Exploring the Relationship between Cognitively Demanding Physical Activities, Mood, Attention, and Behaviour among Primary Aged Students.

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Kate Shepherd

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II
ABSTRACT

Objective: Acute bouts of physical activity (PA) have shown positive effects on children's cognitive, behavioural, and socio-emotional development. However, the impact of differing levels of cognitive demand (CD) during physical activity remains unclear. This study aimed to explore how the combined and/or separate effects of physical activity and cognitive demand affect mood, attention, and behaviour of children. *Design:* In a 2x 2 within-subjects experimental design, 24 children experienced four school-based conditions consisting of physical activity interventions which varied in physical exertion (high PA vs. low PA) and cognitive demand (high CD vs. low CD). *Methods:* The variables, mood, attention, and behaviour were measured before and immediately after each of the 25-30 minute interventions. A self-reported measure (AAPE) and classroom observations (DOF) were used to investigate whether change to these variables was due to the main effect of PA or CD or an interaction of both, ANOVAs were conducted for each intervention. *Results:* Compared to baseline data, all four conditions were significant in improving mood, time on task, and reducing negative behaviour. Interaction effects were found for PA and CD in mood, time-on-task, and behaviour. Contrary, to the hypotheses, higher cognitive demand without PA showed the most improvement in mood and behaviour. *Conclusions:* The results indicate that short breaks from learning that include either physical activity, cognitive demand, or a combination of both improve mood, attention and reduce negative behaviours that can affect peers and individuals from learning in the classroom. Future research should continue to expand on these findings by investigating how these variables are affected over the day, completing these conditions over time (e.g. 6 -8 weeks), develop a measure that clearly defines CD, consider age differences, and include measures that assess how academic learning is directly affected. The findings here are promising in that children benefitted from all the interventions after only one session, thereby providing further justification for increasing daily opportunities for physical activities that also consider the level of cognitive demand for children.

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CHAPTER 1

INTRODUCTION

1.1 The Need for Increasing Physical Activity

Recommending physical activity participation is not a new notion as the ancient Greeks were among the first to promote physical activity with Socrates himself stating: "Surely a person of sense would submit to anything, like exercise, so as to obtain a well-functioning mind and a pleasant, happy life" (Kraser, 2017). Present-day research has shown both short and long-term physical, emotional, social, and cognitive benefits from being physically active (Wu et al., 2017). Specifically, in terms of maintaining healthy cardiovascular, musculoskeletal, and weight outcomes, reducing the risk of obesity, cardiometabolic problems (e.g. blood pressure, glucose, insulin resistance), and certain types of cancers (Kristensen et al., 2010; Small et al., 2013; Wu et al., 2017). Physical activity (PA) has also been associated with reducing the risk of depression, and anxiety and improving self-perception, confidence, and social skills (Sharma., 2006; Kunzi, 2015; Kandola et al., 2018; Huang et al., 2020). Furthermore, research has shown evidence for the improvement in symptoms associated with disorders such as Attention Deficit Hyperactive Disorder (ADHD), Fetal Alcohol Spectrum Disorder (FASD), and Autism Spectrum Disorder (ASD), and in reducing risks for drug and alcohol addiction, particularly in adolescents if regular participation in physical activities are maintained (Janssen & Leblanc, 2010; Small et al., 2013; Wu et al., 2017; Bull et al., 2019).

In the last two decades, researchers have started to investigate how physical activity (PA) affects executive functioning in children, with results showing improvement in areas such as self-regulation, attention, working memory (WM), and goal-oriented behaviours. All these functions support social and emotional skills, including academic learning (Best et al., 2010; Tomporowski, Lambourne, & Okumura, 2011; Veraksa et al., 2021). Yet, despite the increasing evidence supporting the benefits of maintaining regular physical activity on physical and mental health, reports are showing particularly in the last 20 years of school-aged children being insufficiently active (World Health Organisation [WHO], 2022). The World Health Organisation (WHO) recommends maintaining good health, children and adolescents should do an hour of moderate-to-vigorous intensity physical activity every day, with activities that strengthen muscles and bones, at least 3 days a week (WHO, 2022).

However, worldwide, an estimated 81% of children and adolescents are not meeting these guidelines (WHO, 2022). In New Zealand, only an estimated 7% of youth achieve these recommendations (Anderson et al., 2017; Mizdrak et al., 2021; WHO, 2022). Instead, chronic diseases and health problems that typically in the past have not emerged before adulthood (e.g. early cardiovascular risk, type 2 diabetes) are now being seen by health professionals (Manu, 2012; Cardelino, 2022). Childhood obesity is also rising with studies over the last 30 years showing a 12% increase in those classified as obese. (Lobstein & Jackson, 2016; Roth & Jain, 2018; WHO, 2022). In New Zealand from 1990 to 2016, reports stated an increase of 45% in obesity (Hawkins, 2021; WHO, 2022). New Zealand has also made the ranking as the second-worst nation for childhood obesity, with reports stating that 39% of Kiwi children are overweight or obese (Anderson et al., 2017; New Zealand Ministry of Health [MOH], 2021; Bendor et al., 2020; Hawkins, 2021).

Globally, the number of children being diagnosed with new cases of type 2 diabetes which is associated with being overweight, has increased over the last ten years (Dayal, 2020; Lawrence, 2021; WHO, 2022). This is particularly concerning as there is a higher risk of early mortality, cardiovascular, and chronic kidney disease than adults who are diagnosed because of the longevity of having the disease (Dayal, 2020; Lawrence, 2021).

Similar trends have also been reported in studies pointing to a decline in children's fundamental motor skills (FMS) which are developed by being active (Adank et al., 2018). Specifically, these motor skills include balance, muscle endurance, coordination, and providing the core strength needed for fine motor skills to develop (Adank, 2018). These skills are needed, not just for those who aspire to compete in sports, but also to support the ability to move well in daily life activities across the lifespan (Tomporowski et al., 2019; Biino et al., 2021).

Overall, this research has highlighted how important it is in developing and implementing effective physical activity interventions to address the increase in sedentary behaviour for young people (Tomporowski et al., 2019; Salway et al., 2019; Dayal, 2020; Lawrence, 2021). Some studies have suggested that the ages of 7-12 should be the focus, due to these ages being considered the 'skill-hungry years', or critical phase for motor skills to develop (Salway et al., 2019; Tomporowski et al., 2019; Lawrence., 2021). Therefore, making it easier to implement physical activity program's and making it more likely that young people will acquire the motor skills to feel confident in engaging in physical activity as they age (Salway et al., 2019).

While no single cause explains why physical activity participation in young people is decreasing, a range of factors have been taken into consideration (Egger et al., 2018; Ding et al., 2022). These include parental safety concerns, restrictions on physical activity opportunities, low socioeconomic status (SES), and the advancement and comforts of technology which encourage sedentary behavior (Egger et al., 2018; Ding et al., 2022). For example, cars, television, and video games (Egger et al., 2018; Ding et al., 2022). In addition, the COVID-19 lockdown restrictions disrupted children and adolescents in attending school and sports activities (Ding et al., 2022). As a result, recent studies are showing that children and adolescents since the restrictions were lifted are now spending even less time being active when compared to children of a similar age before the pandemic (Neville et al., 2022; Planinsec et al., 2022). These studies showed that physical activity was replaced with screen-time, which increased by 20-60% over lockdown (Bates et al., 2020; Ding et al., 2022; Neville et al., 2022). With reports stating that young people on average are spending 8 hours a day engaging in sitting leisure activities such as gaming and social media (Bates et al., 2020; Neville et al., 2022).

Together, these factors have increased sedentary behaviour for children, with researchers now indicating that younger generations for the first time in history might live less healthy lives than their parents (Salway 2019; Bates, 2020; Neville et al., 2022; Bu et al., 2021; Wachira et al., 2021). Therefore, it is important that solutions are found that are shown to be effective in encouraging young people to be more physically active.

1.2 Rational for Current Study

Children can find school to be challenging. For students to learn they need to be capable of following instructions, sitting still and paying attention for long periods (Harlacher et al., 2006). Although schools do attempt to manage students that find these expectations more difficult by providing extra staff support (e.g. teacher aides), this is ultimately dependent on the school's access to funding. If support is not received, the risk of failure academically, suspension/exclusion from school, teacher burnout, and social stigma for the child can increase (O'Regan, 2010; Ford et al., 2018). Reports state that being more active during school hours could be a strategy that not only addresses the increasing sedentary habits of young people (Ford et al., 2018; Taylor et al., 2019). Doing more physical activity could also benefit children's' ability to focus, learn and behave more positively in school (Ng et al., 2017; Ford et al., 2018; Taylor et al., 2019). Therefore, reducing the negative outcomes experienced by those children who struggle at school and for the school staff that manage them (Trudeau and Shepard 2008; Arnold et al., 2013; Ng et al., 2017; Ford et al., 2018; Taylor et al., 2019).

While physical education (PE) still exists in schools as an opportunity for students to engage in structured active time, in New Zealand (NZ), the PE curriculum does not specify a minimum time for PE. Unlike countries such as Australia, whose curriculum states at least two hours of physical education per week is provided (Mizdrak et al. 2021). Therefore, it is possible that physical education lessons in NZ, may not receive priority, particularly if teachers do not value the importance of being active or are under pressure to increase time spent on academic subjects (Taylor et al., 2019). In addition, knowing what physical exercises (PE) should be practiced can be challenging, as physical activity does vary. For example, a run around the field or a team game may be used, amongst an abundance of other options (Taylor et al., 2019).

Playtime/recess is another opportunity for students to be physically active, yet relying on children being physically active during this time cannot be expected. Studies have shown that what children do during playtime varies, while some may spend most of the time being active, others may prefer to sit with a friend (Basset et al., 2013; Frank et al., 2018; Alvarez-Bueno et al., 2017). In a recent literature review examining studies that measured movement during recess using accelerometers. Results showed that children aged < 7 tended to be more physically active than older children. Furthermore, on average boys engaged in higher-intensity activities than girls (Alvarez-Bueno et al., 2017). Additional studies have also shown that playtime/recess does not exert as much energy compared to more structured physical activity breaks (Scruggs, Beveridge, & Watson, 2003; Basset et al., 2013; Frank et al., 2018; Pulido- Sanchez et al., 2021). For example, Bassett et al., (2013) compared the effectiveness of a range of schools that had access to playground equipment during lunchtimes to students' energy expenditure. Results showed that playground equipment even when equipment was increased did not exert as much energy when compared to more structured after-school activity programs, classroom activity breaks, or physical education (PE). Overall, these studies suggest that it should not be assumed that children are meeting the recommended physical activity guidelines during school hours. Therefore, it is important that a focus on structured physical activities is regularly implemented into the school day, particularly if young people are not engaging in activities at home or in the community (Scruggs et al., 2003; Bassett et al., 2013; Frank et al., 2018; Taylor et al., 2019)

In terms of the types of physical activities that are most beneficial for children, preliminary studies have begun to show that physical activity that is higher in cognitive demand (CD) may be more effective than lower cognitively demanding exercises (e.g., running) particularly for attention and memory (Diamond & Ling 2011: 2015; Schmidt et al., 2016; Egger et al., 2019; Biino et al., 2021). Therefore, investigating how higher cognitively demanding physical activity effects children particularly in a school/classroom context should be further examined (Schmidt et al., 2015; Bedard et al., 2021).

If the results are shown to be promising, this could provide schools with the evidence they need to prioritise physical activity. Furthermore, physical activity (PA) may be another option to support children who are struggling at school as PA can be cost-effective, inclusive, and all children can partake, therefore, reducing the stigma often associated with programs that segregate these children from their peers. As Barkley (2004) stated, “Any treatment must be able to be maintained over months and years to be effective in altering outcomes.” Physical activity meets this criterion as there are plenty of physical activities that can be explored to suit the interest and abilities of the individual for sustainability. Lastly, the majority of studies on physical activity have found no negative effects resulting from physical activity as an intervention (Arnold et al., 2013; Ng et al., 2017). Instead, research has shown that physical activity produces more robust and longer-lasting beneficial cognitive and behavioural effects if applied consistently during childhood (Bidzan-Bluma & Lipowska, 2018). Therefore, it is important that this study investigates how cognitive demand and physical activity plays a role in supporting young people’s social, emotional, and behavioural skills.

CHAPTER 2
LITERATURE REVIEW

Existing literature emphasise the potential benefits of physical activity on children’s physical fitness, motor skills, cognition, learning performance, and mental wellbeing (Best et al., 2010; Tomporowski et al., 2011; Veraksa et al., 2021). However, globally young people’s physical activity levels are decreasing and health problems are increasing (Janssen & LeBlac., 2010; Lobstein & Jackson-Leach., 2016; Lawrence, 2021; WHO, 2021). Numerous factors have been linked to this, including the increased use of digital technology (Egger et al., 2018), Covid restrictions (Bates et al., 2020), parental hesitancy, unsafe environments (Christain et al., 2016), low SES (Ke et al., 2022) and pressured academic expectations in schools (Gomwe et al., 2022). Schools have been identified in a range of studies as an important space for promoting physical activity and healthier lifestyles (Tremblay et al., 2016). Research has shown that schools are found to be ideal environments for implementing physical activity interventions due to the ease of the structured school environment, increased time children spend at school, and low to no cost for families (Webster et al., 2015; Hills et al., 2015). Additionally, adding more physical activity to the school curriculum is not detrimental to student academic achievement (Arnold et al., 2013; Ng et al., 2017). Instead research has shown physical activity can be beneficial to students learning and behaviour (Trudeau and Shepard 2008; Arnold et al., 2013; Ng et al., 2017). The present literature overall supports school-based physical activity interventions as an effective strategy for improving health outcomes (Seljebotn et al., 2018) academic achievement (Schmidt et al., 2016), and behaviour (Bacon & Lord, 2021) for children and adolescents. Positive effects have also been found in terms of brain function (Viggiano, 2012) maintaining student attention (Lindsay et al., 2020), and increasing physical activity habits that continue into adulthood (Hillman et al., 2008).

Overall, this review will examine the research that has investigated the relationship between physical activity and cognition. The review will begin with the current understanding of physical activity (PA) and how this impacts the brain, followed by research that has examined the effects of physical activity (PA) on learning, behaviour, and mood. Studies that have specified frequency, duration, intensity, and type of physical activity with school-aged children will be the focus.

2.1. Physical Activity, Cognitive Demand & Motor Skills

Physical activity has been defined as "any bodily movement produced by skeletal muscles which result in energy expenditure above resting to develop or maintain physical fitness and/or health" (Thompson et al., 2003; WHO, 2022). Physical activity can be aerobic, where heart rate and breathing increase for a sustained period. (e.g. swimming laps, running, or cycling). Or it can be anaerobic, which involves quick bursts of energy performed at maximum effort for a short time. (e.g. jumping, sprinting, or heavy weight lifting). Studies have examined a wide range of exercises, each with different outcomes. For example; yoga, running, team sports, and martial arts (Fedewa & Ahn, 2011; Small et al., 2013; Wu et al., 2017; Bull et al., 2019).

It is common for studies to investigate either the immediate effects of a single session of physical activity (acute) or the impact of multiple sessions (chronic) which can be weeks, months, or years (Hillman et al., 2015; Suarez-Maanzano., 2018). For younger children, physical activity usually involves less structured activities. For example they engage in more play-based movements which vary and are in shorter bursts rather than sustained periods of moderate to vigorous physical activity (Borland et al., 2022). As children reach middle childhood (7-12), this type of play reduces, typically their bodies become slimmer, and muscle strength and lung capacity increases (Borland et al., 2022). This makes it more possible to engage in higher-intensity physical activities for longer periods (Borland et al., 2022). Furthermore, during this time physical growth slows down, as a result, gross motor skills typically improve (Alves & Alves, 2019). Children can improve their gross motor skill abilities by engaging in sports that require more complex movement (e.g. basketball, riding a bike) (Hillman et al., 2015; Suarez-Maanzano., 2018; Wu et al., 2017; Bull et al., 2019).

Children's physical activity has been measured in a variety of ways in previous studies. For example, self-reporting, observation, questionnaires, and diaries. Including fitness tests (e.g. beep test) and objective measures such as heart rate, accelerometer, and maximal oxygen consumption (VO2 max) (Hillman et al., 2015; Suarez-Maanzano., 2018; Wu et al., 2017; Bull et al., 2019).

Cognitive Demand

The focus on cognitive demand in physical activity (PA) studies has generally been based on the theory of cognitive stimulation in which higher demanding body movements that include balance, coordination and less repetitive, unpredictable physical activities may be more effective in activating parts of the brain that are used to control higher-order cognitive processes (Best, 2010; Diamond & Lee, 2011). Higher-order cognitive processes can include short-term memory, processing speed, and attention which are needed to be successful in a learning environment (Pontifex et al., 2019). To activate higher-order cognitive processes using physical activity suggestions have been made to apply three principles of mental engagement (1) contextual interference (e.g. random movements or order), (2) mental control (e.g. P.A that cognitively challenges), and (3) discovery (e.g. creative movements) (Diamond & Lee, 2011). Contextual interference involves changing the physical activity practice structure, either by adding different tasks or being unpredictable in terms of sequences or actions that are performed when learning a new skill (Diamond & Lee, 2011; Shaw, 2021). Mental control can be induced when the physical activities utilised can challenge executive functioning domains such as inhibitory control or working memory. Discovery encompasses physical activities that tend to require more problem solving abilities, creativity, and/or include a variety of different movements (e.g. boxing, dancing) (Diamond & Lee, 2011).

To understand the effect of higher cognitively demanding physical activities on outcomes such as cognition and behaviour, it is important to first determine how much cognitive demand is present in the activity (Pontifex et al., 2019). For example, consider how much cognitive demand takes place while participating in a sport like Taekwondo compared to walking on a treadmill. During a Taekwondo tournament, an individual is required to use a combination of complex moves which include different kicking techniques, jumping, spinning, and balance, as well as observing what the other competitor is doing and therefore needing to react quickly (Chu et al., (2019). However, complexity of the physical movements are not the only factor to consider. Factors such as age (e.g. brain development) and familiarity (e.g. practice) with the physical tasks can influence cognitive demand (Diamond & Lee, 2011). New experiences require more cognitive demand, the more familiar one is with the actions or rules of the PA or sport, the less cognitively demanding it is (Diamond & Lee, 2011). However, while these factors should be considered when designing cognitively demanding interventions, a specific tool for measuring cognitive demand difficulty has yet to be developed. At this stage, cognitive demand in PA studies is often measured based on self-report questionnaires or with physiological measures such as fMRI (Schmidt, et al., 2015).

Fundamental motor skills

Research has proposed that physical activity with higher cognitive demand increases physiological arousal, which activates brain areas that are linked to executive function (EF) (Egger et al., 2019; Schmidt et al., 2015). However, it is the type of physical activity (PA) that has been shown to play a role in engaging these higher-order cognitive processes, such as PA that use strategic play, planning, and interactions with other players (Schmidt et al., 2015; Egger et al., 2019). However, to gain these benefits research has stated that motor skills are necessary to engage in these physical activities (Gao et al., 2021). During early childhood, children begin to learn a group of motor skills that are referred to as fundamental motor skills (FMS), these skills form the foundation for the body to move confidently across the lifespan (Bolger et al., 2021; Xia et al., 2022). Fundamental motor skills include both locomotor and object control skills (Bolger et al., 2021). Locomotor skills involve moving the body through different environments and include skills such as skipping, hopping, climbing, and jumping. Object control skills include handling different objects with control, such as catching, kicking, and bouncing a ball (Bolger et al., 2021).

Early to middle childhood is considered the fundamental period for developing and refining these motor skills. Therefore this period should be focused on practicing a range of movements, as this will make it easier for their bodies to adapt to different contexts (Bolger et al., 2021). If children are not able to proficiently balance, run, jump, catch, and throw then they will be limited in their ability to engage comfortably in physical activity (Hulteen et al., 2018). These fundamental motor skills not only apply to engaging in physical activity and sports, these skills also support everyday movement (e.g. carrying a shopping bag, walking on different surfaces (Bolger et al., 2021; Xia et al., 2022)

It is commonly believed that children will naturally learn fundamental motor skills (FMS) as they age, however, a growing body of evidence is showing that an increasing number of children are not achieving proficiency in these in these motor skills (Hulteen et al., 2018; De Meester et al., 2018; Adank et al., 2018) More recently, reports are emerging that children are increasingly starting school developmentally delayed in FMS, with similar data on older children and adolescents (Cho et al., 2017; Hulteen et al., 2018). This is particularly prominent in children living in lower social economic areas, and/or cities compared to those in higher-income and rural areas (Kwon & Neill, 2020).

Studies have found that the level of improvement in cognitive functioning through physical activity may be connected to the motor movements involved and the environment of the activity (Guo et al., 2016; Chang et al., 2017; Gu et al., 2019). Gu et al., (2019) describe these skills as open and closed skills. Open skills are performed in an active and alternating environment, which can be unpredictable and often require faster decision-making actions. (i.e. basketball, rugby, and boxing) (Gu et al., 2019). Whereas, closed skills take place in more predictable and fixed environments where physical movements tend to be self-paced and follow set patterns that require fewer cognitive demands. For example, swimming, and running (Di Russo et al., 2010; Gu et al., 2019). Studies have shown that participants perform better in executive function domains (e.g., inhibitory control and cognitive flexibility) after doing open-skill exercises than participants who did closed-skill exercises (Carey et al., 2005; Wang et al., 2013). However, younger children should be introduced to a range of physical activity experiences that include both closed and open-skill exercises so that they can develop the fundamental motor skills that are essential for sustaining engagement in physical activities and everyday activities as they age (Wang et al., 2013).

In light of the above findings, it is necessary to consider the development of motor skill ability, particularly if not all children get the opportunities to refine them (Hulteen et al., 2018). Based on the research, to support motor skills and to increase the level of cognitive demand, consideration needs to be given to incorporate unpredictable sequences, actions, and movement problems that are solved in multiple ways and performed in dynamic and changing environments (Diamond & Lee, 2011; Wang et al., 2013; Pan et al., 2017). In a practical sense, this means that a diverse range of body movements (i.e. skipping, balance, jumping, catching, and throwing need to be considered when designing a physical activity program to support the aim of increasing cognitive demand.

2.2 Impact of Physical Activity on Cognitive and Behavioural Functioning

This section will begin with a review of the key brain structures and functions that are impacted by physical activity. Followed by a review of current research that has examined physical activity on cognitive and behavioural functioning in children. These studies have investigated outcomes related to academic performance, executive functioning skills (EF), mood, and behaviour. Including how intensity, duration, and frequency play a role in these functions.

2.2.1 Physical Activity Effects on the Brain

Physical activity encourages physiological changes which contribute to the improvement of brain health and cognitive functioning (Viggiano, 2012). Promising evidence has been shown that even a short amount of physical activity can benefit brain development (Chen et al, 2016). Physical activity has been shown to target executive functioning (EF) domains (e.g. attention and self-regulation), learning, and memory, and has been shown to reduce neurodegenerative aging in older populations (Padulo, Di Capua 2012, Viggiano, 2012; Gheller et al., 2015), regulate sleep cycles (Lang et al., 2013), improve mood and the negative effects of psychological disorders, including depression and anxiety (Chen et al, 2016; Chan et al., 2019). To understand how physical activity can support brain health, it is important, to begin with, a brief and basic explanation of brain structure and the factors required in supporting cognitive functioning.

The human brain is often described as being inherently malleable because it can adapt and change through experience (Di Liegro et al, 2019). While eating well, learning new skills and minimalizing stress support healthy brain changes, being regularly active has also been shown to be important (Di Liegro et al, 2019). Physical activity stimulates the brain which benefits the brain's ability to take in information from external experiences and learn (McMorris & Hale, 2012; Steven-Smith, 2016). Some studies have suggested that this is because parts of the brain that process movement are the same sections for processing learning (McMorris & Hale, 2012; Di Liegro et al, 2019).

The brain is made up of billions of brain cells called neurons. Neurons (also called nerve cells) that act as communicators and are fundamental for the functioning of the brain and nervous system (Colzato et al, 2017). These cells are responsible for receiving sensory information from the external world, and for directing every thought and action in the body (Lin & Kuo, 2013). Overall, it could be said that these interactions define who we are as people. These neurons carry messages through neurotransmitters which are chemical signals that the body cannot function without (Colzato et al, 2017). When the signal is repeatedly communicated, the connection between the neurons becomes stronger (e.g. the neurons that fire together, wire together) (Lin & Kuo, 2013; Krupic; 2017).

For brain health, and cognitive functioning that can support learning and memory, the brain needs to have the ability to produce neurons and make connections when associated with new learning experiences (Lin & Kuo, 2013; Krupic; 2017). These connections are supported by growth factors which increase the number of new neurons and support their longevity (Di Liegro et al, 2021).

Being physically active has been shown to support the regulation of growth factors Specifically, Fibroblast growth factor 2 (FGF2), Insulin-like growth factor 1 (IGF1), and Brain-derived neurotrophic factor (BDNF) all of which are essential for good health and well-being (Lebowitz et al., 2021; Colzato et al., 2017). Fibroblast growth factor 2 (FGF2) has been shown in preliminary animal studies to protect the heart from injury (e.g. heart attacks) and improve function after reperfusion (i.e. restoring blood flow to an organ or tissue after having been blocked) (House et al., 2003). Recent evidence has also shown that low levels of FGF2 play a role in anxiety (Perez et al., 2009). Whereas Insulin-like growth factor 1 (IGF-1), supports growth hormones in the body, together providing normal growth of bones and tissues (Dixit et al., 2021). As for Brain-derived neurotrophic factor (BDNF), this protein is referred to as the fertiliser for the brain (Fotuhi, 2013). BDNF induces the survival, growth, and development of neurons and synapses, which overall, play a crucial role in the brain's learning processes (Fotuhi, 2013). BDNF like the other factors mentioned is enhanced by engaging in physical activity, overall supporting domains connected to higher-order thinking (i.e. Executive Function), recall (i.e. memory) as well learning (Fotuhi, 2013; Colzato et al, 2017). A range of studies has found an increase in BDNF after only a short bout of moderate to vigorous physical activity (MVPA), with levels remaining high for weeks following more regular sessions (Marquez et al., 2015; Van Dongen et al, 2016). For example; Huang et al., (2014) study found that only one physical activity (PA) session that increases the heart rate for an average of 10 minutes increases BDNF levels, and frequent physical activity further increased the effect. Additional studies on BDNF levels showed that these levels increased yet differed depending on the type of physical activity and gender of the participants (de Fochesatto et al., 2023). Higher BDNF levels were found in more cognitively demanding (CD) exercises and males rather than females after doing similar physical activity sessions (Fochesatto et al., 2023). In another study, Van Dongen et al., (2016) showed an increase in BDNF after exercise was positively correlated with cognitive performance. Participants showed improved memory efficiency/recall 4 hours after learning information for an exam compared to the control group who did not do any exercise (Van Dongen et al, 2016). This study suggested that doing some form of physical activity after studying may support memory, recall, and processing of information more effectively.

Physical activity also supports Fibroblast growth factor 2 by promoting angiogenesis which creates and maintains healthy blood vessels by increasing the heart rate and encouraging oxygen and blood to flow (Kwak et al., 2018). In turn, this helps to keep the vascular network dense with branches of blood vessels, which provides more nourishment for neurons, keeping them strong and alive (Kwak et al., 2018). As a result, this provides more effective retention in the brain's pathways by allowing different parts of the brain to communicate more efficiently (Kwak et al., 2018). Physical activity has also been shown to influence the process of myelination which is in the pre-frontal cortex of the brain. Myelin enables nerve cells to transmit information fast and allows for more complex brain processes such as planning, reasoning, and decision-making (Tomlinson et al., 2016). Myelin can also support inhibiting responses in the frontal lobe more efficiently, demonstrating greater self-discipline (Huang et al., 2014; Tomlinson et al., 2016; De Giorgio et al., 2018). While these findings have mostly been based on older participants (18-50 years), results have been promising (Chaddock et al., 2011: 2014; Hillman et al., 2008; Whiteman et al., 2016; Lopez-Vicente et al., 2017). A range of studies have found positive effects of physical activity on the pre-frontal cortex. With increases in cognitive control after physical activity interventions. (Rodriguez et al., 2019; Scott & Schoenberg., 2010). Research has shown that individuals that had better cognitive control in childhood were found to be more prepared to learn and performed better academically at school (Chaddock-Heymanet al., 2013; Angel Latorre-Roman et al., 2021).

Overall, these studies have provided evidence for a range of neurobiological mechanisms that are enhanced by participating in physical activity (Lubans et al., 2016; de Greeff et al., 2018; Donnelly et al., 2016; Singh et al., 2018). Physical activity has been found to play an important role in regulating functions in the body that allow positive changes to occur to improve brain health. Studies have shown that physical activity can reduce the effects of psychological disorders (e.g. anxiety), improve memory and contribute to information being processed more efficiently in the brain. Furthermore, physical activity has been shown to produce global changes in children's brain functions, which support learning and the ability to be successful in school academically, behaviourally, and socially (Sanchez-Lopez et al., 2019; Sember et al., 2020; Angel Latorre-Roman et al., 2021).

2.2.2 Impact of Physical Activity on Executive Functioning

In some meta-analytical reviews small, yet significant effect sizes have been shown in the domain of executive functioning (EF), particularly inhibitory control after the even lower intensity and shorter sessions of physical activity (Jackson et al., 2016; de Greef et al., 2018). Recent studies utilising Magnetic Resonance Imaging (fMRI) technology which show various brain characteristics, including cortical thickness and surface area have supported the positive effects of physical activity on executive functioning after exercising. For example, Hillman et al., (2014) study with children aged 8- to-9-years-old showed activation in a region of the right anterior prefrontal cortex straight after one aerobic physical activity session using the fMRI. The exercise participants demonstrated higher executive functioning (EF), particularly in working memory (WM) and inhibition using neuropsychology measures compared to the control group who did not demonstrate any changes in brain activation or testing pre to post-test (Hillman et al., 2014; Erickson et al., 2015). Similar results were supported in a randomised control trial (RCT) study with 20 children aged 8-10 years who were assigned to either an aerobic 20-minute physical activity (PA) intervention or the control condition with no PA. Scanned fMRI results showed increases in prefrontal cortex activity with better performance when completing a math task compared to the control group (Jung et al, 2023). The researchers suggested that physical activity supports brain functions, particularly in areas such as attention and working memory (WM), which support children's abilities to engage and learn in an educational context (Jung et al., 2023).

In some studies, higher fitness levels have been shown in children to positively impact more efficient brain processes and executive functioning (Herting & Nagel, 2013; Chaddock-Heyman et al, 2014). For example, a study that used fMRI technology found that there was higher white matter volume in the hippocampus combined with higher performance in completing executive functioning measures associated with memory in children who were fitter, than those who were not (Chaddock-Heyman et al, 2014). Further studies have demonstrated similar results with adolescents. For example; Herting et al., (2016) study examining the brain activity of teenagers using an fMRI found that regular exercisers showed different outcomes in the brain connection to the hippocampus and task performance. Participants were presented with randomly paired words and told they would be tested on these word pairs later. Brain activity was recorded during the task with fMRI scans sorted into categories later based on if the participant remembered or forgot the word pair. Results showed that despite the task performance being similar between both groups, the hippocampus of the less active teenagers was significantly more active than the fitter participants (Herting & Nagel, 2013). Researchers suggest that physical activity may influence how the brain encodes new memories and that lower-fit teens may need to use additional brain resources to learn something new. Overall, suggesting that teens who are more regularly active may be more brain efficient in areas such as memory and recall (Chaddock-Heyman et al, 2014; Herting et al., 2016).

In another similar study, participants aged 13-14 years were categorised into either fit or unfit groups after completing fitness tests (i.e., the shuttle run) (Hogan et al., 2015). The intervention required participants to complete short bouts of aerobic exercise or rest. They then completed neurocognitive tasks that measured inhibition and attention (i.e. Flanker Task) while their brains were scanned using an Electroencephalogram (EEG). It was found that the fit adolescents displayed enhanced response monitoring (i.e. the ability to monitor one's actions and progress towards a predefined goal) compared to lesser-fit teens who were found to demonstrate more errors during the neuropsychology tasks (Hogan et al., 2015). In conclusion, researchers suggested that being unfit may lead to poorer efficiency in the cognitive areas required for attention (Hogan et al., 2015). These results were also found in a longitudinal study with younger children aged 6-10 which found that lower levels of physical activity showed significantly poorer results in memory tests (Lopez-Vicente et al., 2017).

Overall, studies have suggested that being fitter improves the brain's ability and efficiency to process external information. Research has found that fitter participants produce fewer errors in cognitive tests, particularly for attention, working memory, and inhibition Chaddock-Heyman et al, 2014; Hogan et al., 2015; Herting et al., 2016; Lopez-Vicente et al., 2017).

2.2.3 Impact of Physical Activity on Learning

Studies are showing that children and adolescents today are increasingly experiencing a downward trend in being active at school (Novo & Forman, 2019). Instead increased time is being spent on academic subjects due to the belief that that more time spent on these subjects will increase performance (Trudeau and Shepard 2008; Arnold et al., 2013; Ng et al., 2017). However, this may not be the most effective strategy to take, particularly with the increase in children’s sedentary behaviour which has been linked to poorer psychological, health and learning related outcomes (Taylor et al., 2019).

As an alternative to the current situation, studies are suggesting that increasing the opportunity to be physically active will lead to the improvement in cognitive abilities such as attention, memory, and behaviour and therefore increase learning and academic ability for children in school (Trudeau and Shepard 2008; Arnold et al., 2013; Ng et al., 2017).

Therefore, this section aims to outline the studies that have examined the potential benefits of engaging in physical activity and how this affects children and adolescents' learning/academic abilities (e.g. math, spelling), attention, and on-task behaviour in the classroom.

One factor that has been shown to support learning is fitness level. Studies have suggested that physically fit participants, score higher on intelligence quotient (IQ) tests compared to those who have lower fitness levels (O'Callaghan et al., 2012; Aberg et al., 2014). For example, this was demonstrated in a study with primary-aged children who participated in sports regularly. The results showed that general intelligence (IQ) was significantly higher on average for children who participated in extracurricular sports on a regular basis than for children who did not (Tomporoski et al., 2008). While there are a range of factors that support the ability of students to learn at school, intelligence has been shown to play a role. As intelligence encompasses the cognitive ability to understand concepts, remember information, reason, reflect and solve complex problems, all of which are linked to learning ability and success (Tomporoski et al., 2008).

Another factor for learning ability and success at school is attention (Steinmayr et al., 2010; Steele et al., 2012). The construct of attention is generally distinguished as divided, sustained, and selective (Lindsay et al., 2020). These components are expressed through the executive functioning (EF) part of the brain that supports areas such as inhibition/self-control and ignoring certain stimuli while attending to others (Lindsay et al., 2020). In general attention is essential for learning and has been shown to have a strong association with children's academic performance (Steinmayr et al., 2010; Steele et al., 2012). A number of studies that have examined how different physical activity interventions with children have affected academic achievement have shown improved literacy and math outcomes (Hillman et al., 2011; Duncan & Johnson, 2014). For example, Hillman et al. (2011) study with children aged 7-10 years old compared a physically active intervention of walking on a treadmill to a control group who did not do any physical activity. Results showed significant benefits on outcomes in reading performance. In another similar study with younger children, Duncan, and Johnson (2014), compared a moderate intensity cycling (exercycle) intervention with a resting (sitting) group. Results showed that spelling and reading tests completed immediately after the conditions where higher for the active group compared to the sedentary group. This was also shown in study (n= 58, age 9-11) where the participants completed spelling activities while doing hopscotch and then spelling while sitting. Results showed that the spelling and movement condition improved spelling significantly ($p < 0.01$, $d = 0.42$) compared to the learning and sitting condition (Llewellyn et al., 2022).

Another way researchers' have measured learning is to observe the time spent being focused on learning tasks, often in a classroom environment (Bartholomew & Jowers 2011). If students can pay attention for longer periods of instructional time in the classroom, the higher likelihood that this will improve learning ability (Owen et al., 2016) Attention is linked to on and off task behaviour, because it encompasses being attentive, following instructions, and inhibiting inappropriate actions (Owen et al., 2016). On-task behaviour has been defined as being engaged and focused on the present task (Ma et al., 2014). Whereas off-task behaviour is the disengagement from the learning task. This may look like (1) verbal (e.g. talking to other students, speaking when not asked to by teacher), (2) motor (e.g. walking around the classroom with no purpose, fidgeting), or (3) and passive (e.g. daydreaming) (Ma et al., 2014). Studies have found that students who can stay on-task for extended periods are more likely to experience academic success, including achieving more positive outcomes vocationally beyond school years (Thijs et al., 2011; Heemskerk et al., 2022). Studies have also shown that on-task behaviour increases after only 10 minutes of quick exercises in class (e.g., jogging on the spot, star jumps) (Mahar et al., 2006; Howie et al., 2012; Mullender-Wijnsma et al., 2015; Heemskerk et al., 2022). Whereas those who did not complete any exercises have shown significant increases for off-task behavior, pre- to post-activity (Heemskerk et al., 2022). For example, a study with 62 children aged 8-11 completed exercises (e.g., star jumps, jogging on the spot) for 10 minutes in class before continuing with learning. Results showed that the children who completed the physical movements had a significant increase in time being on task in the classroom compared to baseline data (p <0.01, $d = 0.60$) (Mahar et al., 2006). This was demonstrated in another study examining physical activity and time (i.e., duration) on behaviour (Howie, et al., 2012). Children (age 9-12, n = 96) were placed in physical activity groups for different lengths of time (e.g. 5, 10, 20 minutes) and required to do a range of aerobic exercises (e.g. running, sit-ups). Observational measures showed that the participants who completed the exercises for 10 minutes (p <0.01, d=0.50) with 20 minutes approaching significance ($p = 0.56$, d =32) were on task longer compared to the 5-minute exercise group and control (sitting), which showed increases in off-task behaviour (Howie, et al. 2012). The benefits of shorter periods of physical activity were also shown in another school-based study examining on-task behaviour with two different age groups (age 7-8, n =20) and (age 9-10, n = 22). Children completed a range of vigorous-intensity aerobic exercises (e.g. squats, jumping, scissor kicks) for 20 seconds, with 10 seconds of rest over 10 minutes. This was compared to a control group that remained sedentary (e.g. sitting) learning about healthy eating, being active, and the history of sport. Results showed that participants were more focused after the session (e.g., less fidgeting and distracted) with the greatest improvement observed in children aged 9-10 years, where passive behaviour (e.g., daydreaming) $p < 0.01$, $d = 0.74$; Motor (e.g., fidgeting) $p < 0.01$, $d = 1.076$) decreased (Ma et al., 2014; Szabo-Reed et al., 2017). In another study with 81 participants aged 8-9 who completed 20 minutes of moderately vigorous physical activity (MVPA) while doing learning activities (e.g., multiplication) (Mullender-Wijnsma et al., 2015). Results showed a significant effect on time-on-task after the intervention ($p < 0.05$, $d= 0.41$) compared to no effect on control (i.e. math and sitting) (Mullender-Wijnsma et al., 2015).

The intensity of physical activity has been shown to also play a role in the impact of attention (McMorris & Hale, 2012; Mullender-Wijnsma et al., 2015; Owen et al., 2016; de Greeff et al., 2018). With many studies demonstrating more benefits for moderate to vigorous (MVPA) physical activities compared to lighter or vigorous/intense only physical activities (Roorda et al. 2011; McMorris & Hale, 2012; Mullender-Wijnsma et al., 2015; Owen et al., 2018; de Greeff et al., 2018). For example, an observational study examining the effects of low, moderate, or vigorous intensity physical activity on behaviour in a sample of 9-year-olds in the classroom found that moderate physical activity increased energy, positive mood, and on-task behaviour (de Greeff et al., 2018). With passive off-task behaviour being reduced (e.g. aimlessly flipping through pages in a book, doodling/drawing when not assigned, and daydreaming). However, low physical activity increased motor off-task behaviour (e.g. walking around the classroom with no purpose, inappropriate calling out). Whereas no direct effects were found for vigorous physical activity (de Greeff et al., 2018).

In summary, physical activity has benefits in playing a role in increasing academic performance (Lucht & Herdig, 2013; Duncan and Johnson, 2014; Owen et al., 2016). Studies have shown that physical activities that are moderately intense and/or are combined with learning activities for a minimum of 10 minutes have a significant impact on children aged 7-10 years old academic performance, particularly in math and spelling (Lubans et al., 2016; Duncan and Johnson, 2014). The studies also showed that children's behaviour after physical activity improves, attention and staying on-task in the classroom (Thijs et al., 2011; Heemskerk et al., 2022). Participants showed less passive off-task behaviour (e.g. daydreaming) motor off-task behaviour (e.g. walking around the classroom with no purpose) and verbal off-task (e.g. talking to other students, speaking when not asked to by the teacher) (Ma et al., 2014; Szabo-Reed, 2017).

Overall these studies have shown that physical activity is a complementary strategy that should be used in the classroom to support learning. Physical activity increases students' ability to remain on-task with learning activities for longer and process the information and knowledge that is being taught more effectively. Therefore, having a greater chance of success, academically.

2.2.4 Physical Activity and Neurodiversity

Research has suggested that physical activity may promote neural growth and development in children who are Neuro-diverse. Neurodiversity is a broad term that encompasses a wide range of diagnoses that include Dyslexia, Dyspraxia, Communication Disorders (CD), Autism Spectrum Disorder (ASD), Attention Deficit/Hyperactivity Disorder (ADHD); Specific Learning Disorders (SLD); Traumatic Brain Injury (TBI); and or Fetal Alcohol Syndrome Disorders (FASD) (Skelling, 2020). In New Zealand, it is estimated that 15% of students are catagorised as Neuro-diverse. While no clear data has yet been collected reports estimated that 114,402 children fall within the Neuro-diverse population (Ministry of Education, 2016). Executive functioning impairment is common amongst this population with studies finding a negative association with a wide range of school-related learning and behavioural problems (Friedman et al., 2007; Baird et al., 2023). Physical activity studies focused on ADHD populations, have shown considerable improvement in measures associated with attention, concentration, and social functioning in the classroom with self-reports from parents and teachers reflecting positive changes after exercise for children with ADHD (Arumugam et al., 2019). It has been demonstrated that engaging in regular physical activity for 30 minutes daily significantly improved children's behavioural symptoms associated with ADHD both at home and school (Wendt, 2000). This included participants who were taking ADHD medication and those who were not. (Wendt, 2000). In another study 43 children aged between 7-12 years old diagnosed with ADHD exercise showed improvements in executive functioning (i.e., working memory) however, this depended on the kind of physical activity that was used. For example, two different 12-week training programs were conducted. One group focused on coordination abilities (e.g. ball skills, balance) and sports games, and the second group engaged in the sports games without any direct focus on skills. A control group received no intervention. Results showed significant improvement over time for both physical activity groups compared to the control group, however, more benefits were shown with the focused coordination abilities group compared to the other physical activity group (Ziereis & Jensen, 2015).

Autism Spectrum Disorder (ASD) studies have shown that children with ASD are at risk of greater negative outcomes physically, psychologically, and socially therefore lowering their quality of life (De Vries & Geurts, 2015; Pan et al., 2019). This has been highlighted by the caregivers of those with children diagnosed with ASD (Pan et al., 2019). These reports have shown significantly reduced emotional and psychosocial functioning, then parents with children diagnosed with other psychiatric disorders (Bastiaansen et al., 2004; Pan et al., 2019). However, physical activity may be an effective complementary intervention to reduce these negative outcomes. Physical exercise has been found to improve the physical motor deficits commonly found in children with ASD (Batey et al., 2014) time management tasks (Oriel et al. 2011), cognitive functioning (Bremer et al., 2016; Tan et al., 2016), aggressive behaviours (Neely et al., 2015) and socioemotional functioning (Bodnar et al., 2020).

Children diagnosed with Foetal Alcohol Syndrome Disorders (FASD) have shown benefits, particularly in improving executive functioning domains that are commonly impaired by this disorder (Orr et al., 2018). For example, a study with 30 children diagnosed with FASD, aged 7–14 years participated in aerobic physical activity sessions two times a week for 1.5 hours over 8 weeks. Executive functioning was measured using the Children's Colour Trails Test (e.g. sustained attention, sequencing). Results showed significant improvements in attention immediately after the physical activity intervention with improvement being sustained 3 months post-program (Orr et al., 2018).

The inclusion of physical activity into treatment approaches for children who are neuro-diverse may be especially beneficial given the higher risk of negative outcomes.

Overall, these studies have shown that being more active improves health, well-being, and cognitive impairments experienced by neuro-diverse children (Wendt, 2000; Ziereis & Jensen, 2015; Neely et al., 2015; Bremer et al., 2016; Tan et al., 2016; Orr et al., 2018; Arumugam et al., 2019).

2.2.5 The Effects of Frequency and Intensity of PA on Cognition

Further research has taken into consideration the impact of frequency on cognition with each showing positive impacts on academic abilities and executive function (EF) skills (Hillman et al., 2011; Suarez-Manzano et al., 2018). Distinctively in cognitive areas such as; inhibitory control (e.g. thinking before acting), working memory (WM) attention span, perception, and visuomotor coordination (e.g. handwriting) (Best, 2010; Donnelly et al., 2016). However, results have been diverse, with variability depending on whether the physical activity is acute or chronic (Best, 2010).

Acute physical activity is often described in research as being a single session of physical activity which may cause immediate shifts to how the brain functions (Pesce, 2012; Chang et al., 2012). Whereas chronic physical activity (PA) often includes multiple sessions or longer-term physical activity, which can cause cognitive changes over a longer period (Pesce, 2012; Chang et al., 2012). In general, the studies examining acute sessions of PA and cognition have suggested that sessions that last between 11-20 minutes that are moderately intense are most effective in improving cognitive outcomes in children (Chang et al., 2012). Studies on acute physical activity interventions have shown that even single sessions of exercise can improve processing speed (Ellemberg & St-Louis-Deschênes 2010).; Tam., 2013; Stranda et al., 2019). For example, in a study with participants aged 9-10 years who were selected to ride either a stationary bike for 30 minutes while watching TV or sitting and watching TV and then measured straight after the session on processing speed TV (Ellemberg & St-Louis-Deschênes 2010). Results showed that while accuracy on both tasks did not improve for either group, those in the physical activity group responded significantly faster in response speed compared to those who sat watching TV (Ellemberg & St-Louis-Deschênes 2010).). Not all the research has found benefits from participants engaging in acute physical activity interventions. A study with 8-12-year-old children who were randomised by the school they attended, were placed into either a physical activity group which included 15 minutes of daily moderately high-intensity exercises for 1 week, or a non-exercise control group who participated in story time, music, and art (Hill et al., 2011). Participants completed a series of cognitive tests that measured attention (e.g. listening span) and working memory (e.g. digit-span backward) before the intervention and at the end of the week. The results did not show any main effect from the physical activity condition; however, it was noted that both groups completed the interventions after lunch and were measured just before the end of the school day in a group setting. This may have affected the results as the students could have been more tired and or rushed their responses due to it being the end of the day. Additionally, being in a group setting (e.g., distraction) may have affected the participant's results (Hill et al., 2011).

Longer-term chronic physical activity interventions have also shown beneficial results. Fisher et al., (2011) study trialed a 10-week physical activity intervention from 6 primary schools with 64 children aged 5-6 years old. Each session included two hours per week of aerobic moderately intense exercise that replaced the normal 2 hours per week of physical education (control group). Outcome measures consisted of cognitive tests for working memory (WM), planning; attention, and processing speed. This also included the short form of Connor's Parent Rating Scale, which measures attention and behaviour. Results showed that the aerobic physical activity group showed improvements in working memory and parental improvement ratings in attention and behaviour, however, there were no significant differences between the intervention and control group in the other domains.

Another study that examined children over 9 months doing physical activity exercises to improve cardiorespiratory fitness and working memory (WM) found that the participants that showed an increase in cardiorespiratory fitness also showed better results in the tests used to assess working memory (WM) (Fisher et al., 2011). The researchers suggested that there may be a relationship between the physical activity group's increased cognitive performance due to the amount of time children spent in the moderate to vigorous intensity zone, as opposed to lower intensity physical activity (Fisher et al., 2011).

In general, the literature has shown that both acute (1 session) and chronic physical activity sessions (up to 9 months) regardless of the specific type of physical activity have shown positive effects on various cognitive domains in children (Ellemberg & St-Louis-Deschênes 2010; Hillman et al., 2011; Pesce, 2012; Chang et al., 2012; Tam., 2013; Stranda et al., 2019). Taken together, the studies provide tentative evidence that both acute and chronic sessions of moderately-vigorous physical activity enhance cognitive and behavioural functioning in children (Ellemberg & St-Louis-Deschênes 2010; Hillman et al., 2011; Pesce, 2012; Chang et al., 2012; Tam., 2013; Stranda et al., 2019).

Further considerations for the time of the day and duration of the physical activity session have been considered by a few studies with suggestions that physical activity performed first thing in the morning between 15-40 minutes is effective for children (Van den Berg et al., 2016). The measures used by the researchers in this field and the specific domains tested are still inconsistent making it difficult to draw conclusions on what is most effective in terms of intensity, duration, and frequencies of physical activity and how this affects specific cognitive functions of children (Van den Berg et al., 2016; Wilson et al., 2016; Szabo-Reed et al., 2017).

Overall, the research that has been conducted has shown promising results that physical activity can play a role in improving cognition and behaviour to support learning and success in the school context (Van den Berg et al., 2016; Wilson et al., 2016; Szabo-Reed et al., 2017). These studies showed that level of fitness may be correlated with IQ and academic performance (O'Callaghan et al., 2012; Aberg et al., 2014). In addition, moderate-intensity physical activity may have a more significant impact on supporting young people's concentration, attention, and on-task behaviour in the classroom compared to vigorous or lower-intensity exercise (Ellemberg & Deschenes, 2010; Hillman et al., 2011; Pesce, 2012; Chang et al., 2012; Tam., 2013; Stranda et al., 2019).). Physical activity has also been shown to benefit a diverse range of cognitive abilities, suggesting that physical activity may be a complementary form of treatment for those who are neuro-diverse (Wendt, 2000; Tantillo et al., 2002; Ziereis & Jensen, 2015; Neely et al., 2015; Bremer et al., 2016; Tan et al., 2016; Orr et al., 2018). However, overall, this is still an area that needs further research.

2.3 Effects of Physical Activity on Mood

Having emotional well-being is important, as it provides resilience and perseverance in learning new things and facing challenges (Dray et al., 2017). Being able to express emotions in healthy ways also supports positive relationships, empathy, and dealing with stress (Durlak et al., 2011). While evidence has shown that emotion is influenced by a range of genetic, physiological, and environmental factors (Southam, Gerow & Kendall., 2002; Wang et al.,2013) external interventions are necessary, particularly for children due to the brain still being in a period of growth and development (Zeman et al., 2006).

Research has shown that the rate of depression and anxiety in children has increased over the past 20 years, which has led to researchers exploring different interventions that may help to alleviate these rates (Bitsko et al., 2018). A variety of interventions have been examined to support and enhance positive emotions in children, such as music and art (Eisenberger et al., 2010; Chan et al., 2019). However, due to the increase in children's sedentary behaviour which is linked to poorer physical and mental health/well-being researchers are investigating physical activity as an approach to improving emotional well-being for young people (Rodriguez-Ayllon et al., 2019).

Current research has shown that physical activity boosts mood in both adults and children (Biddle et al., 2011; Verburgh et al., 2014; Aylett et al., 2018) In part, this is due to findings that have shown that physical activity releases neurochemicals that are associated with positive emotions such as endorphins and serotonin (Hecht, 2013). Further studies have shown that physical activity can alleviate the symptoms of depression, anxiety and can also help control feelings of anger (Weir, 2011; Verburgh et al., 2014; Aylett et al., 2018). Cho et al., (2020) review showed that being physically active improved mental wellbeing in young people particularly in self-esteem and optimism. In recent years, articles on physical activity interventions and emotions have shown that age, intensity, and duration of physical activity may produce different effects on specific emotions (Goldfield et al., 2015; Bao and Jin et al., 2015; Balchin et al., 2016; Costigan et al., 2016; Chan et al., 2019). The following section will review the research that has examined these factors (i.e., age, duration, intensity) associated with physical activity and how this affects emotion in young people.

2.3.1 Intensity, Frequency, and Duration of Physical Activity on Mood

The intensity of exercise may play a role in mood. For example, studies have suggested that different intensities of exercise that are either aerobic or anaerobic are positively associated with higher ratings of positive mood (Balchin et al., 2016; Chan et al., 2019). Higher-intensity physical activity (PA) has shown positive effects, particularly with adolescents. Costigan et al., (2016) study with boys aged 14-16 who were placed in either a high-intensity interval training (HITT), aerobic low-intensity (stretching), or control (no PA). Each PA group completed the exercises for 8-10 minutes over 3 days. Results showed a small improvement in psychological well-being with an improved positive effect in the physical activity groups compared to no effect in the control group. Goldfield et al., (2015) study with adolescents aged 14-18 years completed either a high-intensity aerobic, anaerobic (e.g. strength training), or combined intervention for 45 minutes 3 days a week. Results showed that the combined group had a significant reduction in self-esteem and depressive symptoms with the aerobic group showing improvement in vigor/energy and the strength training (i.e. anaerobic) group showing an overall improved body image rating.

Bao and Jin et al., (2015) study with 16 adolescents aged 13-16 who took part in Tai chi or gymnastics for 60 minutes for 5 days showed significant reductions in anxiety in the Tai Chi group. However, no significant differences in how participants felt about them-selves physically or their level of happiness was found in either group.

Current studies have shown that moderate-intensity physical activities that include aerobic, anaerobic, or combined exercises are more effective for positive mood change in younger children aged 8-13 (Bourke et al., 2021). For example, Strauss et al. (2001) found higher self-esteem ratings in children who participated in moderately-vigorous physical activity (MVPA). Whilst Dunton et al. (2014) reported that, in children aged 9-13, completing MVPA for 30 minutes showed children reporting higher levels of positive affect and feelings of being calmer. MVPA may also benefit self-esteem, Telles et al.,(2013) study with 8-13 years doing either yoga or MVPA for 45 minutes for a week showed that social self-esteem was higher in the MVPA group compared to the lower intensity yoga group. In another study, improved self-esteem was found to be significant in a small sample (n=20) of boys aged 8-12 years who took part in 2-days of football for 60-90 minutes compared to following their normal school routine (i.e. control) (Seabra et al., 2014). However, results are still inconsistent with physical activity effects on mood as some studies have shown no clear relationship between physical activity intensity and mood changes (Buscombe & Inskip, 2013; Maurer et al., 2020). Or no significant difference between the different types of exercises (e.g. aerobic and anaerobic) on mood (Ramalho et al., 2018).

At present due to the small sample sizes and diversity of study designs in this area, clarity on whether there are differences between the type and intensity of physical activity on emotional functioning in young people cannot be concluded as further research is necessary. In general, researchers state that regular moderately intense physical activity leads to an increase in positive feelings and a reduction in negative affect in the longer term (Bourke et al., 2021). Some studies have found evidence for physical activity having a positive effect on mood. With studies suggesting that physical activity sessions that run for 20-60 minutes regularly and are moderately vigorous in intensity have shown the most improvement in positive mood states. A few studies have pointed out that physical activity for too short a time may not achieve an effect on mood (Hinkley et al., 2014).

Overall, the findings of these studies provide preliminary evidence that physical activity affects improving mood in young people. However, follow-up research is required that provides more detail on the types of physical activity on mood in younger children.

2.4. Effects of Cognitive Demanding Physical Activity

Researchers studying the effects of physical activity on cognition have only recently begun to recognise the importance from a practical point what types of physical activities are most effective in promoting cognitive functions (Best, 2010; Schmidt et al., 2015; Tomporowski et al., 2015; Egger et al., 2019). As recent studies have shown not all types of physical activity are equally beneficial on cognition, mood, and behaviour (Best, 2010; Schmidt et al., 2015; Tomporowski et al., 2015; Álvarez- Bueno et al., 2017; Vazou et al., 2019; Egger et al., 2019). One characteristic of physical activity more recently discussed is cognitive demand (Egger et al., 2019). While some degree of cognitive demand is inherent in all types of physical activities, it is the movements that are more complex, change continuously, or require higher strategic actions that have been classified as being higher in cognitive demand (e.g., martial arts, gymnastics) (Best, 2010; Tomporoski et al., 2015; Schmidt et al., 2015; Oyen, 2019; Egger et al., 2019).

While the research in this field is still relatively new. Results have been promising with findings that suggest that higher cognitively demanding PA is superior to simple repetitive aerobic exercises or cognitive activities alone (Best, 2010; Schmidt et al., 2015; Tomporowski et al., 2015; Álvarez- Bueno et al., 2017; Vazou et al., 2019; Egger et al., 2019). Recent studies with children have revealed positive effects on cognitive performance in support of cognitively challenging physical activities (Budde et al., 2008; Pesce et al.,2013; Crova et al., 2014; Schmidt et al., 2015; Benzing, et al., 2016; Egger et al., 2019; Oppici et al; 2020; Nejati et al., 2021; Meijer et al., 2021; Vazou et al., 2021).

Pesce et al. (2013) study showed that attention improved in children aged 9-10 after 6 months of a cognitively demanding intervention compared to an intervention with lower cognitive demands, which showed no effects. In another similar study with older children, the cognitively demanding physical activity group showed a significant increase in inhibition compared to the other group who completed the normal school physical education (PE) program which had lower cognitively demanding exercises showing no effect (Crova et al., 2014). Harwood-Gross et al., (2021) study used martial arts as the higher cognitively demanding physical activity which showed a significant cognitive improvement, particularly in inhibition, flexibility, speed of processing, attention, and a reduction in aggression in a small sample of at-risk adolescents who practiced twice a week for 6 months. Schmidt et al. (2015) conducted a study of 9-10- year old's comparing a pure aerobic physical activity intervention to a higher cognitively demanding PA intervention (e.g. a team game using both physical and cognitive demands). Positive effects were found for children's ability to transition from one activity to the next (shifting performance) after doing higher cognitive-demand physical activities compared to aerobic exercises that were lower in cognitive demand. However, the study did not include a cognitive condition only, which allowed for the possibility that the cognitive demand factor, not the physical activity promoted these executive functioning abilities. However, a further study with a cognitive demand-only condition found that the higher cognitive demand physical activities (PA) was the crucial factor for increasing outcomes of attention and processing speed in children aged 11-12 years old (Best, 2010). These findings were also shown in Egger et al., (2019) study with children aged 7 to 9 years doing a 20-week intervention which included a 1) higher cognitive demand PA condition, 2) lower cognitive demand PA condition (aerobics), and 3) a higher cognitive demand only condition. Results showed that only the higher cognitively demanding PA condition displayed enhanced cognitive performance (e.g., shifting, attention). However, the authors noted that the performance decreased after 10 weeks due to the participants becoming familiar with the exercises as they were kept the same.

Mood and memory have also been found to be more significant in higher cognitive PA, for example, Oppici et al., (2020) study used two different ways of teaching dance to 80 students aged 8-10 years old. In one group the participants copied the teacher's dancing to reduce cognitive demand. The other group had fewer demonstrations from the teacher and was required to recall the dance moves. A control group continued normal PE sessions with no dance allowed. Lessons were twice a week over 7-weeks. Results showed that compared to the lower CD group, working memory and mood were significantly correlated with the higher cognitive group. No effects were found for the control. Furthermore, the females were found to have improved more on working memory than the boys, however, the authors did note this may have been because the girls enjoyed the dancing more compared to the boys which influenced engagement in the study. While some studies have shown positive relationships between higher cognitively demanding physical activities and improved cognitive outcomes, some studies have found mixed results. This has resulted in a few studies suggesting that cognitive demand alone could be the main factor in increasing cognitive outcomes, not the physical activity (Schmidt, Benzing, and Kamer, 2016; Egger et al., 2019). Other studies supported higher cognitively demanding physical activity (PA) conditions when compared to lower cognitive PA conditions (Budde et al., 2008; Pesce, et al., 2009; Jäger et a., 2014; Schmidt et al., 2015; Oppici et al., 2020; Nejati et al., 2021), or no effect for either CD, PA or a combination of both have been found (Meijer et al., 2021). Authors too have reported that higher physical exertion with higher cognitive demand may over-exert younger children, resulting in a decrease in cognitive abilities/outcomes in children due to fatigue, even if the children enjoyed the PA activities (Egger et al., 2018; Bedard et al., 2021). For example, Egger et al. (2018) study examined the effects of high and low physical activity with different levels of cognitive demand on attention and memory with 216 children aged 7-8 years old. Results showed no effect for the high-intensity cognitively demanding condition compared to the other conditions.

In summary, while results have been promising in support of higher cognitively demanding physical activity, particularly for the improvement of specific Executive Functioning (EF) domains such as attention, inhibition, and working memory. Other studies have found no effect for children. Additionally, studies have not been consistent in terms of the designs used (e.g., between and within subjects), PA durations (e.g., 5 to 50 min), different environments (e.g., in school, community), cognitive measures (e.g., memory recall, attention, and EF), and in determining the level cognitive demand (e.g., used different exercises). Therefore, it is still difficult to draw conclusions on the benefits of higher cognitive demand physical activities on children until further studies have been conducted that use the same variables, ages and can examine how these effect children at school.

2.5 Summary of Literature Findings

A majority of the research supports the view that all types of physical activities benefit the brain, cognitive functioning, mental health, and wellbeing of all ages. Positive results have been found for children and adolescents of all abilities, that link physical activity to the improvement in a variety of executive functioning domains, that support efficiency in learning, positive behaviour, and mood. Research also implies that greater levels of physical activity during the developing years optimises brain functioning with benefits continuing across the lifespan, particularly in physical health, motor functions, memory, and social/emotional outcomes (Khan & Hillman., 2014; Bunketorp et al., 2015). Studies investigating higher cognitively demanding physical activities are still limited (Egger et al., 2019; Oppici et al., 2020; Nejati et al., 2021). However, results have been promising, with these studies showing that higher cognitive demand incorporated into physical activity is more beneficial for children's cognitive abilities than lower cognitive demanding physical activities (Budde et al., 2008; Pesce, et al., 2009; Jäger et a., 2014; Schmidt et al., 2015; Oppici et al., 2020; Nejati et al., 2021).

2.6 Literature Review Key Themes and Findings to Consider for Study

- The brain area that deals with movement is the same area that supports learning.
- Physical activity has been shown to play a role in improving academic performance and emotional well-being for children.
- Physical activity (PA) completed earlier in the school day produces higher outcomes in academic subjects compared to PA done later in the day.
- Physical activity breaks increase on-task behaviour in the classroom and reduces negative behaviours that can distract from learning.
- Physical activity improves students who are experiencing learning and behavioural difficulties at school.
- Neuro-diverse students benefit from regular physical activity to help them expend energy, feel better and focus on classroom tasks.
- Physical activities (PA) that include components such as memory, complex movements, and attention are more effective for children's cognitive domains than simple repetitive aerobic physical activities or higher cognitive activities alone.
- Martial arts are considered to be higher in cognitive demand. Studies investigating this form of PA have shown significant improvements in inhibition, flexibility, processing speed attention, and aggression (Gross et al., 2021).

2.7 Methodological Considerations

- Variability still exists in terms of what is being measured (e.g. cognitive, behaviour, mood) and how (e.g. type of measure).
- Results remain inconsistent on whether physical activity, cognitive demand, or a combination of both, are the most promising for children's cognitive and behavioural abilities.
- The majority of the research has been on the effects of aerobic repetitive exercises (e.g. low cognitive demand).
- A limited number of studies have considered different levels of cognitive demand as a variable.
- Further research is needed on the benefits of PA on children in classroom/school environments.
- Limited research exists on physical activity and mood on children younger than 12-years.
- Fitness level, motor-skill ability, enjoyment and motivation should to be considered as a variable in studies.
- Studies have reported that physical activities need to be diverse to suit all abilities and be continually challenging to sustain engagement and effect.
- The majority of studies have focused on chronic, i.e. long-term interventions, used short classroom breaks (e.g. 5min), or integrated physical activity during academic time (Vazou & Skrade, 2016). Further studies on acute, longer duration (20 – 30 minutes), and non-integrated PA programs are required.

2.8 Conclusion

Previous research has shown that being physically active not only benefits young people in the classroom but for the rest of their lives (Oppici et al., 2020; Nejati et al., 2021). However, the research in this field is still broad, resulting in a lack of confidence and possible confusion from educational institutions that encouraging physical activity will improve behaviour and learning rather than disrupt 'academic' time. Therefore, the need to further examine the type of physical activity and how this impacts children within the school context is required. Particularly, if doing so, enhances young people's wellbeing, learning abilities, and success in education.

2.8 Aims and Hypothesis

In summary, while a number of studies have shown that there is scope for the positive benefits of higher cognitively demanding physical activities, particularly in attention and memory this is an area that still requires further investigation due to the number of studies with mixed and inconsistent outcomes. In addition, very few studies have investigated how behaviour and mood in the classroom are affected after engaging in acute bouts of Moderately Vigorous Physical Activity (MVPA) that are higher in cognitive demand, particularly in children between the ages of 6-10. (Best, 2010; Diamond, 2015; Kao et al., 2017; Pontifex et al.,2019). Therefore, the aim of this exploratory study was to gain further knowledge on whether physical activity (PA) level (high or low) and cognitive demand (CD) difficulty (high or low) either separately or in combination affects children's mood, attention, and behaviour.

This study is consistent with research that has indicated that there are beneficial effects on neurocognitive functioning, particularly in attention, inhibition, and mood after engaging in physical activity with larger effects shown when the exercises require more cognitive demand (de Greeff et al., 2018; Sun et al., 2021).

Therefore, it is hypothesised that (1) doing moderately vigorous physical activity (MVPA) with higher and lower cognitive demanding (CD) exercises (e.g., *combined, and aerobic condition)* will be more effective in improving mood, time-on-task (i.e., attention), and reducing negative behaviours in the classroom than baseline (e.g., normal morning classroom routine). And (2) physical activity with higher CD physical activities (PA) *(e.g., combined condition)* will be most effective in improving mood, time on task, and reducing negative behaviour compared to lower CD/PA (e.g., *aerobic condition*) and low and high CD activities only (e.g., *low, and cognitive condition*).

Considering the clinical importance of improving attention and behavior in children, particularly in school to support success and learning. It remains to be investigated whether physical activity and increasing mental load (cognitive demand) has a positive effect on mood and the ability to increase focus on learning tasks for younger children in a New Zealand context.

CHAPTER 3
METHODS

3.1 Introduction

The purpose of this chapter is to present the research design used in this study. Specifically, this will provide a description of how the study sample was obtained, the data collection process, methods, and measures used. Additionally, potential threats to the validity of the study and statistical analyses will be discussed.

3.2 Research Design

This study used a within-subjects two-by-two (2x2) experimental design. Which consisted of four different conditions systematically differing in the level of cognitive demand and physical activity (refer to Figure 1).

Figure 1

Within Subjects 2 x 2 Factor Study Design

		IV Physical activity Level (PA)	
		Level 1 High	Level 2 Low
IV Cognitive Demand difficulty (CD)	Level 1 High	Mood & Behaviour	Mood & Behaviour
	Level 2 Low	Mood & Behaviour	Mood & Behaviour

All the 24 participants experienced the four conditions of the study: (1) *Combined Condition:* a moderately-vigorous physical intensity program with high cognitive demand, (2) *Aerobic condition*: a moderately- high physical intensity program with low cognitive demand, (3) *Cognitive Condition:* Low physical activity (sedentary/sitting) with high cognitive demanding activities, and (4) *Low*: Low physical activity (sedentary/sitting) with low cognitive demand. Information on the following background variables was gathered before the first condition commenced, including age, gender, culture, and physical activity level. Behaviour and mood was measured before (pre-test) and mood and behaviour immediately after each intervention (post-test). Each of the four interventions were carried out for one week each, twice weekly.

3.3 Justification and Internal Validity

The purpose of the experimental design is to observe the effects of the factors, physical activity (PA) exertion and cognitive demand (CD) difficulty, and how these factors act together and/or in isolation to impact the outcome variables (mood, attention, and behaviour) in a 'real-world' setting (i.e., the classroom). By using a within-subjects design the same individuals will participate in all four conditions. This means that a large sample size is not required, and the design is statistically powerful due to the reduced risk of individual differences on the outcome measures compared to a between-subjects design where participants receive only one condition/treatment. Overall, although this type of study design can be challenging to implement effectively because of the real-world setting (i.e. the classroom), challenges were overcome by maintaining as much control as possible over the four conditions. This was achieved by the researcher being in charge of running all four conditions with the participants, with the teacher and teacher aide (TA) acting as support personal only to sustain consistency. Teachers and teacher aides were instructed on the conditions and asked to provide environments that were less stimulating (e.g. quiet) so that the participants could complete the self-report mood scales. Clear instructions explaining the interventions and how they would be implemented over the weeks were given to all involved in the study (teachers and students). For example, this included visual examples of how the exercise circuits would work and the groups that they would be in. In addition, tasters of some of the physical activities were provided before the beginning of the study to familarise students with some of the exercises and to reduce anxiety, confusion, and time away from the classroom. The self-report mood rating was also modelled and explained and trialed with the participants, so that they understood the language and how to fill it out.

3.4 Informed Consent and Ethical Considerations

A meeting was arranged with the school principals to inform them about the study and if they would be interested in participating. A letter to the board of trustees (BOT) was written up explaining the study details (see Appendix A for letter). Once consent was received from both the principal and BOT. The principal chose the classroom to participate and spoke to the teacher to gain consent. Once teacher consent was received, the researcher met with the teacher to discuss the study and how it could fit into the classroom schedule. Information about the study and informed consent which was approved by the ethics committee was sent home with students by their teacher, signed by their caregivers and the child and returned to the teacher (see Appendix B and C for information and consent letter). The teacher then informed the researcher that all students had assented to the study. The researcher talked to the students about the study in terms of the activities they would be doing, and time was given 2-3 weeks before the study to have a go experiencing some of the physical activities. This was done to reduce hesitance and anxiety, which some indicated was a concern. All students once the taster was completed were asked again whether they wanted to participate in the study, all of the students consented. They were also reminded that they could discontinue at any time during the study. Ethical approval for this study was granted by the Massey University Research Ethics Committee with recommendations that participants had sufficient adult supervision while doing the physical exercises. This was accepted and amended during the study by having less groups doing the circuit and more staff supervision.

3.5 Participants and Setting

The study was conducted with year 4 and 5 (ages 7.5-8) students in term 3 and 4 of 2022 (Oct-Dec). Data were obtained from two schools from two different settings (1) a rural primary school (years 1-8), and (2) an urban primary school (years 1-6). One school’s roll was 211, with gender composition of male 59%, female 41%. And ethnicity, Māori 48%, Pākehā 47%, and Pacific, other 5%. The other school’s roll was 259, with gender composition of male 55% and female 45%, including, ethnicity Māori 81%, Pākehā 15% and Pacific and other groups 4%. The average class size for both schools was 24 students with a range of 22-26. In total 48 children from two different classrooms and schools took part in the study conditions as it was convenient for the classroom teachers for all students to be involved then only a few. In total N = 24 participants data was collected (male, 70%, female, 29.2%). Students who were chosen had their names randomly selected by a name selector app. Students were eligible to participate if they did not have any physical, cognitive impairments that would affect them participating safely and comfortably in the conditions.

3.6 Procedure

The data was collected over 6 weeks on twelve different mornings at the same period of time (9.15 -11am) for each of the two schools in the study (refer to Appendix D for data collection process). At the beginning of the testing students were informed of the conditions with the researcher explaining what the students would be doing and how to follow the activities to reduce confusion and keep to the scheduled 30 minutes. They were also familiarised with the mood rating measure, how to fill it out. A discussion to the students also occurred with what the emotional language meant and looked like (e.g. calm, anxious) in the mood measure.

Before the first testing session, participants got to experience tasters of some of the physical activities including the martial arts techniques. This was done to obtain feedback on enjoyment of the activities, so that changes could be made before the first physical activity condition. Additionally, this was done to reduce anxiety in participating in the interventions and to be more familiar with the physical activities, particularly the lower cognitive PA condition.

Prior to data being collected for observation, the main researcher trained the Teacher aides on how to use the Direct Observational Measure (DOF). The teacher aides were able to practice doing an observation with one of the participants 1-2 weeks before the baseline data was collected and given time to clarify any issues or ask questions with the researcher. When all of the observational data was completed both the researcher and teacher aides discussed the shared observations. Overall, 90% of the shared observations where similar, suggesting that the two observers were in agreement with the behaviours they had seen. The remainder (10%) of the observations were analysed and a final behaviour score was decided upon unanimously.

Baseline data collection took place 1-2 weeks before the first intervention. As a class, all students completed the PAQ-C measure on their physical activity habits so that they did not know who was being studied. The researcher and teacher aide then observed the 24 selected participants behaviour in class over the course of two mornings (2-3 hours). This followed the classes normal morning routine where students sat together in front of the teacher on the floor for 30-40 minutes and went through the morning greetings, news, daily schedule and intructions for the morning activity. Both classes completed math activities, with one class doing a writing assessment for one session till morning tea. One class went out for a 10 minute group game and the other class for quick run around half of the field for one observation and no exercise (due to it raining) for the other observation. Completely blinding the students to the study was not possible, however, students were told that the conditions were being carried out to see how the activities made them feel (mood ratings) they did not know who was being observed and what for. The participants were used to the researcher being in the classroom as multiple visits had been made to the classrooms before the beginning of the study. This made the observations more natural and less distracting for the students.

One week after baseline data was collected, the 1st of 4 conditions were run with participants. The classroom was split into groups by their teacher with whom they completed each PA and cognitive only activity. Each group consisted of 4-6 students. Both schools completed one of the four conditions a week with two sessions a week over the course of 4-weeks. Each school completed the four conditions in different orders. School one: (1) lower cognitive/sedentary condition, (2) higher cognitive/PA, (3) lower cognitive/PA and (4) higher cognition, sedentary last. School two: (1) higher cognitive /PA, (2) lower cognitive, sedentary, (3) low cognitive/PA, (4) higher cognitive, sedentary last.

Within 10 minutes before commencing each condition the whole class completed the self-report mood measure on how they were feeling at that time and then repeated the same measure immediately after participating in each of the four conditions.

For, the two physical activity conditions, the students were asked to consistently move during the sessions (e.g., jogging on spot if waiting). Movements where quick and fast paced, waiting time was not long (30 seconds). The PA sessions included a warm-up/warm-down phase of 5-10 mins and a core phase of 20-25 minutes. Immediately after each of the sessions, participants headed back to the classroom to continue with their regular learning schedule. For the high cognition, no PA condition students worked in small groups completing a series of brain games and the low cognition, no PA the class watched a short film. The lead researcher then observed six participants per session after each condition and the teacher aide 3-4 participants. Names were randomly selected to ascertain observation order. Lastly, the researcher interviewed the teachers at the end of the week after each condition to gain their perspective of how the interventions affected the students.

3.7 Experimental Conditions

Each participant completed each of the four conditions that varied physical activity and cognitive demand in a 2 x 2 grid (see Table 1). Each condition lasted 25-30 minutes replacing the usual scheduled physical education lessons which on average lasted 10-12 minutes.

Conditions were designed by the lead researcher who is a qualified teacher with fifteen years of teaching experience and is well acquainted with the PE education curriculum. For the low and high cognitively demanding physical activity interventions, input from a black belt Taekwondo martial arts instructor and personal trainer with over twenty years' experience was included. In that way it was ensured that these two conditions would differ *(*see Appendix E for lesson plan). All conditions were delivered by the lead researcher and supported by the classroom teacher and teacher aide of the classroom.

Table 1

Description of physical activity and cognitive demand conditions for a 2x2, within subjects, study design

	High Cognitive Demand	**Low Cognitive Demand**
High Physical Activity	*Combined* (High Activity/High Cognitive) High co-ordination and balance movements combined with problem solving activities that require working memory, inhibition and shifting. Activities shown once (recall) Majority of time in moderately-vigorous intensity	*Aerobic* (High Activity/Low Cognitive) Familiar, simple repetitive movements Supported by visual reminders at each station (recognition). Majority of time in moderately-vigorous intensity

	Cognitive (Sitting/ High Cognitive)	*Low* (Sitting/Low Cognitive)
Low Physical Activity	Mazes, problems solving that require working memory, inhibition and shifting.	Watching short animated films Colouring in.
	Mostly sedentary (sitting) and light intensity (moving to next activity table)	Mostly sedentary (sitting) and light intensity (moving to work tables)

1. Aerobic condition: Lower cognitively demanding physical activities.

The aerobic intervention included activities specifically designed to target moderate-to-vigorous intensity while avoiding high cognitive demands. The focus was on higher repetitive and familiar movements, using a circuit training design (e.g. running, weights, squats. Six circuits were used with groups of 3-5 participants placed at each of the circuit activities. Participants repeated the exercises for 3 minutes, rested for 20-30 seconds and then moved to the next circuit. All groups completed the circuit over 20 minutes. Information with instructions and pictures were placed at each activity to support understanding. All exercises had been demonstrated beforehand and were exercises that most of the participants had experienced previously (e.g. sit-ups, press-ups, star jumps). Warm-up and warm-down was 5-10 minutes. Participants warmed up with a 100 metre jog and warm down with yoga stretching and deep breathing at the end of the circuits. Children were asked to monitor their own intensity level and encouraged by staff walking around to continue exercising (jogging on the spot) if waiting for their turn during some of the activities.

2. ***Combined condition: Higher cognitively demanding physical activities.***

Participants were placed into four groups (4-6 students). Individuals from each group took turns to complete an obstacle course that included a series of complex coordination movements, including martial arts and parkour (e.g. summersaults, jumping over obstacles,). Exercises where demonstrated once with no visual prompts to remind them what to do. At the end of the 4 different courses, participants had to complete a memory test or collect letters that the group had to turn into words when enough letters were collected. Participants had 5 minutes at each activity with 30 seconds break in between to transition. In addition, the instructor would randomly call out a word (e.g. apple or orange) that represented a movement (e.g. jogging while rubbing tummy and patting head). Participants had to stop and do the movements straight away. While waiting for their turn, participants were encouraged to jog on the spot to keep heart rate up. Participants could enter the obstacle course once the person in front had completed 3 of the 8 exercises to keep up the movement pace. Warm up and down involved following instructions from the instructor doing a series of martial arts kicks, punching techniques and teaching them a Taekwondo Poomse (i.e. a carter).

3. Cognitive condition: Higher cognitive demand, sedentary/sitting.

Consisted of 6 seated table activities. Students were placed in small groups and completed paper handouts of individual memory games, word puzzles, mazes, origami and a children's brain game app on the iPad for 5 minutes and then rotated to the next activity. At different stages the instructor would randomly call out a word (e.g. apple or orange) that represented a clapping combination. Participants had to stop what they were doing immediately and do the clapping sequence associated with the word.

4. Low condition: Lower cognitive demand, sedentary/sitting condition.

Participants were instructed to sit or lie quietly and watch two short, animated films. In total the films lasted 10-15 minutes. Students then had to remain seated in the classroom and colour in a picture (chosen by the teacher) for 10-15 minutes. No questions, discussions or activities on the films or artwork were initiated to reduce cognitive demand.

3.8 Measures and data collection

PAQ-C

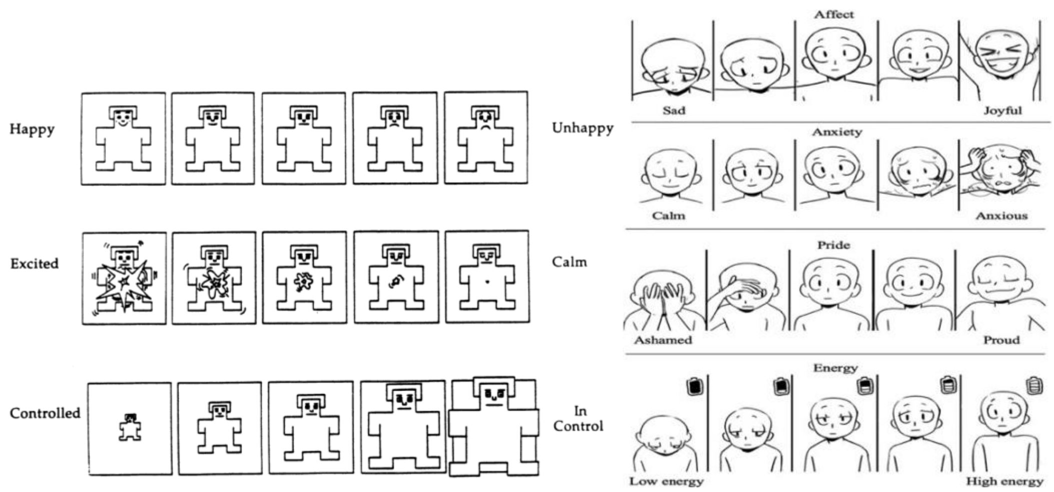
The Physical Activity Questionnaire for Children (PAQ-C) measures physical activities that are linked to common sports and/or physical leisure activities (games, school P.E). The PAQ-C has been shown to be appropriate for children aged 7-14 who attend school experience playtime/recess, and physical education regularly. The PAQ-C strengths are the use of recall cues to support children to remember what physical activities they do, it is also cost and time efficient, and easy to administer to large-scale populations (Kowalski et al., 1997). The PAQ-C is set up to be self-administered using recall to measure the level of physical activity over a 7-day period. The PAQ-C has a total physical activity (PA) score from nine items, where each item is scored using a 5-point scale to indicated how often or intense the participates participation has been doing those physical activities. The first item is an activity checklist with common activities, this supports recall and memory cues to confidently answer the following items. The last item asks if the child was sick or otherwise prevented from engaging in regular PA. Both items are not used in the calculation of the final activity score. When a value from 1 to 5 for each of the items is obtained, the mean of items is taken, resulting in a final PAQ-C activity summary score. A higher score indicates higher levels of activity. Overall, the PAQ- C has had relatively strong correlation coefficients with other physical activity measures compared to other recall measures (Kowalski, Crocker, & Faulkner, 1997). The PAQ-C has been supported as a valid and reliable measure of general physical activity levels from childhood to adolescence (PAQ-A). The PAQ-C demonstrated acceptable psychometric properties with an acceptable-to-good internal consistency, test–retest reliability, and sensitivity to detect gender differences. The reliability of the PAQ-C has been shown to be good in other studies from different countries and with children of different ethnicities (Kowalski et al., 1997). Results confirm a satisfactory internal consistency of the questionnaire ($\alpha = 0.76$), which is in line with other studies reporting similar results (Schmidt et al., 2015).

Multidimensional Visual Scale (AAPE)

The Multidimensional Visual Scale Assessing Affect, Anxiety, Pride, and Energy (AAPE) is designed to be accessible to people who may have limited literacy skills. Studies have shown that the measure is adequate for children and adolescents with a diverse range of cognitive abilities. The AAPE was designed to accommodate young people with ASD, with illustrative images that were found to be most effective in representing emotional state. Four dimensions exist in the measure including 1) Affect: Sad to happy, 2) Anxiety: Calm to anxious, 3) Pride: Ashamed to proud, and 4) Energy: Low to high. The AAPE has been appropriated from the widely used Self-Assessment Manikin (SAM) (see Figure 2).

Figure 2

Example of the SAM and AAPE measure



note. SAM (left side), AAPE measure (right side)

The SAM measure has been commonly used in studies with researchers who want to research emotions. The SAM scale uses illustrative neutral-gender images, that provides participants with a 5-point scale that rates emotional valence, arousal, and dominance (Ricco et al., 2020. However, while the SAM measure has been proven as a useful method in rating participants' feelings, the illustrations used in SAM have not always been found to be easily interpreted (Ricco et al., 2020). In addition, the manual instructions that are read to participants to support understanding is long, even when adapted (words reduced) (Ricco et al., 2020). Ricco et al., (2020) study showed that the long verbal instructions with the measure required higher levels of concentration and language comprehension, therefore limiting children and those with language and communication problems. To compensate for this, the AAPE scale was designed and found to be successful with children, adolescents and individuals diagnosed with Autistic Spectrum Disorder (ASD), with the majority of participants' finding that the AAPE was easier to understand (Ricco et al., 2020). The study showed that the internal consistency of the AAPE, or how the items (e.g. positive affect, low anxiety, pride, and energy) in the measure aligned with one another, was acceptable. For children $\alpha = 0.92$; adolescent $\alpha = 0.71$ (Ricco et al., 2020).

In this study, a discussion with the participants about what the words (e.g., ashamed, and proud) meant and looked like was held with the teacher and researcher before the study began. During the study, the participants circled each category based on how they were feeling 10-20 minutes before condition and within 10 minutes post condition.

Direct observation Form (DOF)

The DOF (McConaughy & Achenbach, 2009) provides a standardised method for recording and quantifying observations of children's behaviour in school classrooms, at playtime/lunch, and in other group settings (see Appendix F for DOF measure). Paraprofessional staff (e.g. teacher aides) are able to be trained to use the DOF for school-based observations. The manual provides clear guidelines and exemplars for how to rate the behaviours during the observations. The DOF requires approximately 15-25 min for each observation. The observer writes a narrative description of the child's behaviour in the classroom and rates their on task or off task behaviour during the last 5 seconds of each 1-minute interval over a ten minute period. Immediately after this 10-min observation. An additional 10-15 min is required to rate the child on 89 problem items, using a 4-point scale. Each point scale represents time seen expressing this behaviour *(a)* 0 = no occurrence, *(b)* 1 = very slight occurrence, *(c)* 2 = definite occurrence with mild to moderate intensity/frequency and less then 3 minutes in duration, *(d)* 3 = definite occurrence with severe intensity, high frequency, or 3 or more minutes in total duration. Item 89 is open-ended for rating other problems not covered by Items 1 through 88. The *0-1-2-3* item ratings are summed to obtain a total raw score for each DOF problem scale. The DOF problem items are scored on five empirically based syndrome scales *1)* Sluggish Cognitive Tempo, *2)* Immature/Withdrawn, *3)* Attention Problems, *4)* Intrusive, *5)* and Oppositional). McConaughy and Achenbach (2009) rated internal consistency alphas from .49 to .87 for the five problem scales. Interrater reliabilities were .88 for the five subscales and .97 for On -task. Abikoff et al., (2002) study noted that most traditional observation measures were limited due to not being able to capture low base rate behaviours, they were conducted in clinical settings, rather than natural settings, or they were limited on the number of behaviours observed. However, the DOF has been shown to be effective in natural environments such as schools. The DOF has been designed to assess a wide range of observable behaviours. For example some scales include more overt behaviours (e.g., "out of seat" and "argues"), whereas others include less overt behaviours (e.g., won't try, and "doesn't get involved with others, withdrawn").

CHAPTER 4
RESULTS

4.0 Statistical Analysis

All statistical analyses were performed using SPSS 29.0 (SPSS Inc, NY, USA). Analysis consisted of the mean and standard deviation for pre and post mood, time spent on task and negative behaviour in the classroom. Figures were created using SPSS 29.0 and Microsoft Excel (Microsoft Corporation, 2018). The Shapiro–Wilk method was used to test normality of the data. This was followed by a two-way repeated measures ANOVA used to investigate the differences of the two independent variables (1) cognitive demand difficulty and (2) movement level. If a significant interaction effect was found ($p < 0.0.5$) , Follow- up post hoc tests, with Bonferroni adjustments were conducted to discern the difference between the 4 conditions. Confidence intervals (CI) 95% were included and statistical significance was set at $p < 0.05$. The effect sizes were calculated to understand the magnitude of the mean differences, and these were interpreted using as 0.01 (small), 0.06 (medium) and 0.14 (large) using partial eta-squared η^2 (Sullivan & Feinn, 2012). Cronbach's alpha coefficient was used to determine the reliability and internal consistency of the 8-item PAQ-C scale. The results indicate that scale mood has good reliability and internal consistency (Cronbach's alpha coefficient = 0.78). Cronbach's alpha coefficient was used to determine the reliability and internal consistency of the (89) item DOF scale. The results indicate that scale behaviour has good reliability and internal consistency (Cronbach's alpha coefficient = 0.89).

The sample consisted of 24 participants aged 7-8 years old, no gender analysis were done as the power was too low. Additional descriptive information collected at (pre) baseline for the participants as shown in Table 2.

Table 2

Means (standard deviations in parenthesis) for Sample Characteristics at Baseline

Sample Characteristics	%/M	Cronbach's Alpha	N of items
Gender			
Male %	70%		
Age (years)	7.79 (.415)		
Ethnicity			
Māori %	37.5 %		
Pākeha %	58.3 %		
Other %	4.2 %		
Physical activity level (PAQ-C)	16.64 (5.09)	.84	8

note. % = percentage, M= Mean.

Results showed that boys overall engaged in higher levels of physical activity (see Table 3). Boys also were involved in more intense physical activities at school in physical education (PE), and during recess (e.g. playtime and lunchtime) (*M*=11.35, *SD*= 3.74) compared to girls (*M*=9.00, *SD*=2.52).

Table 3

Mean and Standard Deviation of Physical Activity Levels of Participants at Baseline

PAQ-C Scale	All (n=24)	Female (n=7)	Male (n=17)
	M (SD)	M (SD)	M (SD)
Physical exercise (PE)	2.96 (.999)	2.71 (.951)	3.06 (1.02)
Playtime	2.67 (1.40)	1.86 (.900)	3.00 (1.46)

Lunch	1.92 (1.01)	2.29 (.951)	1.76 (1.03)
After school	2.08 (.974)	2.29 (1.25)	2.00 (.866)
Late afternoon	1.50 (.590)	1.29 (.490)	1.59 (.618)
Weekend	2.29 (.690)	2.00 (.580)	2.41 (.712)
Intensity	3.12 (1.26)	2.14 (.690)	3.53 (1.23)

note. Self-reported measure of general physical activity levels over the last 7-days before 1st intervention. PAQ-C item score 1-5, with 5 being highest involvement for PA engagement.

4.1 Mood

At pre-test, the average mood rating was (M = 10.69, SD = 1.23), with skewness of -.627 and kurtosis of -.187. Approximately 75% of children scored 11 at pre-test, meaning their mood was moderate. Approximately 50% of females scored 10, with boys scoring slightly higher at 11. Straight after each of the conditions, participants completed the AAPE again. The average mood rating across conditions was M=15.69 (SD = 1.68), with skewness of -1.75 and kurtosis of 4.07. Here, only 5% of children scored 10 at post-test and 95% scored 12 or above. Both the *Combined* high and low *aerobic* cognitively demanding (CD) physical activity conditions showed an increase in positive mood compared to the *low* CD/sitting condition, post-test. Interestingly, the *Cognitive* (high CD, sitting) condition produced the highest average improvement in positive mood across all conditions for both males and females (see Table 4).

Table 4

Pre and Post Mean and Standard Deviation of Mood of Participants for all Conditions

Multidimensional Visual Scale (AAPE)	Aerobic Low CD/PA	Combined High CD/PA	Cognition High CD/low PA	Control Low CD/Low PA
Total Mood	M (SD)	M (SD)	M (SD)	M (SD)
Pre	10.25 (2.23)	10.62 (1.96)	11.17 (1.24)	10.75 (1.85)
Post	16.54 (2.97)	16.08 (2.74)	17.37 (2.28)	12.79 (1.06)
Female				
Pre	9.75 (2.5)	9.50 (2.67)	11.00 (.92)	10.62 (1.50)
Post	16.00 (1.85)	16.80 (1.64)	17.75 (2.25)	12.75 (.70)
Male				
Pre	10.50 (2.33)	11.18 (1.32)	11.16 (1.23)	10.81 (2.04)
Post	16.81 (3.4)	15.68 (3.13)	17.37 (2.28)	12.81 (1.22)

note. (CD) Cognitively demanding level, (PA) Physical activity, Low PA Sitting. Total maximum score is 20 which represents a highly positive mood.

When mood was subcategorised (e.g. affect, anxiety, pride, and energy), results showed on average the *cognitive* (high CD/sedentary/sitting) condition had the highest improvement in mood across all four sub-categories at post-test (see Table 5).

Table 5.

Pre and Post Mean and Standard Deviations of Mood Subcategories for Participants for all Conditions.

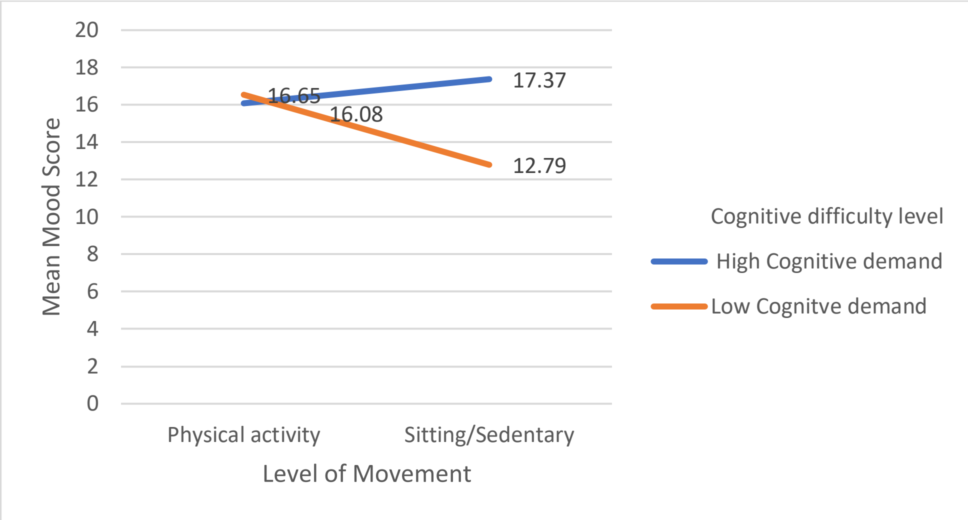
Mood subcategories	Aerobic Low CD/PA M (SD)	Combined High CD/PA M (SD)	Cognitive High CD/Sed M (SD)	Control Low CD/Sed M (SD)
Affect				
Sad - Happy				
Pre	2.58 (.88)	3.17 (.81)	3.13 (.79)	3.13 (.79)
Post	4.33 (.63)	4.17 (1.20)	4.38 (.49)	3.13 (.44)
Anxiety				
Proud-Anxious				
Pre	3.08 (.83)	2.96 (.75)	2.54 (.77)	2.54 (.77)
Post	4.29 (.85)	4.17 (1.20)	4.50 (.78)	4.38 (.49)
Pride				
Ashamed - Proud				
Pre	2.46 (.77)	2.29 (.62)	3.42 (.77)	3.08 (.40)
Post	4.08 (1.21)	4.04 (.99)	4.50 (.78)	3.00 (.00)
Energy				
Low - High				
Pre	2.13 (.99)	2.21 (.83)	2.08 (.71)	2.00 (7.8)
Post	3.83 (1.27	3.29 (1.04)	4.50 (.78)	2.29 (.85)

*note. (*CD) Cognitively demanding level, (PA) Physical activity, (Sed) Sedentary/Low movement/Sitting. Anxiety subcategory was reverse scored during analysis. Highest rating for positive mood per subcategory, 5 total.

A two-way repeated measures ANOVA was run to determine the effect of movement level and cognitive demand difficulty on mood. As assessed by the Shapiro-Wilk test of normality, no suggested outliers were found greater then ± 3 standard deviations. The results revealed the main effect of physical activity level on mood was significant $F(1,23) = 7.446$, $p = .012$, partial η^2 . 245. In addition, the main effect of cognitive demand difficulty on mood was significant $F(1,23) = 37.176$, $p = .001$, partial η^2 . 618. However, these main effects were qualified by a significant interaction between cognitive demand and movement , $F(1,23) = 41.382$, $p = .001$, partial $\eta^{2\,=}$ .643 (refer to Figure 3). In other words, this meant the change in mood scores was dependent on both factors, the level of movement and cognitive demand difficulty.

Figure 3

The Effect of Movement and Cognitive Demand Level on Mood scores.



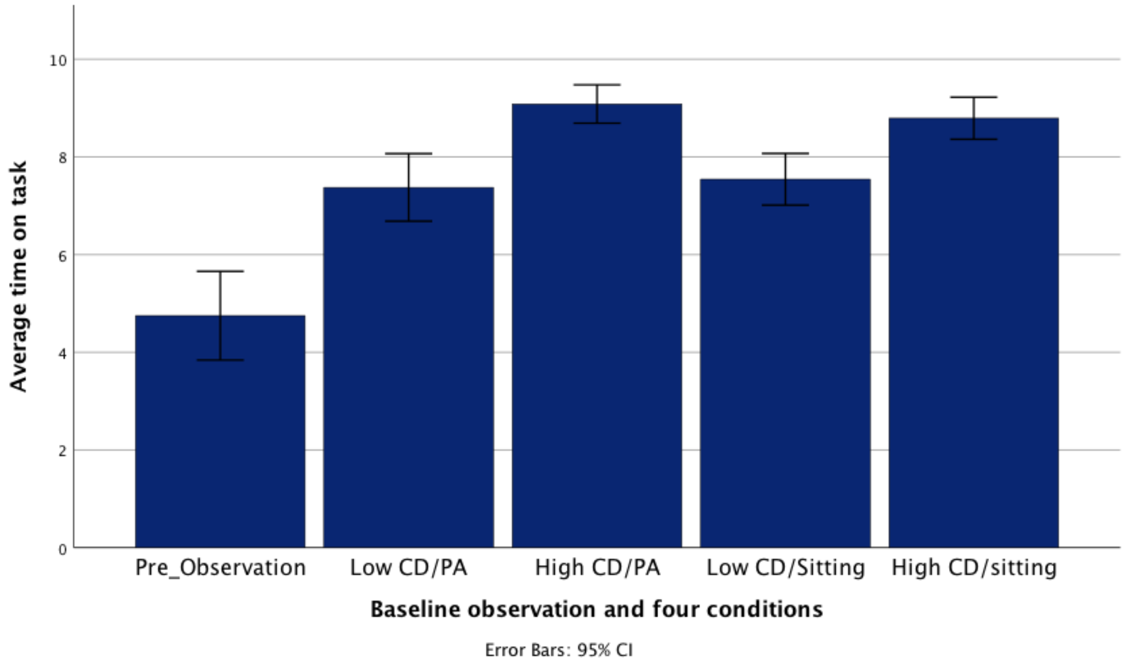
To explore the nature of the interaction, simple main effects tests were calculated. For physical activity level mood was not statistically significantly different in the *combined* (PA/ high CD) post condition (M = 16.08, SD = 2.75) compared to the *aerobic* (PA/low CD) post condition (M= 16.54, SD = 2.96), F(1, 23) = .569, p. 458 a mean difference of 0.46, CI [0.79, 1.71]. For cognitive demand difficulty, mood was statistically significantly different, with participants feeling more negative in the *Low* (no PA/low CD) post condition (M = 12.79, SD = 1.06) compared to the *cognitive* (no PA/high CD) post condition (M = 17. 37, SD = 2.29) post interventions F (1,23) = 126.231, p = < .001, a mean difference of 4.59, 95% CI [3.74, 5.42]. Mood was statistically significantly different with participants feeling more positive in the *cognitive* (no PA/CD) post condition compared to the *combined* (PA/CD) post condition, F(1, 23) = 4.724, p = .040, a mean difference of 1.2 , 95 % CI [.062, 2.52]. Taken as a whole these results suggest that participants mood improved the most after doing higher cognitive demand activities without physical activity.

4.2 Attention: Time on-task

Participants were observed 1-2 weeks before the first condition using the Direct Observational Measure (DOF) for on/off task behaviour over ten minutes, across a period of two hours. At baseline (pre), the average time on-task was 4.75 minutes (SD = 2.15) with skewness of 0.11 and kurtosis of -1.228. Approximately 75% of children were on-task for 6 or less minutes, with both males and females showing similar averages for time on-task at baseline (refer to Figure 4). Immediately after each of the conditions, the participants were observed again. On average participants were on-task for 2.50-4.75 minutes longer across all four conditions compared to their baseline time on-task.

Figure 4

Participants Time On-Task at Baseline Observation and Across all Four Conditions.



The two higher cognitively demanding conditions both for the physical activity and sitting activities showed that on average, participants were on-task for 4- 4.75 minutes longer compared to baseline (Pre) observation (see Table 6).

Table 6

Mean and Standard Deviation of Observed Minutes On Task for Participants at Baseline and All Conditions

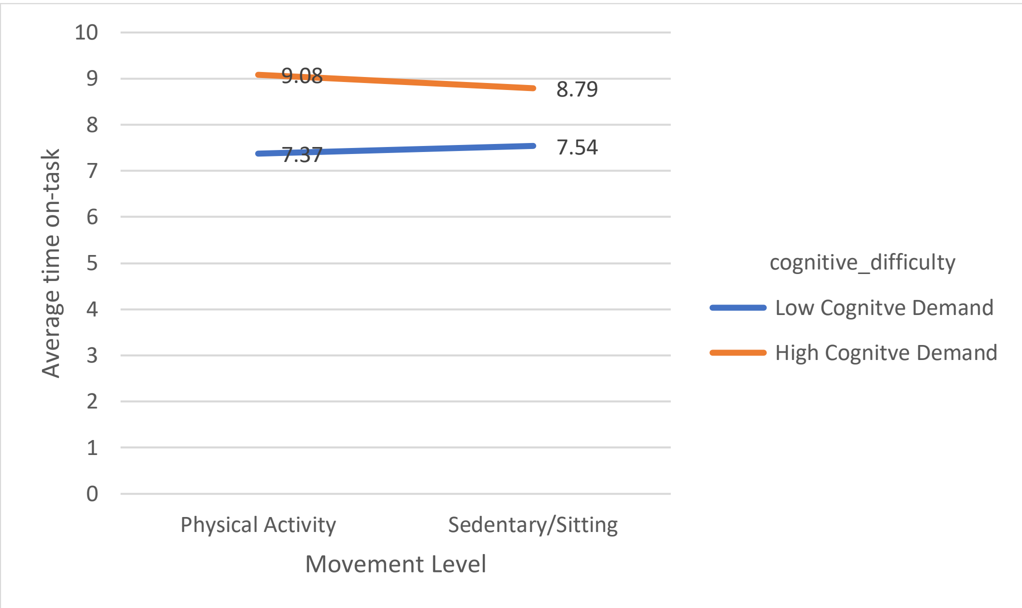
Variable	Baseline	Aerobic Low CD/PA	Combined High CD/PA	Cognitive High CD/Sed	Low Low CD/Sed
All	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
On task	4.75 (2.15)	7.38 (1.64)	9.08 (.93)	8.79 (1.02)	7.54 (1.25)
Female	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
On task	5.29(1.70)	8.29 (1.11)	9.29 (.75)	9.00 (1.00)	8.29(.76)
Male	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
On task	5.24(2.36)	7.00(1.30)	9.00(1.00)	8.71(1.04)	7.00(1.70)

note. (CD), Cognitive Demand, (PA), Physical activity, (Sed), Sedentary/sitting. Total time observed for on/off task behaviour was 10 minutes.

A two-way repeated measures ANOVA was run to determine the effect of movement intensity and cognitive demand difficulty for time on-task behaviour in the classroom post each condition. As assessed by the Shapiro-Wilk test of normality, no outliers were found greater then ± 3 standard deviations. The main effect of movement level on time on-task behaviour was not significant $F(1,23) = .087$, $p = .770$, partial η^2 .004. However, the main effect of cognitive demand level on time on task behaviour was significant, $F(1,23) = 51.969$, $p = .001$, partial η^2 .693. However, these main effects were qualified by a significant interaction between cognitive demand difficulty and movement level, F (1,23) = 4.467, p = .046, partial η^2 .163 (refer to Figure 5). These results suggest that the change in time-on task score were dependent on the level of movement and cognitive demand difficulty.

Figure 5

The Effect of Movement and Cognitive Demand Level On Time On-Task.



To explore the nature of the interaction, simple main effects tests were run. For physical activity level, time on-task was statistically significantly different with participants on-task longer in the *combined* (PA/ high CD) post condition (M = 9.08, SD = (.93) compared to the *aerobic* (PA/low CD) post condition (M= 7.37, SD = 1.64), F(1, 23) = 46.082, p. <0.01 a mean difference of 1.76. CI [1.19, 2.22]. For cognitive demand difficulty, time on-task was statistically significantly different with participants on-task longer in the *cognitive* (no PA/high CD) post condition (M = 8.79, SD = 1.02) compared to the *Low* (no PA/low CD) post condition (M = 7.54, SD = 1.25), F (1,23) = 35.204, p = < .001, a mean difference of 1.25

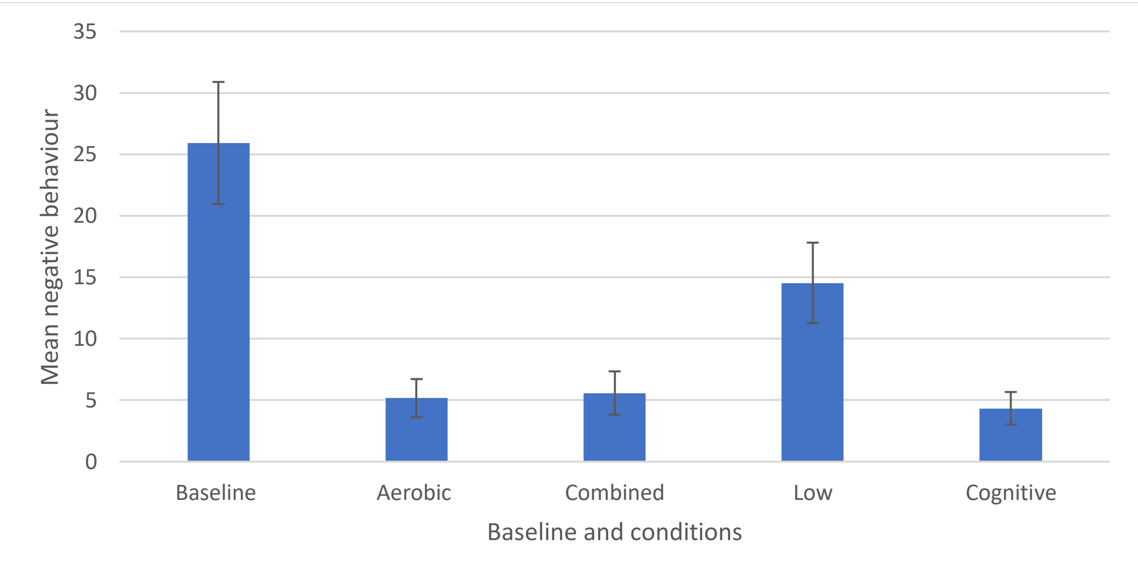
minutes, 95% CI [1.68, .81]. Time on-task was not statistically different in the *combined* (PA/ high CD) post condition (*M* = 9.08, *SD* = .93) compared to the *Cognitive* (no PA/high CD) post condition (*M*= 8.79, *SD* = 1.02), *F*(1, 23) = 1.881, *p*. 183, a mean difference of .29 seconds, CI [1.18, 2.22]. In summary, these results show that engaging in higher cognitively demanding activities with or without physical activity increases children's ability to stay on task for longer in the classroom than lower cognitively demanding activities with or without physical activity.

4.3 Classroom Behaviour

Participants were observed 1-2 weeks before the first condition using the Direct Observational Measure (DOF) behavioural checklist that measures slow cognitive response, immaturity, attention, intrusive and oppositional behaviours in the classroom. At baseline, participants displayed higher negative behaviours in the classroom compared to the four conditions (refer to Figure 6).

Figure 6

Participants Negative Behaviour at Baseline and all Conditions.



note. Lower score, less negative behaviours observed in the classroom.

When behaviour was subcategorised (refer to Table 7), baseline results showed on average males scored lower at sustaining attention (*M*= 6.12, *SD* = 2.98) compared to females

(M = *3.57*, *SD* = 1.81) and scored higher in oppositional behaviours (*M* = 4.06, *SD* = 2.99), compared to females (*M* = 1.71, *SD*, 1.50).

Table 7

Mean and Standard Deviation of Observed behaviour for Participants at Baseline and All Conditions

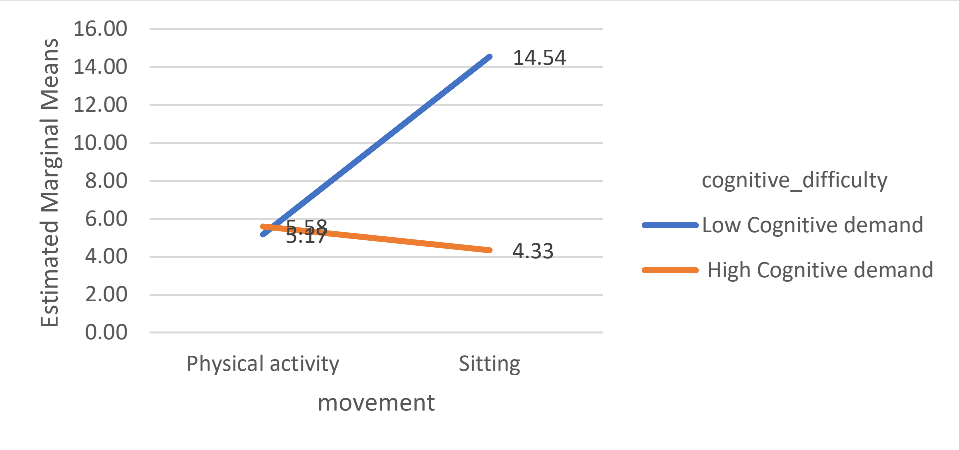
DOF Scale Empirically based Syndromes	**Baseline**	**Aerobic** Low CD/PA	**Combined** High CD/PA	**Low** Low CD/Sed	**Cognitive** High CD/Sed
All	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Sluggish cog tempo	7.20 (2.41)	1.46 (1.29)	3.29(2.75)	4.42 (2.81)	1.17 (1.30)
Immature/Withdraw	5.42 (2.95)	1.04 (1.08)	1.29 (1.43)	2.00 (1.79)	.13 (.448)
Attention problems	5.38 (2.90)	.67 (.702)	.50 (.834)	2.96 (1.60)	1.71 (1.39)
Intrusive	4.54 (3.39)	1.63 (1.71)	.42 (.830)	2.71 (2.59)	1.08 (1.44)
Oppositional	3.38 (2.830	.38 (2.83)	.08 (.282)	2.46 (2.20)	.25 (.532)
Female					
Sluggish cog tempo	7.28(1.38)	1.14 (.69)	2.85 (1.57)	4.43 (3.87)	1.14 (.69)
Immature/Withdrawn	4.43 (2.76)	.43 (.54)	.428 (.77)	1.14 (.69)	.00 (.000)
Attention problems	3.57 (1.81)	.14 (.38)	.00 (.000)	2.43 (1.61)	.86 (.90)
Intrusive	4.29 (2.98)	2.14 (2.41)	.43 (.535)	2.50 (1.71)	1.43 (1.62)
Oppositional	1.71 (1.50)	.00 (.000)	.00 (.00)	1.43 (1.13)	.00 (.000)
Male					
Sluggish Cog tempo	7.17 (2.76)	1.59 (1.46)	3.47 (3.14)	4.41 (2.40)	1.18 (1.51)
Immature/Withdrawn	5.82 (3.00)	1.29 (1.16)	1.65(1.50)	2.35 (2.00)	.18 (.529)
Attention problems	6.12 (2.98)	.88 (.697)	.71 (.920)	3.18 (1.59)	2.06 (1.43)
Intrusive	4.65 (3.62)	1.41 (1.37	.41 (.939)	2.76 (2.93)	.94 (1.39)
Oppositional	4.06 (2.99)	.53 (.717)	.12 (.332)	2.88 (2.42)	.35 (.606)

note. (cog) cognitve, (Sed) Sedentary/sitting, (CD) Cognitive Demand.

The main effect of movement level on behaviour was significant (*F* (1,23) = 7.446, *p* = .012, partial η^2.672). Additionally, the main effect of cognitive demand level on behaviour was significant (*F* (1,23) = 37.176, *p* = .001, η^2.718). However, a two-way ANOVA revealed that there was a statistically significant interaction between the effects of movement level and cognitive demand difficulty (*F* (1,23) = 37.176, *p* = .001, η^2.683 (refer to Figure 7). This shows that the change in behaviour scores were dependent on the level of movement and cognitive demand difficulty.

Figure 7

Observation of Negative Behaviour Across All Four Conditions



note. lower score, less negative behaviours in classroom.

For physical activity level, behaviour was not statistically significantly different in the *combined* (PA/ high CD) post condition (*M* = 5.59, *SD* = (4.17) compared to the *aerobic* (PA/low CD) post condition (*M*= 5.17, *SD* = 3.60), *F*(1, 23) = .302, *p*. 588 a mean difference of .41 in behaviour scores, CI [-1.15, 1.98]. For cognitive demand difficulty, behaviour was statistically significantly different with higher negative behaviours observed in the *Low* (no PA/low CD) post condition (*M* = 14.54, *SD* = 7.75) compared to the *cognitive* (no PA/high CD) post condition (*M* = 4.33 *SD* = 3.16), *F* (1,23) = 75.297, *p* = < .001, a mean difference of 12.64, , 95% CI [7.77, 12.64]. Behaviour was statistically significantly different in the *combined* (PA/high cognitive) post condition (*M* = 5.58, *SD* = 4.16) compared to the *cognitive* (no PA/high cognitive) post condition (*M* = 4.33, *SD* = 4.33) *F (1,23 = 4.434, p = .046*, a mean difference of *1.25 , 95% CI [.022-2.47]* with an increase in negative behaviours observed in the high cognitive, physical *(combined)* condition compared to the high cognitive, no physical activity *(cognitive)* condition. These results suggest that engaging in physical activity (PA) with low CD reduces observed negative behaviour compared to low CD with no physical activity. However, when cognitive demand (CD) is increased, combining physical activity (PA) results in a small increase in observed negative behaviours compared to doing only higher cognitively demanding (CD) activities alone. Together, higher cognitively demanding (CD) activities alone has been shown to be most effective in reducing negative behaviour in the classroom.

4.4 Teacher Perceptions

An exit interview was provided and completed by both of the teachers (see Appendix G for questions). Generally the teachers believed that both the physical activity conditions were beneficial for the students, subjectively both did observe more focussed behaviour after the students participated in the physical activity sessions. One teacher noticed *"some of the students were more tired later in the day (after lunch) after completing the high cognition physical activity condition. They seemed a bit more slow with answering my questions and moodier".* However, it was also mentioned by the same teacher that straight after one of the CD/PA sessions the classroom had to do a writing assessment. *"I had to do a writing assessment with the classroom. Normally, the students struggle to remain focussed for 40 minutes to do this. However, I have to be honest, I was impressed by their focus, including the students who I know struggle with writing".* The other teacher noticed that after both the PA sessions a few of her students who often struggle to transition quickly into their learning tasks displayed more independence (e.g. less need for the teacher to guide them) and seemed more focussed. Furthermore, one teacher noticed that the students seemed like they were in a better mood doing the learning activities after the higher cognitive condition with no PA. *"Students were smiling, getting on with each other and, happily discussing the brain activities while doing their learning task".* Both said that they felt that they would be easily able to implement the physical activity conditions, and noticed that overall the students seemed to enjoy doing the martial arts exercises. Both teachers noticed that specific students who often choose to *'sit out'* or make excuses that they weren't feeling well during regular PE, fully participated in the intervention PA activities.

CHAPTER 5
DISCUSSION

5.1 Overall Findings

The purpose of this study was to examine whether the implementation of different levels of physical and cognitive exertion improved primary-aged children's mood, attention, and behaviour in the classroom. It was hypothesised that (1) engaging in physical activity with either high or low cognitive demand would improve mood, attention, and behaviour relative to the normal classroom routine (baseline). And (2) that the effect on mood and behaviour would show the most improvement after the children completed the cognitively demanding physical activity intervention (combined) (Egger et al., 2019; Schmidt et al., 2016).

Contrary to hypothesis (1) results showed that all the conditions (e.g., low, and high PA and low/high CD) had an immediate improvement in participant's mood and behaviour in the classroom after completing one session compared to baseline. Participants reported feeling calmer and happier and on average were on-task with learning activities 4-4.75 minutes longer than baseline. In addition, negative behaviours decreased significantly overall. For example, rates of disturbance towards peers and teacher, impulsivity (i.e., calling out), slower responses listening to instructions, and settling down during transitions improved across all four conditions.

These results support studies that have investigated the effects of different *'brain breaks'* at school, including physical movements, listening to music, and making art. Results of these studies showed significant improvements in mood and decreases in the frequency of negative behaviours (Carlson et al., 2015; Mahar et al., 2006; Orlowski et al., 2013; Howie et al., 2014; Drake, 2021). Similar results were found for on-task behaviour increasing after implementing breaks that included physical and non-physical activities (e.g., singing, listening to a song) (Carlson et al., 2015; Mahar et al., 2006; Orlowski et al., 2013; Howie et al., 2014).

Therefore, this study's results suggest that starting the school day with a physical, and/or a non-physical activity that includes either cognitively demanding physical exercises, tasks such as colouring in or brain games (e.g., mazes), in principle, could contribute to the improvement of children's mood and behaviour in the classroom (Carlson et al., 2015).

Physical activity conditions

This study found that the two physical activity conditions (e.g., *aerobic and combined*), results were significant in producing a larger effect on mood, attention, and behaviour when compared to sitting while watching a short film *(low condition)*. These findings are similar to Ellenberg and St Louis-Deschenes (2010) study which compared 30 minutes of stationary bike riding with sitting and watching TV. Their study demonstrated that participant's attention and processing time when responding to questions improved more after engaging in the physical activity condition.

The results of this study also showed that physical activity (PA) with higher cognitive demand (*combined condition*) showed a significant difference between physical activity with lower cognitive demand (*aerobic*) for time-on-task. As the participants stayed on task for 1.7 minutes longer after engaging in the higher cognitively demanding exercises. However, no difference between the PA conditions was shown for mood and behaviour. These results are similar to studies that have shown that higher cognitively demanding physical activities compared to repetitive aerobic PA activities have stronger positive effects on cognitive abilities and behaviour in children (Pesce et al.,2013; Crova et al., 2014; Schmidt et al., 2015; Benzing, et al., 2016; Egger et al., 2019; Oppici et al; 2020; Nejati et al., 2021; Meijer et al., 2021; Vazou et al., 2021). However, it is important to mention that only Egger et al., (2018) study included a cognitive demand condition only. This study showed that the combined group (high CD/PA) benefited the most in cognitive tests (e.g., shifting) and math performance (Egger et al., 2018). However, results also demonstrated that the high cognitive demand only condition also increased in math performance. As for the aerobic group (low CD/PA), no effects were found.

To my knowledge, no previous studies have specifically explored the effects of a cognitive demand only condition on time-on-task and mood. Furthermore, the majority of studies in this area have used cognitive tests such as the Flanker test of inhibition and the d2 test of attention (Crova et al., 2014; Schmidt et al., 2015; Benzing, et al., 2016; Egger et al., 2019; Oppici et al; 2020; Nejati et al., 2021; Meijer et al., 2021; Vazou et al., 2021.Therefore, the results of these studies cannot be directly compared to this study's outcomes because of the differences in conditions used and measures.

Higher Cognitive Demand and Physical Activity

In contrast to hypothesis (2) the study did not find support for the higher cognitively demanding physical activity intervention eliciting the greatest improvement in mood and behaviour. Instead, the higher cognitive demand only *(cognitive)* condition demonstrated the highest results for improving mood and behaviour. However, no significant difference was found for time-on-task for the *combined* and *cognitive* conditions. This finding contrasts with Egger et al., (2019) study comparing these four conditions in primary school-aged children, which found larger effects for cognitively demanding physical activities. However, again this study measured cognitive abilities such as working memory (WM) and inhibition using neuropsychology tests, not specifically mood, and behaviour. Additionally, the study was conducted over a longer period (e.g., 20 weeks) which may have accounted for the results (Egger et al., 2019).

Therefore, the results of this study suggest that doing an acute bout (1 session) of higher cognitive demand activities only may be most effective in improving children's mood and behaviour while doing learning tasks in the classroom. In consideration of this outcome, and that no other study has found substantial support for higher cognitive demand only as being most effective for mood and negative behaviour in the classroom, some factors could explain the current results (Egger et al., 2019). Including, the study's physical activity and cognitive demand difficulty, duration, and individual characteristics such as fitness level, cognitive ability, and level of enjoyment.

Firstly, the amount of cognitive demand in the physical activity condition may have been too high compared to the cognitive demand condition without physical activity (Schmidt et al. 2016; Egger et al., 2019). The high cognitive physical activity condition consisted of moderate to vigorous intensity exercises, with a high level of cognitive flexibility and memory ability required to complete the tasks. For example, the martial art move demands (calling out different moves quickly) or working under pressure on the letter task at the end of the obstacle course (creating words together). Whereas the cognitive condition moved at a slower pace and involved no collaboration. Therefore, some participants may have found it more difficult to inhibit negative behaviours in the classroom after the combined (CD/PA) condition compared to the cognitive (CD/no PA) condition because they were more physically and cognitively depleted (Muraven et al., 1998; Audiffren, & André, 2015; Schmidt et al., 2016).

Additionally, it is possible that the cognitively demanding physical activity condition may have been too intense or lasted too long (i.e., 25-30 min) for children in this age range (i.e., 7-8). Studies have suggested that longer durations of physical activities that include higher cognitive demands require higher amounts of self-control (e.g., collaboration, focus) therefore impairing the ability to self-regulate in the classroom after completing these exercises (Englert, 2016, Egger 2018). Most of the studies showing positive effects of cognitive demand physical activities used durations ranging from 10 to 20 min (Benzing et al., 2016; Koutsandreou et al., 2016; Schmidt et al., 2016; Vazou & Smiley-Oyen, 2014). Findings by Howie et al. (2014) who examined exercise duration in participants aged 9-10 found that a duration of 15 min showed positive effects on cognitive measures and durations longer than 35 min had no effect. In Chang et al. (2012) review it was reported that a duration between 12 and 25 min improves cognitive functions than shorter or longer durations for children. Additionally, Gallotta et al., (2015) study examining a cognitively demanding physical activity intervention that lasted 40 min led to lower cognitive improvement compared to physical activity without cognitive demand. Although for this current study, both the physical activity conditions were designed by a teacher with experience working in physical education to ascertain that the cognitive load was age appropriate. It is still possible that the higher cognitive demand PA session was too demanding, resulting in less of an effect (Best., 2010; Pesce et al., 2013: 2021; Schmidt et al., 2016). Furthermore, a few studies have found that physical activity may lead to a state of excitability which could deteriorate behaviour for a certain period immediately after completing the exercises (Hannaford, 2005; Jensen, 2005; Kibbe et. al., 2011; Weslake & Christain, 2015). This was shown in Kibble et al., 2011 study that showed participants who engaged in higher-intensity physical activity breaks took 5-8 minutes longer to settle down physically and verbally compared to lower intensity physical activities (Hannaford, 2005; Jensen, 2005; Kibbe et. al., 2011; Gay, 2013).

Additionally, individual fitness level may have affected the results. Studies have shown that children with lower fitness levels do not process information as efficiently as fitter children (Chaddock-Heyman et al, 2014; Hogan et al., 2015; Herting et al., 2016; Lopez-Vicente et al., 2017). Therefore, participants who were normally less active may have found the physical activities conditions too challenging compared to the more active participants (Chaddock-Heyman et al, 2014; Hogan et al., 2015; Herting et al., 2016; Lopez-Vicente et al., 2017).

Lastly, mood was shown to be most improved after engaging in higher cognitive demand activities alone. To account for this result, studies have suggested that mood improves if individuals find tasks interesting and/or novel ((Isen and Reeve, 2005; Pressman et al., 2010; Wienke & Jekauc., 2016). Based on this concept the participants in this study may have found specific conditions more enjoyable based on their abilities, strengths, and needs. For example, some participants may find the higher cognitive, sitting activities more enjoyable to complete than the higher cognitively demanding exercises, therefore affecting mood outcomes.

From this perspective, the current findings could be interpreted as suggesting that schools that want a strategy that will show the most improvement in behaviour should focus on cognitively demanding activities without physical activity. The interpretation would not be wrong, but not all of the story. Physical activity with higher cognitive demand did demonstrate a higher positive outcome in children's mood, time-on-task, and behaviour compared to baseline, lower CD/PA and sitting watching a movie. Therefore, physical activity that combines exercises that require more cognitive demand should still be integrated into the school day. Particularly when no detrimental long-term effects for physical activity have been published so far (Schmidt et al., 2015; Benzing, et al., 2016; Egger et al., 2019; Oppici et al; 2020; Nejati et al., 2021; Meijer et al., 2021; Pesce et al., 2021).

Overall, the results suggest that personal preference, physical, cognitive ability, and age may contribute to the level of improvement in mood and behaviour after completing each of these conditions. One student may prefer doing a maze sitting down, whilst another might find enjoyment in engaging in more complex physical activities. Either way, this study demonstrated that a short break at the beginning of the school day that uses any of these conditions has been shown to be effective for students' ability to engage positively in their learning tasks at school.

5.2 Limitations and Future Directions

One limitation of the current study is the potential for bias or lack of objectivity. The lead researcher conducted the intervention activities and measures including visiting the classroom multiple times which formed relationships with the students in the class. However, this also could be a strength as she knew what the participants' normal range of mood and behaviour was before the study began. In addition, teacher aides were used to observe some participants and collaborated with the researcher during analyse of the measure. Future studies could film the students in the classroom after each intervention as an observational backup, as it is possible to miss behaviours when multiple students are observed during the same period.

Another limitation is working in schools, which can present challenges in finding appropriate spaces to carry out physical activities. In this study, the weather was not ideal and both schools had no sheltered outdoor areas. This meant that there may have been inconsistency with how strenuous the physical activities were. For one school the physical activities had to be carried out for some of the sessions in the classroom. This may have meant that the students did not move as much as they did when they got to do the activities outside with more space available. Future studies could use heart rate monitors which could provide further data on the intensity level and support to keep the intensity level consistent. Future studies should also consider observing multiple time points across the whole day and/or the effect of these conditions over a longer period (e.g., weeks, months, years). Additionally, studies should continue to examine the effects of behaviour and mood using differing levels of duration (e.g.,10, 20, 30 minutes) with different ages of children using the conditions used in this study.

Another limitation is not collecting enough data on individual characteristics such as gross motor skill coordination, and academic abilities. Studies have shown that children with lower academic achievement may experience attentional overload at a quicker rate. (Schmeichel, 2007; Jager et al., 2014). Following this line of argument, it is uncertain whether some participants may have been over or under-challenged. Future studies should access this information to ascertain if academic ability has any effect on these outcomes (e.g., mood and behaviour).

Additionally, future studies should examine neurodiversity and the way that students with those disabilities respond to the conditions explored in this study.

The mood measure used in the study included a subcategory on energy levels. Naturally, participants scored lower for energy after doing the physical activity conditions. This may have led to the lower average mood score for the PA conditions compared to the sedate/sitting conditions. Future studies should consider using more than one mood measure to compensate for this.

Finally, research still lacks a measure for cognitive demand that can be used with children. Therefore, it is difficult to know if the conditions reflected the true cognitive demand level the study was aiming for. Future research should attempt to create a valid measure for cognitive demand level as it is important to understand when different children reach their optimal cognitive load. Studies have suggested that children who exercise at their specific skill level show higher beneficial effects on cognitive and behavioural outcomes (Egger et al., 2018; Pesce et al., 2021).

5.3 Conclusion

The present study addressed a topic that has significant implications for children's abilities to function successfully in school and to reach their full potential in education. Having a positive mood and being able to focus on learning is crucial not only for academic performance but also individual's social connection, health, and well-being. Negative behaviour in the classroom causes distractions for the teacher, other students, and the individual students themselves from thriving in this environment. However, by examining interventions, such as short bouts of physical activity that consider combining different levels of cognitive demand, it is possible that these issues could be addressed. Particularly when these activities are easy to implement in the classroom and of little cost to the school.

In conclusion, completing physical activities at the beginning of the school day has shown improvement in mood, attention, and behaviour for students in the classroom. This study found that consideration should also be given to the benefits of non-physical activities that challenge, distract, and calm students. From this viewpoint, at the very least it can be said that time spent participating in being active or engaging in the activities used in this study will not worsen mood, attention, and behaviour.

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APPENDICES

Appendix A. BOT Consent Letter

To the Board of Trustees,
(date)

About the researcher
Hi there, my name is Kate Shepherd and I am currently working as a teacher and finishing my psychology master's degree at Massey University. As a part of my study, I am required to carry out a research project and I am hoping to receive permission to carry it out at your school in Term 2 this year.
About the research & background
I am interested in researching how physical activity/PA can improve concentration/focus, mood, and behavior in children aged 8-11years old.
Research is emerging in support of physical activities (PA) showing an improvement in concentration levels, and focus. Furthermore, research is showing that PA enhances neural growth and development, and improves behavioural functioning by increasing the ability to focus, lowering stress, and decreasing impulsivity.
Research focused on physical activity is increasing, particularly in relation to adults, however, further research is still required to understand how PA effects children and their ability to learn in the classroom.
Aim of the study
I will be focusing on children aged 8-11 years old. They will undertake a program that has been adapted from these studies where they will complete moderate/high intensity movements that are cognitively engaging (box-fit, Taekwondo techniques and HITT (High intensity training) exercises/movements.
It is important that the program is fun and engaging for all students and easy for teachers to carry out as a part of their P.E component if it is to be used in schools. Furthermore, it is a low-cost option as the resources most likely already exist within schools.
Overall, this research aims to explore whether children experience greater improvement in their concentration levels, behaviour, and mood after exercise to ascertain if this can be considered as a complementary, regular addition to the teaching program to support children to be successful in their learning.
Details of the intervention
I would like for the school to choose one classroom for myself to carry out the intervention. Information about the study and consent provided (forms attached) will be sent home with the students by the school. It is important that I do not receive any information about the children to sustain confidentially and bias from myself as a researcher.
The program will be led by myself and I am hoping with the support of two of your teacher aides (to help with the exercise stations). It will consist of a 30-40 min session 1-2 times a week over a period of 6 weeks.
Both the caregivers and child must provide written consent to participate. If any caregivers or children choose not to consent to the program. They will remain in the classroom with the teacher during the sessions.
Students will complete exercise stations in small groups that each last 5- min with an estimated total of 25 min of MVPA. The balance of time will be used for warm up/down and transitions (e.g., drink breaks, changing activity stations).
The activities will be done outside, however, if the weather is not good I hope to be able to use the hall.
Any equipment that I will need, the school already has. Any other equipment I will bring with me. So, there will be no cost involved for the school.
Collecting data
I will be visiting the classroom 1-2 weeks before the start of the intervention to complete some baseline measures and observe the students in their classroom. I will then run the 6-week intervention. During the intervention immediately after a weekly session 3-5 different students in the classroom will be randomly selected to complete attention tests (take 10-15 minutes) and be observed on their concentration and on-task behaviour by myself for 2-3 hours. Once the 6-weeks is completed I hope to have collected data on all of the participants in classroom.
Post- measures will be completed 1-2 weeks following the program; teachers, parents, and staff will also provide overall improvement ratings at the end of the program.

Participant/student recruitment

- The school will need to identify which classroom is chosen for my research.
- The school will send home the information and consent (forms attached).
- I will make myself available Wednesday mornings before the intervention starts for caregivers to discuss any further questions and hand in the written consent if they would like for their child to participate.

Overall, I am hoping that this research contributes to supporting all children and education staff to learn about the effects of engaging in physical activity that may improve learning, confidence and mood.

Regards,
Kate Shepherd

Appendix B. Parental/Child Study Information

PARTICIPANT INFORMATION FORM

Your child is being invited to take part in study to understand how different levels of brain/cognitive demand and physical activity/inactivity impacts children's concentration and behaviour in the classroom. Before you decide, it is important for you to understand the study and what it will involve for yourself and child. Please take time to read the following information carefully. If you have any further questions or need more information, please get in touch with me. I can make myself available by email, phone and also can meet you in person at school if you have any further questions.

Thank you !!

About the researcher

Hi there, my name is Kate Shepherd and I am currently working as a teacher and studying for my psychology master's degree at Massey University. As a part of my study, I am required to carry out a research project which I would like to do at your school.

Does my child have to take part?

Participation is voluntary and your child does not have to take part.

Will my taking part in this project be kept confidential?

Yes. All personal information relating to you and your child will be kept confidential and kept safe.
All information that I collect for this project will be anonymised so that you and your child cannot be identified in the research in any way. For example, names, the school, and where you live will be removed.

What will happen to my child if they take part?

Your child will take part in four different weekly programs twice a week for 30 minutes in the morning. These programs will include**:**

1) a moderately- high physical intensity program with high brain/cognitive demand 2) a moderately- high physical intensity program with low brain/cognitive demand, 3) Inactive with brain/cognitive demand activities, and 4) Inactive with Low brain/cognitive demand.

All students are invited in the classroom to participate. However, only ten students will be selected randomly in your child's classroom to be observed over the 4 weeks to measure the impact of these programs on their concentration and behaviour in their classroom by myself and a teacher aide. These observations will occur 1-2 weeks before the programs start, immediately after the sessions and 1-2 weeks after all programs have been completed.
The physical activities (PA) are similar to recommended P.E programs in the physical education primary school curriculum. For example; gymnastics, and athletics/sprints. However, to provide physical activities that have shown evidence in using higher cognitive domains (e.g. co-ordination, planning, memory) some activities will be based on box-fit and martial arts techniques (kicking patterns). Please note that there will be no sparring between students for safety. Adults supporting will be using pads to help with the martial arts and boxing. The physical activity program with low cognitive demand will mostly involve running.
For the inactive programs, the participants will remain seated in class. Higher cognitive demand will involve activities such as pen and paper mazes, memory card games and other brain-based games (e.g. connect 4). The lower cognitive activities will involve listening to a book being read and colouring in.
Overall, your child will commit to 1 hour a week for the study. In total 4 hours over the 4 weeks.

What are the possible disadvantages and risks of taking part?

There are minimal risks associated with this study and it is hoped that your child enjoys taking part. The program will run on school grounds and if there are any injuries the school procedure will be followed. For example; the injury will be assessed by a staff member who is trained in first aid and you will be immediately contacted if the injury is serious.

Exclusion criteria to participate in the study:

If your child has any health conditions, physical impairments that might affect their participation to safely participate.

Further information:

Both yourself and your child must both provide written consent to participate in the program.

The study aims to have all of your child's peers in the classroom involved. However, if you or your child choose not to participate they will remain with their teacher in the classroom during the sessions.

You will be informed on when the programme begins once confirmed.

If you are interested in your child participating please take the time to read and complete the written consent with your child and hand the form into the school office by *(Date).*

Additionally, please feel free to contact me for any further information on the project: I can make myself available on Monday mornings in the school office from 8.30-9.30am before the study begins if you would like to meet in person.

Kate Shepherd

Richard Fletcher
Massey University Supervisor
r.b.fletcher@massey.ac.nz

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 22/22. If you have any concerns about the conduct of this research, please contact Dr Negar Partow, Chair, Massey University Human Ethics Committee: Southern A, telephone 04 801 5799 x 63363, email humanethicsoutha@massey.ac.nz.

Appendix C. Consent Form for Caregivers and Child

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Consent form

Principle researcher: Kate Shepherd

I have read and understand the Information Sheet. I have had the details of the study explained to me, any questions I had have been answered to my satisfaction, and I understand that I may ask further questions at any time. I understand participation is voluntary and that my child may withdraw from participating in the study at any time. I understand that if I do not consent to the data being used I have 1 week from when the data has been collected to withdraw. I understand that both I and my child must sign the consent to be involved in the study.

	Initial Showing Consent
I confirm that I have read and understand the information sheet for the project in which my child has been asked to take part and have had the opportunity to ask questions.	
I understand that my child's participation is voluntary and that I am free to withdraw my child at any time from the study without giving any reason.	
I understand that that I am free to withdraw my data without giving any reason until [1-week after the first session].	
I understand that the all data collected will be stored securely and only seen by the researcher (Kate Shepherd) and her Massey University supervisor Richard Fletcher.	
I understand that my child's identity will be anonymised in the data collection and report, and that the report will be seen by markers / examiners of the thesis.	
I understand that all personal data about your child will be kept confidential.	
I agree for my child to take part in the above research project.	

My child …………………………………………………………………………… (full name) hereby volunteers to participate in the study.

Signed (caregiver) ……………………………   Date……………………………………

CHILD'S CONSENT:

I ……………………………………. would like to be involved in the physical activity program at school.

YES ✓   **or**   **NO** ✗

Appendix D. Data Collection Process

Enrollment
All Eligible and chose to participate (n=46)

<u>School 1</u>
1 classroom (n= 22)
12 participants randomly selected for data collection

<u>School 2</u>
1 classroom (n= 24)
12 participants randomly selected for data collection

<u>2 weeks pre 1st Condition</u>
Baseline data collected
PAQ-C measure completed (n=24)
Classroom observation behaviour measure (DOF) completed by 2 observers (n=24) completed

<u>1 Week Pre 1st Condition</u>
All participants (n= 46) introduced to some of the exercises to reduce anxiety and confusion. Shown how to complete mood measure.

<u>School 1</u>
Complete conditions 1 to 4
2 sessions per week, per condition.
Total 4 weeks

<u>School 2</u>
Complete reverse order 4 to 1
2 sessions per week, per condition.
Total 4 weeks

<u>Mood Measure</u>
All participants (n = 46) before (Pre) each condition and straight after (Post) self-report mood. Only the 24 participants randomly selected mood data is analysed.

<u>Classroom behaviour observation (DOF)</u>
Post each of the 4 conditions
2 hours observation period
Two observers randomly assigned to 6 students of the 12 participants per classroom/school for Session 1 and then switch for session two.
Observers compared and discussed observation results for each participant. Averaged the two scores if different.
90% same observation scores.

Appendix E. The Four Conditions Lesson Plan

Combined Condition High Cognitive Demand and Physical activity	Warm-up: (6 min) Instructor calls out a taekwondo kick (e.g. roundhouse, front kick) or punch (e.g. straight, jab). Line up, run to the cones when instructor says orange, if the instructor says apple and the students get caught moving they are out and have to do star jumps. Line up, different movements to the next cones e.g. Opposite rotating arms, skipping, bear crawl, rub tummy/pat head and jog, dynamic kicks. **Core work out: 20 minutes** *Participants placed into 4 groups* **Four obstacle courses: 4.00 minutes each with 30-40 second break.** **1.** Skipping rope pattern, Jump onto numbers 1-10 (mixed up), crawl under net, jump over the small jumps, foot pattern using floor ladder, sit up x 10 – pick up a letter and bear crawl  back to line. **2.** Skipping pattern, balance beam, summersault, jumping burpees x 5, crab walk, weight and squat x 5. Find the answer to the math equation (numbers on the floor), Running side kick with pad (choice) and/or Gallop like a horse back to the line. **3.** Twist jump, Balance beanbag on head and step over boxes, tight rope walk, hop to cushions, play memory game – jog backwards back to the line **4.** Medicine ball wheel barrow,  And pick up bean bags along the way.  6 x Commando press-ups Fast Kick/punch combo pad work called out by pad holder (e.g. front kick, round house, jab and hook or roundhouse, hammer kick, straight and jab) Play memory skip back to the line. Instructor to call out orange (jump Twist), apple (pat head, rub tummy and jog on spot) or pear (balance on one leg and squat). Students need to stop and carry out the movement associated with the fruit called

<table>
<tr>
<td></td>
<td>
<u>Warm – Down (6 minutes)</u>
<u>Taekwondo Poomse and yoga stretches</u>


</td>
</tr>
<tr>
<td>Aerobic Condition
Low Cognitive Demand and Physical Activity</td>
<td>
<u>Warm -up</u>
1. Run to the goal post – 50 metres
2. 10x start jumps and 10 x sit ups.
<u>Core workout:</u>
Circuit made up of 5 stations
1. 10x start jumps, press ups and basketball - Shoot the hoop once. Repeat.
2. Squats, one leg squats, stretch band squats. Repeat.
3. Sit up, weight sit up, bicycle sit ups, leg up. Repeat.
4. Boxing pads (jab/straight x 2) and jog to cones while waiting. Repeat.
5. Kicking Pads (front and roundhouse kick x 2) shadow box with rope while waiting. Repeat.
<u>Warm down. Stretch.</u>
</td>
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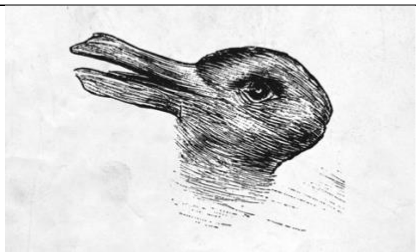
<tr>
<td>Cognitive Condition</td>
<td><u>Warm-up – 3 minutes</u> - Illusions (what do you see in the pictures, write it down.)</td>
</tr>
</table>

High Cognitive Demand and Sitting	e.g. Rabbit or duck **Core cognitive activities: 5 table stations – rotate every 5 minutes** 1. Follow written and visual instructions on how to make origami paper sculpture and make as many as they can in the time frame. 2. mazes, word find, problem solving activities. 3. Write and draw as many ideas on what to do with a brick and a cotton ball. 4. Memory game (instructor shows them 20 items for 20 seconds, participants have to write down what they remember). If finished early they could play the memory card game. 5. Mind-up game for kids on I-pad.	
Low Condition Low Cognitive Demand and Sitting	Watch 2 short animated films and then colour in some cartoon pictures.	

Appendix F. Direct Observational Form (DOF) behaviours

Please print. Be sure to answer all items.

For each item that describes the child during the 10-minute observation period, circle:

0 = no occurrence

1 = very slight or ambiguous occurrence

2 = definite occurrence with mild to moderate intensity/frequency and less than 3 minutes total duration

3 = definite occurrence with severe intensity, high frequency, or 3 or more minutes total duration

The 3-minute duration is a guideline for choosing between ratings of 2 and 3. Rate only the item that most specifically describes a particular observation. ***Be sure to rate all items.***

0 1 2 3 1. Acts too young for age
0 1 2 3 2. Makes odd noises
0 1 2 3 3. Argues
0 1 2 3 4. Cheats
0 1 2 3 5. Defiant or talks back to staff
0 1 2 3 6. Brags, boasts
0 1 2 3 7. Doesn't concentrate or doesn't pay attention for long
0 1 2 3 8. Difficulty waiting turn in activities or tasks
0 1 2 3 9. Doesn't sit still, restless, or hyperactive
0 1 2 3 10. Clings to adults or too dependent
0 1 2 3 11. Confused or seems to be in a fog
0 1 2 3 12. Cries
0 1 2 3 13. Fidgets, including with objects
0 1 2 3 14. Cruel, bullies, or mean to others
0 1 2 3 15. Daydreams or gets lost in thoughts
0 1 2 3 16. Difficulty following directions
0 1 2 3 17. Tries to get attention of staff
0 1 2 3 18. Destroys own things
0 1 2 3 19. Destroys property belonging to others
0 1 2 3 20. Disobedient
0 1 2 3 21. Disturbs other children
0 1 2 3 22. Doesn't seem to feel guilty after misbehaving
0 1 2 3 23. Doesn't seem to listen to what is being said
0 1 2 3 24. Eats, drinks, chews, or mouths things that are not food, excluding junk foods (describe): ____________
0 1 2 3 25. Difficulty organizing activities or tasks
0 1 2 3 26. Fails to give close attention to details
0 1 2 3 27. Forgetful in activities or tasks
0 1 2 3 28. Out of seat (see rating rules in Manual)
0 1 2 3 29. Gets hurt, accident prone
0 1 2 3 30. Gets in physical fights
0 1 2 3 31. Gets teased
0 1 2 3 32. Interrupts
0 1 2 3 33. Impulsive or acts without thinking, including calling out in class
0 1 2 3 34. Physically isolates self from others
0 1 2 3 35. Lies
0 1 2 3 36. Bites fingernails
0 1 2 3 37. Nervous, highstrung, or tense
0 1 2 3 38. Nervous movements, twitching, tics, or other unusual movements (describe): ____________
0 1 2 3 39. Loses things
0 1 2 3 40. Too fearful or anxious
0 1 2 3 41. Physically attacks people
0 1 2 3 42. Picks or scratches nose, skin, or other parts of body (describe): ____________
0 1 2 3 43. Runs about or climbs excessively
0 1 2 3 44. Apathetic, unmotivated, or won't try
0 1 2 3 45. Responds before instructions are completed
0 1 2 3 46. Disrupts group activities
0 1 2 3 47. Screams
0 1 2 3 48. Secretive, keeps things to self, including refusal to show things to teacher
0 1 2 3 49. Avoids or is reluctant to do tasks that require sustained mental effort
0 1 2 3 50. Self-conscious or easily embarrassed
0 1 2 3 51. Slow to respond verbally
0 1 2 3 52. Shows off, clowns, or acts silly
0 1 2 3 53. Shy or timid
0 1 2 3 54. Explosive or unpredictable behavior
0 1 2 3 55. Demands must be met immediately, easily frustrated
0 1 2 3 56. Easily distracted by external stimuli
0 1 2 3 57. Stares blankly
0 1 2 3 58. Speech problem (describe): ____________
0 1 2 3 59. Wants to quit or does quit tasks
0 1 2 3 60. Yawns
0 1 2 3 61. Strange behavior (describe): ____________
0 1 2 3 62. Stubborn, sullen, or irritable
0 1 2 3 63. Sulks
0 1 2 3 64. Swears or uses obscene language
0 1 2 3 65. Talks too much
0 1 2 3 66. Teases
0 1 2 3 67. Temper tantrums, hot temper, or seems angry
0 1 2 3 68. Threatens people
0 1 2 3 69. Too concerned with neatness or cleanliness
0 1 2 3 70. Underactive, slow moving, or lacks energy
0 1 2 3 71. Unhappy, sad, or depressed
0 1 2 3 72. Unusually loud
0 1 2 3 73. Overly anxious to please
0 1 2 3 74. Whining tone of voice
0 1 2 3 75. Withdrawn, doesn't get involved with others
0 1 2 3 76. Sucks thumb, fingers, hand, or arm
0 1 2 3 77. Fails to express self clearly
0 1 2 3 78. Impatient
0 1 2 3 79. Tattles
0 1 2 3 80. Repeats behavior over & over; compulsions (describe): ____________
0 1 2 3 81. Easily led by peers
0 1 2 3 82. Clumsy, poor motor control
0 1 2 3 83. Doesn't get along with peers
0 1 2 3 84. Runs out of class (or similar setting)
0 1 2 3 85. Behaves irresponsibly (describe): ____________
0 1 2 3 86. Bossy
0 1 2 3 87. Complains
0 1 2 3 88. Afraid to make mistakes
0 1 2 3 89. Other problems not listed above: ____________

Please be sure you answered all items.

Appendix G: Teacher Reflection Questions

<u>Teacher perception questions:</u>

1. What did you notice immediately after the students completed the session?
2. What did you observe over the morning while the students completed their work?
3. How was the students behaviour?
4. Do you think there was a difference in the students compared to the normal program/routine they do in the morning?
5. Would you find doing these physical activities easy to do on a regular basis?
6. Do you think the children liked the physical activities. Which ones?