The Effects of Antecedent Exercise on Students’ Aggressive and Disruptive Behaviours: Exploratory Analysis of Temporal Effects and Mechanism of Action

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Abstract

Low autonomic arousal, as measured through resting heart rate, has been shown to be one of the best-replicated biological correlates of antisocial and aggressive behaviour. According to the stimulation seeking theory, low arousal represents an unpleasant physiological state. In line with this theory, antisocial individuals purposely engage in antisocial and aggressive acts in an attempt to increase stimulation and achieve more agreeable arousal levels. If, as the stimulation seeking theory suggests, the function of antisocial behaviour is to increase physiological arousal levels, exposing antisocial individuals to functionally equivalent forms of arousing situations (e.g., aerobic exercise) should result in a reduction in aberrant conduct. Although a growing body of literature indicates that antecedent exercise is effective at reducing antisocial and aggressive behaviours, the present investigation sets out to explore two fundamental questions about this approach that remain unclear. First, there is a paucity of research examining the temporal effects of antecedent exercise. Secondly, little is known about the mechanism of action accounting for behavioural improvements following exercise.

The present investigation involved 4 students (age range 11-14) enrolled in a closed behavioural classroom due to severe aggressive, disruptive, and oppositional behaviours. Through the use of an alternating treatment design with baseline, students were first exposed to
baseline conditions and then to two experimental conditions, (i.e., an antecedent exercise condition and a control condition) in a randomized fashion. Results indicated that 30 minutes of moderate to intense aerobic exercise resulted in approximately 90 minutes of behavioural improvements. In addition, results suggest an inverse relationship between arousal levels and behavioural difficulties. The potential utility of antecedent exercise as a treatment alternative in schools for students with severe antisocial behaviours is discussed.
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Table of Contents

Abstract........................................................................................................................................ii
Acknowledgements....................................................................................................................iv
Table of Contents...........................................................................................................................v
List of Tables .................................................................................................................................ix
List of Figures ...............................................................................................................................x
List of Appendices .........................................................................................................................xii
Chapter 1: Introduction..................................................................................................................13
  1.1 Rationale for the Study ............................................................................................................13
  1.2 Childhood Antisocial Behaviour .........................................................................................14
  1.3 Antisocial Behaviour in Schools ..........................................................................................15
  1.4 Treatment Approaches for Antisocial Behaviours ..............................................................16
  1.5 New Treatment Directions for Antisocial Behaviour ..........................................................18
  1.6 The Etiology of Antisocial Behaviour: Biological Contributions ..........................................20
    1.6.1 Androgens ....................................................................................................................20
    1.6.2 Hypothalamic-pituitary-adrenal axis activity and Cortisol ..............................................24
    1.6.3 Neurotransmitters .........................................................................................................26
    1.6.4 Serotonin (5-HT) .........................................................................................................26
    1.6.5 Norepinephrine (NE) ....................................................................................................27
    1.6.6 Dopamine (DA) ............................................................................................................28
  1.7 Neurophysiological Impairments and Antisocial Behaviour: Frontal Lobe and Executive Functioning Deficits ...................................................................................................................28
  1.8 Autonomic Nervous System functioning ..............................................................................30
  1.9 Resting Heart Rate and the Intergenerational Transmission of Antisocial Behaviours ................33
  1.10 How Low Heart Rate May Predispose to Aggressive and Antisocial Behaviour .................34
1.11 Stimulation Seeking Theory ................................................................. 35
1.12 Underarousal and Aggression: Potential Treatment Implications .............. 35
1.13 Summary and Rationale for the Current Investigation ............................... 38
1.14 Research Questions and Hypotheses ..................................................... 40
   1.14.1 Replication ..................................................................................... 40
   1.14.2 Temporality ................................................................................... 41
   1.14.3 Mechanism of Action ..................................................................... 41
Chapter 2: Method ......................................................................................... 42
   2.1 Participants ......................................................................................... 42
      2.1.1 Participant 1 (Bobby) ................................................................. 42
      2.1.2 Participant 2 (Kyle) ................................................................. 42
      2.1.3 Participant 3 (Dan) ................................................................. 43
      2.1.4 Participant 4 (Tom) ................................................................. 43
   2.2 Classroom Setting and Staff ................................................................. 43
   2.3 Research Design .................................................................................. 44
   2.4 Data Collection and Interobserver Agreement ......................................... 44
      2.4.1 Observer Training ........................................................................ 44
      2.4.2 Observation Sessions ................................................................... 44
   2.5 Measures ............................................................................................ 46
      2.5.1 General Health Screener ............................................................ 46
      2.5.2 Teacher Ratings ......................................................................... 46
      2.5.3 Observational Measures ............................................................. 47
      2.5.4 Disruptive Behaviours .................................................................. 47
      2.5.5 Prosocial Behaviours ................................................................. 47
      2.5.6 Compliance to Teacher Requests .................................................. 48
      2.5.7 Physiological Measures of Arousal ............................................... 48
      2.5.8 Resting Heart Rate ....................................................................... 49
      2.5.9 Heart Rate during Exercise and Control Sessions ............................ 50
      2.5.10 Heart Rate during Observational Periods ...................................... 50
      2.5.11 Target Heart Rate Zone .............................................................. 51
List of Tables

Table 1: Resting and Target Heart Rates ................................................................. 59
Table 2: Correlations among Behavioural and Physiological Measures for Participant 1 (N=17) .......................................................... 84
Table 3: Correlations among Behavioural and Physiological Measures for Participant 2 (N=17) .......................................................... 85
Table 4: Correlations among Behavioural and Physiological Measures for Participant 3 (N=19) .......................................................... 86
Table 5: Correlations among Behavioural and Physiological Measures for Participant 4 (N=19) .......................................................... 87
List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1:</td>
<td>Frequency of disruptive behaviours for all baseline, control, and exercise sessions</td>
<td>62</td>
</tr>
<tr>
<td>Figure 2:</td>
<td>Overall mean frequency of disruptive behaviours across baseline, control, and exercise conditions</td>
<td>63</td>
</tr>
<tr>
<td>Figure 3:</td>
<td>Frequency of prosocial behaviours for all baseline, control, and exercise sessions</td>
<td>65</td>
</tr>
<tr>
<td>Figure 4:</td>
<td>Overall mean frequency of prosocial behaviours across baseline, control, and exercise conditions</td>
<td>66</td>
</tr>
<tr>
<td>Figure 5:</td>
<td>Percent compliance to teacher requests across all baseline, control, and exercise sessions</td>
<td>68</td>
</tr>
<tr>
<td>Figure 6:</td>
<td>Overall percent compliance to teacher requests across baseline, control, and exercise conditions</td>
<td>69</td>
</tr>
<tr>
<td>Figure 7:</td>
<td>Frequency of disruptive behaviours across all baseline, control, and exercise sessions. X axis represents session number and Y axis represents the frequency of disruptive behaviours</td>
<td>72</td>
</tr>
<tr>
<td>Figure 8:</td>
<td>Mean frequency of disruptive behaviours for baseline, exercise, and control conditions across T1, T2, T3, and T4</td>
<td>73</td>
</tr>
<tr>
<td>Figure 9:</td>
<td>Frequency of prosocial behaviours across all baseline, control, and exercise sessions. X axis represents session number and Y axis represents the frequency of prosocial behaviour</td>
<td>75</td>
</tr>
<tr>
<td>Figure 10:</td>
<td>Mean frequency of prosocial behaviours across all baseline, control, and exercise conditions for T1, T2, T3, and T4</td>
<td>76</td>
</tr>
<tr>
<td>Figure 11:</td>
<td>Percentage of compliance to teacher requests across all baseline, control, and exercise sessions. X axis represents session number and Y axis represents the percent compliance to teacher requests</td>
<td>78</td>
</tr>
<tr>
<td>Figure 12:</td>
<td>Average compliance to teacher requests for all baseline, control, and exercise conditions for T1, T2, T3, and T4</td>
<td>79</td>
</tr>
<tr>
<td>Figure 13:</td>
<td>Average heart rate levels while engaged in experimental conditions</td>
<td>79</td>
</tr>
<tr>
<td>Figure 14:</td>
<td>Heart rate during baseline and following experimental conditions across T1, T2, T3, and T4</td>
<td>82</td>
</tr>
<tr>
<td>Figure 15:</td>
<td>Overall mean self-report scores for bored/excited visual analog scale</td>
<td>80</td>
</tr>
<tr>
<td>Figure 16:</td>
<td>Overall mean self-report scores for tired/full of energy visual analog scale</td>
<td>90</td>
</tr>
</tbody>
</table>
Figure 17: Overall mean self-report score for tense/relaxed visual analog scale ............91
List of Appendices

Appendix A:  General Health Screener ................................................................. 134
Appendix B:  SPORTLINE Solo 920 Heart Rate Watch ® ........................................... 135
Appendix C:  Data recording Sheets for Heart Rate during Experimental Conditions .... 136
Appendix D:  Data recording Sheets for Heart Rate during Observational Periods ........ 137
Appendix E:  Visual Analog Scale (Tense-Relaxed Scale) ........................................ 138
Appendix F:  Visual Analog Scale (Tired-Full of Energy Scale) ................................. 140
Appendix G:  Visual Analog Scale (Bored-Excited Scale) ........................................ 142
Appendix H:  Behavioural Coding Sheet ................................................................. 144
Appendix I:  Mann-Whitney U Test Statistics ......................................................... 146
Chapter 1: Introduction

1.1 Rationale for the Study

Antisocial behaviour among school-aged children is a major societal and clinical concern. Notwithstanding extensive efforts to provide support and treatment services to children with such behavioural repertoires, the prevalence of antisocial behaviour remains high. Advancements in our understanding of the biological substrates of antisocial behaviour may help us understand such responding and potentially lead to novel and innovative treatment alternatives. To date, low resting heart rate is considered one of the best replicated biological correlates of antisocial and aggressive behaviour. According to the stimulation seeking theory, low arousal represents an unpleasant physiological state. In line with this theory, antisocial individuals purposely engage in antisocial and aggressive acts in an attempt to increase stimulation and achieve more agreeable arousal levels. If the function of antisocial behaviour is to increase physiological arousal levels, then exposing antisocial individuals to functionally equivalent forms of arousing situations (e.g., aerobic exercise) should result in a reduction in maladaptive behaviours.

A substantial body of literature indicates that antecedent exercise (i.e. exercise that is applied non-contingently with the intent of reducing subsequent disruptive behaviour) is effective at reducing antisocial and aggressive conduct. The objective of this study is to investigate two fundamental aspects of antecedent exercise that are not well understood. First, there is a paucity of research examining the temporal effects of antecedent exercise (i.e., how long the effects of exercise last). Secondly, very little is known about why exercise results in a reduction in aberrant behaviours (i.e., the mechanism of action). The present research was
designed to further investigate each of these aspects as a means of gaining greater understanding about antecedent exercise and its biological substrates.

1.2 Childhood Antisocial Behaviour

Childhood antisocial behaviour is a significant social and clinical concern (Scott et al., 2010; Van Goozen, Fairchild, & Harold, 2008; Mayer, 2001). Youngsters exhibiting chronic patterns of antisocial behaviour are often identified as having oppositional defiant disorder (ODD) or conduct disorder (CD) (Reinke & Herman, 2002). ODD is characterized by a recurrent pattern of negativistic, defiant, disobedient, and hostile behaviour that is directed toward authority figures (DSM-IV; American Psychiatric Association, 1994). Prominent features of CD include a repetitive and persistent pattern of behaviour in which the basic rights of others or major age-appropriate societal norms or rules are violated (DSM-IV; American Psychiatric Association, 1994). ODD and CD are commonly associated with depression, substance abuse, and attention deficit hyperactivity disorder and thus often result in a high degree of impairment (Petermann & Natzke, 2008; Isper & Stein, 2007).

Recent estimates suggest that approximately 5-10% of the general child population meet diagnostic criteria for ODD or CD (Van Goozen, Fairchild, & Harold, 2008; Stadler, Grasman, Fegert, Holtman, Poutska, & Schmeck, 2008; Loeber et al., 2000), resulting in one-third to half of all clinic referrals (Isper & Stein, 2007; Kazdin, 1995) and making child antisocial behaviour one of the most costly child mental health problems (Kazdin, 2007; Cohen, 1998). Early-onset antisocial behaviour is an important predictor of major dysfunction and maladjustment in adolescence and adulthood. Children who exhibit chronic levels of such behaviour prior to age 13 are at increased risk for academic failure and drop-out, violence, unplanned pregnancies,
unemployment, substance abuse, depression, suicide, antisocial personality disorder, and difficulties with interpersonal relationships such as parenting and marriage (Trentacosta, Shaw, & Cheong, 2009; Van Goozen, Fairchild, & Harold, 2008; Wright, John, Livingstone, Shepard, & Duku, 2007; Loeber & Farrington, 2000; Ronks & Pulkkinen, 1995; Magnusson, 1992; Farrington, 1991; Caspi, Elder, & Herbener, 1990).

1.3 Antisocial Behaviour in Schools

Children who engage in antisocial behaviours represent a major challenge in the school system (Cihak, Kirk, & Boon, 2009) and account for the largest proportion of placements in special education classes (Knitzer, Steinberg, & Fleisch, 1990). Studies indicate that as many as 20% of students in the primary grades engage in mild but frequent forms of antisocial behaviour (Wheldall & Merrett, 1988). Despite the high prevalence of these response patterns in schools, teachers often receive little or no specialized training in behaviour management (Obenchain & Taylor, 2005) and feel unprepared to deal with these students (Obenchain & Taylor, 2005; Stromont, Lewis, & Beckner, 2005; Fox, Dunlap, & Cushing, 2002; Gordon, 2001; Silvestri, 2001; Skiba & Peterson, 2000).

When dealing with antisocial and disruptive students, teachers tend to be reactive (Sherrod, Getch, & Ziomek-Daigle, 2009) and rely on punitive approaches (Skiba & Peterson, 2000; Bear, 1998). Common disciplinary strategies include time-out, exclusion, verbal reprimands, and suspensions (Geiger, 2000; Bear, 1998). Mounting evidence suggests that the use of harsh and punitive disciplinary strategies do not result in long-term reduction of maladaptive behaviours (Sherrod, Getch, & Ziomek-Daigle, 2009; Skiba & Peterson, 2000) and
may actually heighten such problems (Doumen, Verschueren, & Buyse, 2009; Sherrod, Getch, & Ziomek-Daigle, 2009; Safron & Oswald, 2003; Skiba & Peterson, 2000).

Teachers of students with antisocial behaviour often spend a disproportionate amount of their time and effort addressing disruptive responding instead of academic and teaching tasks (Sherrod, Getch, & Ziomek-Daigle, 2009; Kulina, Cothran, & Regualos, 2006; Matheson & Shriver, 2005; Scates, 2005; Greenwood, 1991). Such behaviour can lead to excessive teacher stress and burnout, job dissatisfaction, and high attrition rates (Baker, Lang, & O’Reilly, 2009; Abel & Sewell, 1999; Centre & Callaway, 1999; Frank & McKenzie, 1993; Pullis, 1992; Feitler & Tokar, 1982). When teachers are stressed, all students in the classroom (those with and without challenging behaviour) are likely to suffer serious consequences (Bru, 2009). Stressed teachers may devote less time and energy to job commitment, teacher-pupil rapport, student motivation, and educational goals (Kulina, Cothran, & Regualos 2006; Abel & Sewell, 1999).

1.4 Treatment Approaches for Antisocial Behaviours

Given the concerns associated with antisocial behaviour, it is evident that effective interventions are needed for prevention and treatment. A number of behavioural (e.g., McMahon & Forehand, 2003; Kazdin, 2003; Barkley & Benton, 1998), cognitive-behavioural (McCloskey, Noblett, Deffenbacher, Gollan, & Coccaro, 2008; Martsch, 2005; Kendall, Reber, McLeer, Epps, & Ronan, 1990; Lochman, Lampron, Gremmer, Harris, & Wyckoff, 1989), family (e.g., Markie-Dadds & Sanders, 2006; Shaw, Dishion, Supplee, Gardner, & Arnds, 2006; Leung et al., 2003; Webster-Stratton & Hammond, 1997) and multifaceted (e.g., Koegl, Farrington, Augimer & Day, 2008; Lipman et al., 2008; Webster-Stratton, Reid, & Hammond, 2004) psychotherapeutic programs have been devised to either prevent or treat early-onset antisocial responding. In
addition, several school-based and class-wide interventions have been developed (e.g., Dufrene, Doggett, Henington, & Watson, 2007; Massey, Boroughs, & Armstrong, 2007; Schechtman & Ifargn, 2007; Daunic, Smith, Brank, & Penfield, 2006; Smokowski, Fraser, Day, Galinsky, & Bacallao, 2004).

Although these interventions may result in a range of child gains, significant limitations have been cited (Baker, Lang, & O’Reilly (2009). First, long-term effectiveness is limited (Van Goozen et al., 2007; Kazdin, 1997, 1995). Second, notwithstanding demonstrated efficacy in research settings, generalizations of these interventions to clinical or classroom settings is rarely established (Scott el., 2005). Third, while there is an abundance of empirically-validated treatments for children with antisocial behaviour, few have been validated for adolescent populations (Fossum, Handegard, Martinussen, & Morch, 2008). Fourth, many of these interventions are lengthy and require much time and effort to implement (Axelrod, Garland, & Love, 2009). In fact, the most effective treatments are often the most time-intensive (Wilson & Lipsey, 2010) and may lead to participant attrition (Fernadez & Eyeberg, 2005). Within the school setting, psychotherapeutic interventions often demand a great deal of teacher time and effort to effectively implement (Wagner et al., 2006; Booth & Faribank, 1984) and are therefore not perceived as practical solutions by teachers and school officials (Boxer, Musher-Eizenman, Dubow, Danner, & Heretick, 2006).

In addition to psychotherapeutic approaches, pharmacotherapy is frequently considered in the treatment of children and adolescence with antisocial behaviours (Isper & Stein, 2007). While there is currently no registered medication for the treatment of maladaptive behaviours associated with CD or ODD (Isper & Stein, 2007), there has been a dramatic increase in the use of pharmacological interventions for aggressive, disruptive, violent, and oppositional children
Several different medications have been used for the treatment of children with conduct difficulties including risperidone (e.g., Pandina, Aman, & Findling, 2006; Buitelaar, 2000; Findling, McNamara, Branicky, Schluchter, Lemon, & Blumer, 2000; Scheier, 1998), haloperidol (e.g., Campbell et al., 1984), lithium (e.g., Rifkin et al., 1997), valporic acid (Donovan, Stewart, Nunes, Quitkin, & Parides, 2000; Deltito, Levitan, Damore, Hajal, & Zambenedetti, 1998) and methylphenidate (e.g., Klein, Abikoff, Klass, Ganeles, Seese, & Pollack 1997; Gadow, Nolan, Sverd, Sprafkin, & Paolicelli, 1990).

Although pharmacological treatments for children and adolescents have been associated with varying degrees of success (e.g., see Ipser & Stein, 2007; Bassarath, 2003 for reviews), several serious concerns have been raised. There may be mild and serious side-effects (Ipser & Stein, 2007; Wilens, Jefferson, & Biederman, 2006), concerns with long-term safety and efficacy due to a lack of long-term studies (Oord, Prins, Oosterlaan, & Emmekkamp, 2008; Ipser & Stein, 2007; Bassarath, 2003), and treatment challenges presented by their potential noncompliance to medication regimens (Charach, Gajaria, Skyba, & Chen, 2008; Charach, Volpe, Boydell, & Gearing, 2007; Ipser & Stein, 2007).

1.5 New Treatment Directions for Antisocial Behaviour

Despite the wide range of psychotherapeutic and pharmacological interventions available, a number of researchers have emphasized the importance of developing more cost-effective, safe, and innovative treatment approaches (Scott et al., 2010). As discussed by Carr, Robinson, and Palumbo (1990), one way to maximize the effectiveness of a treatment is to ensure that it is “functionally based”. Traditional functional approaches, such as applied behaviour analysis (an approach to intervention based on operant learning principles), attempt to identify correlations
between the behaviour and the environment and involve looking primarily outside rather than inside the organism to establish functional relations (Thompson, 2007). A hallmark of applied behaviour analysis is promoting changes in behaviour by carefully modifying various contextual variables, especially the consequences or outcomes of the responses that contribute to problem behaviour.

Much research has demonstrated that most problem behaviours occur because they lead to a more positive environmental outcome for the individual (Conroy & Fox, 1995). Within this contextualist paradigm, however, some researchers have recognized that these desired outcomes are sometimes internal to the organism. Skinner (1945), the father of modern applied behaviour analysis, noted the importance of considering factors “beneath the skin” when examining the behaviour of an organism. More recently, Thompson (2007) emphasized the potential benefits of considering endogenous components (especially internal biological factors) when trying to understand the functions of various behaviours. Thompson (2007) argues that an organism’s biologically driven processes are intricately related to the behaviours displayed and that this interplay is influenced by operant principles. To illustrate this point, Thompson (2007) describes how the biological and genetic abnormalities associated with Prader-Willi Syndrome (PWS) contribute to the stereotypical behaviours demonstrated by those afflicted with this rare genetic disorder. PWS is characterized by a specific gene deletion as well as elevated levels of ghrelin (a specific hormone found in the blood), leading to constant and chronic levels of hunger and making food a highly potent source of reinforcement. Behaviourally, individuals with PWS have an insatiable appetite and engage in chronic levels of overeating (Thompson, 2007). Understanding the disrupted biological state of individuals with PWS allows us to better understand the function of their frequent eating behaviours.
Similar to the case of PWS, investigating disrupted biological mechanisms in individuals with antisocial behaviours may allow for a better understanding of the various “functions” served by externalizing conduct. Over the past 15 years there has been much progress in our understanding of the biological basis of antisocial behaviour (Raine, 2002), potentially providing the foundation for development of treatment approaches that target key biological substrates contributing to antisocial behaviours.

1.6 The Etiology of Antisocial Behaviour: Biological Contributions

The etiology of antisocial behaviour is a complex interplay of both environmental and genetic influences (Hicks, South, DiRago, Iacono, & McGue, 2009). A number of environmental risk factors have been associated with the development of antisocial behaviours including birth complications (Raine, 2002), parental divorce (Breivik, Olweus, & Endresen, 2010), single-parent childrearing (Gagnon, et al., 1995), low socio-economic status (Lahey, et al., 1988), poor parental supervision (Frick et al., 1992), and parental psychopathology and criminality (Cadoret, et al., 1995; Frick et al., 1992). In addition, several biological factors play a role (Van Goozen & Fairchild, 2008).

1.6.1 Androgens

Androgens are a class of steroid hormones that are more abundant in males than in females (Kalat, 2001). Testosterone is the major androgen in males and plays a key role in the development of male reproductive tissues (e.g., testes and prostate) and secondary sexual characteristics (e.g., muscle and bone mass, hair growth, etc.) (Bagatell & Fairchild 2003, pg.3). The testes are the source of more than 95% of the circulating testosterone in adult males (Bagatell & Fairchild, 2003, pg. 3). In addition to testosterone, other major androgens include
dehydroepiandrosterone (DHEA), dehydroepiandrosterone sulphate (DHEA-S), androstenedione, androstenediol, androsterone, and dihydrotestosterone (Bagatell & Fairchild, 2003, pg 5). Males have higher concentrations of circulating androgens as well as a higher prevalence of antisocial, aggressive, and violent behaviours than females (Van Goozen, Fairchild, Snoek, & Harold, 2007; Pasterski, Hindmarsh, Geffner, Brook, Brain, & Hines, 2007), leading to questions about the relationship between androgens and antisocial conduct. Notwithstanding the different types of androgens, testosterone has been the most extensively studied hormone in relation to aggression and antisociality (Ramirez, 2003).

The relationship between androgens and aggression has been studied extensively in animals. For the most part, elevated concentrations of androgens in a variety of different species have been associated with increases in aggressive behaviours (Higley et al, 1993, Brain & Haug, 1992; Higley et al., 1992), although the available findings in humans are more complex. In adults and older adolescents (between 17 and 18 years of age), elevated levels of testosterone have been clearly linked with antisocial behaviour and violent crimes (Banks & Dabbs, 1996; Scerbo & kolko, 1994; Dabbs, Jurkovic, & Frady, 1991; Dabbs & Morris, 1991). In prepubertal children however, the relationship between testosterone and antisocial and aggressive behaviours does not appear to be as robust. In a number of well designed studies, researchers have failed to show an association (Van Goozen, Matthys, Cohen-Kettens, Thijssen, & Van Engeland, 1998; Constantino et al., 1993), suggesting a need to consider testosterone secretion in a developmental context.

In typically developing males, testosterone secretion rises in three distinct periods of life. The first major peak in levels occurs in utero from approximately 2 months of gestation until birth. The second occurs at approximately 2 months after birth and lasts for a few months. The
third and most significant peak in testosterone occurs at puberty (Ramirez, 2003). Thus, prepubertal children do not have high concentrations of testosterone. In fact, during childhood (from around age 6 until puberty), children go through a period referred as adrenarche (Van Goozen, Van den Ban, Matthys, Cohen-Kettenis, Thijssen, & Van Engeland, 2000). In this phase of life, the androgens in the child’s body are predominately produced by the adrenal cortex and not the testes (Van Goozen, et al., 2000). Adrenal androgens include DHEA, DHEA-S, and androstenedione (and not testosterone). Once puberty arrives, gonadal androgens such as testosterone become much more prevalent in the male body and the levels of adrenal androgens dramatically decline (Van Goozen et al., 2000). Given the developmental time-line associated with androgen secretion in males, researchers have started to investigate the relationship between adrenal androgens (e.g., DHEA, DHEA-S, and androstenedione) and aggressive and antisocial behaviour among prepubertal children; several studies have found an association (e.g., Maras, 2003; Dmitrieva, Oades, Hauffa, & Eggers, 2001).

For instance, Van Goozen et al. (1998), measured plasma levels of testosterone and DHEA-S in 15 boys with CD and 25 normal control boys. The two groups of children did not differ on measures of testosterone; however, boys with CD had significantly higher levels of DHEA-S compared to the normal controls. Furthermore, results indicated that DHEA-S levels were significantly positively correlated with the intensity of the children’s aggression and delinquency. Van Goozen et al. (1998) concluded that adrenal androgen functioning plays an important role in the onset and maintenance of aggression in young boys. In a more recent study, Van Goozen et al. (2000) measured DHEA-S in 24 children with ODD, 42 psychiatric controls, and 30 normal controls. Children with ODD had higher DHEA-S levels than both the psychiatric
and normal control groups. DHEA-S levels did not differ between the psychiatric and normal control groups.

Although several studies have demonstrated an association between increases in adrenal androgens and child antisocial behaviour, at least one study did not. Constantino et al. (1993) measured DHEA and DHEA-S in 18 highly aggressive hospitalized prepubertal boys aged 4 to 10. The hospitalized boys were compared to a group of age-and race-matched controls residing in the same demographic area and were screened negative for aggressive behaviour problems. There were no significant differences between aggressive and non-aggressive boys for either DHEA and DHEA-S. Based on the findings, Constantino et al. (1993) concluded that androgens do not appear to be a useful biological marker for aggressivity in early childhood. A major limitation of the Constantino et al. (1993) study is that 10 out of the 18 aggressive boys had a co-morbid psychiatric diagnosis. As discussed by Krusi et al. (1990), studies investigating aggression typically exclude individuals with psychosis because the aggression experienced as part of a psychotic episode differs from the more persistent and chronic aggression found in children with ODD and CD.

A number of medical disorders involving androgen abnormalities have also been used to assess the relationship between testosterone and antisocial and aggressive behaviours. For instance, congenital adrenal hyperplasia (CAH) is an autosomal recessive disorder occurring in approximately 1 in 15,000 births (Pang & Shook, 1997). Due to a specific enzymatic deficiency, CAH results in an over production of adrenal androgens beginning prenatally (Miller & Levine, 1987). As a result of the high androgen concentrations, females with CAH are typically born with ambiguous genitalia and engage in male-typical behaviours from early childhood (Pasterski, et al., 2007). Paterski et al. (2007) examined aggression levels in 3- to 11-year old children with
CAH (38 girls, 29 boys) and in their unaffected siblings (25 girls, 21 boys). Results from the study indicated that females with CAH were significantly more aggressive than their unaffected sisters. These results provide evidence favoring androgens’ role in aggressive and antisocial behaviour.

Not all studies involving androgen abnormalities provide support for the relationship between elevated androgen levels and aggression. For example, De La Marche, Prinsen, Boot, and Ferdinand (2005) evaluated the aggressive behaviours in a 4 year-old boy who had a testosterone producing testicular tumor. Due to the tumor, the child had androgen levels that were over 30 times greater than typically developing boys his age. Despite having pubertal levels of testosterone and DHEA-S, the child did not display any evidence of elevated levels of antisocial or aggressive behaviours.

In summary, a large body of evidence suggests that elevated concentrations of androgens are related to aggressive and antisocial behaviours, although some studies have failed to establish this relationship. Clearly, additional research is needed to further elucidate this relationship, especially in younger children (Van Goozen, Fairchild, Snoek, & Harold, 2007).

1.6.2 Hypothalamic-pituitary-adrenal Axis Activity (HPA-axis) and Cortisol

The hypothalamic-pituitary-adrenal axis (HPA) is a complex set of interactions involving the hypothalamus, the pituitary gland, and the adrenal gland (Jansen, Beijers, Riksen-Walraven, & Weerth, 2010). Among other important functions, the activity of the HPA-axis controls our reaction to stress, trauma, and injury (Abelson, Khan, Young, & Liberzon, 2010). Cortisol is an important corticosteroid hormone produced by the adrenal gland and is often used as an index of
HPA axis activity (Hawes, Brennan, & Dadds, 2009). Elevated plasma cortisol levels are thought to reflect increased activation of the HPA-axis.

A number of studies have found a relationship between low resting cortisol levels and heightened levels of aggressive and antisocial behaviours (Murray-Close, Han, Cicchetti, Crick, & Rogosch, 2008). The inverse relationship between cortisol and antisociality has been well established in a number of animal studies (Halasz, Liposits, Kruk, & Haller, 2002; Haller, van de Schraaf, & Kruk, 2001) as well as human studies involving adults (Virkkunen, 1985; Woodman, Hinton, & O’Neill, 1978), adolescents (Shoal et al., 2003; Pajer, Gardner, Rubin, Perel, & Neal), and children (Van Goozen et al., 1998; McBurnett, Lahey, Capasso, & Loeber, 1996). McBurnett, Lahey, Rathouz, and Loeber (2000) examined salivary cortisol concentrations in typical school-aged boys. In this investigation, boys with low levels of salivary cortisol had three times the number of aggressive symptoms than boys with higher levels of cortisol. Furthermore, when compared to boys with high cortisol, boys with reduced cortisol concentrations were three times as often identified by peers as being the most aggressive in their classroom.

Although much evidence suggests that there is an association between hypo-activation of the HPA-axis (i.e., as reflected in low cortisol concentrations) and antisocial behaviours, some studies have failed to replicate this relationship (e.g., Azar, Zoccolillo, Paquette, Quiros, Baltzer, & Tremblay2004; Schulz, Halperin, Newcorn, Sharma, & Gabriel, 1997). In fact, one study found a positive relationship between cortisol concentration and antisocial behaviours (e.g., Van Bokhoven et al., 2005). Although these mixed findings may be due in part to the different methods used to collect cortisol (e.g., salivary, plasma, urinary free cortisol), inconsistent findings call into question the validity of this relationship. Furthermore, a majority of the studies
have been correlational, making it more difficult to conclude a causal relationship or to use cortisol levels to predict antisocial behaviour (Van Goozen & Fairchild, 2008). Finally, very few studies have empirically examined the diagnostic specificity of the relationship between cortisol and antisociality (Van Goozen & Fairchild, 2008). It is plausible that hypo-activation of the HPA-axis is common among other types of childhood psychopathologies and therefore not useful as a distinct index of antisocial behaviour.

1.6.3 Neurotransmitters

Neurotransmitters are chemical substances that carry vital information from one neuron to the next across synapses (Santrock & Mitterer, 2001, pg. 76). Although more than 75 neurotransmitters have been identified in the central nervous system, only the monoamines (i.e., norepinephrine, dopamine, and serotonin) have been systematically studied in relation to antisocial behaviours (Van Goozen & Fairchild, 2008). Among all the monoamines, serotonin has been most widely studied with respect to antisocial and aggressive behaviours (Van Goozen & Fairchild, 2008).

1.6.4 Serotonin (5-HT)

The serotonergic system is either directly or indirectly involved in the regulation and modulation of mood, emotion, sleep, and appetite (Santrock & Mitterer, 2001, p. 76). Reduced 5-HT activity has been linked to violent forms of aggressive behaviours for decades (Coccaro, Lee, & Kavoussi, 2010; Natarajan, de Boer, & Koolhaas, 2009). The so-called 5-HT deficiency hypothesis of aggression (Brown, Goodwin, Ballenger, Goyer, & Major, 1979) has been supported in a number of studies involving a variety of animal species (e.g., Belen, Sylvia, Marta, Gema, Ainara, & Jorge, 2010; Higley, Mehlman, Taub, & Higley, 1992; Higley,
Mehlman, Taub, Higley, Suomi, Vickers, & Linnoila, 1992; ) as well as human studies involving both normative and clinical adult male samples (e.g., Cleare & Bond, 1997; Virkunnen, Nuutila, Goodwin, & Linnoila, 1987; Lidberg, Tuck, Asberg, Scalia-Tomba, & Bertilsson, 1985).

The role of 5-HT in childhood antisocial behaviour is less clear than in animal and adult studies. While some studies have yielded negative correlations between 5-HT and aggression (e.g., Hanna, Yuwiler, & Coates, 1995) others have found the opposite (e.g., Unis et al., 1997; Hughes, Petty, Sheikha, & Kramer, 1996). Additional findings suggest that, when compared to normal and psychiatric controls, antisocial children do not differ on measures of 5-HT concentrations (e.g., Cook, Stein, Ellison, Unis, & Leventhal, 1995; Rogeness, Hernandez, Macedo, & Mitchell, 1982).

1.6.5 Norepinephrine (NE)

NE is both a hormone and a neurotransmitter. As a hormone, NE interacts with epinephrine and helps give our bodies quick bursts of energy in time of stress (Santrock & Mitterer, 2001, p. 76). As a neurotransmitter, NE is directly or indirectly involved in modulating arousal, attention, and mood (Santrock & Mitterer, 2001, pg. 76). Animal based studies provide evidence of a positive correlation between NE activity and aggressive behaviours (Higley et al., 1992). In studies involving adult humans, a positive relationship has also been found between antisocial behaviour and NE concentrations. For instance, Brown, Goodwin, Ballanger, and Goyer (1979) measured a major NE metabolite (3-methoxy-4-hydroxyphenyglycol, also referred as MHPG) in a group of 26 military men. Results revealed a significant positive correlation between measures of MHPG concentrations and aggression ratings.
Studies assessing the relationship between NE and antisocial behaviours in children have been mixed (Raine, 2002). Although some studies have found positive correlations between NE activity and antisocial behaviours (e.g., Gabel, Stadler, Bjorn, Shindledecker, & Bowden, 1993), other studies have reported negative correlations (e.g., Rogeness, Javors, Maas, & Macedo, 1990) or no relationship at all (Van Goozen, Matthys, Cohen-Kettenis, Westernberg, & Van Engeland, 1999).

1.6.6 Dopamine (DA)

DA is involved in a number of important functions including voluntary movement, attention and working memory. In addition, the DA system plays an important role in our responsiveness to various rewards, punishments and motivations (Wahlstrom, White, & Luciana, 2010; Wahlstrom, Collins, White, & Luciana, 2010). Results from animal studies generally suggest that increased dopamanergic activity is associated with elevated levels of aggressive behaviours (e.g., Margolis, Lock, Hjelmstad, & Fields, 2006; Ferrari, van Erp, Tornatzky, & Miczek, 2003; Louilot, Le Moal, & Simon, H. 1986). Studies investigating the DA role in antisocial adult and child populations, however, have yielded mixed results. With respect to adults, studies assessing a DA metabolite (i.e., Homovanillic acid) have shown both an inverse relationship between DA functioning and antisocial behaviour (e.g., Virkkunen, et al., 1994) as well as no relationship at all (e.g., Virkkunen, Nuutila, Goodwin, & Linnoila, 1987). With regard to children, some studies have shown evidence of decreased DA functioning in conduct disordered youth (e.g., Van Goozen et al., 1999; Gabel, Bjorn, Shinledecker, & Bowden, 1993), while others have failed to establish this relationship (Kruesi, et al., 1992; 1990).

1.7 Neurophysiological Impairments and Antisocial Behaviour: Frontal Lobe and Executive Functioning Deficits
The neurophysiological and neurobiological correlates of antisocial behaviour have also been extensively studied. Specifically, researchers have explored the relationship between deficits in frontal lobe functioning and antisocial conduct (Cauffman, Steinberg, & Piquero, 2005; Raine, 2002). The frontal lobe is an important brain structure involved in a number of higher order cognitive processes related to executive functioning (e.g., planning, impulse control, affect regulation, attention, etc) (Cauffman, Steinberg, & Piquero, 2005; Morgan & Lilienfeld, 2000). Positron emission tomography (PET), single photon emission computerized tomography (SPECT), functional magnetic resonance imaging (fMRI), and electroencephalogram (EEG) activity have all been used to assess frontal lobe functioning (Raine, 2002).

Evidence of deficient frontal lobe functioning (e.g., reduced glucose metabolism in the prefrontal regions, reduced frontal region cerebral blood flow) in adult antisocial behaviour is mixed (Raine, 2002). While some studies provide a clear link between frontal lobe deficits and antisocial behaviour (e.g., Soderstrom, Tullberg, Wikkelsoe, Ejhikm, & Forsman, 2000; Volkow, et al., 1995), other studies have failed to find this relationship (e.g., Seidenwum, Pounds, Globus, & Valk, 1997). As discussed by Raine (2002) and in contrast to adult research, there is a dearth of brain imaging studies (e.g., PET, EEG) assessing the relationship between frontal deficits and antisocial behaviour in children; instead, researchers have assessed executive functioning abilities. Given that the frontal cortex controls executive functioning (Raine, 2002; Morgan & Lilienfeld, 2000), deficits in this area (e.g., impairments in self-regulation, inhibitory control, sustained attention, planning, and organization) in antisocial children would support the hypothesis that frontal functioning abnormalities and antisocial behavior are linked. A meta-analysis conducted by Morgan and Lilienfeld (2000) examined this relationship and showed a
significant correlation between executive dysfunction and CD (.40) and executive dysfunction and juvenile delinquency (.86).

Although there is compelling evidence supporting a relationship between deficient executive functioning abilities and antisocial behaviours, these findings must be interpreted with caution. Children with antisocial behaviour (e.g., CD, ODD) often have co-morbid ADHD (Deault, 2010). It is well established that children with ADHD have significant executive functioning deficits (e.g., Holmes, Gathercole, Place, Alloway, Elliott, & Hiton, 2010; Oosterlaan, Scheres, & Sergeant, 2005). Thus, it is possible that the relationship between executive dysfunction and antisocial behaviour is a result of co-morbid ADHD. Additional research is needed to examine whether executive functioning deficits prevail in antisocial children after controlling for ADHD (Raine, 2002).

1.8 Autonomic Nervous System Functioning

The autonomic nervous system (ANS) comprises both the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) (Guyton & Hall, 1997). The SNS and PNS typically function in direct opposition to one another. For instance, when confronted with a stressful situation, the SNS plays an integral role in preparing the body for a “fight or flight” response. In order to effectively prepare the body for such a response, the SNS initiates a cascade of internal physiological reactions resulting in increased heart rate and breathing, along with a simultaneous reduction in digestive activities (Kalat, 2001, pg. 91). In contrast, the PNS plays an integral role in calming the body by promoting relaxation and healing (i.e., the so-called “rest and digest” response; Santrok & Mitterer, 2001, p. 394). Once activated, the PNS causes a reduction in heart rate and breathing, and an increase in digestive activity (Santrok & Mitterer,
A substantial body of evidence suggests that antisocial behaviour is strongly related to ANS functioning (Raine, 2002). Specifically, researchers have examined the role of resting heart rate (which reflects both SNS and PNS activity; Lang, Tulen, Kallen, Rosberg, Dieleman, & Ferdinand, 2007) in relation to the development and maintenance of antisocial behaviours. The relationship between low resting heart rate and antisocial behaviour has been extensively examined using animal models (e.g., Eisermann, 1992) and human studies involving toddlers (e.g., Calkins & Dedmon, 2000), children (e.g., Raine, Venables, Sarnoff, & Mednick, 1997) adolescents (e.g., Raine & Venables, 1984) and adults (e.g., Braggio et al., 1992).

Resting heart rate appears to be the best-replicated biological correlate of antisocial and aggressive behaviours in children and adolescents (Raine, 2002). Results from a recent meta-analysis involving 40 studies comprising 5,868 children revealed a significant negative relationship (-.44) between heart rate levels and antisocial behaviours (Ortiz & Raine, 2004) that was broadly the same for males and females. The relationship between resting heart rate and antisocial and aggressive behaviours has been replicated across seven different countries, including the United States (e.g., Rogeness, et al., 1990), Canada (Mezzacappa et al., 1997), England (Wadsworth, 1976), Germany (Schmeck & Poutska, 1995), New Zealand (Moffit & Caspi, 2001), Mauritius (Raine, Venables, & Mednick, 1997) and Siberia (Slobodskaya, Roifman, & Krivoschekov, 1999). Importantly, the relationship between low resting heart rate and increased antisocial behaviour does not appear to be an artifact of other conditions given that studies have repeatedly ruled out a range of potential confounds including height, weight, body bulk, physical development and muscle tone, poor scholastic ability and IQ, drug and alcohol use, engagement in physical exercise and sports, low social class, divorce, family size, teenage pregnancy, and other psychosocial adversity (Ortiz & Raine, 2004).
Unlike other biological correlates of antisocial behaviour, it appears that resting heart rate is diagnostically specific to antisocial behaviour. As discussed in the meta-analysis conducted by Ortiz and Raine (2004), antisocial children were found to have significantly lower heart rates compared to psychiatric controls as well as normal controls. It appears that no other psychiatric condition is characterized by low resting heart rate (Ortiz & Raine, 2004). Individuals who have conditions such as anxiety, depression, schizophrenia, hyperactivity, alcoholism, and posttraumatic stress disorder demonstrate either elevated levels of heart rate or no difference from controls. Such diagnostic specificity is considered rare and suggests a potentially unique perspective from which antisocial behaviour in children can be understood (Ortiz & Raine, 2004).

Other lines of research have investigated the potential utility of employing heart rate levels as a predictor of future antisocial and criminal behaviours. Kindlon et al. (1995) demonstrated that low resting heart rate from ages 5-12 years is associated with increased fighting from ages 9-12. Furthermore, a five year prospective study of crime development by Raine, Venables and Williams (1990) revealed that low cardiac arousal at age 15 years in normal unselected school boys predicted criminal behaviour at age 24 years. In this study, measures of arousal correctly classified 75% of all subjects as criminal/non-criminal, a rate significantly greater than chance. Lastly, in a longitudinal study conducted by Raine et al. (1997), resting heart rate at age 3 was assessed in 1,795 male and female children from Mauritius. Aggressive and non-aggressive forms of antisocial behaviour were then assessed at age 11 through the use of the Child Behavior Checklist (Achenbach, 1991). The results indicated that aggressive children had significantly lower heart rates than non-aggressive children, suggesting that low resting heart rate at age 3 years predisposes children to aggression at age 11. These findings, along with those
from the meta-analysis conducted by Ortiz and Raine (2004), suggest that low resting heart rate is as strong a predictor of children’s future antisocial behaviour as their current behaviour.

Whereas low resting heart rate appears to be a marker for future antisocial behaviour, mounting evidence suggests that high heart rate may protect against adult crime (Raine, Venables, & Williams 1995). For instance, Brennan, et al. (1997) found that Danish boys who had a criminal father but who did not become criminals themselves demonstrated elevated levels of cardiovascular activity compared to both offspring of non-criminal controls and criminal offspring with criminal fathers.

1.9 Resting Heart Rate and the Intergenerational Transmission of Antisocial Behaviours

Advancements in the area of genetics have enabled researchers to better understand the intergenerational transmission of genetic information. Mounting evidence suggests that antisocial and aggressive behaviour may be passed on in this manner (Eley, Lichenstein, & Stevenson, 1999; Raine, 1993). As discussed by Farrington et al. (2001), support for the genetic contributions of antisocial behaviours is found in studies highlighting that antisocial behaviour appears to be concentrated in a fairly small percentage of families. For instance, in a study of a high-risk population in inner-city London, 63% of boys classified as having delinquent fathers were convicted of a criminal behaviour compared with only 30% of those whose fathers had never been accused of any criminal acts (Farrington, 1997). Moreover, data from sophisticated family, twin, and adoption studies provide additional support for the notion of a substantial genetic influence in the transmission of antisocial behaviours from one generation to the next (e.g., Lahey et al., 1988; Stewart, deBlois, & Cummings, 1980).
Family studies have consistently reported a two-to three-fold increase in the incidence of aggressive behaviour among the first and second degree relatives of aggressive boys, compared to clinic controls (Hamdan-Allen, Stewart, & Beeghly, 1989; Lahey et al., 1988). Genetic factors appear to exert a moderate to strong influence on the expression of aggression and antisocial behaviour as it has been shown to account for approximately 28-47% of the variance (Coccaro et al., 1997).

Given the mounting evidence in support of the intergenerational transmission of antisocial behaviours, there is increasing interest in investigating heritable biological processes that may act as markers for antisocial behaviour (Ortiz & Raine, 2004). It is well documented that heart rate and other cardiovascular properties are highly heritable (Boomsma & Plomin, 1986). Based on this evidence, researchers have questioned whether low cardiac activity is the neurobiological mechanism passed from antisocial parents to their antisocial offspring. Indeed, children who have criminal parents have been found to have lower resting heart rate in at least two independent studies (e.g., Venables, 1987). The fact that antisocial parents and their antisocial offspring appear to share a similar biological substrate to aggressive behaviours provides preliminary support for a heritable biological process that may account for the intergenerational transmission of antisocial and aggressive behaviour.

In summary, it appears that low autonomic arousal as measured through resting heart rate is one of the best-replicated biological correlates of antisocial and aggressive behaviour in children and adolescents. This relationship characterizes both males and females, is not artifactual, has been shown to have diagnostic specificity, and has been replicated in at least seven different cultures. Low heart rate in childhood and adolescence predicts antisocial and criminal behaviour in adulthood and high heart rate may protect against crime development.
1.10 How Low Heart Rate May Predispose to Aggressive and Antisocial Behaviour

Although low resting heart rate represents one of the best replicated, most easily measured, and most promising biological correlates of antisocial and aggressive behaviours in children and adolescents, it is perhaps one of the most poorly understood biological markers (Raine, 2002). Researchers have questioned why low resting heart rate may predispose individuals to antisocial behaviours. While several theoretical possibilities exist, one of the most prominent theories accounting for this phenomenon is the stimulation seeking theory.

1.11 Stimulation Seeking Theory

One of the most parsimonious physiological explanations for the relationship between low heart rate and increased antisocial and criminal behaviour is that low physiological arousal predisposes to antisocial and aggressive behaviour (Eysenck, 1997; Raine et al., 1990). According to the stimulation seeking theory, low arousal represents an unpleasant physiological state. The underlying premise of any arousal modulation theory is that humans try to maintain some optimal level of central nervous system arousal and prefer an environment that provides neither too much nor too little stimulation (Berlyne 1969; as cited in Hughes, 1999). When desired arousal levels cannot be maintained due to a lack of environmental stimulation, the person experiences boredom and seeks stimulation. In line with this theory, antisocial individuals purposely engage in antisocial and aggressive acts in an attempt to increase stimulation and achieve more agreeable arousal levels (Eysenck, 1997; Quay, 1965; Raine et al., 1997).

1.12 Underarousal and Aggressions: Potential Treatment Implications

If, as the stimulation-seeking theory suggests, one of the functions of children’s antisocial and aggressive behaviour is to increase their arousal level, the concept of functional equivalence
(Carr, 1988; Horner & Day, 1991) may provide a potential pathway to intervention. Functional equivalence is the behavioural process documented extensively in the applied behaviour analysis literature whereby the same function or reinforcer for a behaviour is achieved by means of two or more topographically different responses.

To illustrate, an individual can sometimes achieve the same outcome (e.g., obtaining a toy from a peer) by means of either a prosocial (e.g., asking the child to share) or antisocial (e.g., grabbing the toy without asking) manner. Because the topographically different responses lead to the same class of reinforcement (i.e., access to the toy), they are considered functionally equivalent (Ducharme, 2000). Similarly, aggressive and antisocial children may learn that the easiest and most effective/efficient way to alter underarousal is to engage in socially inappropriate and aggressive acts. Thus, aggressive behaviours displayed by underaroused children may serve the specific function of increasing stimulation. The concomitant boost in arousal may serve as a positive reinforcer, increasing the probability of the response patterns that led to increased arousal (e.g., aggression).

The concept of functional equivalence can be considered in relation to physiological arousal. If children with aggressive and antisocial tendencies could increase their arousal level through socially acceptable alternative behaviours, they may not need aggression to serve that function. Exercising or physical activity may be one socially acceptable strategy with the potential to serve that function for children. Based on the stimulation seeking theory, disruptive children might find that exercise provides enough physiological stimulation to increase arousal, thereby rendering antisocial responses unnecessary for achieving that outcome.
In fact, a substantial body of evidence suggests that children with aggressive and disruptive behaviours display a decrease in problem behaviour after being exposed to exercise or physical activity. In a review and meta-analysis of 42 group and single case studies, Allison, Faith, and Franklin (1995) described the effects of antecedent exercises for the treatment of disruptive behaviours. The authors used the term antecedent exercises to describe any exercise condition (i.e., activities that resulted in some degree of physical exertion) that was applied non-contingently with the intent of reducing subsequent disruptive behaviour (i.e., not following behaviour as with punishment). The meta-analysis revealed that this approach is effective at reducing a range of problem behaviours (e.g., disruptive classroom behaviour, self-stimulating behaviours, aggression, attention-span and impulsivity, etc.) across a variety of populations (individuals with developmental delays, autism, emotional difficulties, and elementary school youths referred for disruptive school behaviours).

Although previous research has demonstrated that antecedent exercise is broadly efficacious, socially acceptable, can be implemented with treatment integrity, and has benign side-effects (Allison, Faith, & Franklin 1995), two fundamental aspects of this approach remain unclear and require additional research. First, although the internal validity of antecedent interventions is well-established, temporal impact has not yet been determined. To our knowledge, only one study (e.g., Celiberti, Bobo, Kelly, Harris, & Handleman, 1997) has examined the temporal effects of exercise. In this study, exercise was used to suppress the self-stimulatory behaviour of a five-year-old boy with autism. Following the exercise condition, behaviours were observed for a period of 40 minutes. The authors reported sharp reductions in aberrant behaviours immediately following the exercise intervention. These behaviours gradually increased but did not return to baseline levels over the 40 minute observational period. Given
that the participant's aberrant behaviours remained below pre-exercise baseline levels at the end of the observational period, it is evident that the beneficial effects of exercise were still present. Although this study provides some useful information regarding the temporal effects of exercise (i.e., the effects last for at least 40 minutes), it fails to delineate the precise length of time that the child experienced improvements in behaviours. Research assessing the temporal effects of exercise will be most informative when post-exercise observations occur long enough for target behaviours to return to pre-exercise baseline levels.

Another important dimension of antecedent exercise that has received considerably less attention is the mechanism of action accounting for behavioural changes. Although arousal appears to be a plausible mechanism, fatigue has also been discussed as a possible mechanism accounting for behavioural improvements (Allison, Faith, & Franklin, 1995). According to the fatigue hypothesis, individuals expend a high degree of energy while engaged in exercise. Following exercise, individuals are simply too fatigued to engage in confrontational interactions with others (Allison, Faith, & Franklin, 1995). To our knowledge no study has been able to determine what mechanism(s) best accounts for exercise induced behaviour change (i.e., arousal or fatigue).

1.13 Summary and Rationale for the Current Investigation

Antisocial behaviour in youth represents a serious societal and clinical concern (Scott et al., 2010; Van Goozen, Fairchild, & Harold, 2008; Mayer, 2001). Left untreated, children who engage in antisocial behaviours are at serious risk for a number of negative outcomes during adolescence and adulthood (Trentacosta, Shaw, & Cheong, 2009; Van Goozen, Fairchild, Harold, 2008; Wright, John, Livingstone, Shepard, & Duku, 2007; Loeber & Farrington, 2000;
Ronks & Pulkkinen, 1995; Magnusson, 1992; Farrington, 1991; Caspi, Elder, & Herbener, 1990). Within schools, students who engage in mild but frequent forms of antisocial behaviours (e.g., talking out of turn, teasing, aggression, etc), represent major challenges for teachers and contribute to teacher stress, burnout, and attrition (Baker, Lang, & O’Reilly, 2009; Abel & Sewell, 1999; Peterson, Beekley, Speaker, & Pietrzak, 1996). Disruptive classroom behaviours have also been shown to seriously impact both the quality and the quantity of academic instruction (Bru, 2009).

Given the serious concerns associated with antisocial behaviours, researchers have explored a variety of different treatment options (e.g., behavioural interventions, cognitive-behavioural approaches, family-based interventions, multi-faceted treatments, pharmacological interventions) (e.g., Kazdin, 2003; Barkley & Benton, 1998; McCloskey, Noblett, Deffenbacher, Gollan, & Coccaro, 2008; Martsch, 2005; Leung et al., 2003; Webster-Stratton & Hammond, 1997; Koegl, Farrington, Augimer & Day, 2008; Iper & Stein, 2007). Notwithstanding the beneficial effects demonstrated with these approaches, few result in long-term reductions in antisocial behaviour (Van Goozen et al., 2007; Kazdin, 1997, 1995). Furthermore, the most beneficial interventions tend to be both time and resource intensive (Axelrod, Garland, & Love, 2009), rendering them impractical for implementation in schools (Wilson & Lipsey, 2010).

Advancements in our understanding of the biological and neurophysiological substrates of antisocial behaviour may lead to new and innovative treatment alternatives. To date, several distinct biological and neurophysiological correlates of antisocial behaviour have been identified (e.g., androgens, neurotransmitters, cortisol, and frontal lobe deficits) (e.g., Banks & Dabbs, 1996; Maras, 2003; Dmitrieva, Oades, Hauffa, & Eggers, 2001; Shoal et al., 2003; Bjork, Dougherty, Moeller, & Swann, 2000; Soderstrom, Tullberg, Wikkelsoe, Ejhikm, & Forsman,
Of all the biological correlates, resting heart rate levels appear to be the best-replicated biological marker of antisocial behaviour (Raine, 2002). The relationship between low resting heart rate and increased levels of antisocial behaviour has been demonstrated in animal (e.g., Eisermann, 1992) and human studies involving toddlers (e.g., Calkins & Dedmon, 2000), children (e.g., Raine, Venables, Sarnoff, & Mednick, 1997) adolescents (e.g., Raine & Venables, 1984) and adults (e.g., Braggio et al., 1992). The stimulation seeking theory proposes that low resting heart rate reflects diminished levels of physiological arousal (Eysenck, 1997; Raine et al., 1990). Given that all living organisms strive for optimal levels of physiological arousal (Berlyne, 1969), antisocial individuals may engage in aggressive, disruptive, and violent acts as a means of increasing their physiological arousal levels to a more optimal state.

If, as the stimulation seeking theory suggests, the function of antisocial behaviour is to increase physiological arousal levels, exposing antisocial individuals to functionally equivalent forms of arousing situations (e.g., exercise) should lead to a reduction in antisocial conduct (Carr, 1988; Horner & Day, 1991). Although a growing body of literature indicates that antecedent exercise is associated with substantial reductions in aggressive, disruptive, and antisocial behaviours (e.g., Allison, Faith, & Franklin, 1995), fundamental questions about this approach remain unanswered. First, there is a dearth of research examining the temporal effects of antecedent exercise. Secondly, little is known about the mechanism of action accounting for behavioural improvements (i.e., why exercise leads to improved behaviours).

1.14 Research Questions and Hypotheses

The present empirical investigation sets out to investigate the following research questions and hypotheses:
1.14.1 Replication

Can the beneficial effects of antecedent exercise (i.e., reduction in disruptive and aggressive behaviour) be replicated with a group of elementary school children who have low levels of physiological arousal and demonstrate severe levels of antisocial and aggressive behaviours? With regards to this question, we hypothesize that school-aged children will exhibit a reduction in disruptive behaviours following 30 minutes of vigorous aerobic exercise.

1.14.2 Temporality

What are the temporal effects of antecedent exercise (i.e., how long following the completion of exercise do students display improved behaviours)? We expect that the beneficial effects of exercise will last for a duration of at least 40 minutes.

1.14.3 Mechanism of Action

Do heightened levels of arousal account for the relationship between antecedent exercise and reductions in disruptive behaviours? We hypothesize that students’ physiological and self-report measures of arousal will be inversely related to the frequency of their disruptive behaviours.
Chapter 2: Method

2.1 Participants

Study participants were 4 male students (age range 11 – 14) enrolled in a closed behavioural classroom due to severe aggressive, oppositional, and disruptive behaviours. All 4 students were described by their teacher as being unresponsive to traditional forms of classroom based interventions (e.g., social skills training, anger management programs, problem-solving training).

2.1.1 Participant 1 (Bobby)

Bobby was a 13-year-old Caucasian male in the eighth grade. He was placed in a closed behavioural classroom with partial integration (i.e., 20% of the time) for Math class, the only subject area in which he was performing at grade level. According to teacher reports, he was lacking in social skills, showed extreme opposition to rules and authority figures, and demonstrated high levels of disruptive and aggressive behaviour. Bobby was formally diagnosed with a learning disability in the 3rd grade and had a history of behavioural difficulties resulting in several suspensions.

2.1.2 Participant 2 (Kyle)

Kyle was a 14-year-old Caucasian male enrolled in a grade eight closed behavioural classroom with no integration. Kyle was performing below grade level in the areas of English, History, Geography, Science, Math and Religion. Although not formally diagnosed with any disorders, his high degree of anxiety related to social situations prevented him from attending school trips or being integrated into other classrooms. He rarely participated in classroom
discussions or activities, had unpredictable aggressive outbursts, and was a major distraction to his classmates due to his disruptive behaviours.

2.1.3 Participant 3 (Dan)

Dan was a 12-year-old Black male in the seventh grade. Dan was placed in a closed behavioural classroom with partial integration (i.e., 30% of the time). Teacher reports indicated that he was below grade level in all areas of academic functioning and demonstrated aggression, short temper and disruptive classroom behaviour. Dan was formally diagnosed with a non-verbal learning disability in the 4th grade and had a longstanding history of behavioural and academic difficulties.

2.1.4 Participant 4 (Tom)

Tom was an 11-year-old Black male in the fifth grade. Tom was integrated into mainstream classrooms for approximately 30% of the day and spent the remainder of his time in a closed behavioural class. Teacher reports indicated that he was performing below grade level in all subject areas. He often exhibited disruptive behaviours, poor decision making (e.g., throwing objects out of the classroom window at students, cutting holes in the school bus seats), and violations of others property (e.g., stealing). Tom was diagnosed with a learning disability in the 3rd grade and experienced severe fine motor deficits.

2.2 Classroom Setting and Staff

The present study was conducted in a special education classroom within an elementary school in the local school board. Staffing included one special education teacher and one child and youth worker. The classroom comprised only the four students participating in this study.
2.3 Research Design

An alternating treatment design with baseline (Krishef, 1991; Wacker, McMahon, Steege, Berg, Sasso, & Melloy, 1990; Barlow & Hayes, 1979; Barlow & Hersen, 1973) was employed. In this time series design, students were first exposed to baseline conditions and then to two experimental conditions, (i.e., an antecedent exercise condition and a control condition) in a randomized fashion. This design allowed for a sequential comparison between baseline and experimental conditions and a simultaneous comparison between exercise and control conditions. Research in the field of special education has been increasingly employing single-subject designs to investigate the effectiveness of educational practices and interventions for students with a variety of disabilities (Tankersley, Harjusola-Webb, & Landrum, 2008).

2.4 Data Collection and Interobserver Agreement

2.4.1 Observer Training

To assist with observational data collection, eight undergraduate research assistants (RAs) were recruited from the Psychology department at the University of Toronto. All RAs received approximately 15 hours of face-to-face training. On the first day of training (approximately 5 hours), RAs were provided with an information package outlining the nature of the study. Included in this package were (i) a description of the observational and coding procedures to be used (ii) a description of the operational definitions of all target behaviours, and (iii) copies of the data recording sheets that were to be used to collect all behavioural and physiological measures. After going through the information package with the RAs, the primary investigator answered their questions related to the material and encouraged them to carefully review the information provided before the second training session.
On the second day of training (approximately 5 hours), the RAs were assigned to small groups and asked to brainstorm a variety of student behaviours (both positive and negative). After generating a sufficient list, RAs were asked to consider how they would categorize and code the behaviours. Finally, group members were instructed to present their list of coded behaviours to the larger group.

The final training session took place in the actual school where the remainder of the study was to take place. RAs were introduced to the school staff and the students enrolled in the study. Following introductions, RAs were assigned to students and asked to code their behaviours. This session enabled RAs to become familiarized with the observational and coding procedures and acclimatized research participants to being observed in their classroom.

2.4.2 Observation Sessions

Participant observations took place in the students’ classroom while they were engaged in regular classroom activities. A RA who was blind to experimental conditions coded the occurrence of a variety of target behaviours of each participant. For the purpose of interobserver agreement, 20% of all baseline, exercise, and control sessions were randomly selected and simultaneously coded by the primary investigator. For the baseline, exercise, and control conditions, agreement was obtained for both disruptive and prosocial behaviours (see definitions below) as well as compliance to teacher requests. Percentage agreement was obtained by dividing the number of agreements by the sum of agreements and disagreements in each session, and multiplying by 100. Mean interobserver agreement for behaviour was 92% (range = 89% to 94%) for baseline sessions, 93% (range 88% to 100%) for exercise sessions, and 94% (range = 89% to 97%) for control sessions. Mean interobserver agreement for compliance to teacher
requests was 91% (range = 84% to 100%) for baseline sessions, 93% (range = 87% to 100%) for exercise sessions, and 92% (range = 82% to 100%) for control sessions.

2.5 Measures

The measures in this study included a general health screener completed by parents/caregivers, teacher ratings, observational measures, physiological measures, and student self-report measures.

2.5.1 General Health Screener

Given that the participants were being asked to engage in physical activities, it was important to determine whether they had any pre-existing health conditions that could compromise their well-being during exercise routines. For this reason, parents/caregivers were asked to complete a general health screener (see Appendix “A”) geared at identifying any health or medical concerns experienced by their child.

2.5.2 Teacher Ratings

The emotional and behavioural profiles of the participants were assessed through the use of the Teacher Report Form (TRF) (Achenbach, 1991) at the commencement of the study. The TRF is an individually administered questionnaire designed to measure teachers’ perceptions of children’s academic performance, adaptive functioning, and emotional/behavioural problems. The questionnaire is designed for students between the ages of 6 and 18 and contains 120 items. The TRF has sound psychometric properties. Achenbach (1991) found the range of test-retest reliability to be 0.62 to 0.96, the range of internal consistency to be 0.72 to 0.95 and the inter-rater reliability to be 0.60.
2.5.3 Observational Measures

Participant students were observed in their classrooms for a duration of 2 hours for all observational periods (i.e., baseline, following exercise and following control). The teacher and classroom assistant were instructed to perform regular classroom routines and activities during all observational sessions.

2.5.4 Disruptive Behaviours

Disruptive behaviours were divided into 6 categories. Negative verbal behavior was defined as any aversive or antisocial statements, questions, or comments directed at peers or teachers including threats, insults, swearing, name-calling, and blaming. Physical aggression towards others was defined as any aversive or antisocial action directed towards another peer or teacher, including hitting, kicking, tripping, spitting, and biting. Physical aggression towards objects was defined as any aversive action involving an object including throwing of objects, breaking pencils, writing on desks, kicking chairs, etc. Disruptive behaviours towards others was defined as any behaviour that was disruptive towards peers or teachers including speaking during lessons, calling out answers, interrupting peers, etc. Out of seat behavior was defined as the student leaving his seat without asking permission from the teacher or classroom assistant. Finally, coders used an “other” category for any problem behavior not adequately covered by the aforementioned categories.

2.5.5 Prosocial Behaviours

Prosocial physical behaviours were defined as any spontaneous or self-initiated cooperative action directed towards a peer or teacher including helping and sharing. Prosocial verbal behaviours were defined as any spontaneous or self-initiated friendly or co-operative
statements, questions, or comments directed at peers or classroom staff including praising, thanking, apologizing, or inviting peers to engage in a game or activity.

2.5.6 Compliance to Teacher Requests

Percentage of compliance to teacher requests served as another dependent measure. Participants were considered compliant if the appropriate response to the teacher request was initiated within 10 seconds of the request and the student followed through on completion. If the teacher was required to repeat the request, the participant was coded as non-compliant. All teacher requests within the observational period were coded.

2.5.7 Physiological Measures of Arousal

In the present investigation, heart rate was used as an objective measure of physiological arousal and participants’ heart rate was assessed throughout all conditions. Heart rate is determined by the number of heartbeats per unit of time, typically expressed as beats per minute (BPM) (Guyton & Hall, 1997). Heart rate levels have frequently been used in research to assess and quantify autonomic arousal levels (e.g., Borusiak, Boukidis, Liersch, & Russel, 2008; Fleming & Rickwood, 2001). Although several different techniques and methods can be used to assess heart rate (e.g., manually checking the carotid or radial pulse, electrocardiograph, various commercial heart rate monitors), the present study required a measuring device that allowed for efficient and accurate recordings yet was simple enough for use by school aged children. For the present study, all physiological measures of heart rate/arousal were obtained through the use of a SPORTLINE Solo 920 Heart Rate Watch ® (hereafter referred to as heart rate monitor) (see Appendix “B”). The heart rate monitor works like a standard watch, but includes an advanced heart rate sensing technology (i.e., S-Pulse™ Technology) that measures the electrical signals on
the skin in the same manner that an electrocardiogram (EKG) does. Although the heart rate monitor is attached to the wrist, it does not measure radial (i.e., wrist) pulse, but instead measures heart rate by reading the individual’s EKG signal, that is, the electronic signals generated by the beating heart that pass through the body. Located on the heart rate monitor are two metal sensors, one on the face of the watch and the other on the back against the wrist. The EKG measurement is obtained when the individual places their index finger on the face sensor for 3-8 seconds. This creates a “loop” that is read by the monitor. A beeping sound notifies the individual of a successful reading and the heart rate is then displayed on the screen. The heart rate monitor provides EKG accurate readings (SPORTLINE Solo 920 Heart Rate Watch ® Manual, 2006).

All participants received training on how to correctly monitor their heart rate. To ensure that the watch did not serve as a distraction during classroom lessons, participants were permitted to check their heart rate only when instructed by the researchers. Students who were distracted by their watch during lessons were given a warning by their classroom teacher. If a second warning was warranted, the student was asked to remove the watch and place it in his desk. When the watch was required for heart rate measures, the student was then asked to replace the watch on his wrist.

2.5.8 Resting Heart Rate

Resting heart rate levels were obtained prior to the commencement of baseline sessions. This measure was taken to assess the level of physiological arousal experienced by each of the participants and was also required for calculations of participants target heart rate (see below). To obtain measures of resting heart rate, each participant was asked to join the primary
investigator in the hallway in a quiet spot free from distractions. The participant was asked to relax with eyes closed on a mat for 5 minutes. Following the 5 minutes, each student was asked to use the heart rate monitor to measure his resting heart rate. To ensure accuracy of measurement, this procedure was conducted three times. The mean of all 3 recordings was used as the measure of resting heart rate.

2.5.9 Heart Rate during Exercise and Control Sessions

Participants’ heart rate levels were obtained several times throughout exercise and control conditions that were each 30 minutes in duration. Heart rate was obtained during the exercise and control conditions to objectively measure the extent to which arousal levels differed between the experimental conditions. To obtain arousal levels, each participant was approached by the primary investigator and asked to use the heart rate monitor to measure his heart rate. The primary investigator read the heart rate value from the watch and recorded it on a coding sheet (see Appendix “C”). Participants were asked to refrain from discussing their heart rate levels with classmates.

2.5.10 Heart Rate during Observational Periods

During baseline and following exercise and control conditions, participants were observed in their classroom for 2 hours. At several pre-determined times during the observational periods, participants were approached by a RA and asked to check their heart rate. These values were verified by the RA and recorded on a coding sheet (see Appendix “D”). These heart rate measures provided participants’ arousal levels during baseline as well as arousal levels following exposure to the experimental conditions. Arousal measurements following the experimental
conditions allowed for an exploration of the mechanism of action underlying potential
behavioural improvements following exercise.

2.5.11 Target Heart Rate Zone

Target Heart Rate (THR), is the most favorable heart rate range during aerobic exercise,
enabling the heart and lungs to receive optimal benefit from a workout. This theoretical range
varies across individuals based on physical condition, gender, and previous training.

Research suggests that vigorous exercise (defined as moderate to intense) is most
effective at reducing disruptive behaviours (Celiberti et al., 1997). As exercise intensity
increases, individuals experience an elevation in heart rate level. A moderate level is commonly
defined as exercise that enables individuals to achieve 50-70% of their maximum heart rate
(Guyton & Hall, 1997). For the purpose of the present investigation, it was crucial that
participants engaged in moderate levels of exercise intensity (i.e., 50-70% of their maximum
heart rate). To confirm that participants achieved the desired exercise intensity level, we
calculated their individualized THR. During exercise, participants’ heart rates were monitored to
ensure that they were consistently exercising within the predetermined THR zone.

Prior to starting the exercise conditions, the THR for each participant was individually
calculated using the Karvonen method (e.g., Robergs & Landwehn, 2002). This method was
selected because it considers each individual’s unique resting heart rate in calculation of THR.
The Karvonen method uses the following formula:

$$
THR = ((HR_{max} - HR_{rest}) \times \% \text{ Intensity}) + HR_{rest}
$$
For demonstration purposes, the Karvonen method is used here to calculate the THR of a 13-year-old male who has a resting heart rate of 80 beats per minute (and desires to achieve 50% to 70% of his maximum heart rate during exercise).

**Step 1: Calculate HRmax**

\[
HR_{max} = 220 - \text{age [of individual]}
\]

\[
HR_{max} = 220 - 13 = 207
\]

**Step 2: Calculate THR for 50% exercise intensity**

\[
THR = ((HR_{max} - HR_{rest}) \times \% \text{ Intensity}) + HR_{rest}
\]

\[
THR = ((207 - 80) \times .50) + 80
\]

\[
THR = 143.5
\]

**Step 3: Calculate THR for 70% exercise intensity**

\[
THR = ((HR_{max} - HR_{rest}) \times \% \text{ Intensity}) + HR_{rest}
\]

\[
THR = ((207 - 80) \times .70) + 80
\]

\[
THR = 168.9
\]

Thus, according to the Karvonen method, a 13-year-old male with a resting heat rate of 80 BPM is exercising at an optimal level (i.e., at a moderate to intense level) when his heart rate is maintained in the range of 144 to 169 BPM throughout exercise.

2.5.12 Self-Report Measures

In addition to the behavioural and physiological measures, a variety of self-report measures were used. Visual analog scales were used to obtain participants’ perception of (i) how relaxed or tense they felt (see Appendix “E”), (ii) how fatigued or full of energy they felt (see
Appendix “F”), and (iii) how bored or excited they felt (see Appendix “G”). Participants were asked to draw a line on the scale that best designated how they were currently feeling. To quantify the participants’ self-report ratings, a ruler was used to measure where on the line the participants placed their mark unit of measurement. Participants practiced completing the scale before the start of the study and were typically able to complete all analogue scales in less than 25 seconds.

2.6 Procedures

2.6.1 Baseline

Before students arrived to class during baseline, RAs were randomly assigned to observe one of the four participants and a heart rate monitor was placed on each student desk. The 2 hour observation period began as soon as students entered the classroom. The teacher was instructed to perform his daily routines and activities. RAs sat at the back of the room and remained out of the direct view of the participant they were observing. Each RA was provided with data sheets containing a check list of behaviours to be coded (see Appendix “H”). RAs circled the item on the check list that best corresponded to the behaviours observed. RAs also obtained heart rate measurements and analogue self-report measures. Heart rate and self-report measures were obtained 4 times throughout the 2 hour observational session at 30 minutes, 60 minutes, 90 minutes, and 120 minutes. RAs were instructed to interact with participants in a “neutral” manner (e.g., no praise statements, no criticism) when obtaining measures. Heart rate and subjective measures were typically collected in less than 2 minutes and resulted in minimal disruptions to regular classroom activities.
During the observational period, some participants received partial integration, requiring them to spend part of the observational period in a different classroom. In such circumstances, the assigned RA followed the student to the alternate classroom and resumed observations. The only interruption in coding occurred when the students went outside for their 15 minute morning recess break.

2.6.2 Antecedent Exercise Condition (10 sessions)

All exercise sessions were conducted by the primary investigator and one RA. When a RA assisted with implementation of the exercise sessions, they were not included in data collection for that session. All exercise sessions occurred during the students’ first period class and took place either in the school gymnasium or on the school playground.

Before starting each session, participants were provided with a heart rate monitor. Each exercise session lasted 30 minutes and comprised the following components:

(i) Warm-up phase (5 minutes): A warm-up phase was conducted to reduce the likelihood of student injury. In this phase, participants were asked to gather in a circle and demonstrate a muscle stretch of their choice for the group to imitate. The exercise phase did not begin until all major muscle groups were adequately stretched.

(ii) Exercise Phase (20 min): The exercise phase was 20 minutes in duration and included a variety of aerobic exercise activities including jogging, skipping, sprints, and circuit training. To achieve the goal of increased heart rate, participants were reminded before each exercise session of their unique target heart rate and were encouraged to achieve this level throughout the exercise session.
(iii) Cool-down Phase (5 minutes): During the cool down phase, participants were asked to engage in less intense forms of exercise. This involved walking two laps around the gym followed by a series of stretching exercises (conducted as in the warm-up phase).

Throughout all exercise sessions, students were asked to stop on four occasions (i.e., at 10 minutes, 15 minutes, 20 minutes, and 30 minutes) to provide heart rate and self-report measures. When students remained below their target heart rate (i.e., below 50% of their maximum heart rate), they were asked to “work as hard as they could”. If the participants’ heart rate level exceeded 70% of their maximum heart rate (and were thus at risk of injury due to overexertion) they were asked to “slow down the pace for a couple of minutes”.

Following the exercise condition, participants returned to their classroom and were observed by RAs who were blind to the experimental condition. Observations following exercise sessions lasted 2 hours and followed the same coding procedures as in baseline.

2.6.3 Control Condition (9 sessions)

The 30 min control condition was designed to maintain participant heart rates as close as possible to the resting state. All control sessions occurred during the participants’ first period class. Before students arrived at school, the primary investigator placed a variety of reading materials (e.g., sports magazines, comic books) and heart rate monitors on a desk at the front of the classroom. Students were instructed to select one or two items from the selection of reading materials as well as a heart rate monitor. The session started once participants had returned to their seats with their reading materials. To increase the likelihood that students would engage in 30 minutes of silent reading, participants were informed by the teacher that their daily journal entry had to include a response to the information that they read. As in the exercise condition,
participants provided heart rate and self-report measures at 4 time periods (i.e., 10 minutes, 15 minutes, 20 minutes, and 30 minutes).

Following the 30 minutes of silent reading, students were asked by the teacher to start working on their daily journal. Participants were then observed for 2 hours by RAs who were blind to the experimental condition. The same observational coding procedures that were used during baseline were carried out following control sessions.
Chapter 3: Results

3.1 General Health Screener

Results from the general health screener indicated that all participants were in good health and had no medical or physical conditions that would prevent them from partaking in 30 minutes of aerobic exercise.

3.2 Emotional and Behavioural Functioning

Emotional and behavioural functioning was assessed through the Teacher Report Form (Achenbach, 1991). Results for each of the 4 participants are described below.

3.2.1 Participant 1 (Bobby)

On the TRF, Bobby scored in the normative range on all measures of internalizing behaviours. Regarding externalizing behaviours, Bobby fell in the clinical range (T Score = 71). Within the externalizing domain, Bobby was rated in the borderline clinical range for rule-breaking behaviour (T Score = 69) and in the clinical range for aggressive behaviours (T Score = 71), oppositional defiant problems (T Score = 70), and conduct problems (T Score = 75).

3.2.2 Participant 2 (Kyle)

TRF scores suggest that Kyle was in the clinical range for both internalizing (T Score = 71) and externalizing (T Score = 68) behaviours. Within the internalizing domain, Kyle fell in the borderline clinical range for withdrawn/depressed behaviour (T Score = 69) and in the clinical range for anxiety problems (T Score = 73). Regarding externalizing behaviours, Kyle fell in the borderline clinical range for rule-breaking behaviour (T Score = 67), aggressive behaviour
(T Score = 67), oppositional defiant problems (T Score = 65), and conduct problems (T Score = 68).

3.2.3 Participant 3 (Dan)

Dan did not experience significant difficulties with internalizing behaviours. Dan did, however, score in the clinical range for externalizing problems (T Score = 65). Within the externalizing domain, Dan fell in the borderline clinical range for rule-breaking behaviour (T Score = 68), oppositional defiant problems (T Score = 65), and conduct problems (T Score = 68).

3.2.4 Participant 4 (Tom)

Although Tom did not experience significant difficulties with internalizing behaviours, he fell in the borderline clinical range for anxiety problems (T Score = 65). With regards to externalizing difficulties, Tom fell in the borderline clinical range (T Score = 61). Within the externalizing domain, Tom scored in the borderline clinical range for both rule-breaking behaviour (T Score = 66) and conduct problems (T Score = 66).

3.3 Resting and Target Heart Rate (THR)

Table 1 provides resting and THR rate values for each of the 4 participants. THR was calculated using the Karvonen method. For the purpose of the present investigation, the THR for each participant was calculated to be 50% to 70% of their maximum heart rate.
Table 1

*Resting and Target Heart Rate*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Resting Heart Rate</th>
<th>Target Heart Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bobby</td>
<td>77</td>
<td>142-168</td>
</tr>
<tr>
<td>Kyle</td>
<td>82</td>
<td>144-169</td>
</tr>
<tr>
<td>Dan</td>
<td>72</td>
<td>140-167</td>
</tr>
<tr>
<td>Tom</td>
<td>92</td>
<td>151-174</td>
</tr>
</tbody>
</table>

*Note.* All heart rate levels reflect number of beats per minute (BPM)

3.4 *Effects of Antecedent Exercise on Behavioural Functioning*

To investigate the effects of antecedent exercise on behavioural functioning, two measures were included. The first measure was used to investigate the overall extent to which exercise was associated with improved behaviours. For this measure, observed student behaviours following experimental conditions were combined over the entire observational duration (i.e., 2 hours). The second measure was used to investigate potential temporal effects associated with exercise. For this measure, the two hour duration of observed student behaviours following experimental conditions was divided into four 30 minute intervals (i.e., 0 to 30 minutes, 30 to 60 minutes, 60 to 90 minutes, and 90 to 120 minutes).
3.5 Overall Effects of Antecedent Exercise on Behavioural Functioning (2 hour duration)

3.5.1 Disruptive Behaviours

**Baseline.** The frequency of disruptive behaviours in baseline and following control and exercise sessions are presented in Figure 1. The frequency of disruptive behaviours during baseline was high for all 4 participants. The overall mean frequency of disruptive behaviours across all participants was 45.4 (range of 20 to 74).

**Control Condition.** The frequency of disruptive behaviours remained relatively high following the control sessions for all 4 participants. The overall mean frequency of disruptive behaviours across all participants was 47.1 (range of 17 to 69).

**Exercise condition.** All 4 students experienced a substantial reduction in disruptive behaviours following exercise sessions. The overall mean frequency of disruptive behaviours throughout all exercise sessions was 26.4 (range of 9 to 47). The mean for disruptive behaviours was 20.75 responses lower per session than in the control condition.

Visual analysis of data trends in Figure 1 suggests that exercise had a very strong reductive effect on disruptive behaviours for each individual participant. Data for exercise sessions are characterized by little variability and relatively low frequency. Analysis of Figure 1 also reveals few overlapping data points between exercise and control sessions. These data suggest that participants consistently engaged in less disruptive behaviour following exercise sessions than following control sessions.

In addition to visual analysis, Mann-Whitney U tests were used to determine statistical differences between exercise and control sessions. Separate Mann-Whitney U tests were
conducted for each participant (see Appendix “I” for all Mann-Whitney U test statistic values for each participant). This analysis demonstrated that all participants were significantly less disruptive following exercise sessions compared to control sessions.

Figure 2 presents the averaged group data for disruptive behaviors across baseline, control, and exercise sessions.
Figure 1: Frequency of disruptive behaviours for all baseline, control, and exercise sessions.
3.5.2 Prosocial Behaviours

Baseline. The frequency of prosocial behaviours in baseline and following control and exercise sessions are presented in Figure 3. As can be seen in this figure, baseline rates of prosocial behaviours were generally low for all 4 students. The overall mean frequency of prosocial behaviours across all 4 students was 12.8 (range of 8 to 19).

Control Condition. Similar to baseline rates, the frequency of prosocial responding during control sessions was low for all participants. The overall mean frequency of prosocial behaviours was 9.5 (range of 1 to 18).

Exercise condition. All 4 students demonstrated an increase in prosocial behaviours following exercise. The overall mean frequency of prosocial behaviours throughout all exercise sessions...
was 17.6 (range of 7 to 31), an overall mean of 8.11 prosocial behaviours per session higher than in the control condition.

Visual analysis of data trends in Figure 3 suggests that exercise had a modest effect on student prosocial behaviours. Data in baseline and control sessions were characterized by a high degree of variability at generally low frequencies. Although data for exercise sessions were variable, they were generally at higher levels relative to baseline and control sessions. These data suggest that following exercise, all 4 participants demonstrated some improvement in prosocial behaviours.

In addition to visual analysis, Mann-Whitney U tests were conducted to compare exercise and control conditions. This analysis demonstrated a statistically significant increase in prosocial responding for all four participants following exercise sessions compared to control sessions.

Figure 4 presents the averaged group data for prosocial behaviours for all baselines, exercise, and control sessions.
Figure 3: Frequency of prosocial behaviours for all baseline, control, and exercise sessions.
3.5.3 Compliance to Teacher Requests

Baseline. The percentage of compliance to teacher requests in baseline and following control and exercise conditions is presented in Figure 5. As can be seen in this figure, baseline levels of compliance for all 4 students were generally low. The overall mean percentage of compliance was 52.55% (range of 39% to 74%).

Control Condition. Participants demonstrated low levels of compliance (comparable to baseline) following control sessions. The overall mean percentage of compliance across all 4 participants in this condition was 50.60% (range of 27% to 72%).

Exercise condition. Exercise was associated with heightened levels of compliance compared to the control condition. The overall mean percentage of compliance for all participants was 68.71% (range of 48% to 86%). Compliance levels following exercise was 17.86% higher than compliance levels following the control condition.
Visual analysis of data trends in Figure 5 suggests that exercise had a moderate effect on student compliance. Although there is some overlap between compliance data following exercise and control sessions, data for the exercise condition is characterized by slightly less variability at generally higher levels than baseline and control conditions.

With the Mann-Whitney U Tests, significant differences in compliance to teacher requests were found between exercise and control sessions for all 4 participants.

Figure 6 presents the averaged group data for compliance to teacher requests across all baseline, exercise, and control sessions.
Figure 5. Percent compliance to teacher requests across all baseline, control, and exercise sessions.
3.6 Effects of Antecedent Exercise (Temporal Effects)

To determine potential temporal effects of antecedent exercise, we measured behavioural functioning in baseline and following exercise and control conditions across 4 durations: 0 to 30 minutes (T1), 30 to 60 minutes (T2), 60 to 90 minutes (T3), and 90 to 120 minutes (T4).

3.6.1 Disruptive Behaviours

Baseline. The overall frequency of disruptive behaviours for all 4 participants for baseline and following exercise and control conditions across all 4 durations is presented in Figure 7.

The mean frequency of disruptive behaviours for all participants during baseline was 11.60 (range of 6.4 to 15.6), 10.53 (range of 5.4 to 15.2), 11.90 (range of 3.6 to 16.4) and 11.60
(range of 4.6 to 14) for T1, T2, T3, and T4 respectively. As is evident in Figure 7, the frequency of student disruptive behaviors remained relatively constant over the 2 hour observational period.

**Control.** The mean frequency of disruptive behaviors following control sessions was 11.07 (range 8.78 to 14.1), 12.77 (range 7.89 to 15.56), 12.57 (range of 7.33 to 15.38), and 11.23 (range 5.67 to 17.38) for T1, T2, T3, and T4 respectively. Consistent with baseline data, the average frequency of disruptive behaviors was relatively constant throughout the 4 time periods following control sessions.

**Exercise.** The mean frequency of disruptive behaviors following exercise sessions was 4.02 (range 2 to 6), 4.81 (range 2.2 to 6.89), 5.99 (range 3.7 to 8) and 11.92 (range 6.5 to 14.3) for T1, T2, T3, and T4 respectively. In comparison to the control condition, exercise was associated with 7.05 fewer disruptive behaviors for T1, 7.96 fewer behaviors for T2, and 6.58 fewer behaviors for T3. The frequency of disruptive behaviors was slightly higher (i.e., 0.69) in the exercise condition compared to the control condition for T4.

As is evident in Figure 7, the frequency of disruptive behaviors is relatively high and stable for all participants during baseline and control sessions across the 4 time periods. A comparison of data points in the exercise and control conditions for T1, T2, and T3 however, reveals few overlapping data points for all 4 participants (especially for T1, the duration that immediately followed the exercise condition). A slight degree of caution is warranted when interpreting the T3 data trends for participant 4. Although the effects of exercise are slightly harder to discern for this participant, it appears that on average, participant 4 displayed fewer problems behaviors following exercise compared to control sessions. By examining T3 for participant 4, it appears that the sessions with the lowest frequency of disruptive behaviors (i.e.,
sessions 6, 8, 12, 13, 22, and 23) occurred following exercise. On the contrary, the highest frequencies of disruptive behaviours for participant 4 occurred following control sessions (i.e., sessions 7 and 24). Moreover, the mean frequency of disruptive behaviours following exercise (i.e., 3.7) was substantially lower than the mean frequency of disruptive behaviours following control sessions (i.e., 7.3). Taken together, these trends suggest that participant 4 displayed less disruptive behaviour for T3 following exercise compared to control. For T4, all 4 participants demonstrated a high degree of overlapping data points between the exercise and control sessions.

Mann-Whitney U tests were conducted for each participant for all 4 time periods. The frequency of disruptive behaviours was significantly lower following exercise sessions compared to control sessions for all participants across T1 and T2. With the exception of participant 4, exercise continued to result in a significant reduction in disruptive behaviour compared to the control session for T3. It should be emphasized, however, that for T3, participant 4 was just shy of achieving statistical significance (thus suggesting a trend that exercise sessions were associated with a reduction in disruptive behaviours compared to control sessions). No significant differences were found for T4.

In summary, results from the visual analysis suggest that when compared to the control condition, exercise resulted in reductions in the frequency of disruptive behaviours for approximately 90 minutes. However, between 90 and 120 minutes post-exercise, the beneficial effects of exercise appear to subside with little difference between the exercise and control sessions. With the exception of one finding (T3 for participant 4) results from the Mann-Whitney U test are highly consistent with the visual analysis.
Figure 7: Frequency of disruptive behaviours across all baseline, control, and exercise sessions. X axis represents session number and Y axis represents the frequency of disruptive behaviours.
3.6.2 Prosocial Behaviours

*Baseline.* The overall frequency of prosocial behaviours for all 4 participants is presented in Figure 9. Data are presented for baseline and following control and exercise sessions for T1, T2, T3, and T4. The mean frequency of prosocial behaviours during baseline was 3.15 (range of 2.4 to 3.6), 3.2 (range of 2.4 to 4.2), 2.95 (range of 1.6 to 3.6) and 3.05 (range of 1.8 to 4.0) for T1, T2, T3, and T4 respectively. During baseline, the frequency of prosocial responding was relatively low for all participants across all 4 time intervals.

*Control.* The mean frequencies of prosocial behaviours following control sessions were 2.42 (range 1.88 to 3.11), 2.52 (range 1.25 to 3.44), 1.83 (range of 1.13 to 2.78), and 2.51 (range 2.13 to 3.11) for T1, T2, T3, and T4 respectively.

*Exercise.* The mean frequencies of prosocial behaviours following exercise sessions were 6.82 (range 4.44 to 8.50), 5.38 (range 3.89 to 6.80), 3.77 (range 2.22 to 4.90) and 1.93 (range 1.22 to 2.60) for T1, T2, T3, and T4 respectively. When compared to control sessions, exercise was associated with a greater frequency of prosocial responding for T1 (increase of 4.4 prosocial
behaviours), T2 (increase of 2.86 prosocial behaviours), and T3 (increase of 1.94 prosocial behaviours) but not T4 (decrease of 0.58 prosocial behaviours).

Visual analysis of data trends in figure 9 reveals that exercise had a positive impact on prosocial behaviours for all participants for T1, T2, and T3 as evidenced by a small number of overlapping data points between exercise and control sessions. The positive effects of exercise on prosocial behaviours were substantially reduced by T4 for all participants, as evidenced by the large number of overlapping data points between exercise and control sessions.

Results of Mann-Whitney U tests were consistent with visual analysis. When compared to the control condition, all participants demonstrated statistically significant increases in the frequency of their prosocial responding following exercise for T1, T2, and T3. No significant differences were found between exercise and control conditions for T4 for any of the participants.
Figure 9. Frequency of prosocial behaviours across all baseline, control, and exercise sessions. X axis represents session number and Y axis represents the frequency of prosocial behaviours.
3.6.3 Compliance to Teacher Requests

**Baseline.** The percentage of compliance to teacher requests for baseline and following exercise and control sessions are presented for T1, T2, T3, and T4 in Figure 11. The mean percentage of compliance during baseline was 53.25% (range of 49.4% to 58.4%), 51.55% (range of 46.6% to 5.6%), 49.75% (range of 43.6% to 58.6%) and 57.05% (range of 48% to 65.4%) for T1, T2, T3, and T4 respectively.

**Control.** Similar to baseline levels, the percentage of compliance to teacher requests during control sessions was 50.31% (range 45.5% to 56%), 49.75% (range 43.88% to 53.44%), 50.94% (range of 41% to 63.44%), 51.74% (range 48.5% to 60.67%) for T1, T2, T3, and T4 respectively.

**Exercise.** The mean frequencies of compliance to teacher requests following exercise sessions were 82.68% (range 80.7% to 85.67%), 73.05% (range 64.9% to 81.44%), 67.45% (range 52.1% to 76.9%) and 53.11% (range 45% to 64.56%) for T1, T2, T3, and T4 respectively. In comparison to the control condition, compliance was higher following exercise for T1 (difference of 32.37%), T2 (difference of 23.33%), T3 (difference of 16.57%) and T4 (slight difference of 1.37%).
Visual analysis of data for exercise and control conditions at T1 and T2 reveals few overlapping data points for all 4 participants. Participants 1, 2 and 4 continued to show few overlapping data points between exercise and control sessions for T3. This trend is not as apparent for participant 3. By T4 there was a greater amount of overlapping data points between exercise and control sessions for all participants with the exception of participant 4, who continued to experience slight improvements in compliance.

Results from the Mann-Whitney U test differed slightly compared to the visual analysis. According to the Mann-Whitney U test, all 4 participants were significantly more compliant to teacher requests following the exercise condition compared to the control condition for the time periods of T1 and T2. However, only participants 2 and 4 continued to demonstrate significantly higher levels of compliance following exercise for T3. None of the participants demonstrated significant differences in compliance levels between exercise and control sessions for T4.
Figure 11: Percentage of compliance to teacher requests across all baseline, control, and exercise sessions. X axis represents session number and Y axis represents the percent compliance to teacher requests.
Figure 12. Average compliance to teacher requests for all baseline, control, and exercise conditions for T1, T2, T3, and T4.

3.7 Heart Rate Levels during Exercise and Control conditions

Participants’ average heart rate levels while engaged in the 30 minute experimental conditions are presented in Figure 13. Results suggest that participants experienced elevated heart rate levels during exercise sessions compared to control sessions.

Figure 13. Average heart rate levels while engaged in experimental conditions.
3.8 Heart Rate Levels during Observational sessions

Figure 14 provides participants average heart rate levels following baseline, control, and experimental conditions for the time intervals of T1-T4. A summary of results for each participant are described below.

3.8.1 Participant 1 (Bobby)

Bobby’s heart rate following exercise was consistently higher than his heart rate during baseline and following the control condition across all 4 time intervals. While Bobby’s heart rate during baseline and following the control condition was characterized by some degree of variability with no clear trends across the 4 time intervals, his heart rate following exercise consistently decreased from T1 to T4 (total decrease of 8.1 BPM). The largest reduction in heart rate following exercise occurred between T1 and T2 (representing a decrease of 7.1 BPM).

3.8.2 Participant 2 (Kyle)

When compared to both baseline and control conditions, Kyle’s heart rate was consistently higher following exercise across all 4 time intervals. While Kyle’s heart rate remained relatively stable across the 4 time intervals during baseline and following the control condition, he experienced a steady reduction in heart rate from T1 to T4 following exercise (total decrease of 6.9 BPM). The largest reduction in heart rate following exercise occurred between T1 and T2 (representing a decrease of 3.2 BPM).

3.8.3 Participant 3 (Dan)

Dan’s heart rate following exercise was consistently higher than his heart rate during baseline and following the control condition across the 4 time intervals. Throughout baseline,
there appears to be a steady, albeit, slight increase in heart rate across the 4 time intervals. Following exercise, his heart rate demonstrated a constant reduction from T1 to T4 (total decrease of 9.5 BPM). Following exercise, Dan’s heart rate dropped a total of 4.6 BPM between T1 and T2, representing his largest post-exercise heart rate reduction across the 4 intervals.

3.8.4 Participant 4 (Tom)

Tom’s heart rate following exercise was consistently higher than his heart rate during baseline and following the control condition across all 4 time intervals. Tom’s heart rate was variable with no consistent trends across the 4 time intervals throughout baseline and following the control condition. Following the exercise condition, Tom experienced a constant reduction in heart rate from T1 to T4 (total decrease of 4.8 BPM). The largest reduction in Tom’s heart rate following exercise occurred between T1 and T2 (representing a decrease of 2.1 BPM).
Figure 14. Heart rate during baseline and following experimental conditions across T1, T2, T3, and T4.
3.9 Correlational Analysis

To determine the extent to which physiological measures (average heart rate during the 2 hour observational period and average heart rate during the experimental condition) were associated with behavioural measures (i.e., frequency of disruptive behaviours, frequency of prosocial behaviours, and percent compliance to teacher requests) a series of correlation coefficients were computed. Correlational analyses were conducted separately for each participant. The results of the correlational analysis for participants 1, 2, 3, and 4 are presented in Tables 2, 3, 4, and 5 respectively.

3.9.1 Participant 1 (Bobby)

The results of the correlational analysis presented in Table 2 indicate that Bobby’s average heart rate during the observational period was negatively correlated with the frequency of his disruptive behaviours ($r = -.60, p = .01$). Bobby’s average heart rate during the observational period was not significantly correlated with the frequency of his prosocial behaviours or his compliance to teacher requests. His average heart rate during the experimental condition was negatively correlated with the frequency of his disruptive behaviours ($r = -.80, p = .000$) and positively correlated with the frequency of his prosocial behaviours ($r = .52, p = .03$) and compliance to teacher requests ($r = .67, p = .003$).
Table 2

Correlations among Behavioural and Physiological Measures for Participant 1 (N = 17)

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* Correlation is significant at the .05 level  
** Correlation is significant at the .01 level

Note:  
DB = Frequency of Disruptive Behaviours  
PB = Frequency of Prosocial Behaviours  
% CTR = Percent Compliance to Teacher Requests  
HRObs = Average Heart Rate During Observational Session  
HRExCond = Average Heart Rate During Experimental Condition

3.9.2 Participant 2 (Kyle)

As can be seen in Table 3, Kyle’s average heart rate during the observational period was negatively correlated with the frequency of his disruptive behaviours ($r = -.78$, $p = .000$) and positively correlated with both the frequency of his prosocial responding ($r = .63$, $p = .007$) and compliance to teacher requests ($r = .64$, $p = .005$). A similar pattern of correlations was found between Kyle’s average heart rate during the experimental condition and his behavioural functioning. That is, his average heart rate during the experimental condition was negatively correlated with the frequency of his disruptive behaviours ($r = -.80$, $p = .000$) and positively
correlated with the frequency of his prosocial responding \( (r = .76, p = .000) \) and compliance to
teacher requests \( (r = .73, p = .001) \).

Table 3

*Correlations among Behavioural and Physiological Measures for Participant 2 (N = 17)*

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* Correlation is significant at the .05 level
** Correlation is significant at the .01 level

Note:

DB = Frequency of Disruptive Behaviours
PB = Frequency of Prosocial Behaviours
% CTR = Percent Compliance to Teacher Requests
HRObs = Average Heart Rate During Observational Session
HRExCond = Average Heart Rate During Experimental Condition

3.9.3 Participant 3 (Dan)

The results of the correlational analysis presented in Table 4 indicate that Dan’s average heart rate during the observational period was negatively correlated to the frequency of his disruptive behaviours \( (r = -.68, p = .001) \). His heart rate during the observational phase was not significantly correlated with measures of prosocial responding or compliance. Dan’s average heart rate during the experimental condition was negatively correlated with the frequency of his
disruptive behaviours ($r = -0.82, p = 0.000$) and positively correlated with the frequency of his prosocial behaviours ($r = 0.75, p = 0.000$) and compliance to teacher requests ($r = 0.64, p = 0.003$)

Table 4

*Correlations among Behavioural and Physiological Measures for Participant 3 (N = 19)*

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* Correlation is significant at the .05 level
** Correlation is significant at the .01 level

Note:
DB = Frequency of Disruptive Behaviours
PB = Frequency of Prosocial Behaviours
%CTR = Percent Compliance to Teacher Requests
HRObs = Average Heart Rate During Observational Session
HRExCond = Average Heart Rate During Experimental Condition

3.9.4 Participant 4 (Tom)

Results of the correlational analysis presented in Table 5 indicate a number of significant correlations between Tom’s average heart rate and his behavioural functioning. Tom’s heart rate during the observational period was negatively correlated with the frequency of his disruptive behaviours ($r = -0.71, p = 0.001$) and positively correlated with measures of his prosocial ($r = 0.55, p = 0.01$) and compliant responding ($r = 0.63, p = 0.004$). Similarly, Tom’s average heart rate during the experimental condition was negatively correlated with the frequency of his disruptive
behaviours ($r = -.73, p = .000$) and positively correlated with measures of his prosocial ($r = .76, p = .000$) and compliant behaviours ($r = .64, p = .003$).

Table 5

*Correlations among Behavioural and Physiological Measures for Participant 4 (N = 19)*

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</table>

* Correlation is significant at the .05 level
** Correlation is significant at the .01 level

Note:

*DB = Frequency of Disruptive Behaviours*
*PB = Frequency of Prosocial Behaviours*
*% CTR = Percent Compliance to Teacher Requests*
*HRObs = Average Heart Rate During Observational Session*
*HRExCond = Average Heart Rate During Experimental Condition*

In summary, results of the correlational analysis revealed a number of significant correlations between participants’ averaged heart rate (both during the observational period and experimental condition) and their behavioural functioning. With regards to averaged heart rate during the observational period, all participants showed a significant and negative correlation between their heart rate and the frequency of disruptive behaviours. These results suggest that higher heart rate during the observational period was associated with a reduced frequency of disruptive behaviours. Two participants (participants 2 and 4) showed significant and positive
correlations between their averaged heart rate during the observational period and the frequency of prosocial responding and compliance to teacher requests. For these participants, higher heart rates during the observational period were associated with an increase in prosocial responding and compliance. All participants demonstrated the same pattern of significant correlations between heart rate during the experimental condition and behavioural functioning. More specifically, results indicated that elevated heart rates during the experimental condition was associated with reduced levels of disruptive behaviours and elevated levels of both prosocial responding and compliance to teacher requests.

3.10 Self-report Measures

3.10.1 Bored/Excited Scale

Overall mean scores for the bored/excited visual analog scale are presented in Figure 15. This score reflects how bored or excited participants perceived themselves to be during all observational sessions in baseline, control, and exercise conditions (higher scores reflect greater levels of perceived excitement). Results suggest that participants experienced heightened levels of excitement following exercise sessions compared to control sessions.
Figure 15: Overall mean self-report scores for bored/excited visual analog scale.

3.10.2 Tired/full of Energy Scale

Overall means scores for the tired/full of energy visual analog scale are presented in Figure 16. These scores reflect how tired or full of energy participants perceived themselves to be during all observational sessions (higher scores reflect elevated levels of perceived energy). Results suggest that following exercise, participants reported higher levels of energy compared to the control and baseline condition.
Figure 16: Overall mean self-report scores for tired/full of energy visual analog scale.

3.10.3 Tense/Relaxed Scale

Overall mean scores for the tense/relaxed visual analog scale are presented in Figure 17. These scores reflect how tense or relaxed participants perceived themselves to be during all observational sessions (higher scores reflect elevated levels of perceived relaxation). Results suggest that following exercise, participants reported feeling greater levels of relaxation compared to both baseline and control.
Figure 17. Overall mean self-report scores for tense/relaxed visual analog scale.
Chapter 4: Discussion

In the present study, we investigated three aspects of antecedent exercise. First, we replicated the beneficial behavioural effects of antecedent exercise in a group of school-aged children demonstrating severe antisocial, disruptive, and aggressive behaviours. Second, we evaluated the temporal effects of exercise and found that behavioural improvements continued for approximately 90 minutes. Finally, we assessed a potential mechanism that may help explain the behavior change following exercise. Findings suggested that increased arousal may play a role in accounting for these improvements.

4.1 Replication of Previous Findings

In a meta-analysis conducted by Allison, Faith, and Franklin (1995), results indicated that exercise was effective at reducing aberrant behaviour in both children and adults with a variety of social, emotional, behavioural and medical disorders. Findings from the present investigation provide additional evidence supporting this effect with 4 students in a behavioural classroom. During baseline sessions, all 4 students evinced high levels of disruptive behaviours and low levels of both prosocial responding and compliance to teacher requests. Following 30 minutes of aerobic exercise, all four participants demonstrated a substantial reduction in the frequency of their disruptive behaviours and sizeable improvements in both prosocial responding and compliance to teacher requests. None of the participants demonstrated improved behaviour following the control condition.

4.2 Temporal Effects

To evaluate the temporal effects of antecedent exercise, behavioural functioning was systematically evaluated across four 30 minute time-intervals following exercise: 0-30 minutes
(T1), 30-60 minutes (T2), 60-90 minutes (T3), and 90-120 minutes (T4). Compared to the control condition, all four participants experienced a reduction in the frequency of their disruptive behaviours for T1, T2, and T3. However, for T4, this effect dissipated and the frequency of disruptive behaviours increased to a level comparable to both baseline and control conditions. A similar temporal trend was observed for prosocial responding. All four participants demonstrated an increase in the frequency of their prosocial behaviours following exercise for T1, T2, and T3 compared to the control condition. However, the observed improvement in prosocial behaviour was no longer present for any of the four participants for T4.

The temporal effects of antecedent exercise on compliance differed slightly from those found for disruptive and prosocial behaviours. For T1 and T2, all four participants evinced improved compliance. Although participants 1, 2, and 4 continued to show improved compliance for T3, the beneficial effects for participant 3 were not as apparent. By T4, compliance gains had dissipated for all participants except participant 4, who continued to experience slight improvements in compliance.

In summary, 30 minutes of moderate to intense aerobic exercise resulted in approximately 90 minutes of behavioural improvement. For some participant behaviours the effects were slightly shorter lasting (i.e., compliance improved for approximately 60 minute for Dan) and in others slightly longer (i.e., compliance improved for the entire 2 hour duration for Kyle).

To date, only one other study has investigated the temporal effects of antecedent exercise (e.g., Celiberti, Bobbo, Kelly, Harris, & Handleman, 1997). In this study, post-exercise behaviours were observed in a 5- year-old boy with autism for a period of 40 minutes. Results
indicated that aberrant behaviours (i.e., physical self-stimulatory and out of seat behaviour) decreased following exercise and remained below baseline levels at the conclusion of the observational period. This finding suggests that the participant was still experiencing beneficial effects of exercise beyond the final behavioural observation. Thus, the precise duration of positive effects was not established. To our knowledge, the present study is the first to systematically assess the temporal effects of antecedent exercise through observations of behaviours until the post-exercise effects have dissipated, providing an estimation of the extent of post-exercise behavioural improvements.

4.3 Mechanism of Action

4.3.1 Evidence from Physiological Data

Physiological measures of arousal (i.e., heart rate) were obtained to better understand potential mechanisms accounting for improved behaviours following exercise. Results from the correlational analyses indicate that elevated arousal levels are associated with reductions in disruptive conduct and increases in prosocial behaviours.

As expected, exercise resulted in elevated heart rate for all participants that gradually decreased over time, suggesting a steady reduction in arousal levels. These findings correspond to those of a study by Forjaz, Matsudaira, Rodrigues, Nunes, & Negrao (1998) in which 12 healthy adults took part in 45 minutes of moderate to intense exercise. Following exercise, participants’ heart rates were assessed for a period of 90 minutes. Results indicated that for 60 minutes after exercise, heart rates remained significantly higher than baseline levels. However, between 60 and 90 minutes post-exercise, heart rates returned to baseline levels. These findings,
along with the present results, suggest that the effects of exercise on physiological arousal diminish between 60 and 90 minutes post-exercise.

To provide evidence supporting the notion that physiological arousal is a potential mechanism accounting for behavioural change, it is necessary to demonstrate that post-exercise behavioural improvements diminish as post-exercise arousal decreases. Our findings indicated that the behavioural benefits of exercise lasted for approximately 90 minutes, appearing to co-vary with gradually decreasing heart rates. This association between heart rate and post-exercise behaviour change suggests that arousal is likely a key variable in explaining the benefits achieved.

4.3.2 Evidence from Self-report Data

To gain further insight related to mechanism of action, a number of self-report measures were completed by participants. When compared to the control condition, exercise was associated with self-reported elevated levels of excitement, greater levels of energy, and heightened relaxation. Our findings suggesting that exercise is associated with positive affect is consistent with previous research (e.g., see Berger & Molt, 2000 and Yeung, 1996 for reviews). For example, in a study conducted by Rendi, Szabo, Szabo, Velenczei, and Kovacs (2008), participants reported an immediate after-exercise “high” following 20 minutes of exercise. Taken together, results from our study and previous research suggest that following exercise, individuals experience a heightened sense of arousal (i.e., greater excitement and energy).

As previously discussed, the stimulation seeking theory (Eysenck, 1997; Raine et al., 1990) suggests that some children engage in antisocial behaviour because they are underaroused. Based on this theory, one would predict that when children are bored and underaroused, they
would engage in more disruptive behaviour than when they are excited (i.e., feeling aroused). Both the physiological and self-report data in the present research are consistent with this prediction. The results of the present study show an inverse relationship between arousal levels and problem behaviour. Thus, it appears that elevated arousal plays a significant role in accounting for behavioural improvements following exercise.

4.4 Implications

4.4.1 Ruling out Competing Mechanism

As previously discussed, the fatigue hypothesis posits that behaviour problems decrease following exercise because individuals become tired (Allison, Faith, & Franklin, 1995). According to this hypothesis, one would predict that participants would report elevated levels of fatigue following exercise along with the concomitant reduction in problem behaviour. To test this hypothesis, participants in the present study were asked to provide self-reports of how “tired” or “full of energy” they felt following experimental sessions. Results indicate that self-reported fatigue levels were highest following control sessions and lowest following the exercise condition, in which participants unanimously reported elevated levels of energy. Thus, our results provide no support for the fatigue hypothesis. In fact, participants in the present study displayed higher levels of problem behaviour when they reported elevated levels of fatigue following the control condition. These findings are consistent with previous research showing an association between fatigue and externalizing conduct (e.g., Haller & Kruk, 2006; Haack & Mullington, 2005; Kuo & Sullivan, 2001; Whalen, Jamner, Henker, & Delfino, 2001).
4.4.2 Potential Generalizability of Antecedent Exercise

The average resting heart rate for children 11 to 17 years of age is between 60 to 100 BPM (Johnson & Moller, 2001). Although the 4 participants in the present investigation had resting heart rate levels within the normative range, a high degree of variability was noted. More specifically, the average resting heart rate for Bobby (77 BPM) and Kyle (72 BPM) was closer to the lower end of the normative range whereas the heart rate for Dan (82 BPM) and Tom (92 BPM) fell towards the middle and upper end of the normative range, respectively.

Three previous studies have measured resting heart rate levels among behaviourally disordered youth in the age range of those in the present study. First, Rogeness et al. (1990) examined resting heart rate and blood pressure in children and adolescents admitted to a psychiatric hospital. Of the total admitted, 173 were males diagnosed with conduct disorder (mean age of 11.6, SD = 3.3); their average resting heart rate was 79 BPM. In a separate study, Davies and Maliphant (1971) found the average resting heart rate of 30 conduct disordered English boarding-school pupils (mean age of 13.6 years) to be 77 BPM. Finally, in Zahn and Kruesi (1993) the average resting heart rate in 34 boys with a diagnosis of conduct disorder (mean age of 11.1, SD = 3.3) was 80 BPM. Thus, the average resting heart rate in these studies ranged from 77 to 80 BPM. In the present investigation, only Tom had a resting heart rate (i.e., 92 BPM) that substantially exceeded this range.

As noted by Ortiz and Raine (2004), only individuals with antisocial, disruptive, and aggressive behaviours are characterized by low resting heart rate. For instance, in the Rogeness et al. (1990) study, male participants (mean age 11, SD = 2.2) diagnosed with separation anxiety had an average resting heart rate of 92 BPM, considerably higher than those with conduct
difficulties. Similarly, participants with lower resting heart rates in the present investigation (i.e., Bobby, Kyle, and Dan) displayed more frequent and severe externalizing difficulties compared to the participant with a higher resting heart rate (Tom). Tom displayed an average of 20 disruptive behaviours per baseline session while Bobby, Kyle, and Dan demonstrated an average of 62, 52, and 48 disruptive behaviours respectively. Moreover, the average compliance to teacher request across all baseline sessions for Bobby (50%), Kyle (53%), and Dan (48%) was lower than that of Tom (59%). Results from the Teacher Report Form are also indicative of more severe problem behaviours among the participants with lower resting heart rate levels. On this measure, all participants were in the clinical range for externalizing difficulties with the exception of Tom, who fell in the borderline clinical range.

In addition to providing further evidence that low resting heart rate is associated with antisocial, disruptive, and aggressive behaviour, the present results suggest the potential usefulness of antecedent exercise for children experiencing a broader range of emotional and behavioural disorders. Tom’s average resting heart rate exceeds what is typically observed in conduct disordered youth his age and is more reflective of anxious individuals (Rogeness et al., 1990). Reports from the Teacher Report Form indicated that Tom was in fact within the borderline-clinical range for anxiety problems (T Score = 65). Notwithstanding this diagnostic disparity with the other participants, antecedent exercise resulted in substantial reductions in Tom’s behavioural difficulties. Although one cannot draw firm conclusions from such a small sample, these findings suggest the possibility that the potential effectiveness of antecedent exercise may extend beyond individuals whose behavioural difficulties are due solely to underarousal.
4.4.3 Clinical Implications: Antecedent Exercise as a Moderating Approach

In the present study, antecedent exercise resulted in immediate reductions in aberrant behaviours and noticeable improvements in prosocial responding and compliance. Notwithstanding these behavioural gains, the beneficial effects of exercise were relatively short lasting (i.e., approximately 90 minutes). Thus, from a treatment perspective, exercise used in isolation does not appear to result in long-term benefits. Unlike many effective treatment approaches for antisocial behaviour (e.g., social skills training, anger management training, problem solving training), our exercise condition did not include any strategies for assisting the students in interacting effectively with the challenges presented by their environment (i.e., skill building components). Under such circumstances, it is not surprising that the students failed to demonstrate longer lasting behavioural improvements.

To better appreciate the potential clinical utility of antecedent exercise, it may be useful to make the distinction between remedial and moderating approaches. According to Ducharme (1999), remedial approaches involve teaching individuals various strategies and skills to replace aberrant behaviours. Once learned, these adaptive skills can be used by the individual to more effectively manage and/or tolerate conditions that formerly contributed to their aberrant behaviours. A fundamental aspect of remedial approaches is the long-term clinical benefit they produce for the individual. On the other hand, moderating approaches lead to immediate alleviation of problem behaviour, but typically do not provide long-term benefits (Ducharme, 1999). Within a clinical context, moderating approaches serve an important purpose as they can be used to increase prosocial responding and reduce problem behaviours enough in the short-term that the individual is more amenable to skill-building approaches. In this regard, Ducharme
(1999) posits that moderating approaches can potentially open up “windows of opportunity” for the use of remedial approaches.

A number of remedial or skill building interventions exist for treatment of antisocial behaviour (e.g., Ducharme, Folino, & DeRosie, 2008; Folino, Ducharme, & Conn, 2008; Sim, Whiteside, Dittner, & Mellon, 2006; Fraser et al., 2005; Ooi & Ang, 2004; Lane, Webby, Menzies, Doukas, Munton, & Gregs, 2003). The underlying goals of these interventions are to replace problem behaviours with more adaptive skills and strategies. Given that individuals diagnosed with antisocial disorders typically present with heightened levels of aggression, non-compliance, disruptiveness, and rule-breaking behaviour (Ladd, Herald, & Kochel, 2006), intervention agents may have difficulty implementing treatment procedures, such as skill-building programs, for these individuals, especially in educational settings. Under such circumstances, exercise may be a useful prelude to remedial approaches. Our findings indicated that a brief bout of exercise resulted in approximately 90 minutes of behavioural improvement and cooperation, potentially an ideal “window of opportunity” for use of skill-building approaches that can greatly increase the likelihood of long-term gains.

In addition to skill building approaches, psychopharmacological interventions are commonly used to treat antisociality among youth (e.g., Pandina, Aman, & Findling, 2006; Rifkin et al., 1997). Despite being somewhat effective in the treatment of antisocial conduct (e.g., see Ipser & Stein, 2007; Bassarath, 2003 for reviews), there is a paucity of controlled studies assessing the safety and efficacy of drugs (Lazaratou, Anagnostopoulos, Alevizos, Haviara, & Ploupidis, 2007). Although psychoactive agents may result in short-term behavioural improvements, implementation of medication alone does not typically teach individuals the
requisite skills to manage difficult circumstances in their environment. As a result, behavioural pharmacology may be best conceptualized as a moderating approach.

Generally speaking, parents often express concern about exposing their children to psychoactive medications (Pescosolido, Perry, Martin, McLeod, & Jensen, 2007) and prefer non-pharmacological treatments for the management of their child’s psychiatric disorders (Lazaratou, Anagnostopoulos, Alevizos, Haviara, & Ploupidis, 2007; Pescosolido, Perry, Martin, McLeod, & Jensen, 2007). Due to the potential risks and side-effects associated with medication (Ipser & Stein, 2007; Wilens, Jefferson, & Biderman, 2006), child advocates argue that pharmacological treatments should be used only after less risky psychosocial interventions have failed (Correll, Kane, & Malhotra, 2010). Given that the potential harm associated with antecedent exercise is minimal (Allison, Faith, & Franklin, 1995), this approach may be a viable treatment option that can be used as an alternative to (or in conjunction with) more intrusive treatment alternatives such as medication. In contrast to pharmacological interventions, the social acceptability of exercise is high for both parents and children, who consistently report positive attitudes towards such activity (Graham, 2008).

4.4.4 Implications for Schools and Educators

The present findings are of particular interest to educators, as teachers commonly seek simple strategies for managing problem behaviours in their classrooms. Moreover, schools have been identified as ideal settings for the promotion of physical activity (Verstraete, Cardon, De Clercq, & De Bourdeaudhuij, 2006). For antecedent exercise to be used most effectively as a means of enhancing prosocial responding in schools, teachers must consider several factors. First, given that the effects of exercise appear to weaken after approximately 90 minutes,
teachers may wish to incorporate brief bouts of aerobic exercise throughout the day for students with severe behavioural difficulties (both gym class and recess provide students with naturally occurring opportunities to engage in vigorous activity). Moreover, teachers may wish to strategically embed exercise activities at times of the day when they would be optimally beneficial to students. For example, our findings suggest that the largest improvements in behaviour occurred immediately following exercise (i.e., 0-30 minutes). Thus, teachers may wish to expose students to vigorous activity just before important lessons, tests, etc. In addition, assuming the student is physically active during recess time, it may be best to plan physical education class approximately 90 minutes after recess so that the students experience optimal durations of behavioural benefit.

Secondly, our findings suggest that students must engage in moderate to intense physical activity to access behavioural gain. As a result, teachers may wish to organize gym and recess activities that incorporate fun aerobic components such as jogging and skipping that are known to increase cardiovascular activity and arousal.

4.5 Limitations and Future Directions

The first limitation of the present investigation involves the sample size of only four students, reducing the potential generalizability of the findings. Although our design allowed for a detailed evaluation of experimental manipulations on individual participants, we were unable to conduct additional statistical analysis (i.e., regressions, etc), to further explore the relationship between resting heart rate, exercise, and behavioural outcomes. It is important to note, however, that although the number of participants in the present study is considered small for traditional research designs, it served as an ideal sample size for intensive time-series examination of the process, temporal outcomes, and physiological effects of the intervention. Given the extensive
time and resources needed to achieve these research goals with four subjects, a larger sample size would have far exceeded reasonable limits for dissertation research.

The second limitation is the absence of female students in the sample. Research suggests that the relationship between resting heart rate and antisocial behaviours is largely the same for males and females (Ortiz & Raine, 2004); however, the present sample precluded an examination of the potential utility of antecedent exercise for school aged females. Although conduct disorders are much more prevalent among males than females (Kindlon, Tremblay, Mezzacappa, Earls, Laurent, & Schaal, 1994), it would be informative in future studies to determine the effectiveness of antecedent exercise with female participants.

The third limitation of the present study is the narrow age range of the participants involved. In our investigation all four participants were either teenagers or pre-teens. Given that behavioural difficulties often begin at much younger ages, it would be useful to include younger participants in a study examining the effects of antecedent exercise.

A fourth limitation involves the manner in which we explored the temporal effects of antecedent exercise. For the temporal analysis, we evaluated student behaviour across four 30 minute time intervals (i.e., 0-30 minutes, 30-60 minutes, 60-90 minutes, and 90-120 minutes) for a total duration of 2 hours. Our decision to segment behavioural observations into 30 minute time intervals was arbitrary. Although this measurement tactic enabled us to determine that the effects of antecedent exercise diminish somewhere between 90 and 120 minutes, shorter time intervals (e.g., every 10 minutes) would have enabled us to make more precise conclusions regarding temporal effects.

Another potential limitation of the present study involved use of a relatively inexpensive heart rate monitor. Given that we needed to record participant heart rates on several occasions
throughout the school day, it was essential to conduct these measurements in an efficient and non-intrusive manner. Although the monitor we used provided such practicality, there are a number of more technically sophisticated devices that can provide greater measurement precision. Note, however, that in their meta-analytic findings on the effects of heart rate on antisocial behaviour, Ortiz and Raine (2004) found that studies involving simple devices (comparable to those used in the present study) produced just as strong an effect size as those using more sophisticated equipment, leading these authors to conclude that more sophisticated technology is not required for these studies.

One final shortcoming of the present investigation relates to the narrow range of circumstances in which observations were conducted. Following all experimental conditions, participants were observed only in their classroom. To determine the persistence of behavioural improvements in a wider range of contexts, it would be informative to conduct observations in alternative settings such as the playground, school assemblies, and hallways where problem behaviours commonly occur.

Another consideration for future research involves the relationship between the intensity of physical activity and the magnitude of the behavioural effects. Although previous research suggests that “vigorous exercise” is most effective at reducing disruptive behaviours (Celiberti et al., 1997; Kern, Koegel, & Dunlap, 1984), there is little research evaluating the minimum duration and intensity of aerobic exercise necessary to produce positive behavioural changes. Although the present study included 30 minute exercise sessions, it is possible that similar behavioural effects could have been achieved with less student effort. Manipulation of duration and intensity in future studies might help to determine the most efficient exercise dosage for optimal behavioural effects.
Future research is also needed to explore the effectiveness of antecedent exercise with other diagnostic groups such as those with anxiety disorder. In our sample, one of the students who scored high on measures of anxiety difficulties demonstrated a reduction in aberrant behaviours following exercise. Although the effectiveness of exercise has been examined most extensively for students with conduct difficulties, additional research is needed to determine if exercise is suitable and effective for individuals from other diagnostic groups.

Finally, although exercise offers a socially acceptable and relatively safe way to increase physiological arousal (Allison, Faith, & Franklin, 1995), physical activity may not be suitable for all students (e.g., those with physical impairments). Future research should investigate the effects on problem behaviour of other forms of arousing stimuli that can be easily incorporated in the classroom. For example, music has been shown to influence cardiovascular activity and heighten physiological arousal (e.g., Oliver, Reinhard, & Eckart, 2009; Lemmer, 2008; Riganello, Quintieri, Candelieri, Conforti, & Dolce, 2008).

In summary, our findings suggest that antecedent exercise is an effective, safe, and socially accepted way to temporarily reduce maladaptive behaviours and increase compliance among school-aged children with severe antisocial behaviours. Given the trend towards inclusive classrooms, teachers require interventions that are not only effective at improving behaviour but also result in the least amount of disruption and ostracization for the student(s) involved. With these goals in mind, exercise based interventions may be a welcomed strategy for teachers developing intervention plans for challenging students.
References


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Appendix A

General Health Screener

Dear Parent/Guardian,

To ensure the safety and well-being of your child, we kindly ask that you inform us of any pre-existing health or medical conditions that your child may experience. Only those children with no pre-existing health difficulties or prohibitive physical conditions will be permitted to participate. Please answer the questions below to the best of your ability.

1) Does your child have any health, medical, or physical concerns that would prevent them from engaging in 20 minutes of physical activity?

[ ] Yes  [ ] No

If yes, please explain:

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

2) Does your child participate in his/her regular physical education class?

[ ] Yes  [ ] No

If No, please explain:

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

3) Is your child currently taking any medication(s) that may increase their risks of injury or health complications if they engage in exercise or physical activities?

[ ] Yes  [ ] No

If yes, please explain:

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________
Appendix B
SPORTLINE Solo 920 Heart Rate Watch ®
Appendix C
Data Recording Sheets for Heart Rate during Experimental Conditions

Date of observation: _____________________

Coders Name: __________________________

ID of student being observed: _________________________

Study Phase: ____________________________

Instructions: Please look down at your watch and write down the number that you see on it.

**Time 1: (10 min)**
Please write down the number that is on your watch: ________________

**Time 2: (15 min)**
Please write down the number that is on your watch: ________________

**Time 3: (20 min)**
Please write down the number that is on your watch: ________________

**Time 4: (30 min)**
Please write down the number that is on your watch: ________________
Appendix D

Data Recording Sheets for Heart Rate during Observational Periods

Date of observation: _____________________

Coders Name: _________________________

ID of student being observed: _________________________

Study Phase: __________________________

Instructions: Please look down at your watch and write down the number that you see on it.

Time 1: (30 min)

Please write down the number that is on your watch: _______________

Time 2: (60 min)

Please write down the number that is on your watch: _______________

Time 3: (90 min)

Please write down the number that is on your watch: _______________

Time 4: (120 min)

Please write down the number that is on your watch: _______________
Appendix E
Visual Analog Scale (Tense - Relaxed Scale)

Instructions: Please place a mark on the line below that best describes how you are feeling right now.

<table>
<thead>
<tr>
<th>Time 1 (30 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tense</td>
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<tr>
<td>Relaxed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time 2 (60 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tense</td>
</tr>
<tr>
<td>Relaxed</td>
</tr>
</tbody>
</table>
Appendix F

Visual Analog Scale (Tired – Full of Energy Scale)

Instructions: Please place a mark on the line below that best describes how you are feeling right now.
Time 3 (90 min)

Tired

Full of Energy

Time 4 (120 min)

Tired

Full of Energy
Appendix G

Visual Analog Scale (Bored – Excited Scale)

Instructions: Please place a mark on the line below that best describes how you are feeling right now.
Time 3 (90 min)

Bored

Excited

Time 4 (120 min)

Bored

Excited
Appendix H

Behavioural Coding Sheets

Coders Name: _________________________

Date of observation: _____________________

ID of student being observed: ________________________

<table>
<thead>
<tr>
<th>Disruptive Behaviours</th>
<th>Prosocial Behaviours</th>
<th>Compliance to teacher requests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
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<td>PV PP</td>
<td>Y N</td>
<td></td>
</tr>
<tr>
<td>V PO POBJ DO OS O</td>
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<td>PV PP</td>
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<tr>
<td>V PO POBJ DO OS O</td>
<td>PV PP</td>
<td>Y N</td>
<td></td>
</tr>
</tbody>
</table>
### Legend

**Disruptive Behaviours**

- **V** = Student demonstrates verbal aggression towards self or others
- **PO** = Student demonstrates physical aggression towards others
- **POBJ** = Student demonstrates physical aggression towards an object
- **DO** = Student is disruptive towards peer or teacher (e.g., speaks to student during lesson, calls out answers without raising hand, etc.)
- **OS** = Student leaves seat without permission
- **O** = Other forms of disruptive behaviours

**Prosocial Behaviours**

- **PV** = Student demonstrates a prosocial verbal behaviour (e.g., complimenting a student)
- **PP** = Student demonstrates a prosocial physical behaviour (e.g., physically helping a student or teacher)

**Compliance to Teacher Requests**

- **Y** = Complied to teacher request
- **N** = Failed to comply to teacher request
## Appendix I

**Mann-Whitney U Test Statistics**

*Mann-Whitney U Test Statistics for the Overall Effects of Antecedent Exercise on Disruptive Behaviours (2 hour duration)*

<table>
<thead>
<tr>
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<th>Critical Value (U)</th>
<th>Sig. (.05)</th>
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</tr>
<tr>
<td>Tom</td>
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<td>10</td>
<td>10</td>
<td>20</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.*
### Mann-Whitney U Test Statistics for the Overall Effects of Antecedent Exercise on Prosocial Behaviours (2 hour duration)

<table>
<thead>
<tr>
<th>Participant</th>
<th>n1</th>
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<th>U</th>
<th>Critical Value</th>
<th>Sig.</th>
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*Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.*
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*Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.*
Mann-Whitney U Test Statistics for the Effects of Antecedent Exercise on Disruptive Behaviours (0-30 min)

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Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.
### Mann-Whitney U Test Statistics for the Effects of Antecedent Exercise on Disruptive Behaviours (30-60 min)

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*Note:* n₁ = Number of data points in the control condition; n₂ = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.
**Mann-Whitney U Test Statistics for the Effects of Antecedent Exercise on Disruptive Behaviours (60-90 min)**

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*Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.*
Mann-Whitney U Test Statistics for the Effects of Antecedent Exercise on Disruptive Behaviours (90-120 min)

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Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.
### Mann-Whitney U Test Statistics for the Effects of Antecedent Exercise on Prosocial Behaviours (0-30 min)

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*Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.*
## Mann-Whitney U Test Statistics for the Effects of Antecedent Exercise on Prosocial Behaviours (30-60 min)

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<tr>
<td>Kyle</td>
<td>8</td>
<td>9</td>
<td>-2.5</td>
<td>15</td>
<td>Yes</td>
</tr>
<tr>
<td>Dan</td>
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<td>2.5</td>
<td>20</td>
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</tr>
<tr>
<td>Tom</td>
<td>9</td>
<td>10</td>
<td>8</td>
<td>20</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.*
### Mann-Whitney U Test Statistics for the Effects of Antecedent Exercise on Disruptive Behaviours (60-90 min)

<table>
<thead>
<tr>
<th>Participant</th>
<th>n1</th>
<th>n2</th>
<th>U</th>
<th>Critical Value (U)</th>
<th>Sig. (.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bobby</td>
<td>8</td>
<td>9</td>
<td>14</td>
<td>15</td>
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</tr>
<tr>
<td>Kyle</td>
<td>8</td>
<td>9</td>
<td>7</td>
<td>15</td>
<td>Yes</td>
</tr>
<tr>
<td>Dan</td>
<td>9</td>
<td>10</td>
<td>13.5</td>
<td>20</td>
<td>Yes</td>
</tr>
<tr>
<td>Tom</td>
<td>9</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.*
### Mann-Whitney U Test Statistics for the Effects of Antecedent Exercise on Prosocial Behaviours (90-120 min)

<table>
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<tr>
<th>Participant</th>
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<th>Critical Value (U)</th>
<th>Sig. (0.05)</th>
</tr>
</thead>
<tbody>
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<td>Bobby</td>
<td>8</td>
<td>9</td>
<td>41.5</td>
<td>15</td>
<td>No</td>
</tr>
<tr>
<td>Kyle</td>
<td>8</td>
<td>9</td>
<td>43.5</td>
<td>15</td>
<td>No</td>
</tr>
<tr>
<td>Dan</td>
<td>9</td>
<td>10</td>
<td>40</td>
<td>20</td>
<td>No</td>
</tr>
<tr>
<td>Tom</td>
<td>9</td>
<td>10</td>
<td>50</td>
<td>20</td>
<td>No</td>
</tr>
</tbody>
</table>

Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.
Mann-Whitney U Test Statistics for the Effects of Antecedent Exercise on Compliance to Teacher Requests (0-30 min)

<table>
<thead>
<tr>
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<th>n1</th>
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<th>U</th>
<th>Critical Value (U)</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Kyle</td>
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<tr>
<td>Dan</td>
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<td>-4.5</td>
<td>20</td>
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<tr>
<td>Tom</td>
<td>9</td>
<td>10</td>
<td>4.5</td>
<td>20</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.
Mann-Whitney U Test Statistics for the Effects of Antecedent Exercise on Compliance to Teacher Requests (30-60 min)

<table>
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<th>n1</th>
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<th>U</th>
<th>Critical Value (U)</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
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<td>Kyle</td>
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<td>Dan</td>
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<td>20</td>
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<td>Tom</td>
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<td>10</td>
<td>10</td>
<td>20</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.
### Mann-Whitney U Test Statistics for the Effects of Antecedent Exercise on Compliance to Teacher Requests (60-90 min)

<table>
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<tr>
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<th>n1</th>
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<th>U</th>
<th>Critical Value (U)</th>
<th>Sig. (.05)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>No</td>
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<td>Kyle</td>
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<td>Dan</td>
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<td>No</td>
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<td>Tom</td>
<td>9</td>
<td>10</td>
<td>7.5</td>
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</tbody>
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*Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.*
Mann-Whitney U Test Statistics for the Effects of Antecedent Exercise on Compliance to Teacher Requests (90-120 min)

<table>
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<th>Sig. (0.05)</th>
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<td>Dan</td>
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<td>39.5</td>
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<td>No</td>
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<tr>
<td>Tom</td>
<td>9</td>
<td>10</td>
<td>54</td>
<td>20</td>
<td>No</td>
</tr>
</tbody>
</table>

Note: n1 = Number of data points in the control condition; n2 = Number of data points in the exercise condition; Sig = significant difference between exercise and control condition.