effects, which was not done in the current study. Though we attempted to make the no noise condition as “quiet” as possible by completing the study in a self-contained lab, it is conceivable that some level of noise was still present that may have impacted performance.

It is also possible that differences in the impact of noise on the reading task versus writing task may be a function of possible differences in the interest level of the tasks for youth with ADHD (i.e., writing about cell phone usage at school may have been more interesting to the participants than reading about immigration). As self-reported interest in each task was not measured in the current study, it is unclear if the effects of noise on academic performance may have been modulated by variations in task interest and engagement.

Finally, though not investigated in the current study, past research indicates that there is a large overlap of sensory processing difficulties and ADHD, in that sensory integration disorder in general, and central auditory processing disorder (CAPD) more specifically, are more common in students with ADHD (Ghanizadeh, 2011). According to Ghanizadeh (2011), such
problems with auditory processing result in difficulties with many aspects of listening, including auditory discrimination, localization of the source of sounds, and distraction from noise related to either a hyposensitivity or hypersensitivity to sounds. Thus, the results from the current study may have been impacted by a comorbid CAPD in some of the youth with ADHD. If they are hyposensitive to environmental noise, then they would have needed more noise to see either a positive or negative effect on the experimental measures. On the other hand, if they are hypersensitive to the environment, the noise levels presented during the tasks may have been too over-stimulating, resulting in a wide-ranging negative effect on performance. As comorbid sensory difficulties were not investigated, it was not possible to investigate the impact of those difficulties on the obtained results.

3.4.2 Implications for Clinical Practice and Future Research

Some researchers advocate a quiet work environment for all students, regardless of their levels of attention. As an example, Boman and Enmarker (2004) state that providing students “with good conditions for learning requires lowering noise levels” (pp. 208). Based on the results of the current study, it does not appear that a quiet environment would be beneficial to all students, especially those with ADHD who may benefit from an optimal level of background noise. Understanding how background noises impact academic performance on an individual basis is important in developing recommendations for optimal environments for both the classroom and home study space. Accommodations related to the physical environment of the classroom, including changes in background noise, are easily implemented and require little effort and time for the teacher (Carbone, 2001). For example, Carbone (2001) recommends setting up a “listening centre” (pp. 78) with earphones as a structural accommodation for children with ADHD in the classroom, in which the earphones could be used to filter out distracting classroom conversations during complex and novel tasks. In contrast, during simple
and familiar tasks, Carbone (2001) recommends using the listening centre to play background noise or music.

Related to task difficulty, more research is needed to understand how background noise impacts performance on different academic tasks for youth with and without ADHD. It may be that the background noise conditions needed for optimal performance on different academic tasks vary. For instance, using a questionnaire to examine the study environments of children in grades 5 through 9 with varying levels of attention, Patton et al. (1983) found that students often changed from quiet settings for reading tasks to non-quiet settings for writing and math tasks. Furthermore, they speculated that, while music and other environmental distractors may have a perceivable and adverse impact on academic performance overall, they may also have benefits, such as increasing the amount of time a student devotes to an academic task (Patton et al., 1983). The current study suggests that some steady noise (i.e., white noise) may also have a beneficial impact on reading time and writing fluency, reducing the amount of time required to complete, and maintain attention on, a given task.

3.4.3 Conclusions and Directions for Future Research

In conclusion, performance on some of the academic measures in the current study is generally supportive of the hypotheses set forth by the MBA model. An optimal level of noise (i.e., white noise) provided the best environment for youth with ADHD on academic tasks particularly related to time spent reading and writing fluency, whereas too little (i.e., no noise) or too much (i.e., babble) auditory stimulation resulted in a relative decrement in performance on those measures. In contrast, results from the academic accuracy tasks (oral retell of the reading passage and the proportion of correct writing sequences) did not support the MBA model. Performance on all academic tasks also did not support previous research suggesting that speech backgrounds are more detrimental than silent backgrounds, except with regards to
difficulty ratings; participants perceived that the tasks were easiest in the presence of no background noise and most difficult in the presence of classroom babble.

More research is needed to bridge the gap between cognitive and educational research in psychology, in order to expand current knowledge of the learning experiences for youth with attention difficulties. In particular, research examining what type of noise is helpful or detrimental for academic performance, and on what type of academic task, can help inform educators with regards to optimal learning environments. Considering that students learn new information in classroom environments where linguistic and other noise is frequently present, it is important to understand under what conditions they learn best, particularly for those students with ADHD who are easily distracted and at significant risk for academic underachievement.
Table 3.1
*Demographic, cognitive, and academic features of the ADHD participants in each background noise condition*

<table>
<thead>
<tr>
<th></th>
<th>No Noise (n = 16)</th>
<th>White Noise (n = 16)</th>
<th>Babble (n = 20)</th>
<th>Difference Statistic</th>
<th>Significance Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (% male)</td>
<td>10 (62.50)</td>
<td>13 (81.25)</td>
<td>11 (55.00)</td>
<td>2.79</td>
<td>.25</td>
</tr>
<tr>
<td>Medication (% yes)</td>
<td>15 (93.75)</td>
<td>8 (50.00)</td>
<td>13 (65.00)</td>
<td>7.46</td>
<td>.02</td>
</tr>
<tr>
<td>Speaks Language Other than English at Home (% yes)</td>
<td>3 (18.75)</td>
<td>5 (31.25)</td>
<td>5 (25.00)</td>
<td>.67</td>
<td>.72</td>
</tr>
<tr>
<td>Born in Canada (% yes)</td>
<td>16 (100.00)</td>
<td>14 (87.50)</td>
<td>16 (80.00)</td>
<td>2.64</td>
<td>.27</td>
</tr>
<tr>
<td>Has an IEP (% yes)</td>
<td>14 (87.50)</td>
<td>12 (75.00)</td>
<td>15 (75.00)</td>
<td>.88</td>
<td>.64</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>15.50 (.98)</td>
<td>15.77 (.91)</td>
<td>15.20 (1.09)</td>
<td>1.43</td>
<td>.25</td>
</tr>
<tr>
<td>Estimated IQ&lt;sup&gt;1&lt;/sup&gt;</td>
<td>105.44 (13.39)</td>
<td>101.38 (14.22)</td>
<td>104.80 (16.87)</td>
<td>.34</td>
<td>.71</td>
</tr>
<tr>
<td>Working Memory&lt;sup&gt;2&lt;/sup&gt;</td>
<td>107.94 (22.40)</td>
<td>98.50 (17.98)</td>
<td>114.70 (21.96)</td>
<td>2.66</td>
<td>.08</td>
</tr>
<tr>
<td>Processing Speed&lt;sup&gt;3&lt;/sup&gt;</td>
<td>9.64 (2.50)</td>
<td>8.36 (2.56)</td>
<td>8.18 (2.04)</td>
<td>1.69</td>
<td>.20</td>
</tr>
<tr>
<td>Receptive Language&lt;sup&gt;4&lt;/sup&gt;</td>
<td>104.50 (12.77)</td>
<td>100.38 (14.48)</td>
<td>103.21 (16.32)</td>
<td>.33</td>
<td>.72</td>
</tr>
<tr>
<td>Reading Fluency&lt;sup&gt;5&lt;/sup&gt;</td>
<td>95.25 (11.41)</td>
<td>93.31 (10.87)</td>
<td>89.26 (14.27)</td>
<td>1.07</td>
<td>.35</td>
</tr>
<tr>
<td>Writing Fluency&lt;sup&gt;6&lt;/sup&gt;</td>
<td>31.19 (11.02)</td>
<td>29.19 (11.73)</td>
<td>28.15 (12.40)</td>
<td>.30</td>
<td>.74</td>
</tr>
</tbody>
</table>

Note.  
1 Estimated IQ is a standard score from the Wechsler Abbreviated Scale of Intelligence (WASI).  
2 Working memory is a standard score from the listening recall subtest of the Working Memory Test Battery for Children (WMTB-C).  
3 Processing speed is a scaled score from a rapid digit naming task from the Comprehensive Test of Phonological Processing (CTOPP).  
4 Receptive language is a standard score from the listening comprehension subtest of the Oral and Written Language Scales (OWLS).  
5 Reading fluency is a standard score from the Test of Word Reading Efficiency (TOWRE).  
6 Writing fluency is a raw score (total number of correct letters written) from the Process Assessment of the Learner (PAL-RW).
Figure 3.1

Outcome measures on the reading comprehension task in each noise condition (with error bars showing the standard error of the mean)

- Reading Accuracy (Oral Retell Total)
- Time Spent Reading (in seconds)
- Difficulty Rating
Figure 3.2
Outcome measures on the writing task in each noise condition (with error bars showing the standard error of the mean)
CHAPTER FOUR

Discussion and Implications
4.1 General Conclusions and Implications

The principal goal of this dissertation was to increase understanding of the relationship between noise and academic performance in adolescents with and without ADHD, including their self-reported sensitivity to and preferences for noise and the impact of different background noises on complex academic task performance. Several main conclusions can be drawn from the overall results.

First, the results of the current dissertation indicate that youth with ADHD perceive themselves to be more distracted by noise than their typically developing peers. Findings from the noise questionnaire showed that youth with ADHD perceive themselves to have greater sensitivity to noise than youth without ADHD. Participants with higher parent- and self-ratings of inattention and hyperactivity/impulsivity reported higher levels of sensitivity to noise. In fact, individual differences in self-ratings of inattention and hyperactivity/impulsivity uniquely contributed to individual differences in reported noise sensitivity beyond the contributions of parent-ratings of inattention, suggesting that noise sensitivity may be an individual characteristic to consider when trying to understand factors that contribute to variation in behavioral inattention. These findings are consistent with those described in previous research that show that individual noise sensitivity is impacted by characteristics of the listener, including their learning needs (e.g., Connolly et al., 2013) and their attentional ability (e.g., Cowan, 1995). Youth with high levels of inattention, though without an ADHD diagnosis, also typically report more problems with distraction and concentration than their peers (Connors et al., 2012). Thus, findings from the current study add to the research that indicates that both students diagnosed with ADHD and those with higher levels of reported inattention perceive themselves to be more distractible by background noise than their peers with good attentional abilities.
It is important to note that self-informant bias may be present in the current results, as adolescents rated themselves on both the noise questionnaire and the self-rating of ADHD symptoms, including inattention and hyperactivity/impulsivity; however, as parent ratings of inattention were also significantly correlated with ratings on the noise questionnaire, it would appear that youth with ADHD are likely more sensitive to noise as a group, especially when they also have many symptoms of behavioural inattention.

Second, noise sensitivity in the current study was not significantly related to measures of cognitive control including working memory and processing speed. The non-significant correlation between self-reported noise sensitivity and working memory ability in the present study is inconsistent with some evidence showing that measures of cognitive control are linked to auditory distraction (Clark & Sörqvist, 2012). One reason why working memory may not be related to distraction is that the level of distraction may be more related to the nature of the distractor rather than an individual’s working memory capacity. Specifically, Sörqvist, Marsh, and Nöstl (2013) suggest that working memory capacity may only be related to the amount of distraction from sounds with one abrupt change in a sequence (e.g., a single word within an instrumental song) but not to sounds that are constantly varying (e.g., a conversation, lyrical songs). Thus, overall, those with poor working memory may not perceive themselves to be more sensitive to noise as only certain types of noise may be distracting to them, whereas they may be better able to tune out background noises such as conversations and music that are continually fluctuating.

Third, despite the significant relation between inattention and noise sensitivity in the current dissertation, the subset of youth with ADHD who took part in the interview study did not overwhelmingly report preferring a silent or quiet environment when studying at home. The majority of these youth with ADHD noted that they found some background noise helpful (e.g.,
music, environmental noises) when studying, with reported benefits including that such noises calm them down, improve focus, prevent boredom, or block out other more distracting noises. This is similar to related studies that found that college students with ADHD often listen to music to block out distractions (Advokat et al., 2011). The experimental study also suggests that some steady noise (i.e., white noise) may improve reading time and writing fluency, reducing the amount of time required to complete, and maintain attention on, a given task. Beneficial effects of music have also been found with students from typically-developing populations, including an increased ability to relax, alleviation of boredom, and improved concentration in the presence of music (Kotsopoulou & Hallam, 2010). As Patton et al. (1983) stated, although music and other environmental distractors may have a negative impact on academic performance overall, they may also have benefits over quiet environments, such as increasing the amount of time a student devotes to an academic task.

The fourth major finding of this dissertation was that youth with ADHD find it most difficult to work in the presence of speech or background conversation. In the interview study, adolescents with ADHD generally reported that chatter is distracting to them when they are studying at home. Furthermore, in the experimental study, participants with ADHD rated the classroom noise condition as being the most difficult background condition for completing both the reading comprehension task and the writing task. This is similar to past studies (e.g., Boman & Enmarker, 2004; Enmarker & Boman, 2004) that found that activity noise, such as chatter and scraping chairs, is considered to be the most distracting noise in the classroom by elementary school students. Past studies have also found an impact of linguistic background noise, such as speech and vocal music, on academic performance. For instance, in a study that examined working memory ability in the presence of vocal music, instrumental music, and irrelevant speech, Alley and Greene (2008) found that both speech and vocal music degraded
performance, whereas instrumental music did not. In that study, however, they also found that the participants were poor judges of the memory impairment resulting from the noisy backgrounds (Alley & Greene, 2008). In contrast, in the current study, participants were able to perceive the negative impact of babble on their reading comprehension and written expression performance, at least related to difficulty ratings of the tasks.

Fifth, the study habits reported by youth with ADHD, either generally or related to preferred noise backgrounds, were quite similar to those reported by adolescents without ADHD, with many of the same types of strategies being identified. Advokat et al. (2011) also examined the study habits of students with ADHD, though the results were obtained through a questionnaire (unlike the interview employed in the current study that allowed for more open-ended responses) and with college students (as opposed to high school students in the current study). Despite methodological differences, some similar results were obtained. For instance, when asked what they do to avoid distraction while studying, both students with and without ADHD indicated that they study alone or in a quiet place, use ear plugs or listen to music to block out distractions, and turn off electronics (Advokat et al., 2011).

Sixth, adolescents with ADHD experienced reduced reading time on the reading comprehension task and improved writing fluency on the text generation task compared to the youth with ADHD in the no noise and classroom babble conditions. Szalma and Hancock (2011) have also suggested that noise has a differing impact on response speed compared to its impact on response accuracy; more specifically, they state that it appears that background speech has a stronger negative impact on measures of response accuracy than on measures of response speed for healthy adults. Based on the results of the current study, it appears that the converse may be true for youth with ADHD (i.e., that some noise has a stronger beneficial impact on measures of response speed than response accuracy).
Relatedly, a seventh finding from the current study was that there was a relative increase in reading time and a relative decrease in writing fluency in both the babble condition and the silent condition compared to the white noise condition. The findings related to speech have been replicated in numerous research studies (e.g., Abikoff et al., 1996; Szalma & Hancock, 2011), indicating that intermittent noise (e.g., speech) appears to be more disruptive to academic performance than more steady noises (e.g., white noise, familiar music) for all participants, regardless of age or attentional ability. Some research has also found that children with ADHD experience similar poor performance in silent conditions than they do in speech or babble conditions (e.g., Söderlund et al., 2007; Abikoff et al., 1996), though research with adolescents who have ADHD is lacking.

Finally, the pattern of findings on the academic accuracy measures (i.e., oral retell, PCWS) suggests that white noise does not result in an improvement in performance accuracy. For oral retell, measuring reading accuracy, the results imply that a no noise condition may be the most advantageous for comprehension based on the fact that the total number of ideas recalled in the oral retell was reduced in the white noise condition (by 17%) and the babble condition (by 15%) relative to the number of ideas recalled in the no noise condition. In contrast, for the writing task, although the participants in the white noise condition had an increase in the total number of words written (by 24%), they did not have a significantly different writing accuracy score from the groups in the other two noise conditions (which were very similar in terms of their PCWS). It is possible that no noise is the most advantageous for higher-level thinking (e.g., comprehension of ideas) while reading, though not necessarily while writing; however, as only correct writing mechanics was assessed by PCWS in the current study, it is possible that noise may have had a larger adverse effect on measures more related to higher-level thinking while writing (e.g., organization, creativity, coherence), which were not
examined in the present study. In addition, measures of correct writing sequences may be more of a reflection of what youth know about writing mechanics based on past learning, whereas measures of performance that require on the spot planning and contemplation during task completion may be more impacted by background noise.

4.2 Implications for Theory and Research

4.2.1 Theoretical Implications

Results of the current study provide some degree of support for the hypotheses based on the MBA model, which states that an optimal level of noise would enhance performance of children and youth with ADHD when they are completing academic and cognitive tasks, whereas too little or too much auditory stimulation would result in a decrement in performance. The results of the noise interview with the small subset of youth with ADHD reveal that these youth seem to have different preferences for noise when studying at home than youth without ADHD. During the interview, the majority of youth with ADHD reported that they consider music and some background noise to be helpful when studying, perhaps because they provide an optimal level of stimulation, whereas silence and chatter may be too over-stimulating, which provides some limited support for the MBA model. The improvements in reading time and writing fluency of youth with ADHD in the white noise condition of the experimental study also provide some support for the hypotheses based on the MBA model. More specifically, results from that study suggest that an optimal level of noise (e.g., white noise) enhanced the performance of youth with ADHD on academic tasks (particularly related to reading time and writing fluency), whereas too little (e.g., no noise) or too much (e.g., babble) auditory stimulation resulted in a relative decrement in performance. Thus, the current dissertation provides some support for the MBA model, especially related to noise preferences, reading time, and writing fluency. In contrast, poorer performance was seen on the reading comprehension
and writing accuracy measures, as well as higher the difficulty ratings, in the two noise conditions. In addition, the youth with ADHD rated themselves as more sensitive to noise on the questionnaire than the youth without ADHD. As such, some support for Stimulus Reduction theory was also obtained, indicating that in some circumstances, youth with ADHD are more distracted by environmental noise than their typically-developing peers.

The applicability of the MBA model for measures of academic fluency and response speed is an important outcome of the current research. As suggested by the model, students with ADHD would have improved reading time and writing fluency in the presence of an optimal level of helpful noise (e.g., steady noises such as white noise or favourite music), whereas they would show a slower reading rate or a decrease in written output in the presence of other noises that either provide too little (e.g., silence) or too much (e.g., speech, activity noises) stimulation. With an increase in time spent to complete work, it is possible that students may lack persistence on lengthy tasks (e.g., essays), as they may only be able to maintain sustained attention for a certain period of time, resulting in a decrement in performance independent of the accuracy of their responses. In addition, for particular academic tasks with time limits (e.g., tests and final exams), students with ADHD may be able to identify the correct responses but would simply not be able to complete the task within the given timeframe. It is also important to note that many tests are administered in silent conditions, which would likely not always be beneficial to youth with ADHD, at least according to the results of this current research and the implications from the MBA model. Thus, providing an optimal level of background stimulation for youth with ADHD during academic tasks is important, not only for decreasing response time, but also for other academic outcomes independent of accuracy, including maximizing performance by reducing the demands on sustained attention for lengthy tasks and allowing students to complete tasks within set time limits.
4.2.2 Research Implications

Although this dissertation provided interesting findings related to the impact of noise on the academic behaviour and performance of youth with ADHD, additional research would be helpful to continue to add to the body of knowledge related to this topic in several areas.

First, while inattention appears to be related to distraction from certain types of noises, other individual characteristics of youth with ADHD may also be related to noise effects, though more research is needed to clarify what those other characteristics may be. For instance, Weinstein (1978) described individual differences in a community sample of college students that led to them being classified as either noise-sensitive or noise-insensitive. Specifically, he found that the noise-sensitive group were more introverted, less comfortable and effective in social situations, less intellectually able, and less able to work persistently. In reference to sensitivity for participants who are introverted versus extroverted, Weinstein (1978) speculated that introverts experience excessive arousal in the central nervous system, whereas extroverts reach an optimal level of arousal, in the presence of background noise; this is similar to the MBA model.

Second, it would be important to examine the perceptions adolescents with ADHD have about many different noises (e.g., music versus speech versus white noise), as there are few studies that examined their reported noise preferences. Overall, there is limited understanding of how assorted noises are perceived by children and youth, and especially those with inattention, despite the fact that they may have vastly differing reactions to diverse types of background noises. As an example, there are several studies on the negative impact of background transportation (e.g., airport, train, and highway) noises on academic and cognitive functioning (e.g., Enmarker & Boman, 2004; Weinstein, 1978); however, when Boman and Enmarker (2004) asked children about disturbing noises in their school, only a small percentage of
respondents indicated that traffic noise or other outside noises were disturbing. By far, the majority found activity noises (such as chatter or sound from the hallway) to be the most disturbing the classroom. Similarly, in the current study, not all participants indicated that background transportation noises were distracting. Instead, there were numerous other noises that participants found either distracting or facilitating within their study environment.

Relatedly, a third area for future research is how music, a popular environmental noise chosen by many youth during academic tasks, affects performance. Despite the preference for music backgrounds during studying by the majority of the 8 youth with ADHD in the interview study, it is unclear from past research how music may impact academic work for that group of students. For example, one recent study showed that, overall, the academic and behavioural performance of children with ADHD was not impacted by background music in the classroom (Pelham et al., 2011). In that study, however, there were individual differences in response to the background music. Specifically, some of the boys with ADHD had improved behaviour and classwork completion in the presence of music whereas others were adversely impacted when compared to their performance in the presence of no background distractors. Though completed with children, these results are similar to the findings in the current study, where not all of the eight adolescents with ADHD reported that they are able to work in the presence of music; instead, individual preferences for background noises during studying were noted during the interview.

Fourth, it is also unknown how students may react to exposure to possible beneficial noise sources over time, as habituation may occur that could negate the optimal stimulation of noise backgrounds, including music and white noise. For instance, a study that examined the impact of background music and speech on the arithmetic performance of boys with ADHD found that the children with ADHD performed best in the music condition (compared to their
performance in the speech or silence conditions), whereas the children in the control group performed similarly in all three of the background conditions (Abikoff et al., 1996). There were significant order effects, however, such that the children with ADHD who received music as their first condition were the only group to experience a facilitative effect of music on math performance. Abikoff et al. (1996) speculated that boredom may have set in after an initial facilitative effect of the music and that the effect may have been maintained if there were changes in the background stimulation to improve its novelty. It is not clear if similar order effects or habituation to sounds would occur with white noise.

Fifth, more knowledge of the impact of music preferences and salience of the noise background on academic performance is needed. In both studies that examined music described above (Abikoff et al., 1996; Pelham et al., 2011), the students voted for which music would be played in the background, which resulted in rock and rap being played in both situations. It may the case that the type of music that is played during academic activity is vital as it relates to the amount of subjective salience experienced by the children and youth with ADHD. Salience of a background noise has been linked to both the amount of effort directed towards a task and the maintenance of effort over time (Abikoff et al., 1996). It is also possible that when students are able to choose their background music or noise during studying at home, increasing its salience, then they will show increased effort towards their academic tasks and improved performance. In future research, it would be important to examine the effects of music that is chosen by participants versus music that is either disliked or unfamiliar to them.

A sixth important area for future research is to develop our understanding of how background noise and music impacts performance on different academic tasks (e.g., reading, writing, mathematics) for youth with and without ADHD. It may be that different background conditions are needed for optimal performance on different academic tasks. For instance, using
a questionnaire to examine the study environments of children in grades 5 through 9 with varying levels of attention, Patton et al. (1983) found that students often changed from quiet settings for reading tasks to non-quiet settings for writing and math tasks. Furthermore, task interest and engagement may influence the impact of noise on academic performance so future research should employ tasks that vary in interest level (e.g., reading a dull versus and interesting passage). Using varying academic tasks in future research is important to examine if noise effects are modulated by various features of the academic task, including task requirements and interest value. The development of virtual reality (VR) classrooms, as described in Adams et al. (2009), may be a helpful tool in future research when looking at the performance of children and youth with ADHD in the presence of background stimulation on different academic tasks. Distractions, including auditory sounds such as ambient noises, people talking, music, and a car driving by, can be presented in the VR classroom in a way that more closely approximates the real-life classroom setting, allowing results to be more generalizable to actual school and home work environments.

Relatedly, a seventh area that should be investigated in future research is the impact of task difficulty on noise effects. For instance, knowledge of how music impacts performance on academic tasks with varying levels of difficulty (e.g., copying versus writing; math computation versus math problem solving) is needed. In the current dissertation, more complex tasks (reading comprehension and written expression tasks, as opposed to single word reading or transcription tasks) were employed to ensure high cognitive demand, as being able to comprehend content and clearly communicate ideas is important to school outcomes. From previous research it is also more likely that background noise (including music) is more distracting during complex cognitive tasks compared to a possible beneficial effect of noise on simpler tasks (e.g., Boman et al., 2005; Furnham & Strbac, 2002). The participants in this study
perceived the babble condition as being the most difficult, suggesting higher levels of cognitive load for the academic tasks in that background. As task difficulty increases, there may be a benefit to performance according to Cognitive Load Theory, which states that learners do best in situations of medium difficulty, with decreased performance on tasks that have markedly low or markedly high cognitive load (Paas, Renkl, & Sweller, 2004); however, it is not known how cognitive load and background noise may interact. It is possible that on cognitively demanding tasks, background noise may increase the cognitive load of the task to a level that makes it too difficult for optimal performance. On the other hand, providing background noise on tasks that have lower cognitive load (e.g., simple addition fluency tasks) may increase performance by providing an optimal level of difficulty. Future research with larger sample sizes is also needed to determine whether the possible advantage of white noise on reading time/writing fluency is offset by a potentially negative effect on higher-level process (e.g., comprehension of the text, coherence and creativity in writing).

Finally, more knowledge related to the study habits of youth with ADHD, including how they incorporate various noises into their study routine is desirable in order to learn how those study habits could be developed to best improve academic achievement. Remarkably, Advokat et al. (2011) found that by simply studying ahead of time for an exam, as opposed to beginning to study a few days before, college students with ADHD were able to attain grade-point averages that were at the same level of the students without ADHD. Furthermore, they stated that students with ADHD, though traditionally at an academic disadvantage, could achieve at a level equal to students without ADHD if they develop beneficial study habits. It is unclear if beneficial study habits may also include the creation of an optimal study environment by either choosing background noise that is optimally stimulating (e.g., white noise, music) or by attempting to create as silent a location as possible.
4.3 Implications for Practice

There are also implications for teachers, clinicians, and mental health practitioners that work with youth with ADHD stemming from the results of the current dissertation, including implications for academic support, diagnosis/assessment of ADHD, and treatment.

4.3.1 Academic Implications

Some noise accommodations related to the physical environment of the classroom are easily implemented and require little effort and time for the teacher, including changes in background noise (Carbone, 2001). For example, Carbone (2001) recommends setting up a “listening centre” (pp. 78) with earphones as a structural accommodation for children with ADHD in the classroom, in which the earphones could be used to filter out distracting classroom conversations during complex and novel tasks. In contrast, during simple and familiar tasks, Carbone (2001) recommends using the listening centre to play background noise or music. He warns, however, of a “honeymoon effect” (pp. 81) in which negative behaviours return after a brief period of compliance due to the student with ADHD becoming accustomed to the environmental changes over time. Based on the current study and the previous literature, it is unclear if such a return to negative behaviours would occur when studying in the presence of music. It is possible that, if the student with ADHD is able to pick his or her own music over time, reflecting updates in the student's musical interests, then the background music may continue to have a beneficial impact on levels of attention and academic performance.

Some researchers advocate a quiet work environment for all students, regardless of their levels of attention or noise sensitivity. As an example, Boman and Enmarker (2004) state that providing students “with good conditions for learning requires lowering noise levels” (pp. 208). Based on the results of the current study, it does not appear that a quiet environment would be beneficial to all students. Only a quarter of participants in the interview study mentioned that
they prefer silence while working; all other participants were able to identify sounds in their
environments that were helpful while they were studying. Similarly, in a study by Smith and
Riccomini (2013), students with learning difficulties, including those with inattention, benefitted
the most from noise-reducing headphones during a reading task in a classroom setting compared
to children without learning difficulties; however, some students did not profit from wearing the
headphones. It would appear that an approach that utilizes differentiated instruction in the
classroom would be most advantageous, including involving students in monitoring their
performance and asking students to comment on how they are impacted by various background
noises. Understanding how background noises, as well as individual noise preferences, impact
academic performance on an individual basis is important when developing recommendations
for optimal environments for both the classroom and home study space.

There has also been speculation in research about different factors that impact the
amount of disruption or facilitation background noises provide, such as ADHD status, individual
noise sensitivity, amount of control over the background noise, and predictability of the noise
(Enmarker & Boman, 2004). As mentioned earlier, children and youth with ADHD are expected
to be negatively impacted by all background noise according to the diagnostic criteria for
ADHD. Predictability of noise and control over noise are important considerations for
practitioners to take into account. Predictability refers to whether a noise is expected or not and
lower levels of predictability increase annoyance and impact from noise (Enmarker & Boman,
2004). Thus, with steady noises, such as white noise, and other predictable noises, such as
favourite music, it would be expected that there would be less adverse impact on academic
performance. Furthermore, if students are able to choose their specific background noise during
academic work, showing control over the noise, a decreased negative impact of noise would also
be expected. This also fits with the MBA model, as increasing control and predictability of noise
makes the noise less over-stimulating, providing a more optimal level of stimulation for students, especially those with inattention or high levels of noise sensitivity.

4.3.2 Clinical Implications for Diagnosis

Results of the current study also have implications for the assessment of attention problems in children and youth. Numerous researchers have asked whether students with ADHD are actually more distractible than students without ADHD, despite the fact that distractibility is a key diagnostic criterion in the DSM (e.g., Abikoff et al., 1996; Pelham et al., 2011). Based on research, it is evident that the amount of distraction that is actually experienced by an individual, if any, is dependent on many factors, including the characteristics of the distractors (e.g., steady versus changing noise, lyrical versus instrumental music). While some noises such as speech and combined visual-auditory distractors have been shown to cause a decrement in performance for children (e.g., Pelham et al., 2011) and youth (e.g., Berger & Cassuto, 2014) with ADHD, other noises such as white noise and music have led to improvements in behaviour (e.g., Abikoff et al., 1996; Söderlund et al., 2007).

Thus, it is not clear that distraction from all types of noise, such that students are unable to pay attention to their academic work in the presence of background noise, is necessarily a core characteristic of youth with ADHD. Instead, certain types of noise that provide the optimal amount of stimulation may actually be helpful for academic performance. For instance, Pelham et al. (2011) found that the academic performance of some children with ADHD was improved in the presence of music, though most were distracted by animated movies, resulting in a decrement in performance. As they suggested, there may be different subgroups of youth with ADHD who are more and less likely to be distracted by background noises, perhaps related to innate levels of internal arousal (Pelham et al., 2011). Similarly, Berger and Cassuto (2014) found that adolescents with ADHD made more errors on a Continuous Performance Task (CPT)
in the presence of visual and combined auditory-visual distractors, compared to no impact (neither an improvement nor a decrement) on performance for youth in the presence of purely auditory distractors. They concluded that distraction is a key marker of ADHD and that difficulty with sustained attention in the presence of distractors is a key characteristic of youth with the disorder (Berger & Cassuto, 2014); however, research more clearly suggests that distraction from certain stimuli, such as video, may be a key characteristic of youth with ADHD, though they may not be uniformly distracted by other stimuli, such as background noise.

It is also possible that distraction is more internally-driven, rather than simply a common observable symptom of ADHD. In addition to attentional control, individual characteristics such as level of interest and a tendency to mind-wander may also account for differences in distraction from background noises that are observed in children and youth with ADHD. For instance, interest level is likely related to task performance in noise, though it is unclear if interest is also related to level of distraction. As an example, Kjellberg et al. (1996) found that adults who were more interested in their work tasks reported being less disturbed by noise than those who found their work boring, though they did not report higher levels of distraction. As has been shown in past research, students with ADHD often experience boredom on tasks that are repetitive and not novel (Abikoff et al., 1996), and boredom is related to declining interest in a task, resulting in a greater difficulties sustaining attention on a task in the presence of distractors. On the other hand, not all students with ADHD show difficulties with sustained attention in the presence of background music and other noises, even on routine tasks (e.g., Pelham et al., 2011). It may be that students with ADHD who are more easily bored during routine tasks (i.e., those who lose interest in tasks quickly) are also more under-aroused in general and require higher background noise levels to optimize their arousal (and reduce distraction) on boring and repetitive tasks.
The propensity for mind-wandering is also an individual characteristic that may impact the amount of distraction from noise experienced by youth with ADHD. As Smallwood, Fishman, and Schooler (2007) note, individuals with ADHD are more likely to experience mind-wandering on a task than other populations. Furthermore, they also stated that those individuals are more likely to mind-wander spontaneously and beyond their control, as opposed to being aware of instances of mind-wandering during a task. Due to a lack of research on the relationship between mind-wandering and distraction from noise, it is unclear how background noise would impact mind-wandering for all students, and especially for students with ADHD. It may be that noise increases mind-wandering on academic tasks, leading to higher levels of distraction and poorer performance. For instance, when asked about their coping strategies when in the presence of noise during academic tasks, older adolescent students with normal levels of attention indicated that they often “disappeared in daydreams” (Boman & Enmarker, 2004, p. 222). It is possible that youth with ADHD may be even more likely to react to noise with increased mind-wandering or daydreaming. Thus, individual characteristics, such as interest levels and tendency to daydream or mind-wander, may impact distraction levels, resulting in varying levels of this key diagnostic criterion among youth with ADHD.

In addition, diagnosing ADHD with adolescents poses unique challenges compared to diagnosing ADHD in children. According to Sibley et al. (2012), adolescents with ADHD often rate their symptoms and impairment as significantly lower than their parents or teachers would rate them, suggesting a possible self-perception bias. In addition, Lineweaver et al. (2012) found that there was a non-significant correlation between college students’ self-reports of ADHD symptoms and performance on working memory tasks in the presence of auditory and visual distractors. Specifically, they found that students who rated themselves as being more inattentive actually had better working memory and experienced less of an impact from the
distractors compared to students who rated themselves as being more attentive. In the present study, ratings of self-perceived noise sensitivity were correlated with parent ratings of inattention, suggesting that the adolescents were able to accurately report noise sensitivity symptoms without a self-perception bias. Thus, it is possible that combining a measure of perceived sensitivity to noise with a measure of self-reported ADHD symptoms would help decrease the self-perception bias seen on many reports from youth with ADHD and improve the overall validity of diagnosis.

4.3.3 Clinical Implications for Treatment

The study of the impact of background noise on youth with ADHD also has implications for the clinical treatment of the behavioural and social/emotional difficulties of those youth. For instance, several studies have investigated music therapy with children and youth diagnosed with ADHD, as well as other emotional and behavioural disorders (e.g., Jackson, 2003; McFerran, 2009; Montello & Coons, 1998). Music therapy can be defined as “the planned and intentional use of the properties of music to achieve nonmusical goals” (McFerran, 2009, pp.72). Further, music therapy sessions with children and youth can be either active or passive. With active music interventions, children or youth are actively involved in the creation of music by learning to read music and play instruments, whereas with passive music interventions, children or youth passively listen to music while completing tasks (Montello & Coons, 1998).

It is not clear from past research which music therapy approach may be better suited for youth with ADHD and in what settings. One study, however, did compare active and passive approaches with preteen youth who were diagnosed with learning, emotional, or behavioural disorders, including ADHD (Montello & Coons, 1998). They found that both interventions led to improvements in attention, motivation, and hostility according to teacher ratings; however, the passive intervention was recommended for participants with attention or learning
difficulties, at least at the onset of treatment, as they perceived it as less threatening and more structured than the active approach. Structure in the music therapy session was seen as especially important for youth with ADHD as it has been hypothesized that exposure to a structured therapy experience could improve the student’s ability to internally structure him- or herself (Jackson, 2003). Finally, in a single-subject case study design, McFerran (2009) also noted an increase in the attention span of a young man with ADHD participating in music therapy. Importantly, it was observed that his behavioural symptoms of ADHD were reduced even further when he was in control of the music during the sessions. The amount of control that a student has over background noise or music was also mentioned earlier as an influential factor in the impact of noise on performance.

Finally, research suggests that students with ADHD can be coached to help them deal with their inattention and associated academic difficulties, particularly related to an understanding of how background noise affects their work. As described by Prevatt, Lampropoulos, Bowles, and Garnett (2011), ADHD coaching allows students with the disorder to cope with symptoms of inattention that adversely impact academic functioning, including difficulties concentrating, poor self-regulation, and organizing their work space. In addition to these symptoms, students with ADHD could be helped to understand the impact of noise on their academic performance and to implement environmental changes to improve their work (e.g., reducing vocal noise, using a white-noise generator or iPod with familiar music, or avoiding quiet workspaces such as the library). By helping teach students to monitor their learning, including the impact that music and other noises have on their performance, students can become more self-regulated learners who are able to independently optimize their learning environments.
References


Carbone, E. (2001). Arranging the classroom with an eye (and ear) to students with ADHD. *Teaching Exceptional Children, 34*(2), 72-81.


Appendix A
Noise Questionnaire

1. How much does noise in your classroom disturb you when you are doing school work?
   1 2 3 4 5
   Not at all Somewhat Very Much

2. Does noise in your classroom make you irritated?
   1 2 3 4 5
   Not at all Somewhat Very Much

3. How often do you think about noise in your classroom?
   1 2 3 4 5
   Not at all Somewhat Very Much

4. How often does noise make it hard for you to concentrate in class?
   1 2 3 4 5
   Never Sometimes Very Often

5. How often does noise make it hard for you to complete work in class?
   1 2 3 4 5
   Never Sometimes Very Often

6. How sensitive to noise do you think you are, compared to others your age?
   1 2 3 4 5
   Not at all Somewhat Very Much

7. How easy it is for you to become accustomed to sounds, compared to others your age?
   1 2 3 4 5
   Very Easy Very Hard
Appendix B
Noise Interview

**Open-ended Question:**
Tell me how you study

**Probed Questions:**
*If noise was not mentioned in the open-ended question, ask:*
What noises do you find helpful during studying?

What noises do you find distracting during studying?

*If music not mentioned yet, ask:* Do you like to listen to music while you work? Why or why not?

*If talking not mentioned yet, ask:* Can you work if people are talking around you? Why or why not?
## Appendix C

Responses to “Tell me how you study” from the noise interview

<table>
<thead>
<tr>
<th>Category (# of respondents)</th>
<th>Illustrative Quotes</th>
</tr>
</thead>
</table>
| Academic strategies used (12 or 75%; 6 ADHD, 6 non-ADHD) | ADHD: Highlight key information; Rewrite notes in different formats; Redo old questions and quizzes; Try making study notes; Look at important things in the textbook  
Non-ADHD: Read notes over and over again; I look at diagrams; I just read over first what I need to do; Write a paragraph on the topic and read it over; If there’s a practice quiz, I’ll do it |
| Memory strategies used (6 or 38%; 4 ADHD, 2 non-ADHD) | ADHD: I have a really good memorization; Make cue cards; I’ll write it down so I remember it; Make up a rhyme or a song to remember it  
Non-ADHD: Just repeat and memory; I try to memorize it; |
| Sounds/noises (4 or 25%; 1 ADHD, 3 non-ADHD) | ADHD: With music in the background  
Non-ADHD: I don’t like noises; Put on quiet music while I study; I find a quiet place |
| Breaks/scheduling (4 or 25%; 2 ADHD, 2 non-ADHD) | ADHD: Wait a little bit and then I come back in half an hour to see if I can remember; I have to take frequent breaks  
Non-ADHD: I like to take small breaks after an hour; I take a break and then I do a little more |
| Aspects of physical environment (2 or 13%; 2 ADHD) | ADHD: Comfortable space or area like my bed or my couch and I’ll have a drink with me; In my room by myself |
| Turning off electronics (2 or 13%; 1 ADHD, 1 non-ADHD) | ADHD: Study with no electronics around  
Non-ADHD: I turn off my computer |

N=16 for all items on the noise interview, with 8 ADHD participants and 8 non-ADHD participants.
## Appendix D
Noises perceived as helpful during studying from the noise interview

<table>
<thead>
<tr>
<th>Category (# of respondents)</th>
<th>Illustrative Quotes</th>
</tr>
</thead>
</table>
| Music (9 or 56%; 4 ADHD, 5 non-ADHD) | **ADHD:** Music that I like; I listen to music when I study; Sometimes music helps if it’s music that’s not all over the place  
**Non-ADHD:** Music with no words; I listen to instrumental because my mom always tells me that the words are really distracting; Some types of music like classical or jazz |
| None (4 or 25%; 2 ADHD, 2 non-ADHD) | **ADHD:** None; I don’t really find any noises helpful  
**Non-ADHD:** No noise; I don’t really find any noise helpful because it’s distracting |
| Environmental noise (3 or 19%; 2 ADHD, 1 non-ADHD) | **ADHD:** Background noise like the people in the kitchen; I like it when I’m in the kitchen and my parents are watching T.V. in the other room  
**Non-ADHD:** Background noise like someone watching the T.V. in the other room. |
| Other (3 or 19%; 1 ADHD, 2 non-ADHD) | **ADHD:** My own voice reading out loud  
**Non-ADHD:** Tapping; White noise |
## Appendix E
Noises perceived as distracting during studying from the noise interview

<table>
<thead>
<tr>
<th>Category (# of respondents)</th>
<th>Illustrative Quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Music (9 or 56%; 3 ADHD, 6 non-ADHD)</td>
<td>ADHD: Music I don’t like; Music or something is really distracting</td>
</tr>
<tr>
<td></td>
<td>Non-ADHD: Music with words; Loud music; Distracting music such as rock music or rap</td>
</tr>
<tr>
<td>Talking (7 or 44%; 4 ADHD, 3 non-ADHD)</td>
<td>ADHD: A lot of other people if I can actually hear their conversation; If I’m studying and I can hear my parents talking I’ll probably focus on what they’re talking about;</td>
</tr>
<tr>
<td></td>
<td>Non-ADHD: People talking; Someone talking right to me</td>
</tr>
<tr>
<td>Environmental noises (4 or 25%; 1 ADHD, 3 non-ADHD)</td>
<td>ADHD: Cars going by</td>
</tr>
<tr>
<td></td>
<td>Non-ADHD: My mom cooking; Someone washing the dishes; When people scratch; Passing cars</td>
</tr>
<tr>
<td>Electronics (3 or 19%; 2 ADHD, 1 non-ADHD)</td>
<td>ADHD: Radio; The T.V. or something on like electronics playing</td>
</tr>
<tr>
<td></td>
<td>Non-ADHD: Reality shows especially</td>
</tr>
<tr>
<td>Loud noises (3 or 19%; 1 ADHD, 2 non-ADHD)</td>
<td>ADHD: Loud noises</td>
</tr>
<tr>
<td></td>
<td>Non-ADHD: Any strong noise; Loud music, loud noises</td>
</tr>
<tr>
<td>Repetitive noises (3 or 19%; 2 ADHD, 1 non-ADHD)</td>
<td>ADHD: If there’s a ticking clock or something repetitive; If someone’s tapping</td>
</tr>
<tr>
<td></td>
<td>Non-ADHD: When my friends click on their pencils, when they tap their feet</td>
</tr>
</tbody>
</table>
Appendix F
Responses to “Do you like to listen to music while you work?” from the noise interview

<table>
<thead>
<tr>
<th>Category (# of respondents)</th>
<th>Illustrative Quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Why?</strong> (Respondents answering yes: 10 or 63%, 6 ADHD, 4 non-ADHD)</td>
<td></td>
</tr>
<tr>
<td>Music is calming (4 or 25%; 2 ADHD, 2 non-ADHD)</td>
<td>ADHD: Calm music usually calms you down so you can do it; It kinda calms me down; Non-ADHD: It’s just soothing; Because it relaxes me and prepares me to take in what I’m studying</td>
</tr>
<tr>
<td>Music improves focus (4 or 25%; 2 ADHD, 2 non-ADHD)</td>
<td>ADHD: It makes it more easier for me to focus; It just kinda helps me concentrate; Non-ADHD: When it’s quiet my mind wanders; It makes you more focussed</td>
</tr>
<tr>
<td>Other reason (4 or 25%; 3 ADHD, 1 non-ADHD)</td>
<td>ADHD: I just like it; I can just listen to music while I do it; It’s kinda just background noise; Non-ADHD: I can still get my work done</td>
</tr>
<tr>
<td>Music prevents boredom (3 or 19%; 2 ADHD, 1 non-ADHD)</td>
<td>ADHD: It prevents me from getting too bored of studying; Or else I get really, really bored and then almost anxious; Non-ADHD: It gives you something to do while you’re working</td>
</tr>
<tr>
<td>Music blocks out other noise (2 or 13%; 2 ADHD)</td>
<td>ADHD: It cuts all the other noises out; It blocks the noise from my room or my house</td>
</tr>
<tr>
<td><strong>Why not?</strong> (Respondents answering no: 6 or 37%, 2 ADHD, 4 non-ADHD)</td>
<td></td>
</tr>
<tr>
<td>Music impairs focus (4 or 25%; 1 ADHD, 3 non-ADHD)</td>
<td>ADHD: I just can’t focus on what I’m reading or I can’t take in information; Non-ADHD: ‘Cause I can’t concentrate; It’s hard to concentrate on two different things</td>
</tr>
<tr>
<td>Music is distracting (2 or 13%; 1 ADHD, 1 non-ADHD)</td>
<td>ADHD: It distracts me; Non-ADHD: I’m trying to read the questions in my head and I’m also trying to follow along with the words in the song so that’s difficult</td>
</tr>
<tr>
<td>Other reason (1 or 6%; 1 non-ADHD)</td>
<td>Non-ADHD: It’s like the genre of music I like to listen to…you can’t focus when you’re listening to rock</td>
</tr>
</tbody>
</table>

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Appendix G
Responses to “Can you work if people are talking around you?” from the noise interview

<table>
<thead>
<tr>
<th>Category (# of respondents)</th>
<th>Illustrative Quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Why?</strong> (Respondents answering yes: 6 or 37%, 2 ADHD, 4 non-ADHD)</td>
<td></td>
</tr>
<tr>
<td>Talking does not impair focus (6 or 37%; 2 ADHD, 4 non-ADHD)</td>
<td>ADHD: ‘Cause I can focus in on what I’m doing; It doesn’t really bother me&lt;br&gt;Non-ADHD: It’s just a basic sound; I don’t mind them talking quietly; I can tune it out if I want to</td>
</tr>
<tr>
<td><strong>Why not?</strong> (Respondents answering no: 10 or 63%, 6 ADHD, 4 non-ADHD)</td>
<td></td>
</tr>
<tr>
<td>Talking is distracting (6 or 37%; 2 ADHD, 4 non-ADHD)</td>
<td>ADHD: If I don’t take my pill I’ll focus on a bunch of things, so if people are talking, it’s like I’ll focus on that as well; If a few people are talking and I can actually hear their conversation then it kinda bothers me and I kinda zone into the conversation&lt;br&gt;Non-ADHD: Because I really want to listen to their conversation; I can’t do my homework if people are talking to me; I get distracted; I want to join in on the conversation</td>
</tr>
<tr>
<td>Talking impairs focus (3 or 19%; 3 ADHD)</td>
<td>ADHD: It’s hard to focus; It makes it more harder for me to concentrate; It’s harder for me to focus on what I’m doing and get my thoughts together when other people are talking</td>
</tr>
<tr>
<td>Other reason (1 or 6%; 1 ADHD)</td>
<td>ADHD: I don’t know the background reason for it, I just can’t</td>
</tr>
</tbody>
</table>