Effects of integrating movements into the learning task on preschool children’s cognition and learning

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Effects of integrating movements into the learning task on preschool children’s cognition and learning

A thesis submitted in the fulfilment of the requirements for the award of the degree

Doctor of Philosophy

from

The Early Start, University of Wollongong

by

Myrto-Foteini Mavilidi

Master of Science in Educational Psychology

School of Education, Faculty of Social Sciences

2017
I, Myrto-Foteini Mavilidi, declare that this thesis, submitted in partial
fulfilment of the requirements for the award of Doctor of Philosophy, in the
Early Start Research Institute, School of Education, Faculty of Social Sciences,
University of Wollongong, is wholly my own work unless otherwise referenced
or acknowledged. The document has not been submitted for qualifications at
any other academic institution.

M. F. Mavilidi

4 September 2017
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I wish to thank the childcare centres and their very influential and helpful directors and educators for the opportunity to conduct research within their centres, and the participating children and parents, for their willingness and commitment to participating in the research process.

Throughout my candidature I was supported by an Australian Postgraduate Award.
Preface

This candidate was involved collaboratively with her supervisors in this research project. More specifically, the theoretical review as well as the design, implementation and evaluation of the four intervention studies was overseen by this candidate, with the assistance of her supervisors, and data collection personnel. Where people other than this candidate, were involved in implementing or evaluating the interventions their involvement is noted throughout this thesis (e.g., data collectors, researchers). Specifically, this candidate’s involvement included: liaising with early childhood education and care centres, organising all equipment, organising necessary assistance (e.g., data collectors), implementing the intervention studies, conducting data collection and providing training for data collectors, entering data, interpreting and analysing data, and writing this thesis. Contributions from other researchers were acknowledged by including their names as co-authors in two chapters (Chapter 2 – Prof. Sofie Loyens and Margina Ruiter, and Chapter 5 – Sidsel-Louise Domazet; see also Appendix V). This thesis has been prepared in journal article compilation style using APA format.
Abstract

The purpose of the theoretical and empirical work described in this Doctoral thesis was to add to the knowledge base of intervention programs that integrate movement into learning activities among preschool-aged children. This interdisciplinary research aimed to investigate the short-term effects of integrating movement into learning activities on children’s cognitive functions and the long-term effects of integrating movement on their cognitive development, and physical and mental health.

Converging lines of research into the effects of gross and more subtle motor movements (i.e., physical activity and gesturing, respectively) on learning, suggest that integrating or combining both types of movements with the learning task can be particularly effective for learning. Theoretical and empirical evidence from educational psychology, movement sciences and public health form the foundation of this research project.

A theoretical review and four experimental studies with preschool children (ages 3.5-5 years) were conducted to examine the effects of integrating movements in the form of physical activity on learning language, geography, maths, and science.

Overall, it can be concluded that learning environments which have integrated physical activities that are relevant to the learning task lead to higher learning outcomes, and are perceived as a more enjoyable way of learning by children than conventional learning environments. Motivating children to engage in adequate levels of physical activity should be an important priority for those who work with and care for children. Regular physical activity not only has benefits for children's health, but
also provides important educational benefits. In addition to the general positive effects on physical and cognitive functioning, an embodied approach to integrating physical and cognitive activities results in specific positive effects on the cognitive tasks that are integrated with the physical tasks.
Chapter 1

General Introduction
Different intervention programs to integrate physical activity with cognitive development and academic achievement (Texas I-CAN, Bartholomew & Jowers, 2011; SPARCO; FITS, Castelli et al., 2011; PAAC, Donnelly et al., 2013; Donnelly & Lambourne, 2011; Take 10!, Kibbe et al., 2011; Energizers, Mahar et al., 2006; Vazou & Smiley-Oyen, 2014) have found improvements in physical activity as well as better academic outcomes in primary school children. Some of these studies incorporated extra hours of physical activity after school (Castelli et al., 2011; Davis et al., 2011), measuring children’s BMI and their performance on cognitive tests. Other studies proposed classroom-based programs that integrated physical activity with learning areas such as maths and language (Bartholomew & Jowers, 2011; Castelli et al., 2011; Donnelly & Lambourne, 2011; Hillman et al., 2009; Kibbe et al., 2011; Lambourne et al., 2013; Mahar et al., 2006; Vazou & Smiley-Oyen, 2014). Classroom-based physical activity is an enjoyable way to promote physical activity and foster executive function in children (Vazou & Smiley-Oyen, 2014). School-based physical activity programs attempt to increase physical activity during the school day, using strategies such as increasing recess time and providing physical activity breaks (Salmon et al., 2011). However, there is little research examining the impact of physical activity interventions on cognitive development and academic performance in preschool-aged children.

Becker et al. (2014) found that when preschool children were involved in active play, their self-regulation skills related to inhibitory control, working memory and attention improved, and in turn they showed higher literacy and scores in mathematics. Quality early childhood programs have also been shown to have a long-term impact (Belsky et al. 2006; Dickinson, 2011), contributing to preschool children’s gross movement skill development (Hardy, King, Farrell, Macniven,
Howlett, 2010). Connecting quality interventions that promote cognitive and physical development seems to substantially contribute to children’s well-being. Preliminary research has shown that the integration of movement experiences with other learning areas results in children being more physically active, enthusiastic and attentive on learning tasks such as maths or language (Trost, Fees, & Dzewaltowski, 2008).

Early support and intervention programs for low-income families can have large developmental benefits in three-year old children’s cognitive, language and socio-emotional functioning, and physical development (Glass, 1999; Love et al., 2005). More specifically, when children from low-income backgrounds received active academic instruction integrated with physical activity, implemented within or after school hours, they adopted healthier behaviors (Ploeg, McGavock, Maximova, & Veugelers, 2014), were more engaged with the learning material (Bartholomew & Jowers, 2011), and spent more time on required tasks (Mahar et al., 2006), leading to better academic outcomes (Dickinson, 2011).

![Figure 1.1. Model of factors associated with the effects of physical activity on cognition and academic achievement.](image-url)
1.1 Aim of thesis

The overall aim of this doctoral research was to conduct a suite of studies to add to the evidence base of interventions that integrate movement (physical activity) into the learning process across four distinct academic areas (language, maths, science, geography) in children aged 3–5 years. This PhD consists of five specific aims:

1. To produce a theoretical review which presented an overview of underlying theories and empirical data on how physical activity and gestures can be embedded into classroom settings.

2. To conduct a study with quasi-experimental design, which investigated the effects of physical activities and gestures on foreign language vocabulary in preschool children. Children in each school were randomly assigned to the experimental conditions.

3. To conduct a study with quasi-experimental design, examining the effects of infusing physical activity into geography learning in preschool children.

4. To conduct a cluster randomised controlled trial, investigating the effects of meaningful movements on learning different mathematics concepts in preschool children.

5. To conduct a study with quasi-experimental design, which examined the acute effects of a science-related integrated program during group time activities in childcare centres context. Children in each school were randomly assigned to the experimental conditions.

1.2 Research Questions

This Doctoral project investigated the effects of gross motor (i.e., physical activity) and subtle movements (i.e., gestures) on preschool children’s learning. More
specifically, it focused on designing effective intervention programs to foster children’s cognitive functions in the short-term, and their cognitive development in the longer-term (i.e., after 10 weeks) as well as health benefits arising from physical activity. The following research questions were addressed:

1. Does physical activity positively affect children’s learning?

2. In which way do task-relevant and task non-relevant physical activities influence learning?

3. Do embodied cognitive tasks positively affect children’s learning?

4. Under what conditions are the effects of physical activity and embodiment more pronounced?

5. Is the combination of physical activity and embodiment more effective for learning than each of the individual factors?

6. Will children enjoy active ways of learning more than the traditional way of learning?

To investigate these research questions, I evaluated existing theories and empirical studies in a theoretical review, and conducted four experimental studies, using a similar quasi-experimental design (in which children per school are randomly allocated to the conditions), but across different learning domains: Study 1 included learning of foreign language vocabulary (i.e., Italian words), Study 2 focused on geography learning (i.e., the continents and characteristics animals living there), Study 3 on learning mathematics (i.e. counting and number line estimation), and Study 4 targeted the area of science (i.e., solar system planets and order based on the distance from the Sun).
1.3 Hypotheses

The review of current literature suggested a new instructional method, which integrated physical activities into the learning process, as an effective way of learning. Consequently, throughout this thesis it was hypothesized that:

1. *The integrated condition, including task-relevant physical activities will have the highest learning outcomes compared with the other conditions.*

2. *The non-integrated condition will have higher learning outcomes than the control condition.*

3. *Positive effects of the combination of embodied and physical tasks on learning will be more pronounced compared to each of the individual factors, in all domains (i.e. foreign language vocabulary, geography, maths, science).*

4. *Children will evaluate the active learning condition as more enjoyable than the sedentary control condition.*

1.4 Overview of the methodologies

This doctoral project consisted of a theoretical review and four autonomous experimental studies. The theoretical review summarised theoretical and empirical evidence on the effects of movement on learning. Regarding the relationship between the movements and the cognitive or learning content, interventions identified in the existing literature were categorised according to: 1) level of integration, ranging from non-integrated to fully integrated; and 2) level of task-relevance, ranging from non-relevant to relevant.

In addition, the four experimental studies designed for this project used a similar methodology but with different learning contents, i.e., language, geography,
maths, science. More specifically, the children were taught basic concepts of each learning domain at their childcare centre. The duration of the intervention was 2-4 weeks, with 1-2 learning sessions per week, lasting 10-20 minutes per day. The learning sessions were run in small groups (with the exception of study 2 - Chapter 4) which was conducted individually with one child at a time), whereas all the assessments occurred individually at the end of the interventions at two time points (immediately post-intervention and several weeks after the end). Different knowledge tests for each learning domain were constructed to assess children’s prior and acquired knowledge, and their ability to recall the information obtained during the learning sessions. At the end of the assessments, children evaluated their interest in the instructional methods. Children in the four intervention studies performed simple physical activities such as running, walking, and jumping. These physical activities were meaningfully linked with the learning domain of each study. Time spent in physical activity was measured with accelerometers during each learning session.

A mixed experimental design was used in all studies, comprising of one control condition representing the conventional way of teaching, and three experimental conditions (for Studies 1 and 3), or two experimental conditions (for Studies 2 and 4; see Table 1.1 for similarities and differences). The experimental conditions consisted of an integrated condition, which included task-relevant physical activities, and a non-integrated condition, involving task-irrelevant physical activities. The first experimental study included an additional experimental condition, in which children were asked to make task-relevant gestures, while the third experimental study incorporated an additional experimental condition, in which children were asked to observe their peers’ performing physical activities during learning (observing physical activity condition).
<table>
<thead>
<tr>
<th>Study</th>
<th>Learning Domain</th>
<th>Condition</th>
<th>Participants (N, Age)</th>
<th>Type of Instruction</th>
<th>Assessment</th>
<th>Physical Activity Measurements</th>
<th>Duration of Learning</th>
<th>No of Learning Sessions - Total Duration</th>
</tr>
</thead>
</table>
| 1     | Foreign Language | Integrated: task-relevant physical activity  
Non-integrated: task-irrelevant physical activity  
Gesturing: task-relevant gesture  
Conventional: no movements involved - traditional sedentary way of learning | 111  
4 - 5 years old | Learning 14 Italian words | Pre-test  
Immediate post-test  
6-week delayed post-test  
Free-recall  
Cued-recall | Accelerometers measured during the duration of the lessons  
Epochs: 15s  
Cut-points for moderate-to-vigorous physical activity (Pate et al., 2006) | 15 - 20 min | 8 lessons  
4 weeks |
| 2     | Geography       | Integrated: task-relevant physical activity  
Non-integrated: task-irrelevant physical activity  
Control: no movements involved -traditional | 87  
4 - 5 years old | Learning the continents and characteristic animals | Pre-test  
Immediate post-test  
5-week delayed post- | Accelerometers measured during the duration of the lessons  
Epochs: 1-s  
Cut-points for | 10 min | 3 lessons  
2 weeks |
| 3 | Mathematics | Integrated: task-relevant physical activity  
Non-integrated: task-irrelevant physical activity  
Observing physical activity: observing task-relevant physical activity from peers of integrated condition  
Control: no movements involved -traditional sedentary way of learning | 115  
3.5 – 5 years old | Learning numeracy skills (counting, number line estimation task, numerical comparison and identification)  
Pre-test  
Immediate post-test  
6-week delayed post-test | Accelerometers measured during the duration of the lessons  
Epochs: 1-s  
Cut-points for moderate-to-vigorous physical activity (Pate et al., 2006) | 15 min | 4 lessons  
4 weeks |
| 4 | Science | Integrated: task-relevant physical activity  
Non-integrated: task-irrelevant physical activity  
Control: no movements involved -traditional sedentary way of learning | 86  
4 - 5 years old | Learning the planets  
Pre-test  
Immediate post-test  
6-week delayed post-test | Accelerometers measured during the duration of the lessons  
Epochs: 1-s  
Cut-points for moderate-to-vigorous physical activity (Pate et al., 2006) | 10 min | 4 lessons  
4 weeks |
The primary outcome in each study was children’s learning performance. Test performance was used to gauge how much children had learnt during the interventions. Secondary outcomes were children’s perceived interest about the instructional methods and their objectively measured participation in physical activity.

1.5 Significance

It is important that time spent in childcare centres is supporting early childhood development, including the development of healthy lifestyles (Erwin et al., 2013; Finn, Johannsen, & Specker, 2002; Pate et al., 2006). Existing programs in early childhood settings (such as “Jump Start”, Jones et al. 2011; “Munch and Move”, Hardy et al. 2010b) mainly focus on health benefits such as promoting physical activity and gross motor skills. At the same time, other early childhood programs aim to improve cognitive and social-emotional functioning, as a way to prevent later cognitive delays and enhance school readiness (Anderson et al. 2003). Applying movement-based learning at pre-primary age will provide all children with a significant cognitive advantage, especially when considering the current lack of opportunities in children growing up in poverty and their negative consequences on brain development and academic achievement (e.g., Luby, 2015; Hair et al., 2015). Playful activities and related cognitive development at preschool age have been linked to proxy indicators of civic engagement later in life (Astuto & Ruck, 2017).

This suite of studies aimed to make a significant contribution to the evidence base, where there is a lack of studies focusing on intervention programs that integrate physical activity into learning during preschool years. This research has been performed at the intersection among research in exercise science, cognition, cognitive
load theory, and embodied cognition. Usually, the main distinction in exercise and public health research lies between short-term and transient effects of an acute (i.e., single) bout of physical activity, and long-term (when measured at follow-up) stable effects of chronic exercise. Classroom-based interventions are an intermediate type, as they are composed of multiple activity bouts, but over a relatively short period of time. However, despite the short duration of the intervention, their effects are longer lasting and not only transient. Developing and testing classroom-based physical activity programs during academic learning has the potential not only to expose children to stimuli to help them develop cognitively, but at the same time promote physical activity during childcare hours. The latter is important given that low levels of physical activity have been reported among children in childcare (Reilly, 2010; Ward, Vaughn, Williams, & Hales, 2009). During the period that this thesis was conducted, very few studies have implemented classroom-based physical activities, assessing both specific learning outcomes and physical activity using objective measures.

1.6 Delimitations

This study was delimited in the following manner:

1. Participants were aged three- to five-years, and were enrolled in the participating childcare centre on the days of the intervention.

2. Participating centres were all drawn from the Illawarra area of NSW and mostly the area around Wollongong. Centres that responded and showed their interest in one or more studies were included.

3. Occasional childcare (centre-based child care allowing flexible care for children, where children have regular attendance on a sessional basis or
irregular basis; Australian Government, Department of Education and Training) or long day centres (operating for a least 8 hours a day on normal working days for children 0-6 year old; Victoria State Government, Education and Training) were not included because children needed to attend the centre consistently for at least twice per week.

4. Physical activity was assessed by collecting accelerometry data from each participant during the learning sessions only. Measurements of the intensity of physical activity (i.e., moderate-to vigorous-intensity physical activity) were collected during the intervention and needed to be at least 10 min in duration per day.

5. Learning outcomes were measured with tests created for the purposes of each study, measured at three time points: at the beginning of the intervention (pre-test), directly after the intervention (immediate post-test), and 5-6 weeks after the end of the intervention (delayed post-test). The only exception was the first study, which did not include a pre-test, as children with Italian background were not included. As such, the participating children did not have prior knowledge.

6. This study focused on designing short physical activity interventions that could be easily integrated with the learning content, targeting improved learning outcomes and physical activity.

1.7 Limitations

The limitations of this project are noted below:

1. The four intervention studies used a similar quasi-experimental design, in which childcare centres were randomly allocated to the different
experimental conditions. However, due to practical issues, it was not possible to use a fully randomised design, where individual children in each centre were randomised to different conditions. Rather, children were randomised at a centre level to a condition. Study 3 (maths – Chapter 5) was a randomised controlled trial, in which group similarities within the same groups (i.e., preschools centres) were taken into account. In Study 4 (Science – Chapter 6) children attending the same preschool centre were randomly assigned to different experimental conditions.

2. The series of studies measured children’s learning performance at specific time points, including an immediate and a delayed post-test. However, no further follow up assessments were performed.

3. The short duration of each intervention aimed at assessing the possible acute effects of physical activity on cognition. However, the long-term effects of physical activity on learning and cognition were not measured.

4. The evaluation of the instructional methods was only based on children’s self-report measures.

1.8 Definition of terms

The following definitions of terms are provided to guide understanding of this project.

*Accelerometer:* Instrument designed to measure time-varying differences in force or acceleration, used for physical activity assessments (Cliff, Reilly, & Okely, 2009).

*Cognitive Load Theory (CLT):* Theoretical framework that deals with the cognitive load that people experience during learning due to the limitations in capacity and duration of working memory. The theory assumes that for effective learning to commence, the instructional design of a learning task should correspond to
the working memory architecture (Paas, Renkl, & Sweller, 2003; Sweller, 1988; Sweller, Ayres, & Kalyuga, 2011).

**Embodiment:** The concept that the body plays a crucial role in cognition in a way that “bodily states can cause and be the effects of the cognitive states” (Barsalou, 2008, p.618).

**Embodied Cognition:** The notion that cognition builds on the interaction of the human body with its physical environment (Barsalou, 2008; Wilson, 2002).

**Enactment:** The tenet of the subject-performed task or enactment effect suggests that motorically performed action phrases such as “brush your teeth” (Engelkamp, 2001; Knopf & Neidhardt, 1989; Kubik, Söderlund, Nilsson, & Jönsson, 2014) are linked with improved memory performance, in the sense that these actions are better recalled when they are performed than read or listened (Engelkamp & Zimmer, 1989).

**Executive functions:** A set of higher-order cognitive processes involved in goal-directed, flexible, and adaptive behavior triggered in challenging, novel, and complex situations. Executive functions include cognitive flexibility, inhibition, shifting, and working memory and more complex executive functions such as anticipation, goal selection, and planning. They develop throughout childhood and adolescence, playing an important role in children’s cognitive functioning, behaviour, emotional control and social interaction (Anderson, 2000; Miyake et al., 2000). Executive functions are also interrelated to metacognition (Roebers, 2017).

**Exercise:** A subcategory of physical activity that is planned, structured, repetitive, and purposive in the sense that the improvement or maintenance of one or more components of physical fitness is the objective. "Exercise" and "exercise training"
frequently are used interchangeably and generally refer to physical activity performed during leisure time with the primary purpose of improving or maintaining physical fitness, physical performance, or health (Centres for Disease Control and Prevention, 2016).

**Health:** A human condition with physical, social and psychological dimensions, each characterized on a continuum with positive and negative poles. Positive health is associated with a capacity to enjoy life and to withstand challenges; it is not merely the absence of disease. Negative health is associated with illness, and in the extreme, with premature death (Centres for Disease Control and Prevention, 2016).

**Moderate-intensity physical activity:** For children, on an absolute scale, physical activity that is done at 4.0 to 5.9 times the intensity of rest (Centers for Disease Control and Prevention, 2016; Cliff, Reilly, & Okely, 2009).

**Moderate- to vigorous-intensity physical activity (MVPA):** Physical activity that at least 4.0 times greater the intensity of rest (Centers for Disease Control and Prevention, 2016).

**Physical activity:** “Any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level. In these guidelines, physical activity generally refers to the subset of physical activity that enhances health” (Centres for Disease Control and Prevention, 2016).

**Physical fitness:** The “ability to carry out daily tasks with vigour and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and respond to emergencies. Physical fitness includes a number of components consisting of cardiorespiratory endurance (aerobic power), skeletal muscle endurance, skeletal
muscle strength, skeletal muscle power, flexibility, balance, speed of movement, reaction time, and body composition” (Centres for Disease Control and Prevention, 2016).

Preschool children: Children aged between three and five years.

Total physical activity: Raw data of physical activity as recorded by an accelerometer and reported as activity counts per minute (CPM; Cliff et al., 2009).

Vigorous-intensity physical activity: On an absolute scale, physical activity that is done at 6.0 or more times the intensity of rest (Centers for Disease Control and Prevention, 2016).

1.9 Overview of thesis

This thesis presents an investigation into the combined effects of physical activity and body movements on children’s cognitive skill development and learning, through engaging children in physical and cognitive activities in a meaningful and creative way.

The first chapter (Introduction) outlines the background of this research, describes the aims, provides a brief overview of the methods, the significance of this project, delimitations and limitations of the studies, and a glossary specific to the terms of this thesis.

Chapter 2 (Literature Review) summarises and reviews the current literature on the effects of physical activity and movements on cognition and learning based on the level of integration and level of relevance of the movements with the learning content.
Chapter 3 (Experimental Study 1 – Foreign Language) presents a study into the effects of integrated physical activity and gestures on preschool children’s foreign language vocabulary learning. A four-week intervention, consisting of 2 sessions per week, evaluated children’s ability to memorise 14 Italian words in free-recall and cued-recall tasks, as measured during the intervention (in week 2), directly after the end of the intervention (week 4), and after a six-week gap. Children’s intensity levels of physical activity were measured. Educational implications are discussed on children’s cognitive and physical outcomes.

Chapter 4 (Experimental Study 2 – Geography) describes whether infusing physical activities into the classroom would have an effect on preschool children’s geography learning. An intervention, consisting of three learning sessions, evaluated children’s ability to memorise the name of the continents and characteristic animals living in each one, as measured before the beginning of the intervention (pre-test), directly after the end of the intervention, and after a five-week gap. Children’s intensity levels of physical activity were assessed. Educational implications are discussed on children’s cognitive and physical outcomes.

Chapter 5 (Experimental Study 3 – Maths) portrays the immediate and delayed effects of integrating physical activity into preschool children’s learning of numeracy skills. A four-week intervention, consisting of 2 sessions per week, evaluated children’s ability on a number line estimation task, as measured before the beginning of the intervention (pre-test), directly after the end of the intervention (week 4), and after a six-week gap. Children’s intensity levels of physical activity were measured. Educational implications are discussed on children’s cognitive and physical outcomes.
Chapter 6 (Experimental Study 4 – Science) presents the effects of integrating physical activities into a science activity on preschool children’s learning and enjoyment. A four-week intervention, consisting of 2 sessions per week, evaluated children’s ability to memorise the name of the planets based on their distance from the sun, as measured before the beginning of the intervention (pre-test), directly after the end of the intervention (week 4), and after a six-week gap. Children’s intensity levels of physical activity were assessed. Educational implications are discussed on children’s cognitive and physical outcomes.

Chapter 7 (General Discussion) summarises the main findings from reviewing the existing literature and from the four experimental studies. Findings from the experimental studies are compared with similar studies. A new instructional method is suggested as well as educational implications of the classroom-based physical activity interventions are further discussed.
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Chapter 2

Infusing Relevant Movements into Learning Tasks to Create More Effective Learning Environments: A Narrative Review


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2.1 Abstract

Engaging in regular physical activity can have substantial cognitive and academic benefits for children, and is generally promoted for its positive effects on children’s physical and mental health. Whereas embodied cognition research has convincingly shown that an intimate relation exists between the human mind and body, in education, physical activity and cognitive activity are typically treated as unrelated processes. Consequently, the physical activities used, are not relevant for, and not integrated into learning tasks. However, results of recent studies suggest that integrated, task-relevant physical activities are most effective for learning. To investigate whether these suggestions can be substantiated, we conducted a narrative review to determine how the extent to which movements are integrated into the learning task and are relevant for the learning task affects cognition and learning performance.

**Keywords:** physical activity, embodied cognition, movements, learning, children
2.2 Introduction

In human life, motor movement and learning are inextricably bound. Starting in early life, children act upon and understand the environment using mainly sensorimotor actions (Thelen, Schöner, Scheier, & Smith, 2001). Broad changes in perception, cognition and behavior take place with the expansion of a child’s sensorimotor repertoire (Piaget, 1970). Different types of motor experiences are common throughout the development from infancy into adulthood, such as reaching and grasping movements (Daum, Vuori, Prinz, & Aschersleben, 2009), gross motor patterns of varying complexity learned in the context of sports and physical activity (Cross, Hamilton, & Grafton, 2006), and gesturing (Goldin-Meadow & Beilock, 2010). All these forms of movements have been shown to affect cognition and learning.

In the literature two main mechanisms through which human movement can affect cognition and learning performance are proposed; physiological and cognitive effects of movements. Firstly, the physiological effects of movements have been considered in studies investigating effects of gross body movements (e.g., physical activity or exercise) affecting cognitive functioning and learning (e.g., Etnier, Salazar, Landers, Petruzzello, & Nowell, 1997). Secondly, the cognitive effects of movements have predominantly been discussed in the context of more subtle and abstract movements, such as gestures, influencing cognitive processes and learning (e.g., Goldin-Meadow & Beilock, 2010).

The main goal of this theoretical review is to describe both research traditions (i.e., physiological and cognitive effects of movements), and to review the literature to determine whether combining approaches from both traditions may have a synergistic benefit of movement for learning. The first tradition focuses on physiological
explanations for the health and general cognitive effects of gross motor movements in the form of physical activity or exercise, and does not consider the relevance of the movements for the learning task. The second tradition focuses on cognitive explanations of small motor movements that are relevant to the learning task. Researchers in this second tradition do not consider the physiological benefits of physical activity or exercise. Finally, we propose a third approach, which combines both traditional approaches looking at integrated, task-relevant physical activities. This new approach will be used to categorise existing studies on the dimensions of task relevance and integration within the learning task. The categorisation will be used to determine how integration and relevance of movements can affect cognition and learning performance. Blending the physiological and cognitive research traditions to improve learning will provide the field of education with concrete guidance on the effective use of movements in learning environments.

2.2.1 Physiological effects of gross motor movements on health and cognition

The first part of this review will focus on the physiological explanations of the relation between movement and cognition. Gross motor movements in the form of physical activity and exercise will be described and associated with learning, cognition, brain structure, and brain function.

The concepts of physical activity, exercise, and physical fitness that are used in this article are based on the definitions provided by the Centres for Disease Control and Prevention (2017) and the American College of Sports Medicine (2013): Physical activity is defined as “any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level.” Exercise is considered as a “subcategory of physical activity that is planned, structured, repetitive, and
purposive in the sense that the improvement or maintenance of one or more components of physical fitness is the objective. "Exercise" and "exercise training" are frequently used interchangeably and generally refer to physical activity performed during leisure time with the primary purpose of improving or maintaining physical fitness, physical performance, or health”. Finally, physical fitness refers to “the ability to carry out daily tasks with vigor and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and respond to emergencies”. Physical fitness includes a number of components consisting of cardiorespiratory endurance (aerobic power), skeletal muscle endurance, skeletal muscle strength, skeletal muscle power, flexibility, balance, speed of movement, reaction time, and body composition” (CDC, 2017).

The positive effects of physical activity are widespread across various domains of human life. In the last decade, the benefits of physical activity have been expanded beyond cardiovascular health and obesity prevention to include cognitive performance, as well as brain structure and brain function (Khan & Hillman, 2014; Sibley & Etnier, 2003). Initial evidence for the direct effects of exercise on the brain was obtained from research conducted with rodents. Physical activity stimulated a cascade of neurological changes in the hippocampus and cerebellum, brain areas that are associated with memory and learning (Brown et al., 2003; Gomez-Pinilla, So, & Kesslak, 1998). Later, the positive relationship between fitness and cognitive functions was further established in research with aging adults. Several findings indicated that cardiovascular fitness through regular exercise induced morphological changes to the brain and enhanced cognitive functioning in older adults (Colcombe et al., 2004; Kramer et al., 1999). Especially, executive functions (EF) appeared to be more sensitive than other aspects of cognition to aerobic exercise training (Colcombe
EF is the part of cognition that encompasses effortful and goal-oriented functions, including inhibition, working memory and cognitive flexibility (Baddeley, 1996; Miyake et al., 2000). From these, higher-order EFs are built such as reasoning, problem solving, and planning (Collins & Koechlin 2012, Lunt et al. 2012). The findings with older adults resulted in the EF hypothesis that proposes that exercise has the potential to induce vascularization and neural growth and to alter synaptic transmission in the neural networks supporting EF, therefore influencing higher-order thinking processes (Khan & Hillman, 2014; Rasberry et al., 2011; Verburgh, Königs, Scherder, & Oosterlaan, 2013).

Children’s cognitive and neural development, and in particular EF and the supporting brain structures, may be sensitive to physical activity (Diamond, 2000; Diamond & Lee, 2011; Hillman, Erickson, & Kramer, 2008; Kolb & Whishaw, 1998). Laboratory-based tests have revealed a stage-like emergence of the components of EF and neuroscientists have linked behavior and test performance to brain development (Casey, Galvan, & Hare, 2005). The consensus is that EF is crucial for mental and physical health, academic success, cognition, and social, emotional and psychological development (Diamond, 2013). It is considered even “more important for school readiness than intelligence quotient” (Bull, Espy, & Wiebe, 2008; Diamond & Lee, 2011, p. 959) and predicts both math and reading competence throughout the school years (Blair & Razza, 2007). EF is subsequently correlated with on-task behavior, as it subserves self-regulation and behavioral inhibition, and the ability to inhibit off-task behavior in service of attending to a classroom material that is a prerequisite for successful learning. Children show increased on-task behaviors after physical activity programs at school (Riley, Lubans, Morgan, & Young, 2014), confirming the notion that physical activity can positively affect classroom behavior.
Prior meta-reviews have reported a favorable relationship in children between physical activity and aerobic fitness on the one hand, and cognition and brain function on the other hand. In 1997, Etnier and colleagues indicated that acute exercise has a significant small positive effect (Hedge’s $g = 0.36$) on cognitive performance with children (6–13 years). Also, later in their meta-analysis with the same age group Sibley and Etnier (2003) reported a similar overall effect size (Hedge’s $g = 0.32$). More recently, Donnelly and colleagues (2016) systematically reviewed the relationship between physical activity, fitness, cognition and academic achievement and concluded that a majority of research findings support the view that physical fitness, single bouts of physical activity, and participation in physical activity interventions benefit children’s cognitive functioning.

**Type and Duration**

Despite the positive associations among physical activity, fitness, cognition and academic achievement, there are many quantitative (i.e., type, amount, frequency, and timing) and qualitative aspects (i.e., task complexity, novelty, and diversity/variety, emotional activation, selection of strategies) of physical activity in relation to cognition that remain to be explored. Concerning aerobic exercise, two lines of research have investigated the effects of movements on cognition. The first type examines the effects of chronic aerobic exercise (i.e., repeated bouts of exercise such as aerobic training; Tomporowski, McCollick, Pendleton, & Pesce, 2015). The main goal of the habitual aerobic exercise program is to improve children’s cardio-respiratory functioning and fitness (Tomporowski et al., 2015). This improvement, in turn, may improve cognitive functioning, which is assessed after the aerobic exercise program has ended (Tomporowski, Davis, Miller, & Naglieri, 2008). The second line of research examines the changes in cognitive functioning immediately following an
acute bout of aerobic exercise (Tomporowski, 2003). Participants’ accuracy, response time, and speed on cognitive tests were assessed immediately after intense aerobic training.

Different lengths and types of exercise provoke diverse effects on the physiological mechanisms of the body. Chronic exercise generates functional morphological changes in the brain regions that are responsible for learning, whereas acute exercise improves cognitive performance by activating neurochemical responses (Best, 2010; Brisswalter, Collardeau, & René, 2002; Chang et al., 2012; Tomporowski, 2003). For instance, single bouts of physical activity can provoke physiological arousal facilitating the available attentional resources and engagement of cognitive functioning (Best, 2012). The single bouts of physical activity are associated with the acute effects on cognition whereas the multiple bouts are connected with physical fitness and its indirect effects on cognition (Best, 2012). Erickson et al.’s (2015) review of effects of physical activity on brain structure, brain function and academic achievement using event-related brain potentials (ERPs) and functional magnetic resonance imaging (fMRI) techniques supports this view. The authors concluded that fitter and more active children showed greater gray matter volume in the hippocampus and basal ganglia, greater white matter integrity, and more effective brain activity patterns.

Also, qualitative aspects of aerobic exercise appear to play a role in the effect of exercise on cognitive functioning. There is tentative evidence that cognitively engaging aerobic exercise in which strategic behaviors, coordination of complex motor movements and adaption to changing task demands is required, has a stronger effect than non-engaging repetitive aerobic exercise on children’s executive function (Best, 2010; Vazou, Pesce, Lakes, & Smiley-Oyen, 2016).
To conclude, research in the fields of public health and human movement science focuses on gross motor movements in the form of physical activity and aerobic exercise, suggesting physiological explanations of the positive movement effects on cognition and learning.

2.2.2 Cognitive effects of movements on learning

Researchers within the field of educational psychology have extensively looked at the effects of subtle movements mainly in the form of gestures on learning. Central in this respect is the theoretical framework of embodied cognition, which holds that cognitive processes are deeply rooted in the body’s interactions with the world (Barsalou, 2008; Glenberg, Witt, & Metcalfe, 2013; Hostetter & Alibali, 2008; Wilson, 2002). This framework is often employed to embed and clarify the cognitive effects of movements on learning. According to Pouw, de Nooijer, Van Gog, Zwaan, and Paas (2014), movements manifest thinking externally and provide support to the internal cognitive processes. As such, the body is considered a fundamental part of the cognitive system and can be used to assist learning (Paas & Sweller, 2012). Body movements, as a form of biologically primary knowledge, impose minimal demands on working memory resources (i.e., low cognitive load), and can be used to assist in the acquisition of biologically secondary knowledge, such as language and math (Paas & Sweller, 2012). Linking abstract concepts with sensorimotor metaphors through mental simulation (e.g., interactive simulation of planetary astronomy; Lindgren, Tscholl, Wang, & Johnson, 2016) can help learners engage in deeper processing and promote longer-lasting learning (Slepian & Ambady, 2014). When abstract concepts are embodied (e.g., walking on a number line to learn counting; Fischer, Moeller, Bientzle, Cress, and Nuerk, 2011), they can be internalized and placed in context, and transfer of learning can be successfully achieved (Pouw, Van Gog, & Paas, 2014).
Since our cognitive functions are directly and indirectly linked with sensorimotor functions (e.g., movements, perception, tactility, vision, and sound reception and production; Radford, 2014), information stemming from multimodal resources (i.e., visual, auditory, kinesthetic) can promote the construction of enriched cognitive schemas (Lindgren & Johnson-Glenberg, 2013). Based on these high-quality cognitive schemas, learners can achieve better learning outcomes using less cognitive resources than learners who have acquired knowledge from unimodal resources. The idea of schema enrichment for students who are engaged in motions and perceptions is also in line with Dual Coding Theory, stressing that students who are engaging in motions and perceptions, are able to connect the kinesthetic “imagery” with visual and verbal cues (Clark & Paivio, 1991). For example, a mental image for the word “Bunsen burner” includes a visual image of the object, auditory and olfactory images for the sound and smell of gas, and motor images for adjusting the flow of gas (Clark & Paivio, 1991).

Research has shown that gesturing is related to the cognitive demands of the task, decreasing learners’ experienced cognitive load, and leading to a “modality effect”. This “modality effect”, in the case that multimodal presentation of information is available, allows faster and better memory performance (Cook, Yip, & Goldin-Meadow, 2012; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; Ping & Goldin-Meadow, 2010; Wagner et al., 2004). Learners can benefit from the modality effect, because it enables them to process more information in working memory (Ginns, 2005; Kalyuga, Chandler & Sweller, 2000). For example, participants who were given the dual task of remembering letters while explaining a difficult math problem, remembered more letters when they gestured while explaining the problem than when they were not allowed to gesture (Goldin-Meadow et al., 2001). This
suggests that gesturing reduced the working memory load imposed by explaining the math problem, leaving more cognitive resources available for the secondary memory task. Further evidence for the relation between gesturing and cognitive load is provided by studies that found a positive relation between cognitive task complexity and gesture frequency, and studies that found gesturing to be especially beneficial for people with low working memory capacity (Chu & Kita, 2011; Pouw, Mavilidi, Van Gog, & Paas, 2016).

Gestures can be distinguished into beats (non-representational gestures), iconic (implying a perceptual relationship between concrete concepts), metaphorical (having a narrative character for abstract concepts), and deictic gestures (when the speaker points to actual objects; Hostetter, 2011; Roth & Lawless, 2002).

Gestures as a form of indexing and enactment have been shown to facilitate learning in domains of language comprehension, primary and secondary language acquisition (Kelly, Özyürek, & Maris, 2009; Macedonia, Müller, & Friederici, 2011; Tellier, 2008). For example, in case of vocabulary learning, Macedonia and Klimesch (2014) taught undergraduate students novel words from an artificial language. Participants enrolled in the gestural condition in which they had to read, repeat the words they heard, and imitate the researcher who was enacting the words with symbolic gestures, recalled more words and for a longer period of time than those who had just read, heard, and repeated the same words. Similarly, gestures can be used to enact sentences or stories to improve reading comprehension, the process of extracting meaning from a text (De Koning & van der Schoot, 2013; Fischer & Zwaan, 2008; Glenberg, 2011; Leopold & Leutner, 2012). For example, Glenberg, Gutierrez, Levin, Japuntich, and Kaschak (2004) found that children who indexed what they were reading (e.g., farm animals) to playset pieces they could manipulate,
remembered more action sentences from the story than children who only read the story. In another recent study on reading comprehension, Berenhaus and colleagues (2015) compared the effect of indexing and enactment on memory of a narrative. Children in the indexing condition used play mobile figures to perform the story while children in the enactment condition took on the role of the characters and acted out the story with gestures and emotional expressions. The results revealed that children in the enactment condition remembered more descriptive parts of the story than children in the read only condition. Moreover, both enactment and indexing benefited children with poor reading ability. Finally, iconic gesturing in the form of actions or object-manipulations has been proven useful for learning, facilitating problem-solving and vocabulary retrieval by activating relevant perceptual-motor information (e.g., Macedonia, Müller, & Friederici, 2011).

Importantly, hands-on experience with numbers enhances mathematical ability and understanding in children, generalizing the knowledge beyond the specific tasks (Novack et al., 2014; Ramani & Siegler, 2008). The premotor cortex is responsible for numerical processing. Neuronal circuits, established in childhood, permit the verbalization of numbers and the use of finger counting habits (Jay & Betenson, 2017; Tschentscher, Hauk, Fisher, & Pulvermuller, 2012). To this end, different body postures can affect spatial-numerical information. The role of fingers is foundational for numerical cognition (Fischer & Brugger, 2011), formation of number sense and thus development of calculation skills (Gracia-Baffaluy & Noel, 2008). For instance, Fischer et al. (2011) evaluated preschool children’s performance on counting principles, object counting, Arabic digits, number words, and calculation of numbers 0 – 10. Children were enrolled in the experimental condition in which they were presented with a spatial number line and used a dance mat for spatial-motor
responses, or in the tablet PC training condition in which neither the presentations or response formats contained explicit spatial information. Results revealed that sensory-motor spatial-numerical training using a dance mat was more beneficial for children’s arithmetic learning than non-spatial control training.

Overall, the theoretical framework of embodied cognition advocates that task-relevant body movements can facilitate learning, varying from a continuum of subtle (i.e., gesturing; Goldin-Meadow, Cook, & Mitchell, 2009) to gross motor movements (i.e., whole body-movements; Boncoddo, Dixon, & Kelley, 2010; Novack et al., 2014; Ruiter, Loyens, & Paas, 2015; Shoval, 2011; Mavilidi, Okely, Chandler, & Paas, 2015, 2016, 2017).

2.3 How body movements can influence learning. A matrix of task relevance and integration levels

Although this is a narrative review, given the very broad inclusion of (1) physical activity tasks, (2) cognitive/learning outcomes, (3) length of interventions and of single activity bouts, (4) intervention settings, arising from the two research traditions (i.e., physiological and cognitive effects of movements), a minimum of selection criteria were applied: acute and chronic physical activity interventions, gross and fine-motor training tasks, and age (children, adolescents, and adults).

The second part of this review will categorise the selected studies on a continuum based on the relevance of the movements for the cognitive/learning task and the integration of the movements into the cognitive/learning task to infer about the way that produces the most prominent results for learning:
1. **Relevance of the movement and the cognitive/learning task:**

This categorization refers to the level of embodiment or relatedness of the physical with the cognitive task. Central to this continuum is the factor of embodiment, referring to the enactment of concepts using the body (Lindgren & Johnson-Glenberg, 2013), ranging from no embodiment, where the movements are not related with the cognitive tasks, to high embodiment, in which full body movements are engaged, meaningfully related with the learning tasks. For example, running laps round a map during geography learning can be considered as non-task-relevant movements (“non-integrated condition”; Mavilidi et al. 2016), whereas dance movements that children perform when learning the foreign language word for dance (“integrated condition”; Mavilidi et al., 2015), or geometrical forms that children shape with their body when learning about geometry (Shoval, 2011) can be considered as task-relevant movements.

2. **Integration of the movement with the learning task:**

This categorisation refers to the temporal connection of the movements with the learning task. If the movements are performed before or after the learning task with an interval in between, the integration is low. If movements are performed during the learning task, the integration is high. For example, walking before or shortly after completing assessments on creative thinking are considered non-integrated movements (Oppezzo & Schwatz, 2014). Conversely, dance movements performed simultaneously during the learning of the
foreign language word for dance are integrated movements (Mavilidi et al., 2015). A continuum exists ranging from non-integrated movements, where there is no temporal overlap between movements and the learning task, to integrated movements, where the movements are connected and included during learning.

Figure 2.1 plots the selected studies in this review across these two dimensions. Research on exercise and cognition (i.e., physiological mechanisms), falls in the low-relevant quadrants, whereas research on integrated movement studies (i.e., embodied learning) falls into the high-relevant quadrants. The theoretical base underlying the two lines of research and their research questions are quite different. Converges of these lines of research have been prompted by two first reviews on the role that the cognitive complexity of movement tasks played in exercise and cognition, shifting the focus from the dose-response to quality-response relations, emphasising the cognitive demands of the physical activity tasks (Best, 2010; Pesce, 2012; Tomporowski et al., 2015). On the other hand, in educational psychology research, more subtle type of movements (e.g., hand movements, whole-body movements and simulated actions), are meaningfully aligned and congruent with the learning content. These movements do not provoke any physical exhaustion, but they are a significant adjunct of the learning process. A discussion of the studies belonging to each of the quadrant is presented below:
Figure 2.1. Graph portraying the selected studies across two dimensions: the horizontal dimension reflects the integration between the physical and the cognitive or learning task (i.e., integrated vs. non-integrated), and the vertical dimension reflects the relevance of the physical task for the learning task (i.e., relevant vs. non-relevant). The quadrants are clustered in thematic units as presented in the text.
2.3.1 Body movements not relevant for, and not integrated into the cognitive/learning task

In the top left quadrant of Figure 2.1, the studies that are plotted include movements that are non-integrated and non-relevant for the learning tasks. Research of this area mostly involves afterschool programs focusing on physical fitness and its indirect relationship with cognitive and academic performance (Castelli, Hillman, Hirsch, Hirsch, & Drollette, 2011; Davis et al., 2011), or studies examining the acute effects of exercise on cognition (Buck, Hillman, & Castelli, 2008; Hillman, Buck, Themanson, Pontifex, & Castelli, 2009a).

According to neurophysiologists, higher fitness levels equal higher school performance due to physiological alterations in the brain structure; e.g., larger hippocampal volume, neurogenesis, synaptic plasticity, oxygenation, and brain circuit of hormones and neurotransmitters among higher fit students (Chaddock et al., 2010a, b; Khan & Hillman, 2014; Chaddock-Heyman et al., 2016). For example, the 9-month afterschool physical activity program “FITkids” for children 7-9 years old to ameliorate brain health and cognitive performance, found improvements in heart rate as a measurement of physical activity, physical fitness, inhibition and cognitive flexibility in children who participated in the intervention group, compared to the control group (Castelli et al., 2011; Hillman et al., 2014). The physical activity intervention offered two hours of physical activity each day after school, in which children were requested to participate for up to 40 min.

In the study of Coe, Pivarnik, Womack, Reeves, and Malina (2006) students were enrolled into a physical education program (including activities such as basketball, soccer, softball, and baseball), or an extra instruction class either in the
first or second semester for 55 min every day and their academic achievement consisted of students’ grades on four core courses (mathematics, science, English, and world studies) and a standardised test. Academic achievement was not influenced by the moderate intensity in the physical education class. However, children who partly or fully met the guidelines of 30 minutes of moderate-intensity physical activity per day for at least 5 days per week, or 20 min of vigorous activity per day for at least 3 days per week, had higher grades than students who were not engaged in vigorous physical activity in both semesters.

Davis et al. (2011) assessed 7-11 year old children’s executive function after randomly assigning them to a 40 or 20 min/day exercise program, or a no exercise control condition for 3 months. Children in the high dose exercise group completed two 20-min per day, whereas children in the low dose exercise a 20-min bout and 20-min sedentary activities (e.g., drawing, board and card games). Standardised cognitive assessments, achievement measures and fMRI were used. Results revealed that regular aerobic exercise improved cognitive performance in both exercise groups compared to the control group, but with more pervasive effects observed in the high dose exercise group. The high dose exercise group also outperformed the other groups in math scores.

In sum, aerobic exercise has been associated with improvements in executive functioning (Buck et al., 2008; Castelli, Hillman, Buck, & Erwin, 2007; Chaddock et al., 2010a, b, 2014; Hillman et al., 2009a, b; Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2011). For instance, preadolescent children had better performance in cognitive tasks gauging attention and inhibitory control after short bouts of 20-min walking compared with children who remained seated (either walking or seating breaks were incorporated in between the cognitive tasks for 3 sessions; Drollette et
Finally, performing physical education lessons in preadolescent students (11-12 years) while alternating degrees of cognitive engagement (circuit training vs. cognitively challenging team sport) showed higher free-recall memory performance when aerobic training was combined with team sport compared to aerobic training only or control groups (Pesce, Crova, Cereatti, Casella, & Bellucci, 2009).

2.3.2 Body movements not relevant for, but integrated into the cognitive/learning task

Examples of these studies are activity breaks or the use of active workstations during completing cognitive tasks, and exergaming.

Activity breaks are interspersed between phases of learning, but they do not overlap in time with the learning tasks. Starting with activity breaks, several studies explored physical activity that occurred in the classroom apart from physical education classes, recess or breaks (Howie, Schatz, & Pate, 2015; Katz et al., 2010; Teldford et al., 2012). Generally, these studies investigated the effects of short physical activity breaks (most commonly aerobic routines for 5-20 minutes) or ways to introduce physical activity into learning activity that were either designed to promote learning through physical activity or to provide purely an opportunity for children to engage in physical activity to increase energy expenditure. The studies examined how introduction of activity breaks in a classroom setting impacted health, cognitive skills (Hill et al., 2010), attitudes (mood, motivation; Vazou, Gavrilou, Mamalaki, Papanastasiou, & Sioumala, 2012), academic behaviors (i.e., on-task behavior, concentration; motivation; Grieco, Jowers, & Bartholomew, 2009; Webster, Wadsworth, & Robinson, 2015) and academic achievement (i.e., standardized test scores, reading literacy scores or math fluency scores) of children. In general, reviews on the relationship between activity breaks with aspects of academic performance
show that activity breaks either have positive effects or do not adversely impact cognitive function and academic performance (Centers for Disease Control and Prevention, 2010; Bartholomew & Jowers, 2011). For example, research has shown that four minutes of in-class high-intensity interval activity improves selective attention in 9- to 11-year olds (Ma, Le Mare, & Gurd, 2014). Likewise, running games or performing fundamental movement skills such as hopping, skipping, and jumping in the classroom could enhance fluid intelligence and academic achievement in 9-11 years old children (Reed et al., 2010).

Another type of integrated, but non-relevant physical activity can be identified in a new area of research focusing on the effects of active workstations (i.e., standing and treadmill desks, cycling workstation) on cognition. Several meta-reviews report a positive relationship between active workstations, mostly examined in office environments, and reductions in sitting time for adults, increments in energy expenditure and improved health (MacDonald, & Burr, 2015; Torbeyns, Bailey, Ros, & Meeusen, 2014). The effect of the use of these active workstations on cognition and applied work tasks, such as computer task performance, needs further investigation before conclusions can be drawn. Research to-date seems to indicate that low intensity exercise does not compromise cognitive functions. For example, Pilcher and Baker (2016) assessed undergraduate students’ performance, motivation (self-reported answers regarding enthusiasm, energy, drive, eagerness, and morale), and engagement (self-reported responses regarding subjective performance, attention, and absorption), when they used a stationary bicycle with a desk top and a traditional desk during the completion of cognitive tasks. Although cognitive performance did not differ, cycling desks improved positive affect, motivation and morale. Likewise, Alderman, Olson,
and Mattina (2014) found no differences in response or accuracy in several cognitive
tasks between a treadmill-desk walking and a seated control condition.

Since active workstations are a novel intervention, particularly within the
classroom environment, to-date there is only one systematic review that has
investigated the physiological effects of standing desks interventions within the
classroom setting (Sherry, Pearson, & Clemes, 2016), suggesting that energy
expenditure is increased when using desk bikes. Overall, implementing active
workstations in classrooms could be used as a way to decrease sedentary behavior
with no detriment of cognitive performance, although more research is needed to
glean insight in their potential as cognition’s enhancers.

Finally, an exercise and game-based learning approach linking digital
technology, mainly video gaming, with exercise and learning is known as
exergaming. Exergaming is a developing area of research with yet to be established
results. It seems a promising way to increase physical activity, improve general
coordination skills, motivation, and cognitive outcomes such as improved attention
and visual-spatial skills through linking exercise with digital technology and learning
(Staiano & Calvert, 2011). Exergames have been found to directly impact executive
functioning in elementary children (e.g., Best, 2012) and adolescents (Benzing,
Heinks, Eggenberger, & Schmidt, 2016). For instance, 6- to 10-year-old children
participated in four experimental sessions that included a video with low cognitive
engagement and physical activity, a sedentary video game with high cognitive
engagement and low physical activity, an exergame with low cognitive engagement
and high physical activity and an exergame with high cognitive engagement and high
physical activity. Although cognitive engagement did not result in changes, physical
activity in exergaming led to faster responses to the visual-spatial stimuli (Best, 2012).

Exergaming has also been implemented in elementary school for different learning contents such as maths, history, and languages and with varying difficulty levels (Lucht & Heidig, 2013). Higher scores in cued-recall were found in the experimental condition, in which children had to jump and move as quickly as possible on a sensor pad when playing a vocabulary game compared to the traditional teacher-center condition. The integration of physical activity into learning games seemed to be an enjoyable and engaging way holding promise for learning in children. These studies had high ecological validity as they took place in real-life situations and existing school lessons. In contrast, Sun (2012) explored the influence of exergaming on physical activity and interest in fourth-grade children. Children alternated between different 30-min exergaming and fitness lessons in a within-subjects design twice per week for a four-week period. In terms of physical activity, only the fitness lessons increased energy expenditure, generating moderate levels of physical activity whereas exergame lessons did not. In terms of situational interest, exergame lessons were more interesting for students than fitness lessons regarding factors such as challenge, exploration opportunity, and instant enjoyment. Lastly, O’Leary et al. (2011) found that only single bouts of treadmill-based exercise compared to a seated rest, videogame play, and exergame, facilitated task performance and inhibitory control, exhibiting decreased reaction time and larger P3 amplitude.

To conclude, it is premature to infer about the effectiveness of active video games on augmenting energy expenditure and learning. However, active video games may have an additional benefit on engaging players with light-to moderate physical activity compared to other sedentary behaviors such as passive video games and rest
Given the length of time and relatively high-frequency that children and adolescents spend in video gaming (at least 1 hour per day on the weekdays and 1.5 hours on the weekend for children 10 to 19 years; Cummings & Vandewater, 2007), successfully designed exergaming has the potential to influence physical activity levels and cognition in children.

2.3.3 Body movements relevant for, but not integrated into the cognitive/learning task

In the top right quadrant of Figure 2.1, studies that include movements relevant for, but not integrated into the learning tasks are presented. This kind of research involves bodily movements, mostly arm movements, with the absence of physical activity, on several measures of cognition such as insight problems or creativity. The movements occurred prior or after the cognitive task, with the key concept being the accordance between the movement and the cognitive task. Thus, these movements function as simulated actions, indirectly fostering information processing (Alibali & Kita, 2010; McMorris, Tomporowski, & Audiffren, 2009). It is argued that the body can work as a scaffold, or conceptual metaphor to abstract cognitive contents (Landau, Meier, & Keefer, 2010; Williams, Huang, & Bargh, 2009), guiding higher order cognitive processing (Thomas & Lleras, 2009).

Thomas and Lleras (2009) allocated university students to exercise breaks either consistent with (swing group) or inconsistent with (stretch group) an insight problem that they had to solve immediately afterwards. They had to solve Maier’s two-string problem, which they could only solve by swinging one of the ties with an object attached. The experiment consisted of eight attempt intervals with 20-sec exercise and 100-sec problem-solving periods. It was found that the swing group was
more successful in solving the problem than the stretch group, without being aware of the swinging arm movements as overt hints to problem-solving. Consistent with these results, Werner and Raab (2013) found a movement-specific influence on participants’ solution of two-string and water-jam problems. They assigned adult participants to two movement groups that were congruent with the problem-solutions or a control group. To this end, Raab and Green (2005) suggested that movement goals rather than the arm position cause activation and internal evaluation process, affecting performance in a word association task.

Another study compared effects of fluid with non-fluid movements on creative thinking (Slepian & Ambady, 2012). A set of drawings was designed in which undergraduate students had to trace either arm movements with or without line curvature (fluid and non-fluid movements, respectively). Subsequently, participants were assessed in creative generation, cognitive flexibility, and remote associations. Fluid movement enhanced creativity in all three domains, even though participants did not consciously perceive this positive affect.

Finally, Glenberg, Sato, and Cattaneo (2008) provided evidence on the causal link between language comprehension and the motor system. Participants were required to perform a 20-min repetitive transfer motor task in which they had to move 600 beans from a wide-mouthed container to a narrow-mouthed container. It was found that the participants’ concrete and abstract language comprehension differed based on the motor task (i.e., arm movements toward vs. away from the body and right-hand vs. left-hand index finger).

2.3.4 **Body movements relevant for, and integrated into the cognitive/learning task**
In the bottom right quadrant of Figure 2.1, studies are plotted that include movements relevant for, and integrated with the learning tasks. The studies included in this quadrant almost exclusively regard the developmental age and the school context. The first part focuses on subtle movements, mainly gestures, to continue with studies involving whole body movements, and finally gross motor movements in the form of physical activity.

To begin with, well-known are the mathematical studies in which 9- to 10-year-old children were taught to make an abstract gesture as a tool for solving new mathematical-equivalence problems in the form of $5 + 2 + 4 = \_ + 4$ (Goldin-Meadow et al., 2009; Goldin-Meadow et al., 2001). Children had to produce a V-point gesture to the first two numbers and then to point at the blank. These movements were designed to help the children understand that the problems could be solved by grouping and adding the two numbers on the left side of the equation that do not appear on the right side and then putting the sum in the blank. The movements were modelled after the spontaneous gestures of children that already had mastered the specific mathematical strategy (Perry, Church, & Goldin-Meadow, 1988). Children who were asked to produce these hand movements during a math lesson benefited more from math instruction than children who were not instructed to gesture. They retained more of the knowledge and were able to extract the underlying grouping strategy, although they were never explicitly told what the movements represented.

Also, in a study by Schwartz and Black, (1999), participants were presented with two glasses with differing widths and equal heights and were asked to imagine the glasses being filled with water to the same level. Participants judged whether the water would spill when glasses were rotated at equal angles. Participants judged whether the water would spill when glasses were rotated at equal angles. Participants were better at predicting when rotating the empty glasses with their eyes closed, compared to when they had to
mentally rotate the glass in order to come up with a solution. Finally, Lubin et al. (2010) stressed the pedagogical role of actions in arithmetic performance of 2-year-old children. Children overcame language bias and showed higher performance when they were able to manipulate the materials themselves (actor only group) compared to the onlooker group, in which children were observing the addition problems being processed by the experimenter.

A dearth of studies used full-body movements on children's learning focusing on different learning outcomes such as mathematics and language, and targeting different age groups, although with absence of physical activity assessments.

Ruiter et al. (2015) examined the process of number building (two-digit numbers) in first grade children by making steps on a ruler across the floor. In the two movements condition, children made small, medium and large steps representing different number units of 1, 5, and 10, respectively, whereas in the two control conditions, children had to verbally construct the two-digit numbers. Results showed higher test performance when children were engaged in full-body movements. A 6-week intervention program (3 math lessons per week of 60 min) evaluated executive functions and mathematical performance in pre-adolescent children (Beck et al., 2016). Children were randomly assigned to a gross motor enrichment condition, in which children performed static and dynamic movement such as skipping, and crawling, to support the mathematical principles and procedures to-be-learnt, or fine motor movement condition, in which children used their hands and fingers to manipulate Lego bricks while solving mathematical problems, or a conventional math teaching condition, with no movements involved. The integrated gross motor activities contributed to mathematical achievement, with greater improvements shown
in normal math performers compared to the other two groups (i.e., fine motor movement and conventional math teaching condition).

Shoval (2011) examined the effects of cooperative active learning when learning angles in geometry class. Second and third grade students were enrolled either in an experimental or a control condition. In the experimental condition, children collectively formed a circle with their bodies to learn about the circle, whereas children in the control condition learned about the subject geometry through the sedentary conventional method. The former obtained better results than the group taught in a conventional way without movements.

Toumpaniari et al. examined the effects of whole-body movements and gestures on learning foreign language vocabulary in four-year old children (Toumpaniari, Loyens, Mavilidi, & Paas, 2015). Firstly, children were shown flashcards with animal names. Children were assigned to one of three groups in which they had to recall animal words, a) through performing physical activities and gestures relevant to the animal words to be learned, or b) gesturing related to the animal words or c) through the conventional way. Results showed that learning a foreign language vocabulary through physical activities and gestures was considered the most enjoyable way of learning, and resulted in the highest learning outcomes.

Finally, studies consisting of gross motor movements in the form of classroom-based physical activity are presented, measuring cognitive and physical activity outcomes. For instance, during the 15-min daily classroom-based physical activity, elementary school children could learn geometry by forming different shapes with their bodies such as squares or triangles while walking or skipping on an outdoor playfield, geography by running to the appropriate area designated for one of the directions (north, south, east, west), or spelling by hopping onto a floor mat with
alphabet letters onto it (Donnelly & Lambourne, 2011). The results revealed significant improvements in academic achievement as well as a significantly lower increase in body-mass index among children in the experimental compared to the control classrooms.

Vazou and Smiley-Oyen (2014) integrated a 10-min bout of acute aerobic activity into math practice. In the integrated condition, preadolescent children performed locomotor skills such as skipping, sliding, walking, hopping, leaping, bear and crab walking, and jumping, while avoiding obstacles when working on math problems. For example, when the answer was an odd number, students were crab walking, otherwise in case of an even number, they were bear walking. In the seated math practice condition, no bodily movements were involved. They found that elementary children in the integrated physical activity group showed significant improvements on accuracy while performing a cognitive task for inhibitory control, and higher scores on enjoyment compared with the seated math practice group. Classroom-based physical activity was an enjoyable way to promote physical activity and foster executive functioning in children.

A series of intervention studies integrating physical activity into learning tasks lasting 10-15 min per day also demonstrated prominent effects in early childhood (Mavilidi, Okely, Chandler, Cliff, & Paas, 2015; Mavilidi, Okely, Chandler, & Paas, 2016, 2017). Children were enrolled in the integrated condition in which children were engaged in meaningful, task-relevant physical activities (e.g., dancing while learning the word dance; imitating animal movements relevant to animals living in each continent while learning about the continents and animals living there; moving from the Sun to Mercury and repeat the same process for all planets while learning about the planets' names and their distance from the Sun), a condition involving task
non-relevant physical activities (e.g., running around the room before the learning task), or control condition (sedentary way of learning). Overall, the integrated condition had higher learning scores and was more physically active compared to the control condition.

2.4 Discussion

This review summarised theoretical and empirical evidence connecting action with perception, cognition and learning. Studies involving movements in the form of gestures or physical activity were assessed. Previous research has demonstrated the positive association of physical activity and mental health (White, Babic, Parker, Lubans, Astell-Burt, & Lonsdale, 2017), as well as the synergistic effects of physical activity, and fitness on cognitive functioning and academic performance (Lees & Hopkin, 2013). Concomitantly, research within the theoretical framework of embodied cognition has shown that embodying knowledge through task-relevant movements can positively impact learning (Barsalou, 2008). Overall, a new view of embodied cognition can be supported in this review, in which motor and cognitive control is managed by the same brain patterns (Pesce & Ben-Soussan, 2016). In accordance with the mirror-neuron system, sensorimotor actions, thoughts or words activate mirror neurons and in turn mental representations responsible for movements, such as action and language for example that are both located next to the Broca’s area in the brain (Aziz-Zadeh, & Damasio, 2008; Aziz-Zadeh, Wilson, Rizzolatti, & Iacobini, 2006). The mirror neuron system is linked with action understanding as well as the ability to observe and imitate others’ actions (Rizzolatti & Craighero, 2004). Van Gog, Paas, Marcus, Ayres, and Sweller (2009; see also Paas & Sweller, 2012) have transferred the mirroring capacity of the human brain in learning when a motor component is encompassed in the cognitive tasks.
Several types of physical activity interventions such as enhanced or enriched physical education, classroom-based physical activity, activity breaks or active play during recess, extracurricular physical activity interventions or after-school programs were included in this review. These contextual factors of physical activity inclusion (e.g., place, type and duration) seem to be important when inferring about the association among physical activity and cognition (i.e., executive functions such as working memory, inhibition, and cognitive flexibility, metacognitive functions such as abstract reasoning, problem-solving, and cognitive life skills such as self-regulation, goal setting), academic achievement (i.e., mathematics, language scores), and academic behaviors (i.e., on-task behavior; Alvarez-Bueno et al., 2017).

Nevertheless, the types of movements used can be summarised as aerobic exercise, motor actions (e.g., gestures), and cognitively engaging physical tasks (e.g., sports or classroom-based physical activity). Improvements on children’s and youth’s cognitive performance have been shown in all of them, with more pronounced effects being observed during the cognitively engaging physical tasks (meta-analysis of Vazou et al., 2016). The mentally enriched and cognitively engaging physical activities offer a range of different inherent qualitative characteristics (such as task complexity, novelty, and diversity/variety, emotional activation, selection of suitable mental strategies). These characteristics act as brain stimulators contributing to enhancements in children’s executive functioning (Diamond & Ling, 2015; Vazou et al., 2016).
Figure 2.2. Schematic graph of the suggested conceptual framework.

On the basis of this review, we propose an innovative instructional method that combines task-relevant physical activities integrated with cognitive tasks. We believe that by adopting this approach, children will benefit from the combined physiological (e.g., increased arousal, neurological alterations in the brain; Best, 2010, 2012) and cognitive effects (e.g., embodied learning; Kontra, Goldin-Meadow, & Beilock, 2012) on cognition and learning. Gathering support towards the integrated task-relevant physical activity programs has the potential to offer paramount health and cognitive outcomes (meta-analysis of Fedewa & Ahn, 2011; systematic review and meta-analysis of Morgan et al., 2013). Existing programs have already received positive social support and feedback within the school environment, because their versatility takes into account time and budget constraints, and limitations in teachers’
experience (Webster, Russ, Vazou, Goh, & Erwin, 2015). Integrated physical activities offer different possibilities and variations based on the level of task complexity, children’s age group, and syllabus’ restrictions. This flexibility promotes high ecological validity including a universal applicability to all classrooms settings in which students are engaged in high quality learning activities in an engaging, motivating, and amusing way. Hence, the classroom instruction integrated with physical activities does not have a detrimental effect on academic time (Sallis et al., 1997; Ward et al., 2006), but rather positions academic content centrally, empowering it.

Notwithstanding, valuable efforts have been taken to increase physical activity through stealth interventions (Robinson, 2010) mostly in elementary years. However, existing programs explored in early childhood settings, for example, mainly focus on health benefits such as reducing sedentary behavior and screen time and increasing physical activity (Jones et al., 2011) or cognitive development (Glass, 1999; Love et al., 2005) in isolation, neglecting the additive benefits from the combined effects. Nevertheless, effective programs in the early years can improve children’s executive functions (Diamond, Barnett, Thomas, & Munro, 2007). No matter whether their focus has been on increasing physical activity and reducing sedentary behavior, or boosting academic performance, coupling physical with cognitive tasks, fosters cognitive development, motivation and engagement (Leppo, Davis, & Crim, 2000; Moreau, 2015). Overall, the integration of movement experiences to learning areas results in children being more physically active, enthusiastic and attentive to learning tasks such as math or language (Becker, McClelland, Loprinzi, & Trost, 2014; Trost, Fees, & Dzewaltowski, 2008). We argue that similar efforts should target all age groups in a way that time spent in childcare centers and schools contributes to
children’s physical and mental wellbeing, cognitive and socio-emotional functioning, and the development of healthy lifestyles with ample directions towards prevention of later cognitive delays and building of school readiness (Anderson et al. 2003; Erwin, Beighle, Carson, & Castelli, 2013; Finn, Johannsen, & Specker, 2002; Pate et al., 2006).

To conclude, in education, physical activity and cognitive activity are typically treated as unrelated processes. In contrast, a more integrated approach is recommended for most effective health and learning outcomes. The current review in no way exhausts the existing literature but rather uses selective examples to draw conclusions and suggest a new instructional approach in which physical activities are intermingled with classroom instruction. Results of recent studies affirm that integrated, task-relevant physical activities have paramount effects on learning. Future research is needed to shed light on the required frequency and duration of the classroom-based physical activity programs, taking into account different age and target groups (including minority or low socioeconomic status children, children of typical development, and diagnosed with developmental disorders), and the feasibility of their implementation in “real-world” settings (including teachers’ preferences, sustainable resources, construction of “user-friendly” manuals, and guidelines for teachers).
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Chapter 3

Effects of Integrated Physical Exercises and Gestures on Preschool Children’s Foreign Language Vocabulary Learning

3.1 Abstract

Research suggests that integrating human movement into a cognitive learning task can be effective for learning due to its cognitive and physiological effects. In this study, the learning effects of enacting words through whole-body movements (i.e., physical exercise) and part-body movements (i.e., gestures) were investigated in a foreign language vocabulary task. Participants were 111 preschool children of 15 childcare centers, who were randomly assigned to one of four conditions. Participants had to learn 14 Italian words in a four-week teaching program. They were tested on their memory for the words during, directly after, and six weeks after the program. In the integrated physical exercise condition children enacted the actions indicated by the words to be learned in physical exercises. In the non-integrated physical exercise condition children performed physical exercises at the same intensity, but unrelated to the learning task. In the gesturing condition, children enacted the actions indicated by the words to be learned by gesturing while remaining seated. In the conventional condition, children verbally repeated the words while remaining seated. Results confirmed the main hypothesis, indicating that children in the integrated physical exercise condition achieved the highest learning outcomes. Implications of integrated physical exercise programs for preschool children’s cognition and health are discussed.

Keywords: learning, preschool children, physical exercise, gesturing
3.2 Introduction

There is no doubt that movement is essential for human life. Research has shown substantial health, cognitive and academic benefits as a result of regular school-based physical activities (e.g., Tomporowski, Davis, Miller, & Naglieri, 2008). Although these benefits have been found even when time for physical activities replaced part of the academic time (e.g., Sallis et al., 1997), the concern that time for physical activities is associated with a loss of academic time is considered a major obstacle to realising greater involvement in school-based physical activities, and the time spent on physical education in schools is actually declining (United Nations Educational, Scientific and Cultural Organization, 2015). One promising approach to relieve this concern is to investigate ways to infuse physical activity within the classroom and find ways to integrate physical activity into learning tasks without compromising learning performance or even improve it. In this study, we investigated whether such integrated physical exercises would result in better learning than non-integrated physical exercises. In addition, it was investigated whether the integrated physical exercises would lead to better learning than the same integrated activities without physical exercise. The latter type of activities refers to expressing information in gesture, which has been found effective for learning in children and young adults (e.g., Cook, Mitchell, & Goldin-Meadow, 2008; Goldin-Meadow, Cook, & Mitchell, 2009; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001). Whereas the effects of gross motor or whole-body movements in the form of physical exercise on cognition and learning have mainly been explained by physiological mechanisms, the effects of more subtle or part-body movements, such as gestures, have mainly been explained by cognitive mechanisms.
3.2.1 Effects of whole-body movements

An important outcome arising from the effects of physical exercise, which can be defined as “planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness” (United States Department of Health, & Health Services, 1996), is that it elicits brain changes that facilitate learning and memory (Hillman, Erickson, & Kramer, 2008; Liu-Ambrose, Nagamatsu, Voss, Khan, & Handy, 2012). In an effort to uncover the underlying mechanisms of physical activity, Erickson, Hillman, and Kramer (2015) reviewed studies of physical activity on brain structure, brain function and academic achievement. They concluded that fitter and more active children showed a range of physiological benefits (e.g., greater grey matter volume in the hippocampus, more effective brain activity patterns), performed better on tasks that require executive control and associative memory, and showed higher academic achievement. There is extensive research supporting the finding that physical activity positively correlates to cognitive performance (for reviews, see Barenberg, Berse, & Dutke, 2011; Erickson et al., 2015; Fedewa & Ahn, 2011; Sibley & Etnier, 2003; Tomporowski, Davis, Miller, & Naglieri, 2008). It has become clear from those studies that the type of activity, level of intensity, duration of exercise required, aspects of cognition, and learner characteristics affect the relationship between physical activity and cognitive performance. For example, Sibley and Etnier’s (2003) meta-analysis revealed a positive impact on children’s cognition, which did not differ as a function of the type of physical activity (i.e., resistance training, perceptual-motor training, physical education classes, and aerobic exercises) on children’s cognition. The effect of physical activity on cognitive performance was the greatest for children in the young elementary and middle school age group. The effect of physical activity on children’s
cognition differed significantly on the type of cognitive assessment used. The largest effect was found for assessments on perceptual skills, followed by IQ, academic achievement, and math and verbal tests. Furthermore, a meta-analysis by Chang, Labban, Gapin, and Etnier (2012) showed that acute bouts of exercise can have beneficial effects on cognitive tasks executed during, immediately after, or after a delay following the exercise. Short bouts of exercise affect cognitive processes by increasing response speed and accuracy (Tomporowski, 2003), improving working memory capacity (Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009), as well as improved performance on free-recall tasks (Coles & Tomporowski, 2008). For example, Drollette et al. (2014) showed that, after 20 minutes of treadmill walking, preadolescent children had better performance on cognitive tasks gauging attention and inhibitory control compared with children who remained seated.

3.2.2 Effects of part-body movements

More subtle movements, such as gestures, are typically integrated into the learning task and are only effective when they are meaningful for or congruent with the learning task (Kelly, McDevitt, & Esch, 2009; Macedonia & Klimesch, 2014; Trofatter, Kontra, Beilock, & Goldin-Meadow, 2015). There is increasing evidence that gesturing has positive effects on learning of different types of cognitive tasks, such as math (e.g., Cook et al., 2008; Goldin-Meadow et al., 2001; Novack, Congdon, Hemani-Lopez, & Goldin-Meadow, 2014), and language (e.g., Allen, 1995; Kelly et al., 2009; Macedonia & Klimesch, 2014; Tellier, 2008; Thomas & Lleras, 2009; Trofatter et al., 2015).

The theoretical framework of grounded or embodied cognition has been used to explain the positive effects of this type of movement on learning. Embodied
cognition is based on the notion that cognitive processes develop from goal-directed interactions between organisms and their environment (Barsalou 1999, 2008; Glenberg, 1997). It assumes that cognitive processes are grounded in perception and action (Barsalou, 1999). Ample evidence for the embodied cognition framework comes from psychological research in a variety of domains, such as research on action semantics (e.g., Lindemann, Stenneken, Van Schie, & Bekkering, 2006), language comprehension (e.g., Zwaan & Taylor, 2006), and neuroscience (e.g., Glenberg et al., 2008). This research shows that visual and motor processes in the brain are active during the performance of cognitive tasks such as reading, comprehension, mental arithmetic, and problem solving, while semantic codes are activated during the performance of motor tasks, suggesting that cognitive and sensorimotor processes are closely intertwined. An explanation for the positive effects on learning is that embodying knowledge through making gestures results in a distinct, visuospatial representational format that can enrich the way information is coded, i.e., the construction of higher quality cognitive schemas (Goldin-Meadow et al., 2001; Paas & Sweller, 2012). Higher-quality cognitive schemas are associated with better and less cognitively demanding learning (Goldin-Meadow et al., 2001; Ping & Goldin-Meadow, 2010), which materialises in faster and more accurate performance on a learning test. An alternative explanation holds that gesturing shifts some of the load from verbal working memory to other cognitive systems. This explanation is consistent with results from cognitive neuroscientific research showing that gesture is represented in cortical areas that differ from those that handle verbal materials (e.g., Decety et al., 1997),

Speech gestures, consisting of pantomimic and non-pantomimic gestures, can assist memory. Pantomimic gestures convey meaning even when verbal speech is
absent (Cohen & Otterbein, 1992). The present study focused on learning of a foreign language vocabulary by acting out the meaning of words through pantomimic or enactment gestures. Empirical work has demonstrated that meaningful engagement of the motor system during language processing enhanced memory encoding and retrieval. Performance on free-recall as well as cued-recall tasks is better when the verbal instructions can be enacted while learning (‘enactment effect’: Cohen & Otterbein, 1992; Engelkamp & Cohen, 1991). Gestures have a representational function, connecting different modalities such as the verbal, visual and motor modality. Enactment effects induced by gestures promote deeper semantic or conceptual processing, facilitating memory performance of younger and older adults on recognition and cued-recall tasks (Feyereisen, 2009).

3.2.3 Empirical evidence

Several studies have provided evidence for the positive effects of gestures on language learning. Macedonia and Klimesch (2014) showed that encoding of novel words from an artificial language was deeper when information was presented through enactment (involving gestures) rather than audiovisually. Tellier (2008) assessed learning vocabulary words from a foreign language. Preschool children had to either to listen and repeat each word, watch a gesture related to the word, and reproduce the gesture (gesture group), or listen and repeat a word, and watch a picture related to the word (picture group). She found that children in the gesture group performed better than children in the picture group in recall tests. Gesturing can be a powerful aid for long-term recall of complex learning such as learning first and foreign languages in preschool children (Rowe, Silverman, & Mullan, 2013).
Previous research has also provided evidence for the positive effects of physical activity on language learning. Pesce, Crova, Cereatti, Casella, and Bellucci (2009) investigated the effects of physical activity on children’s memorization of vocabulary words from a foreign language. They taught children 11-12 years old children words from a foreign language and examined their performance on immediate and delayed recall when they were engaged in circuit training, team games or did not exercise at all. They concluded that acute bouts of physical activity might facilitate memory storage efficiency by minimizing rehearsal and shortening consolidation time. Focusing on the synergistic effects of physical activity and academic performance (Lees & Hopkins, 2013), physical activity programs incorporating short bouts of acute exercise could be effectively applied during daily school schedules to promote physical activity and enhance cognitive performance in children (Drollette et al., 2014). The role of school-based physical activity programs in increasing physical activity during the school day either through recess or breaks or by integrating physical activity with academic content has been investigated in several studies (Bartholomew & Jowers, 2011; Castelli, Hillman, Hirsch, Hirsch, & Drollette, 2011; Davis et al., 2011; Donnelly & Lambourne, 2011; Hillman et al., 2009, Kibbe et al., 2011; Lambourne et al., 2013; Mahar et al., 2006; Telford et al., 2012; Vazou & Smiley-Oyen, 2014). In general, these studies report positive associations between physical activity and learning outcomes in elementary and high school children (Erwin, Fedewa, Beighle, & Ahn, 2012). Classroom-based physical activity is considered an enjoyable way to promote physical activity and foster executive function in children (Vazou & Smiley-Oyen, 2014).

However, there is a dearth of research in younger children in early childhood settings. Interventions in early years have tremendous effects on children’s cognitive
and social development (Ramey & Ramey, 1998), therefore it is considered important to examine the effects that can be found in this specific age group. One of the few intervention programs targeting preschool children found that when they were engaged in moderate to vigorous physical activity play, they showed better self-regulation skills, which resulted in higher math and literary achievement scores (Becker, McClelland, Loprinzi, & Trost, 2014). Moreover, Trost, Fees, and Dzewaltowski (2008) developed a ‘move and learn’ intervention program integrating gross motor movements in all aspects of a preschool curriculum. They found that at the end of the intervention, children were more physically active and also showed more enthusiasm, and attention to the leaning tasks. However, learning outcomes were not measured in this study. In a review, Best (2010) concludes that aerobic exercise can have direct and beneficial effects on executive function, which is crucial for enhancing cognitive development and learning in early childhood.

### 3.2.4 The present study

Taken together, the results of the unrelated lines of research into the cognitive and physiological effects of part- and whole-body movements on learning suggest that an intervention combining both effects by integrating task-relevant physical exercises into the learning task could be more effective than interventions targeting only non-integrated physical exercises or task-relevant gestures. In this study four conditions were compared to investigate this suggestion in preschool children.

The main hypothesis was that an integrated physical exercise condition in which children learn foreign language vocabulary by performing physical exercises to enact the meaning of those words would lead to the highest immediate and delayed retention performance. The integrated physical exercise condition was compared to a
non-integrated physical exercise condition, a gesturing condition, and a conventional condition. In the non-integrated physical exercise condition children performed physical exercises at the same intensity during learning, but unrelated to the learning task. In the gesturing condition children enacted the actions indicated by the words to be learned by gesturing while remaining seated, and in the conventional condition children verbally repeated the words while remaining seated. Based on the results of previous research, it was expected that the non-integrated exercise condition and the gesturing condition would show higher immediate and delayed retention performance than the conventional condition. Finally, children in the two exercise conditions were expected to be equally active, but more active than children in the non-exercise conditions (i.e., gesturing and conventional condition).

3.3 Method

3.3.1 Participants

Participants were 125 preschool children (64 boys and 61 girls) with a mean age 4.94 years ($SD = .56$). Fifteen childcare centers were recruited for this study. However, in the analysis 111 participants were included due to missing data. Participants were recruited from four childcare centers in total in the integrated, four centers in the non-integrated, four centers in the control condition and three childcare centers in the embodied condition. The study was approved by the Human Research Ethics Committee of the University of Wollongong (See Appendix A). All parents completed a written consent form about their children’s participation in the research (Appendices B & C). Only children who attended childcare for 2 days or more per week were eligible to participate in the study. Children who had prior knowledge or relatives speaking the Italian language at home were excluded from the study.
Also, children with developmental disorders and/or learning difficulties did not participate in the study. The childcare centers were randomly assigned, in such a way that there were children from 3-4 centers in total per condition. The resulting number of participants in each condition was: thirty-one in the integrated condition, 23 in the non-integrated condition, 31 in the gesturing condition, and 26 in the conventional condition. Children received stickers when they completed the activity and after testing as a reward for their effort.

3.3.2 Materials


Children were taught 14 words from a foreign language (i.e., Italian). The selected words were: fast, slow, dance, soccer, broom, low, high, swim, fly, jump, march, catch, throw, and roll. The selection of the words was based on every day actions familiar to the children. Also, it was reassured that the words in Italian were no more than three syllabi. The suitability of the chosen words in terms of pronunciation and meaning of the actions for preschool children was evaluated by a teacher with an Italian background. Each day, children were taught seven different words. The order of the to-be-learned words was counterbalanced across the different days and weeks. Static pictures with children doing the relevant activities were displayed to children. After the presentation of each word, the researcher pronounced the words in Italian and children repeated the words afterwards. In the free-recall tests, children were asked how many and which words they could recall regardless of their presentation order. In the cued-recall tests, children were shown the pictures and were asked to say the Italian word (Appendix E). The maximum score on the free-recall and cued-recall
test was 14 and the minimum score was 0. For each correctly recalled word, children received 1 point.

**Measurement of physical activity.** Children were fitted with an accelerometer (Actigraph models GT1M, GT3X and GT3X+/BT, Pensacola, FL), which was positioned over the anterior aspect of the right hip. The accelerometer was attached on an elastic belt, which was worn around the waist. Children and parents were instructed via written consent forms that the accelerometer should be worn every day during the intervention lessons. Accelerometers are instruments measuring variations in time differences in force or acceleration and thus assessing the magnitude and volume of movement as a function of time. The accelerometer collects data known as activity “counts” measured in time sampling intervals or epochs (Cliff, Reilly, & Okely, 2009). Measurements with the Actigraph accelerometer have been found to be valid, and reliable in children aged 3-5 years (Cliff et al., 2009). Because of the sporadic and intermittent type of physical activity in children, we used epochs of 15 s to estimate time in higher intensity activity (moderate and vigorous-intensity physical activity; see, e.g., Rowlands, 2007; Cliff et al., 2009). Lesson times were recorded and filters used to analyze only the data from the start to the end of the lesson each day. Data were reported as the average activity counts per minute, representing total physical activity or movement as a function of time during the lesson. Data were also reported as minutes spent in moderate and vigorous-intensity physical activity, as higher intensity physical activity might potentially be important for cognitive functioning in children (Davis et al., 2007). Age-appropriate cut-points (Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006) that have been shown to be the most accurate in young children (Janssen et al., 2013) were used to define activity
intensity. Out of 790 cases of accelerometry data, 66 cases were removed, because some children did not wear the monitor during the whole intervention session.

3.3.3 Design and Procedure

A mixed 4 (Condition: integrated, non-integrated, gesturing, conventional) x 3 (Time of Testing: during, directly after, follow up) experimental design with repeated measures on the latter factor was used. The dependent variables were children’s performance on the free-recall and cued-recall tests.

The study consisted of three phases: instruction, learning and testing.

Instruction phase. Children were presented once with each English word to ensure that they understood the meaning of all words. Instructions given to children lasted for 20 minutes. Children were told that they would play a memory game and that they had to listen carefully to the teachers’ instructions. After these instructions, they were asked questions about what they had learned. It was explained to them that they had to repeat the words after the instructor and perform an activity at the end of each word.

Learning phase. Children were assigned to a condition at center level, as it was not feasible to randomise children across conditions within each center. There were four different conditions in which children were taught the Italian words by using a different approach. Each one of the seven words that were taught per day was presented once at a time for one minute until finishing all the words. All the words were presented both auditory and visually. Children had to repeat each word after the word was presented by the instructor. The total duration of the learning phase was four weeks, consisting of one 15-minute session per day for 2 days per week.
In the integrated physical exercise condition, children enacted the actions indicated by the words to be learned by physically exercising. For example, for the word “fly”, children ran and moved their hands as if they were flying. The integrated physical exercise condition was a combination of the non-integrated physical exercise and gesturing condition. In the non-integrated physical exercise condition, children performed physical exercises at the same intensity during learning, but these were unrelated to the learning task. In this condition, children were running or walking for all the words regardless the meaning of the word. In the gesturing condition, children enacted the actions indicated by the words to be learned by pantomimic gestures while remaining seated. For example, for the word “fly”, children moved their hands as if they were flying while they remained seated. In the conventional condition, children verbally repeated the words while remaining seated.

**Testing phase.** Children were tested individually on their ability to recall the Italian words. During testing, children were asked to verbally recall as many words as they could remember from the learning phases (free-recall test) and subsequently based on the presentations with the words (cued-recall test). Words recalled were also considered correct when minor spelling errors or singular-plural substitutions had occurred. The total duration of the assessment was 15-20 minutes per child. The total number of words remembered in the free-recall and the number of correct words in the cued-recall test were calculated separately for the week 2 (during), week 4 (directly after), and week 10 (follow up).

In the assessment during the learning phase at the end of week 2, the possible short-term or acute effects of embodiment and physical activity on learning were examined. The assessment directly after the learning phase in week 4 occurred at the
end of the intervention and evaluated the medium-term effects of embodiment and 
physical activity on children’s ability to learn a foreign language. The final follow-up 
assessment was administered six weeks after the learning phase in week 10 to 
determine how well the learned words were maintained in the children’s memory. 
Moreover, emphasis was put on observing children’s learning progress. The 
assessments in the three different time periods were administered in identical form.

A pilot study was first conducted by the researcher to test the efficacy and 
feasibility of the forthcoming procedure. The researcher performed the teaching and 
testing together with three research assistants, who had received a 4-hour training 
session on how to teach and test children before the experiment.

3.4 Results

Mixed 4 (Condition: integrated, non-integrated, gesturing, conventional) x 3 
(Time of Testing; during, directly after, follow up) analyses of variance (ANOVAs) 
with condition as between-subject variable and time of testing as within-subject 
variable were performed. The dependent variables were performance on free-recall 
and cued-recall tests1. Effect size was measured via partial eta squared, in which 
small, medium, and large effects were operationalized as .01, .06, and .14, 
respectively (Cohen, 1988).

The means and standard deviations of free-recall and cued-recall performance as a 
function of the condition are presented in Table 3.1.

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1 Task enjoyment and task complexity were also measured. There were no effects on 
these measures and for reasons of length we deleted this information from the 
manuscript. Statistics can be obtained from the first author.
A mixed ANOVA was performed to examine the effects of condition and time of testing on the free-recall tests. Mauchly’s test indicated that the assumption of sphericity was met, $\chi^2(2) = 3.46, p = .177$. The ANOVA showed that there was a main effect of time of testing, $F(2, 214) = 50.21, p \leq .001, \eta^2 = .33$, indicating that the scores on the free-recall test differed significantly across the weeks of measurement. Polynomial contrasts tests revealed that there was a quadratic relationship for the time of testing, $F(1, 106) = 74.12, p \leq .001, \eta^2 = .41$. From week 2 to week 4, the number of recalled words increased, whereas from week 4 to week 10 it decreased. Children could recall more words in week 4 ($M = 1.83, SD = 1.56$) than in week 10 ($M = 1.32, SD = 1.56$), and more words than in week 2 ($M = .48, SD = .73$). Finally, children in week 2 ($M = .48, SD = .73$) could remember fewer words than in week 10 ($M = 1.32, SD = 1.56$). There was also a significant main effect of condition on free-recall test performance, $F(3, 107) = 5.14, p = .002, \eta^2 = .13$ (see Table 3.1). Post hoc tests revealed that children in the integrated condition ($M = 1.73, SD = 1.34$) remembered more words than children in the non-integrated condition ($M = .97, SD = 1.01$), $p = .006$, the gesturing condition ($M = 1.24, SD = 1.35$), $p = .049$, and the conventional condition ($M = .77, SD = .90$), $p \leq .001$. There were no differences on free-recall test performance among children in the non-integrated condition ($M = .97, SD = 1.01$) and the gesturing condition ($M = 1.24, SD = 1.35$), $p = .327$, as well as the non-integrated condition ($M = .97, SD = 1.01$) and the conventional condition ($M = .77, SD = .90$), $p = .473$, and between children in the gesturing condition ($M = 1.24, SD = 1.35$) and the conventional condition ($M = .77, SD = .90$), $p = .076$. Figure 3.1 displays the average total number of correctly recalled words. Finally, the interaction between time of testing and condition was not significant, $F(6, 214) = 1.98, p = .070$. 

"Free-recall"
Cued-recall

A mixed ANOVA was performed to examine the effects of condition and time of testing on the cued-recall tests. Mauchly’s test indicated that the assumption of sphericity was violated, $\chi^2(2) = 22.83, p \leq .001$. Therefore, the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .84$). The results showed that performance on the cued-recall tests was differentially affected by the time of testing, $F(1.68, 179.26) = 153.16, p \leq .001, \eta^2 = .59$. Polynomial contrasts revealed a quadratic relationship for time of testing, $F(1, 107) = 175.39, p \leq .001, \eta^2 = .62$. From week 2 to week 4, the number of recalled words increased, whereas from week 4 to week 10 it decreased. Children could recall more words in week 4 ($M = 4.42, SD = 2.35$) than in week 10 ($M = 3.84, SD = 2.48$), and in week 2 ($M = 1.21, SD = 1.20$). There was also a significant main effect of condition on cued-recall test performance, $F(3, 107) = 6.74, p \leq .001, \eta^2 = .16$ (Table 3.1). Post hoc tests revealed that children in the integrated condition ($M = 4.00, SD = 2.25$) remembered more words than children in the gesturing condition ($M = 3.17, SD = 2.04$), $p = .044$, and in the conventional condition ($M = 2.09, SD = 1.49$), $p \leq .001$. There were no significant differences between children in the non-integrated condition ($M = 3.20, SD = 1.55$) and the integrated condition ($M = 4.00, SD = 2.25$), $p = .073$, as well as the non-integrated ($M = 3.20, SD = 1.55$) and the gesturing condition ($M = 3.17, SD = 2.04$), $p = .944$. Children in the non-integrated condition remembered more words ($M = 3.20, SD = 1.55$) than children in the conventional condition ($M = 2.09, SD = 1.49$), $p = 0.17$, and children in the gesturing condition ($M = 3.17, SD = 2.04$) remembered more words than children in the conventional condition ($M = 2.09, SD = 1.49$), $p = .012$ (see Figure 3.1). Finally, the interaction between time of measurement and condition was not significant, $F(5.03, 179.26) = 2.45, p = .085$. 
Two separate ANOVAs were performed to assess the levels of physical activity across the different conditions and verify that the level of physical activity did not differ between the integrated and non-integrated exercise conditions. In addition, the analysis was used to verify whether the children in the exercise conditions were more active than the children in the gesturing and conventional condition. The units of measurement of level of physical activity were counts per minute as well as minutes of moderate- to vigorous-intensity physical activity (Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006). Results showed that there was a significant effect of condition on counts per minute, $F(3, 720) = 39.73 \ p \leq .001$, $\eta^2 = .14$. Post-hoc tests
with Games-Howell correction revealed that there were no differences found between the integrated condition ($M = 938.07$, $SD = 552.76$) and the non-integrated condition ($M = 807.56$, $SD = 552.76$), $p = .238$, and between the gesturing condition ($M = 517.57$, $SD = 348.89$), and the conventional condition ($M = 534.66$, $SD = 311.32$), $p = .957$. Both in the integrated condition ($M = 938.07$, $SD = 552.76$) and the non-integrated condition ($M = 807.56$, $SD = 552.76$) more counts per minute were recorded than in the gesturing condition ($M = 517.57$, $SD = 348.89$), $p \leq .001$, and the conventional condition ($M = 534.66$, $SD = 311.32$), $p \leq .001$.

There was a significant effect of condition on the total time spent in moderate-to-vigorous-intensity physical activity (MVPA), $F(3, 720) = 35.20$, $p \leq .001$, $\eta^2 = .13$. Post-hoc tests with Games-Howell correction revealed that there were no differences in time spent in MVPA between the integrated condition ($M = 3.85$, $SD = 3.20$) and the non-integrated condition ($M = 3.47$, $SD = 3.40$), $p = .759$, and between the gesturing condition ($M = 1.92$, $SD = 1.68$), and the conventional condition ($M = 1.75$, $SD = 1.17$), $p = .656$. Both in the integrated condition ($M = 3.85$, $SD = 3.20$) and the non-integrated condition ($M = 3.47$, $SD = 3.40$) children spent more time on MVPA than children in the gesturing ($M = 1.92$, $SD = 1.68$), $p \leq .001$, and conventional condition ($M = 1.75$, $SD = 1.17$), $p \leq .001$. 


<table>
<thead>
<tr>
<th>Type of test</th>
<th>Time of testing</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Week 2</td>
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<tr>
<td></td>
<td>M (SD)</td>
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<tr>
<td>Free recall (0-14)</td>
<td></td>
</tr>
<tr>
<td>Integrated condition</td>
<td>.98 (.81)</td>
</tr>
<tr>
<td>Non-integrated condition</td>
<td>.13 (.34)</td>
</tr>
<tr>
<td>Gesturing condition</td>
<td>.39 (.72)</td>
</tr>
<tr>
<td>Conventional condition</td>
<td>.31 (.62)</td>
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<tr>
<td>Cued recall (0-14)</td>
<td></td>
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<tr>
<td>Integrated condition</td>
<td>1.81 (1.38)</td>
</tr>
<tr>
<td>Non-integrated condition</td>
<td>1.07 (.83)</td>
</tr>
<tr>
<td>Gesturing condition</td>
<td>1.15 (1.10)</td>
</tr>
<tr>
<td>Conventional condition</td>
<td>.71 (1.15)</td>
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</tbody>
</table>

3.5 Discussion

The main goal of this study was to investigate the effects of enacting words through full-body movements in the form of physical exercise and part-body movements in the form of gesturing on learning a foreign language vocabulary. The results confirmed the hypotheses, indicating that the integrated condition, in which children used physical exercises to enact words to be learned, outperformed all other conditions for free-recall performance. For cued-recall recall performance, similar results were obtained, but results of the children in the integrated physical exercise condition did not differ from those of the children in the non-integrated physical exercise condition.
Overall, the scores on the tests were very low, even on the cued-recall test. This can be attributed to the fact that learning a foreign language vocabulary can be considered a very difficult task for 4 to 5 year-old children. Most importantly, children were exposed to the Italian words only during the learning phase and no other stimuli were provided to them during the day. Possibly, longer learning sessions and greater exposure during the day (e.g., more repetitions) would be needed to achieve higher performance scores. The results on the free-recall test, which can be considered more difficult than the cued-recall test, revealed that the integrated condition outperformed all other conditions during, directly after, and six weeks after the learning phase. Although children in the non-integrated and the gesturing condition showed higher performance than children in the control group, these differences were not significant. On the cued-recall task, all conditions outperformed the conventional condition. The integrated condition outperformed the gesturing condition, but not the non-integrated exercise condition. In addition, cued recall performance in the non-integrated and gesturing condition did not differ. In both free-recall and cued-recall tests, performance was the highest in the integrated condition, followed by non-integrated, gesturing and conventional condition. The pattern was the same for the delayed test, followed by the follow up and lastly the immediate test.

In general, the results of the integrated and gesturing conditions indicate that children’s learning of a foreign language vocabulary is positively affected by the cognitive effects of enacting the words through physical exercises or gestures. The positive effects on learning of the non-integrated physical exercise condition are reflective of the physiological effects of physical activities. Interestingly, the results indicate that embodying knowledge through physical exercises that are integrated in the learning task is a particularly effective learning strategy in young children. It is
also clear that the effectiveness of this strategy is caused by its integrated character, because physical exercise of the same intensity in the non-integrated condition resulted in lower free recall performance. This study corroborates findings of previous studies that accentuate the benefits of physical activity on learning and programs that successfully integrated physical activity into school classrooms in older children and elicited positive effects on academic achievement (Kibbe et al., 2011). At the same time, the principles of the embodied cognition framework were confirmed by the positive effects of movements in the form of physical exercise and gestures on learning performance. This study provided a unique contribution to the existing research literature by testing the effects of an integrated intervention program for preschool children, which integrated physical exercises into the learning task.

An alternative explanation for the effectiveness of the integrated physical activities and gestures on learning is that participants in these conditions not only made movements, but also observed other classmates making movements, because of the classroom based experimental setup. Episodic memory is based on the storage and retrieval of temporally dated, spatially located, and personally experienced events or episodes. Episodic information about a word is the information about the event of which the word was the crucial element (Tulving & Thomson, 1973). Observing others’ movements could support episodic memories as encoding of the words relied on the context or the situation elements. Moreover, numerous studies have shown that observing gestures can have positive effects on learning (e.g., Church, Ayman-Nolley, & Mahootian, 2004; Cook, Duffy, & Fenn, 2013; Ping & Goldin-Meadow, 2008). According to research on the mirror neuron system, when people look at others’ people actions, they activate neurons that are related to the same action in the motor cortex (Rizzolatti & Craighero, 2004). In the present study, children in the integrated
condition may have activated the relevant neurons linked with the physical activity actions in their motor cortex, which enhanced by the gestures, transformed that information into knowledge (Rizzolatti & Craighero, 2004). Future research could investigate whether the same effects on learning can be observed during individual learning sessions. This would provide the opportunity to differentiate effects of performing and observing movements on learning.

It is clear that more evidence needs to be obtained in replication studies to be conclusive about the positive effects of integrated physical exercise on children’s learning. In addition, similar future studies in the other domains, such as math and science, and with other target groups, such as adolescents, need to be conducted to determine whether the current results can be generalised across domains and target groups.

The current study has important educational implications. The results suggest that adding gestures or physical exercise to the learning of cognitive tasks leads to better learning that conventional strategies in which students learn by reading or listening to learning materials. The integration of physical activity into a language learning task by asking children to enact words through physical exercises seems especially effective for learning. An additional benefit of regular physical exercise, which has been found in previous research, is its positive effect on children’s physical and mental health. Therefore, implementing integrated physical exercises in early education programs can be expected to have pervasive long-term effects on achievement and academic success especially for children from low-SES backgrounds (Barnett, 1998).


Chapter 4

Infusing Physical Activities into the Classroom: Effects on Preschool Children's Geography Learning


Mind, Brain, and Education, 10(4), 256-263 (Published - Appendix K).
4.1 Abstract

In this intervention study, we investigated the effects of physical activities that were integrated into a geography task on preschool children's learning performance and enjoyment. Eight childcare centres with in total 87 4-5 year old children were randomly assigned across an integrated physical activity condition, an unintegrated physical activity condition, and the control condition without physical activity. Children learnt the names and a typical animal from each of the six continents using a floor-mounted world map with soft toy animals. Both learning conditions with physical activities showed higher performance than the learning condition without physical activities on an immediate retention test, and on a delayed retention test administered five weeks later. In addition, children in the physical activity conditions (integrated and non-integrated) enjoyed their learning method the most. Infusing task-relevant physical activities into the classroom and the learning task is discussed as a promising way to improve children's learning, enjoyment, and health.

**Keywords:** physical activity, cognitive load theory, learning, preschool children
4.2 Introduction

Research has shown that the benefits of physical activity in children are ubiquitous, including health, cognitive, and academic effects (e.g., Tomporowski, Davis, Miller, & Naglieri, 2008). Although the academic benefits of physical activity have even been found when time for physical activity replaced part of the academic time (e.g., Sallis et al., 1997), there is a general concern in schools that time spent in physical activity is associated with a loss of academic time and school success.

Mavilidi, Okely, Chandler, Cliff, and Paas (2015) suggested that infusing physical activity into the classroom by integrating task-relevant physical activities into learning tasks might be an effective way to improve children's health and cognition, and relieve the concern about academic time loss. Indeed, the results of Mavilidi et al. (2015; see also Toumpaniari, Loyens, Mavilidi, & Paas, 2015) showed that preschool children learned a foreign language vocabulary better, when the learning task was combined with physical activities relevant to the learning task than when it was combined with physical activities not relevant to the learning task, gestures related to the task, or with no activities at all. The present study used a similar approach, investigating whether the effects found for integrated physical activity on language learning would generalize to the domain of geography, focusing on the health and cognitive benefits of physical activity on learning.

Physical activity has positive physical and mental health effects, promoting musculoskeletal and cardiorespiratory fitness, preventing the development of some chronic diseases and conditions such as obesity, diabetes, cardiovascular diseases, and cancer, and reducing stress, anxiety and depression (e.g., Hills, King, & Armstrong, 2007; Wamburton, Nicol, & Bredin, 2006). In addition to the health benefits, research
confirms the positive effects of physical activity on children’s cognitive and brain functioning, and academic achievement (e.g., Fedewa & Ahn, 2011; Khan & Hillman, 2014; Sibley & Etnier, 2003). Physical activity and aerobic fitness have been associated with improved cognitive control (Kamijo et al., 2011), and enhanced brain development in specific areas (such as P3 amplitude, greater grey matter volume in the hippocampus, and more effective brain activity patterns; Drollette et al., 2014; Erickson, Hillman, & Kramer, 2015; Hillman, Castelli, & Buck, 2005). For example, physically high fit children of 9 and 10 years of age had better free-recall and cued-recall performance on a geography task than lower fit children (Raine et al., 2013).

Kamijo, Takeda, Takai, and Haramura (2015) examined associations between aerobic fitness and inhibition of task-irrelevant information in preadolescent children (11-12 years). Based on the results of a shuttle-run test, which was administered at the beginning of the academic year, children were categorised into low and high-fitness groups. Demographic measures, as well as data on maternal education (as a measure of socioeconomic status) did not differ between groups. Results showed that higher-fit children were better able to inhibit irrelevant information in an orienting task, and responded faster to target stimuli and task-relevant information than lower-fit children. To conclude, current literature suggests that fitter and more active children display a range of positive physiological and cognitive benefits.

In preschool settings, physical activity has been implemented as a structured and planned activity, for example in the form of physical activity breaks, or as unstructured outdoor play (Bower, Hales, Tate, Rubin, Benjamin, & Ward, 2008). However, with a few exceptions (see e.g., Fedewa, Ahn, Erwin, & Davis, 2015) physical activities have not been used during learning in a way that the activities are relevant to the learning task. Fedewa et al. (2015) implemented an eight-month
intervention to provide physical activity breaks in primary school children. Whereas children in the control group followed the regular curriculum, the experimental classrooms integrated physical activity into the academic curricula through the use of movement cards, for 20 minutes per day, five days a week. These cards consisted of aerobic-based activities (such as children doing jumping jacks with mathematical facts) lasting 5 minutes each. Results revealed that physical activity breaks improved reading and mathematics achievement.

Moreover, there is a dearth of studies focusing on the cognitive effects of movements. These studies use the theoretical framework of embodied cognition, which is about how what we do physically affects how we think. The interactions between the body and the environment offer rich sensorimotor experiences (Wilson, 2002), where conceptual representations are grounded in different modality-specific systems (i.e., perception, action emotion; Barsalou, 2008; Barsalou, Simmons, Barbey, & Wilson, 2003). As such, cognition is grounded in action, thus linking movements with cognitive tasks can have a positive effect on learning. According to the theoretical frameworks of cognitive load theory (e.g., Paas & Sweller, 2012; for an overview see, Sweller, Ayres, & Kalyuga, 2011) and embodied cognition (e.g., Pouw, Van Gog, & Paas, 2014) movements make minimal demands on working memory resources and can be used to assist in the acquisition of knowledge and skills. Furthermore, in addition to simply seeing or hearing information, taking action in response to it, creates a richer memory trace supplying alternative avenues for recalling the information later on (Chandler & Tricot, 2015). Evidence on how encoding through subtle movements such as gestures supports memory exists widely for learning language (Macedonia & Klimesch, 2014) and maths (Goldin-Meadow,
Cook, & Mitchell, 2009). Examples of empirical studies including actions and movements directly related to learning will be discussed next.

Fisher, Moeller, Crenzi, and Nuerk (2011) evaluated preschool children’s performance on numerical skills. Half of the children were enrolled first in the experimental and then a tablet-PC training condition, and the other half were enrolled in these conditions in the reversed order. Children received three training sessions per condition, lasting 10 - 15 min each. In the experimental condition, they were presented with a spatial number line using a dance mat for spatial-motor responses, whereas in the tablet training condition there was no explicit spatial information contained in the presentations or response formats. The sensorimotor spatial-numerical training was found to be more beneficial for children’s arithmetic learning than non-spatial control training.

A school-based physical activity intervention program was developed to improve academic outcomes among 2nd and 3rd grade students (Mullender-Wijnsma, Hartman, de Greeff, Doolaard, Bosker, & Visscher, 2016; Mullender-Wijnsma, Hartman, de Greeff, Bosker, Doolaard, & Visscher, 2015). Within the program, moderate- to vigorous-intensity physical activity was integrated into mathematics and language lessons. At 2-year follow-up, children in the intervention program displayed greater improvements in learning mathematics and language than children in the control group who followed their usual classroom practices.

Classroom-based physical activity programs in elementary school-aged children have attempted to include active body movements in a meaningful way in learning by integrating physical activity with the academic content (Webster, Russ, Vazou, Goh, & Erwin, 2015). The intervention study of Toumpaniari et al. (2015)
examined the effects of combining physical and cognitive activities on learning foreign language vocabulary in four- and five-year-old children. Children were shown flashcards with animal names. In two 1-hour sessions per week for 4 weeks, they either had to recall the words through performing physical activities and gestures relevant to the animal words to be learnt (i.e., children had to move, walk or roll over like “dogs”), make gestures related to the animal words (i.e., children had to pose, sit or stand like “dogs”), or repeat the animal words while sitting. It was found that learning a foreign language vocabulary through physical activities and gestures resulted in the highest learning outcomes with children also enjoying this way of learning the most.

The few studies that have investigated effects of integrated physical activities on learning have focused on the domains of language or maths in primary school children. A notable exception is the study by Donnelly and Lambourne (2011), who focused on several academic content areas, including maths, geography, and science. In the geography task, children learned about the directions (north, south, east, west). Starting from a specific location where a city was called out, children were asked to run or skip in the appropriate direction. They concluded that the physically active academic lessons were enjoyable for teachers and students, and improved students’ academic achievement scores. To the best of our knowledge, similar studies have not been conducted in the preschool years.

The purpose of this study was to investigate the effects of physical activities that were integrated in a geography task on preschool children’s learning performance. Children were taught about the six continents of the world and one typical animal from each of the continents. The assessment of learning performance
was based on children’s memory of the continents and animals. Whereas previous studies mainly focused on direct (i.e., short-term) effects of physical activities on memory (but see Mavilidi et al., 2015), in the current study we looked at direct and delayed (i.e., long-term) effects after a 5-week delay. An integrated condition, in which children were engaged in physical activity related to the geography task (e.g., moving on the map towards the continents) was compared to a non-integrated condition, in which children were engaged in physical activity that was not related to the geography task (e.g., running around the map), and a control condition, in which children had to stand still and were taught the geography task in a conventional way (e.g., they were shown the continents on the map). Physical activity measurements were included in the analyses to examine differences in physical activity between the physical activity conditions (integrated and non-integrated) and the control group.

Based on the existing literature regarding the physiological changes and cognitive benefits associated with physical activity, it was hypothesised that the physically active children in the integrated and non-integrated condition would outperform the non-active children in the control condition on an immediate and delayed recall test. In addition, based on the theoretical framework of embodied cognition, it was hypothesised that children in the integrated condition, who performed physical activities meaningful for the geography learning task, would outperform children in the non-integrated condition, but in a non-meaningful way, on immediate and delayed recall. Finally, children were asked to evaluate the affective effects of the method that they were taught with. It was hypothesized that the teaching methods using physical activities would be rated higher than the conventional method without physical activities.
4.3 Method

4.3.1 Participants

Participants were 90 preschool children ($M_{age} = 4.88$ $SD = .56$; 45 boys and 45 girls) recruited in eight childcare centres. Childcare centres were randomly assigned either to the integrated physical activity condition, non-integrated physical activity or the control condition. The study was approved by the University’s Human Research Ethics Committee (Appendix G). All parents provided written consent for their children’s participation in the research (Appendices H & I). Three children were absent during the delayed test. Consequently, the total number of participants in the integrated, non-integrated, and control condition was 28, 29, and 30, respectively. Children received stickers when they completed the activity as a reward for their effort.

4.3.2 Materials and Procedure

The study was conducted by the lead author at the childcare centres. It consisted of a learning and assessment phase, in which children participated on an individual basis in a separate room. The geography task included learning the six continents of the world and one characteristic animal from each continent (i.e. kangaroo in Oceania, panda bear in Asia, fox in Europe, penguin in Antarctica, giraffe in Africa, and bear in America). A world map was placed on the floor (fabric with dimensions: 550 X 520 cm; See Figure 4.1). The characteristic animals (soft toys) were placed on top of each continent on the map. Children in all conditions performed the same task for 3 learning sessions lasting 10 min each. This duration was chosen to engage children’s attention for a short time without mentally and physically exhausting them. The learning sessions occurred over a two-day period with a one-day break for the first
week, and the same first day in the second week (e.g., Monday-Wednesday-Monday). Children were randomly assigned to one of the three conditions: in the integrated physical activity condition, children “travelled” from one continent to the other imitating the movements of the animal representing the continent (e.g., hop like a kangaroo starting from Oceania). In the non-integrated physical activity condition, children would pick up one animal at a time and then would run in a circle around the map. After their run, they would leave that animal at the same position and then pick up a different animal and run again around the map and repeat this until they finished with all the animals. Finally, in the control condition, children would stand in front of the map and look at it. The researcher would name and point at the continents and their animals while standing next to the child. The order in which the continents and the animals were shown, was the same for all the conditions (Oceania, Europe, Antarctica, Asia, Africa, and America).

The assessment included a pre-test and post-tests which evaluated children’s existing and acquired knowledge, respectively. At the beginning of the learning sessions, a pre-test determined children’s prior knowledge. Children were asked to name any continent they knew and any animal they knew living in a specific continent. The post-tests occurred at two different time points: a direct test at the end of the learning sessions and a delayed test five weeks after the learning sessions. The pre-test and the immediate test took place within a one-week period. In the pre-test, which consisted of two questions, children were asked to name the continents, and match the animals with the correct continent (each question included 6 test items). The maximum total score was 12. In the post-tests, which consisted of four questions, children were asked to name the continents, match the animals with the right continent by placing the animals on the continent, match the continent with the right

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animal by naming the continent and its animal (e.g., Oceania-kangaroo), walk either
from a continent of one animal to a continent of another animal (from the continent of
the fox, to the continent of the bear, the giraffe, and the kangaroo), or walk from one
continent to another (from Africa, to America, Antarctica, and Asia). For each correct
answer, children received 1 point. The maximum total score was 24 (each question
included 6 test items). A reliability coefficient (Cronbach’s alpha) of .81 was found
for the testing materials. At the end of the assessment, children evaluated how much
they liked the type of instruction (“Did you like this game”), and if they would like to
be taught this way in the future (“Would you like to play it again in the future?”) on a
5-point Likert scale with semantic anchors (expressed as a smiley face) ranging from
1, “I didn’t like it all”, to 5, “I liked it a lot”, and 1, “Not at all” to 5, “I would love
to”, respectively (Appendix J). This scale was adopted from the study of Toumpaniari
et al. (2015). A coefficient alpha of .77 was obtained for these questions in this study.
Physical Activity Measurements

To measure children’s intensity of physical activity, children were fitted with an Actigraph accelerometer (model GT3X+/BT, Pensacola, FL) worn around the waist on an elastic belt with the accelerometer positioned over the anterior aspect of the right hip upon the beginning of the learning session and removed afterwards. Actigraphs have established utility, validity, and reliability in children aged 3-5 years (Cliff, Reilly, & Okely, 2009). Data were calculated for the scheduled 10-min time period with epoch length of 1-s intervals. Age-appropriate cut-points (Janssen et al., 2013; Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006) were used to define activity intensity. Data were reported as minutes spent in moderate, and vigorous-intensity physical activity, and the average activity counts per minute, representing the average intensity activity during lessons.

Figure 4.1. Map with continents and characteristic animals.
4.3.3 Experimental Design

A 3 (Condition: integrated physical activity, non-integrated physical activity, control) x 2 (Time of Testing: immediate, delayed) experimental design with repeated measures on the latter factor was used. The dependent variables were children’s performance at the post-test (immediate and delayed), children’s interest on the type of the instruction and children’s interest on the game in the future.

4.4 Results

Cook’s distance indicated no outliers in the datasets and $\eta^2$ was used as an estimate of effect size, with $\eta^2 = .02$ corresponding to a small effect, $\eta^2 = .13$ corresponding to a moderate effect, and $\eta^2 = .26$ corresponding to a large effect (Cohen, 2013).

Learning outcomes

An analysis of variance (ANOVA) with condition as independent variable and pre-test scores as dependent variable showed no significant effect of condition, $F(1, 87) = 1.19, p = .310$, indicating that children’s pre-test scores did not differ across conditions (integrated condition, M = .13, SD = .73, non-integrated, M = .00, SD = .00, control condition, M = .52, SD = 2.19).

A mixed ANOVA was performed to test the hypotheses of this study. The assumption of the homogeneity of variance was met ($p = .908$ for immediate and $p = .855$ for delayed test). Results showed that performance was significantly affected by time of testing, $F(1, 84) = 37.79, p \leq .001, \eta^2_p = .24$. Regardless of the condition, children performed better at the immediate post-test compared to the delayed post-test. In addition, there was a significant effect of condition on the test scores, $F(1, 84)$
= 13.11, p ≤ .001, $\eta^2_p = .24$. Table 4.1 shows the mean scores of performance at the immediate and delayed test as a function of condition. However, the interaction between time of testing and condition was not significant, $F(2, 84) < 1, p = .804$. Post-hoc comparisons revealed that performance was significantly higher in the integrated condition ($M = 16.11, SD = 3.41$) compared to the control condition ($M = 11.37, SD = 3.61, p ≤ .001$), but not compared to the non-integrated condition ($M = 14.50, SD = 3.76, p = .095$). Also, the non-integrated condition ($M = 14.50, SD = 3.76$) performed better on the test scores than the control condition ($M = 11.37, SD = 3.61, p ≤ .001$).

**Evaluation of Instruction**

A mixed ANOVA was conducted to examine the effects of condition and time of testing on children’s evaluation of the way of learning. The evaluation of the instruction was computed as the average scores of the questions: “Did you like this game?” and “Would you like to play it again in the future?”, and was measured at two moments, directly after the immediate and delayed test. Results showed that the evaluation was not significantly affected by the time of testing, $F(1, 84) < 1, p = .585$. However, there was a positive effect of condition on children’s evaluation, $F(1, 84) = 8.64, p ≤ .001, \eta^2_p = .17$. Table 4.1 shows the mean scores of evaluation at the immediate and delayed test as a function of condition. The interaction between time of testing and condition was not significant, $F(2, 84) = 4.53, p = .228$. Post-hoc comparisons revealed that children in the integrated condition ($M = 4.68, SD = .35$) enjoyed playing this game more than children the control condition ($M = 3.92, SD = .98, p ≤ .001$). Also, children in the non-integrated condition ($M = 4.35, SD = .61$) enjoyed the game more than children in the control condition ($M = 3.92, SD = .98, p =
.019). However, the integrated ($M = 4.80, SD = .48$) and non-integrated condition ($M = 4.76, SD = .58, p = .084$) did not differ in terms of how much children enjoyed playing the game.

Table 4.1. Means and Standard Deviations for Performance and Instruction Evaluation at the Immediate and Delayed Tests as a Function of the Condition.

<table>
<thead>
<tr>
<th>Time of testing</th>
<th>Performance $M (SD)$</th>
<th>Evaluation $M (SD)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate (0-24)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated condition</td>
<td>17.07 (3.42)</td>
<td>4.61 (.52)</td>
</tr>
<tr>
<td>Non-integrated condition</td>
<td>15.38 (3.45)</td>
<td>4.36 (.71)</td>
</tr>
<tr>
<td>Control condition</td>
<td>12.50 (3.64)</td>
<td>4.07 (1.11)</td>
</tr>
<tr>
<td>Delayed (0-24)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated condition</td>
<td>15.14 (4.02)</td>
<td>4.75 (.48)</td>
</tr>
<tr>
<td>Non-integrated condition</td>
<td>13.62 (4.35)</td>
<td>4.34 (.87)</td>
</tr>
<tr>
<td>Control condition</td>
<td>10.23 (4.38)</td>
<td>3.77 (1.17)</td>
</tr>
</tbody>
</table>

Physical Activity Outcomes

An ANOVA was used to test children’s physical activity levels across the conditions. The assumption of the homogeneity of variance was met ($p = .115$). The units of measurement of level of physical activity were counts per minute as well as minutes of moderate- to vigorous-intensity physical activity (Pate et al., 2006). Results showed that there was a significant effect of condition on counts per minute, $F(2, 202) = 75.55$ $p \leq .001$, $\eta^2 = .43$. Post-hoc tests revealed that children in the integrated condition ($M = 1038.51, SD = 489.01$) were less active than children in the
non-integrated condition ($M = 1746.89, SD = 622.22, p \leq .001$), but children in both of these conditions were more active than children in the control condition ($M = 603.67, SD = 487.80$, both $ps \leq .001$).

Moreover, an ANOVA performed on the total time (min) that children spent on moderate-to vigorous-intensity physical activity (MVPA). There was a significant effect of condition on the total time spent on MVPA, $F(2, 202) = 111.21, p \leq .001, \eta^2 = .52$. Post-hoc tests revealed that children in the integrated condition ($M = 1.71, SD = .71$) spent less time on MVPA than children in the non-integrated condition ($M = 3.53, SD = 1.21, p \leq .001$), but children in both of these conditions spent more time on MVPA than children in the control condition ($M = 1.11, SD = .93$, both $ps \leq .001$).

4.5 Discussion

This study examined the effects of integrating task-relevant physical activities into a geography learning task on immediate and delayed memory performance. Preschool children learned about the continents of the world and one characteristic animal for each of the continents. In the integrated condition, children performed the animal movements while going from one continent to another. In the non-integrated condition, children ran around the map holding a different animal each time. Finally, in the control condition, children were looking at the map and the animals, but no movements were involved. Results confirmed the first hypothesis that children in the physical activity conditions (integrated and non-integrated condition) would outperform children in the control condition, both on the immediate and delayed test. However, the second hypothesis that children's performance in the integrated condition would be higher than children's performance in the non-integrated condition was not confirmed.
There are several possible explanations for the fact that in contrast to Mavilidi et al. (2015; see also Toumpaniari et al., 2015), we did not find a performance benefit of relevant physical activities over non-relevant physical activities. These explanations relate to the level of activity that children in the different conditions were involved in and the relevance of the physical activities. Firstly, although the measurement of children’s physical activity outcomes in this study, not surprisingly, revealed that children in the exercise groups (integrated and non-integrated condition) were more physically active than children in the control group, children in the non-integrated condition appeared to have been more active (in terms of intensity and time spent) than children in the integrated condition. Children in the non-integrated condition had to run around the map, and therefore travelled a longer distance than children in the integrated condition, who had to run in between continents on the map. For future studies, it is important that the intensity and duration of the physical activity are the same in the physically active conditions, to be able to isolate the effect of the integrated physical activity on learning performance. Secondly, with regard to the relevance of the physical activities, it could be argued that the activities performed in the non-integrated condition were not totally irrelevant as in the Mavilidi et al. (2015) study. In the current study, children in the non-integrated condition had to walk over a continent and pick the specific animal before starting to run around the map, enabling them to spatially locate the information to-be learned. Moreover, although not statistically significant, the means of the integrated condition were substantially higher than the means in the non-integrated condition, both on the immediate and delayed test. At this young age, there is a wide spread in children's physical and cognitive development, which was reflected in the high standard deviations. A higher number of participants might be needed to reveal statistically
significant differences between the integrated and non-integrated activity conditions. Finally, soft toy animals were used to engage children’s attention and motivation. However, children in the integrated condition may have focused more on performing the animal movements rather than spatially travelling in a specific direction across the map. Consequently, the spatial aspects of physical activity, as well as the connection of movements with the learning task, might have been obscured, resulting in the integrated condition being similar to the non-integrated condition. Indeed, in the study of Donnelly and Lambourne (2011), in which participants' attention was only focused on the directions, not on the animals, a positive effect on students’ academic achievement was found. In future studies, it is important to give participants in integrated physical activity conditions the opportunity to focus their attention exclusively on the spatial aspects of the movements.

The last hypothesis of this study relating to the affective evaluation of the instructional methodology was confirmed. Children enjoyed learning through task-relevant physical activities more than learning through physical activities that were not relevant to the learning task, and both ways of learning were perceived as more enjoyable than learning without physical activity. These findings are consistent with the studies of Toumpaniari et al. (2015), Vazou and Smiley-Oyen (2014) and Trost, Fees, and Dzewaltowski (2008). Alternatively, the 10-min duration for the instructional time could be sufficient for the physical activity conditions, but too long for the control condition, resulting in a reduction in children’s interest and motivation for this condition, as confirmed by the evaluation of the instructional methods.

An interesting topic for future study is related to the fact that children in this study performed the activities individually. Activities occurred in a separate place,
isolated from the other children who did not have the possibility to learn by seeing other children moving around the continents. Existing literature attests that observing others’ movements can activate neurons related to the same actions (Rizzolatti & Craighero, 2004; Van Gog, Paas, Marcus, Ayres, & Sweller, 2009). Learning by performing physical activities as a group and by observing other children perform movements might have an additional benefit for learning and would be interesting to be investigated in future research.

Moreover, future research could design interventions using a teacher-led perspective to implement them in more naturalistic contexts. Last but not least, this study was conducted on a specific age group and on retention performance for a specific learning task, i.e. geography. Future research should shed light on whether these results can be generalised to other age groups, learning domains, and types of performance. With regard to type of performance, for example, it would be interesting to look at effects of integrated physical activities on the ability to apply acquired knowledge and skills on tasks that differ from the ones trained on (i.e., transfer performance).

To conclude, the integration of physical activity into learning games seems to be an enjoyable, engaging, and promising approach to enhance learning outcomes in preschool children. This integrated approach includes activities that are very easy to be applied, are age-appropriate and in no way work at the detriment of learning. Overall, a simple and easy intervention that was implemented for a short period of time increased children’s physical activity and engaged them in moderate- to vigorous-intensity physical activity. Importantly, this approach was not only perceived as interesting by children and resulted in cognitive improvements, it can
also be assumed to promote a healthy and balanced well-being across the lifespan (Loeffler, Raab, & Cañal-Bruland, 2016; Sothern, Loftin, Suskind, Udall, & Blecker, 1999).
References


Paas, F., & Sweller, J. (2012). An evolutionary upgrade of cognitive load theory: Using the human motor system and collaboration to support the learning of


Chapter 5

Immediate and Delayed Effects of Integrating Physical Activity into Preschool Children’s Learning of Numeracy Skills

5.1 Abstract

A cluster randomized controlled trial was conducted to examine the effects of a 4-week program that integrated movements into cognitive tasks related to numerical skills. Participants ($N = 120, M_{age} = 4.70, SD = .49; 57$ females) were assigned to one of the following 4 conditions: performing integrated physical activities (task-relevant); performing non-integrated physical activities (task non-relevant); observing physical activities; or conventional sedentary teaching (without performing or observing physical activities). Results showed that children who performed task-relevant, integrated physical activities performed better than children in all other conditions. In addition, children who performed physical activities, either integrated or non-integrated, reported higher scores for enjoyment of the instructional method than the two sedentary learning conditions. Implications for educational theory and practice are discussed.

**Keywords:** learning, preschool children, physical activity, numeracy
5.2 Introduction

The power of human movements in the first stages of young children’s learning has been addressed early by the developmental theories of Piaget (1968; concept of reflective abstraction) and Vygotsky (1967; make-believe play and imagination). Researchers within the field of educational psychology have been showing increased research interest in examining effects of gestures or subtle motor movements on learning. In addition, recent research attests to the physiological, cognitive, and academic benefits of physical activity in childhood learning activities (Khan & Hillman, 2014; Sibley & Etnier, 2003; Tomporowski, Davis, Miller, & Naglieri, 2008). However, this research mostly targeted primary school children (e.g., maths, Mahar, 2011; Ruiter, Loyens, & Paas, 2015). Only a few studies have been conducted in early childhood in different domains such as language (Mavilidi, Okely, Chandler, Cliff, & Paas, 2015), geography (Mavilidi, Okely, Chandler, & Paas, 2016), and science (Donnelly & Lambourne, 2011; Mavilidi, Okely, Chandler, & Paas, 2017). This study will investigate the effects of integrated physical and cognitive activities on preschool children's learning of numeracy skills.

The theoretical frameworks of embodied and grounded cognition lay the foundation for research into the relation between the human motor system and cognition. These approaches assume that perception and action are closely intertwined (Barsalou, 2003). According to Wilson (2002), people learn from the interaction between their body and the physical environment. It is argued that cognitive processes are grounded in action and perception, while mental representations are grounded in different modalities (i.e., perceptual, motor, verbal, visual, auditory; Barsalou, 2008). Body, language and the external resources from the environment can contribute to the construction of conceptual maps and foster the transition from perceptual facts to
symbolic representations (Vitale, Swart, & Black, 2014). In conjunction with the theoretical framework of embodied cognition, the evolutionary perspective of cognitive load theory recognises the significant role of the human motor system in working memory capacity during complex learning (Paas & Sweller, 2012). According to this perspective, human beings have evolved to effortlessly acquire biologically primary knowledge, such as human movement and speaking one’s native language. This means that this type of knowledge does not impose a load on working memory, and can be acquired automatically, without formal instruction. In contrast, we have not evolved to effortlessly acquire biologically secondary knowledge, such as reading and mathematics. Based on these ideas, Paas and Sweller (2012) have argued that human movement as a form of primary biological knowledge can be used to assist the learning of mathematics as a form of biologically secondary knowledge. In line with these ideas, research has shown that connecting action and perception during instruction can be a way to promote memory consolidation, retrieval, and long-lasting learning (Barsalou, Simmons, Barbey, & Wilson, 2003; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; Madan & Singhal, 2012; Paas & Sweller, 2012; Ping & Goldin-Meadow, 2010).

There is a growing evidence that some aspects of mathematical knowledge can be enhanced from the interactions with the physical, social, cultural, and semiotic world (Alibali & Nathan, 2012). Linking abstract mathematical knowledge with sensorimotor metaphors, stemming from the human body and its imaginary motion (i.e., grounding actions), can help transforming it into tangible events or situations that young children are familiar with. For example, numbers placed in a number line can be seen as an ordered path of magnitudes in which one can move along (see, e.g., Núñez & Margheritis, 2015). The studies of Fischer, Moeller, Bientzle, Cress, and
Nuerk (2011) and Link, Moeller, Huber, Fischer, and Nuerk (2013) found improvements on young children’s counting principles from 0 – 10 ($p < 0.05$, $ES = .68$, with no effects for 0 – 20 scale), and spatial numerical representation ($p < 0.02$, $ES = .89$, with no effects for single-digit and two-digit sums, non-symbolic number comparison, and place-value understanding), after walking on a number line. In the first study, kindergarten children either made steps to the left for smaller distances and to the right for larger ones while walking on a dance mat, or performed the same numerical task without the movements on a tablet PC. In the second study, first-grade children either performed task-specific full-body movements while walking on a number line or received number line training without the body experiences. Finally, Ruiter, Loyens, and Paas (2015) examined first-grade children's learning of two-digit numbers by making steps on a ruler mounted across the floor, either while watching their movements in a mirror or not, or in a control condition without movements. In the movement conditions, children made small, medium and large steps representing different number units of 1, 5, and 10, respectively. Results showed that learning the process of number building was better in the conditions with movements, but observing one’s own movements in the mirror did not have an additional benefit.

Applying the idea of embodied learning to geometry, forming geometrical shapes through body movements can help second and third graders to better understand geometrical concepts such as learning about the angles compared to conventional methods (Shoval, 2011). Similarly, Smith, King, and Hoyte (2014) found that students’ understanding of angle and angle measurement was facilitated when the task combined both body-based and abstract visual representations of the angles.
In addition, Hu, Ginns, and Bobis (2014, 2015) showed that 9-12 year old students who had traced information shown in geometry worked-out examples with their index finger achieved higher learning outcomes than children who only studied the worked examples. Lastly, Agostinho and colleagues (2015) found that third and fourth grade students who traced temperature line graphs on an iPad with their index finger during the learning phase performed better on transfer test tasks than students who only looked at the same information.

Nevertheless, the study of Ruiter et al. (2015) found no additional effects of observing movements on mathematics learning. These findings reflect an existing ambiguity in the literature regarding the role of observing others’ movements in perception and learning. Learning by observing others has been explained by the existence of the “mirror neuron system”, a neural system in the motor cortex area of the brain, which is automatically activated when observing others’ actions, and, consequently can support mental simulation and imitation of these actions (Fadiga, Fogassi, Pavesi, & Rizzolati, 1995; Rizzolatti & Craighero, 2004). Van Gog, Paas, Marcus, Ayres, and Sweller (2009; see also Paas & Sweller, 2012) have suggested that this mirroring capacity of the human brain can be exploited during the learning of cognitive tasks involving a motor component. For instance, Cook, Duffy, and Fenn (2013) showed that students from second to fourth grade learned better to solve mathematical equations (i.e. equivalence problems) and maintained this knowledge longer when they observed the instructor’s gestures while verbally explaining to them the process of how to solve the problems, compared to a training consisting of verbal explanation only. The study of Cook and Goldin-Meadow (2006) also looked at the effects of observing others’ movements on learning. When students observed instructors’ gestures during training, they were able to reproduce their own gestures
similar to the observed gestures. The produced gestures entailed information about the underlying problem-solving strategy required for the specific mathematical tasks (Cook & Goldin-Meadow, 2006).

Moving towards a different area of research, substantial empirical work has shown that purposeful engagement of the motor system in the form of physical activity during instruction (e.g., mathematics) enhances cognition and learning. In general, physical activity can be defined as “any bodily movement produced by the contraction of skeletal muscle that can increase energy expenditure above a certain level,” (Centers for Disease Control and Prevention, 2016). It has been associated with positive health outcomes (e.g., reduction and prevention of obesity, diabetes, cardiovascular diseases, cancer, conditions of stress, anxiety and depression; Hills, King, & Armstrong, 2007; Must & Tybor, 2005; Warburton, Nicol, & Bredin, 2006). Importantly, physical activity (e.g., aerobics, martial arts and yoga) and fitness have been found to improve physical condition, along with brain activity, executive function skills and cognitive performance in children (Buck, Hillman, & Castelli, 2008; Chaddock et al., 2010; Diamond & Lee, 2011; Hillman, Buck, Themanson, Pontifex, & Castelli, 2009). Importantly, core executive functions, such as attention, shifting, inhibitory control, working memory and self-regulation, utilised in cognitive processes such as problem-solving, reasoning and planning, are fundamental for the emergent mathematical ability in children (Blair & Razza, 2007; Bull, Espy, & Wiebe, 2008; Bull & Scerif, 2001; Espy et al., 2004).

Studies attempting to induce physical activity during learning, have reported positive as well as no adverse effects on primary school children’s academic achievement (i.e., maths). For instance, Mahar et al. (2006) and Mahar (2011) showed
better learning about space orientation for fourth-grade students who had lined up around the perimeter of the room and moved over, under, around or through different objects each time, or moved steps forward to represent inches, feet, or yards, than students in a conventional control group without movements ($p < 0.017, ES = 0.49$).

Donnelly and Lambourne (2011) completed a randomised controlled trial in 24 elementary schools examining effects of integrating physical activities on academic achievement in reading, math, spelling, science, history, geography, language, and arts. Ten schools followed traditional sedentary classes while 14 schools included classroom-based physical activity. The classroom-based physical activities in math, for example, included running, hopping and skipping while counting laps, forming different shapes, or learning about fractions. Results revealed significant improvements in academic scores, especially in math. However, after 3 years, the group differences in academic achievement observed at the baseline were not significant anymore (Donnelly et al., 2017). Finally, Mullender-Wijnsma et al. (2016) compared second and third grade students’ performance between physically active academic lessons (20-30 min of physical activity, 3 times per week, for 22 weeks) and usual classroom lessons without physical activity. After two years, children in the active-lessons group showed higher learning gains on mathematics ($p < 0.001, ES = 0.42$), mathematics speed test ($p < 0.001, ES = 0.42$), and spelling ($p < 0.001, ES = 0.45$), than children in the control group. However, no significant gains were found for the reading test.

The present study

Summarising the theoretical and empirical work on embodied cognition, the evolutionary account of cognitive load theory and the mirror-neuron system, this
study will investigate the effects of performing or observing movements on young children’s mathematics learning. The study will focus on a new instructional approach for active learning, in which task-relevant physical activities are meaningfully integrated during mathematics instruction. Preschool children were selected as an age group in which research in this domain has been relatively scarce. Children’s numeracy skills were compared across four conditions involving task-relevant physical activities (integrated condition), observing movements from integrated condition (observing physical activity condition), task non-relevant physical activities (non-integrated condition), and the conventional way of learning (control condition).

Based on the theoretical frameworks of embodied cognition, the evolutionary upgrade of cognitive load theory, and the mirror neuron system, we hypothesised that the integrated condition would offer combined physiological and cognitive benefits, and as a result would lead to the highest learning performance on the cognitive tests compared to the other conditions (Hypothesis 1). Because of the “mirror neuron system” theory, we expected that children in the observing condition would score higher on the cognitive tests than children in the control condition (Hypothesis 2). Also, given the existing empirical evidence on the relation between physical activity and cognition, and academic achievement, we expected that children in the non-integrated condition would perform better on the cognitive tests than children in the control condition (Hypothesis 3). Children’s interest regarding the instructional method they were assigned was also examined. It was hypothesized that children in the instructional conditions with physical activities (integrated and non-integrated conditions) would give higher interest ratings than children in the conventional conditions without physical activities (observing physical activity and control conditions; Hypothesis 4). In terms of physical activity, it was expected that the
intensity levels of physical activity would be higher for the two active conditions (integrated and non-integrated) than the sedentary conditions (observing physical activity and control; Hypothesis 5). If the active conditions are exposed to the same duration and intensity of physical activity, any observed learning effect would then be attributable to the relevance of the movements with the learning task. Similarly, if the sedentary conditions produce similar levels of physical activity, improvements on learning would arise from the observation of peers’ movement during learning. Finally, children’s completion time of each assessment (pre-test, immediate post-test, delayed test) was measured. It was expected that children in the integrated condition would complete the tests faster as they would have been engaged in deeper processing and better understanding of the mathematical concepts during the learning phase (Hypothesis 6).

5.3 Method

5.3.1 Participants

Participants were 120 preschool children (57 females, $M_{age} = 4.70, SD = .49$), recruited from 9 childcare centres. These centres were randomly allocated to the experimental conditions, which resulted in 4 centres in the integrated and observing physical activity conditions, 2 in the non-integrated condition, and 3 in the control condition. A further randomisation was performed to assign children to the integrated and observing physical activity conditions, which occurred simultaneously at the same preschool centres. The study was approved by the Human Research Ethics Committee of the University of Wollongong (HE15/287; Appendix L). Parents completed a written consent form for their children’s participation in the research (Appendices M & N). Five participants were excluded from the analysis due to
missing data resulting in 30 children enrolled in the integrated condition, 29 in the observing condition, 29 in the non-integrated condition, and 27 in the control condition. Children received stickers as a reward for their participation in the activities.

5.3.2 Procedure

The lead author visited the childcare centres and was the instructor of the learning sessions throughout the intervention for all conditions to ensure the consistency of the teaching materials. Foam blocks of numbers from 1 to 20 were placed on the floor shaping a straight line (see Figure 5.1). Children performed the cognitive tasks to learn about the numeric symbols (i.e. Arabic digits) and to improve their counting skills from 1 to 20.

The intervention consisted of the cognitive tasks, which were the same for all conditions, and the physical activity tasks, which differed across the conditions. The assessments took place at three time points.

Cognitive tasks. In each learning session, children performed two counting skill tasks: firstly, they counted from 1 to 20 (task 1), and then they counted backwards from 20 to 1 (task 2). Next, children identified selected numbers called aloud by the instructor (task 3: ranging from 1 to 10, task 4: ranging from 10 to 20, task 5: ranging from 1 to 20). The learning sessions included different numbers each time, the order of which was counterbalanced across the weeks.

Physical activity tasks. Children were allocated to one of the four conditions: In the integrated condition, children performed physical activities related to the learning task. They ran, jumped and stepped each time on one number while counting
(task 1), or walked backwards (task 2). For the third task, children ran on the right side when numbers were increasing (e.g., from 2 to 8), and on the left side when numbers were decreasing (e.g., from 10 to 5). For the last two tasks, children ran forward when numbers were increasing and backwards when numbers were decreasing. More specifically, children counted a number on each step when they moved onwards (1-20) and backwards (20-1). In the observing physical activity condition, children observed their peers’ movements in the integrated condition. They remained seated, counted, and looked at the numbers (tasks 1 – 5) on the number line. In the non-integrated condition, children performed physical activities unrelated to the learning task. They performed the cognitive tasks (tasks 1 – 5), separating them with running laps around in the room for 1 min. In the control condition, no physical activities were involved. Children remained seated, counted, and looked at the numbers (tasks 1 – 5) on the number line. Children’s intensity levels of physical activity during the learning sessions were recorded to control children’s physical activity levels across the conditions.

The learning sessions occurred once per week and lasted 15 min per day, for four weeks (adding to one hour in total). The learning activities were conducted in small groups (max 10 children). All children in each group participated in the activities concurrently. For example, children in the integrated and observing physical activity conditions were counting the numbers from 1 – 20 at the same time.

**Assessments.** The assessments took place individually directly before (pre-test) and after the intervention (immediate post-test) and 6 weeks after the intervention (delayed post-test). The material used was the same across the three points of measurement. Children’s completion time of each assessment was recorded. Finally,
at the end of the post-test assessments, children were asked to rate their interest in the instructional method they were assigned to.

![Image](image_url)

*Figure 5.1. Child performing physical activities on the number line.*

5.3.3 Materials

**Math outcome measures.** The assessments, adapted from Ramani and Siegler (2008), consisted of a pre-test, an immediate post-test, and a delayed post-test. The pre-test determined children’s prior knowledge, whereas the immediate post-test and delayed post-test revealed the intervention effect on children’s understanding and
performance of numbers (Appendix O). More specifically, cognitive tests consisted of:

**Counting.** Children counted from 1 to 20, and from 20 to 1. The correct answer was given up to the point of the first error. For example, if the child counted “1, 2, 3, 5”, he or she received 3 points.

**Number line estimation.** Children had to locate the numbers 2, 5, 9, 10, 14, 16, 19 on the number line where only the number 1 was placed at the beginning and number 20 at the end. The rest of the numbers were missing.

**Block counting.** Children had to count a pile of blocks, consisting of 5 and 6 blocks, respectively.

**Numerical magnitude comparison.** Children had to choose which number was bigger between sets of two digits (4 vs. 9, 5 vs. 8, 19 vs. 17, 6 vs. 9, 13 vs. 18, 4 vs. 7, 9 vs. 6).

**Numerical identification.** Children were shown three different numbers at a time and they had to choose the correct number matching to the verbal instructions. This process was repeated three times for the numbers 14, 7, and 8 respectively. Finally, children were shown three numbers (in order, 9, 11, and 16) and were asked to recognize and read aloud the numbers shown.

The total score of the correct answers that children could get was 61, receiving 1 point for each correct answer. A reliability coefficient (Cronbach’s alpha) of .89 was found for the testing materials.

**Instruction evaluation**
At the end of the immediate post-test and delayed post-test, children evaluated the instructional method in which they were enrolled by responding their preference on a 5-point Likert scale with semantic anchors (expressed as smiley faces) ranging from 1, “I didn’t like it all”, to 5, “I liked it a lot”, and 1, “Not at all” to 5, “I would love to”. Specifically, children were asked how much they liked the type of instruction (“Did you like this game?”), and if they would like to be taught this way in the future (“Would you like to play it again in the future?”). This scale was adapted from the studies of Mavilidi et al. (2016, 2017). A coefficient alpha of .75 was obtained for these questions in this study.

Physical activity measure

During the learning sessions, children's physical activity was measured using an Actigraph accelerometer (model GT1M, Pensacola, FL) worn around the waist on an elastic belt with the accelerometer positioned over the anterior aspect of the right hip. Accelerometers are instruments designed to measure time-specific acceleration, used for physical activity assessments. Actigraphs have established utility, validity, and reliability in children aged 3-5 years (Cliff, Reilly, & Okely, 2009). Parents were informed via participant information sheets that the children would wear an accelerometer during the learning sessions. Accelerometers were placed on the child by the researcher at the beginning and removed at the end of the learning session. Accelerometer data were processed using ActiLife v6.12.1 software and were recorded for the scheduled 10-min time period. Only activity during lesson times was recorded. The epoch length was set at 1-s intervals, a time that is recommended for use in preschool children, and age-appropriate cut-points were used to define intensity of activity (Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006). The magnitude of the
recorded accelerations over an epoch was measured in activity counts, as an estimate of total physical activity data (Cliff, Reilly, & Okely, 2009). Cut points were set at ≤ 25 counts/15 s for sedentary behaviour, and ≥ 420 counts/15 s for moderate-to-vigorous-intensity physical activities). These cut-points have been shown to be the most accurate in young children (Janssen et al., 2013). Data were reported as minutes spent in moderate- to vigorous-intensity physical activity (MVPA), and the average activity counts per minute, representing the average intensity activity during the lesson.

Completion time

Children’s total response time was calculated (measured in seconds), aggregating the time of completion needed for every question separately during the three assessments (pre-test, immediate post-test, delayed post-test).

5.3.4 Statistical Analyses

This study was a cluster-randomised controlled trial. Pearson’s correlations were computed for immediate and delayed post-test; Tables 5.1 – 5.2). Separate analyses were conducted for performance (learning outcomes and completion time), interest ratings for the instructional method, and physical activity outcomes. In regards to the learning outcomes, to examine whether contextual factors (i.e., childcare centre, age, gender) and pre-test scores could predict math performance, a hierarchical regression analysis was conducted, with childcare centre, gender and age as predictors in step 1, pre-test scores entered in step 2, and condition in step 3.
A cluster design was chosen because the intervention was implemented in nine childcare centres, where the childcare centre was treated as a random variable with children nested in centres and in conditions (integrated vs. non-integrated vs. observing physical activity vs. control). The childcare centre was set as the cluster unit for the randomisation. Condition was used as the independent variable, performance and completion time at the pre-test, immediate post-test and at the delayed post-test as dependent variables. Children’s interest ratings for the instructional method they were taught were included as covariate. Finally, a separate analysis was performed for the physical activity outcomes, with condition as independent variable, and counts per minute as well as time spent in moderate to vigorous physical activity as dependent variables.

Analyses were completed using SPSS. The significance level was set at .05 (Field, 2009). Hedges’g and eta-squared were used as estimators of effect size with $g = 0.2$ corresponding to a small effect, $g = 0.5$ medium, and $g = 0.8$ as large effect and $\eta^2 = .02$ corresponding to a small effect, $\eta^2 = .13$ corresponding to a moderate effect, and $\eta^2 = .26$ corresponding to a large effect (Cohen, 1988, 2013; Hedges, 2007).

5.4 Results

Performance

Learning outcomes

A hierarchical regression analysis was conducted to determine whether contextual factors (i.e., childcare centre) and pre-test scores classes could predict math performance for the immediate and delayed post-test. The new models with the
extra predictors significantly improved our ability to predict performance in the immediate post-test. Results showed that childcare centre, children’s age and gender did not significantly predict math performance for the immediate and delayed post-test, whereas pre-test scores and condition were significant predictors of performance (immediate and delayed) post-test (Tables 5.1 – 5.4).
Table 5.1. *Correlations for immediate post-test.*

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Childcare centre</td>
<td>-0.02</td>
<td>0.15</td>
<td>-0.13</td>
<td>-0.09</td>
<td>-0.04</td>
</tr>
<tr>
<td>2. Age</td>
<td>-0.07</td>
<td>0.22*</td>
<td>0.31**</td>
<td>0.36**</td>
<td></td>
</tr>
<tr>
<td>3. Gender</td>
<td>0.17*</td>
<td>0.17*</td>
<td>0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Condition</td>
<td></td>
<td>-0.21*</td>
<td>0.49**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Pre-test scores</td>
<td></td>
<td></td>
<td></td>
<td>0.81**</td>
<td></td>
</tr>
<tr>
<td>6. Immediate post-test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < .05
** p ≤ .001

Table 5.2. *Correlations for delayed post-test.*

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Childcare centre</td>
<td>0.36</td>
<td>0.14</td>
<td>-0.48</td>
<td>0.82</td>
<td>-0.07</td>
</tr>
<tr>
<td>2. Age</td>
<td>-0.06</td>
<td>0.23*</td>
<td>0.33**</td>
<td>0.36**</td>
<td></td>
</tr>
<tr>
<td>3. Gender</td>
<td>0.16*</td>
<td>0.21*</td>
<td>0.14*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Condition</td>
<td></td>
<td>-0.25**</td>
<td>0.48**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Pre-test scores</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.82**</td>
</tr>
<tr>
<td>6. Delayed post-test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < .05
** p ≤ .001
Table 5.3. Hierarchical regression analyses for immediate post-test.

<table>
<thead>
<tr>
<th>Step</th>
<th>Variables</th>
<th>Stand. β</th>
<th>t</th>
<th>$R^2$</th>
<th>$R^{\text{change}}$</th>
<th>$F$ change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Childcare centre</td>
<td>-0.05</td>
<td>-0.56</td>
<td>0.14</td>
<td>0.14</td>
<td>6.15**</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.37</td>
<td>4.15**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>0.12</td>
<td>1.23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Childcare centre</td>
<td>0.05</td>
<td>0.86</td>
<td>0.68</td>
<td>0.53</td>
<td>179.12**</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.11</td>
<td>1.19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>-0.05</td>
<td>-0.90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-test scores</td>
<td>0.79</td>
<td>13.38**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Childcare centre</td>
<td>-0.01</td>
<td>-0.28</td>
<td>0.79</td>
<td>0.09</td>
<td>42.51**</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.06</td>
<td>1.28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>0.02</td>
<td>0.48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-test scores</td>
<td>0.72</td>
<td>13.93**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Condition</td>
<td>-0.33</td>
<td>-6.52**</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* $p < .05$

** $p \leq .001$
An analysis of variance (ANOVA) was performed before the main analysis. This analysis yielded no significant differences among the conditions on the pre-test scores, $F(3, 116) = 2.06, p = .110$ (integrated condition, $M = 27.72, SD = 10.83$, observing condition, $M = 24.03, SD = 10.57$, non-integrated condition, $M = 23.34, SD = 12.69$, control condition, $M = 20.57, SD = 10.95$).

A multilevel analysis was used to examine the effects of the intervention at the pre-test, post-test, and delayed test and to examine the effects of the intervention for math performance. Repeated measures multilevel modeling was used to take account of the variability between schools. Children’s performance (at the pre-test, post-test,
and delayed test) was set as level-one units, children as level-two units, and childcare
centres as level-three units (Table 5.5). Adjusting for clustering for childcare centre,
results revealed that the there was a significant effect of condition on math
performance, \( F(3, 123.82) = 7.6, p \leq .001 \) (Figure 5.2). Accounting for multiple
testing, Bonferroni corrections demonstrated that the integrated condition (\( M = 35.25, SE = 1.97 \)) performed better than the observing physical activity condition (\( M = 25.83, SE = 2.00, 95\% \text{ CI} [1.90 \text{–} 16.92], p = .006, g = .82 \)), control condition (\( M = 22.07, SE = 2.09, 95\% \text{ CI} [5.48 \text{–} 20.87], p \leq .001, g = 1.14 \)), and non-integrated
condition (\( M = 27.23, SE = 2.06, 95\% \text{ CI} [.38 \text{–} 15.64], p = .034, g = .61 \)). The non-
integrated condition did not significantly differ from the observing physical activity
(95\% CI [-6.28 \text{–} 9.08], \( p = .999 \)), and control condition (95\% CI [-2.7 \text{–} 13.04], \( p = .485 \)). The pairwise comparison between the observing physical activity and control
condition was not significant (95\% CI [-3.98 \text{–} 11.52], \( p = .999 \)). Finally, the change
in math performance over time varied significantly across children, \( \text{var}(u) = .76, p \leq .001 \).

To explore how learning performance differed for each task, further multilevel
modelling analyses, adjusting for clustering for childcare centre, were conducted, with
condition as independent variable, and performance on the pre-test, immediate post-
test, and delayed post-test task as dependent variable. The results, including the means
and standard deviations for each task are presented in Table 5.6.
Table 5.5. *Means and Standard Deviations for Total Math Scores as a Function of Condition for each childcare centre.*

<table>
<thead>
<tr>
<th>Childcare Centres</th>
<th>Pre-test $M (SD)$</th>
<th>Post-test $M (SD)$</th>
<th>Delayed test $M (SD)$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Integrated Condition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>28.33 (11.69)</td>
<td>42.83 (7.22)</td>
<td>42.00 (8.48)</td>
</tr>
<tr>
<td>2</td>
<td>29.45 (9.40)</td>
<td>43.18 (12.88)</td>
<td>46.90 (11.51)</td>
</tr>
<tr>
<td>3</td>
<td>26.83 (12.60)</td>
<td>39.08 (14.05)</td>
<td>38.63 (10.80)</td>
</tr>
<tr>
<td>4</td>
<td>22.33 (7.57)</td>
<td>28.33 (16.01)</td>
<td>30.50 (19.09)</td>
</tr>
<tr>
<td><strong>Observing Physical Activity Condition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>34.00 (3.39)</td>
<td>36.20 (9.17)</td>
<td>36.80 (10.18)</td>
</tr>
<tr>
<td>2</td>
<td>15.78 (7.22)</td>
<td>20.22 (11.62)</td>
<td>19.11 (13.89)</td>
</tr>
<tr>
<td>3</td>
<td>25.77 (10.48)</td>
<td>26.61 (11.60)</td>
<td>31.09 (11.55)</td>
</tr>
<tr>
<td>4</td>
<td>24.75 (10.37)</td>
<td>24.75 (10.24)</td>
<td>28.75 (10.71)</td>
</tr>
<tr>
<td><strong>Non-integrated Condition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>22.66 (13.05)</td>
<td>31.00 (15.17)</td>
<td>30.53 (14.61)</td>
</tr>
<tr>
<td>6</td>
<td>24.00 (12.87)</td>
<td>29.78 (13.80)</td>
<td>30.28 (13.09)</td>
</tr>
<tr>
<td><strong>Control Condition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>24.71 (7.29)</td>
<td>23.57 (8.56)</td>
<td>25.00 (10.03)</td>
</tr>
<tr>
<td>8</td>
<td>23.66 (12.31)</td>
<td>28.66 (14.74)</td>
<td>28.44 (12.58)</td>
</tr>
<tr>
<td>9</td>
<td>15.08 (8.50)</td>
<td>18.27 (8.31)</td>
<td>18.91 (11.02)</td>
</tr>
</tbody>
</table>
Figure 5.2. Graph depicting the mean differences of performance as a function of time of testing and learning performance.
Table 5.6. *Means and Standard Deviations for Overall Math Scores as a Function of Condition per task.*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Task 3</th>
<th>Task 4</th>
<th>Task 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M \ (SD)$</td>
<td>$M \ (SD)$</td>
<td>$M \ (SD)$</td>
<td>$M \ (SD)$</td>
<td>$M \ (SD)$</td>
</tr>
<tr>
<td>Integrated condition</td>
<td>24.14 (10.03)</td>
<td>1.90 (2.31)</td>
<td>1.69 (.63)</td>
<td>4.43 (1.44)</td>
<td>4.07 (1.53)</td>
</tr>
<tr>
<td>Observing physical activity</td>
<td>17.47 (9.26)</td>
<td>.25 (.69)</td>
<td>1.49 (.76)</td>
<td>3.32 (1.78)</td>
<td>3.05 (1.80)</td>
</tr>
<tr>
<td>Non-integrated condition</td>
<td>19.72 (11.27)</td>
<td>.06 (.36)</td>
<td>1.65 (.66)</td>
<td>3.42 (1.83)</td>
<td>3.10 (1.94)</td>
</tr>
<tr>
<td>Control Condition</td>
<td>14.53 (8.43)</td>
<td>.01 (.10)</td>
<td>1.39 (.81)</td>
<td>3.24 (1.69)</td>
<td>2.89 (2.07)</td>
</tr>
</tbody>
</table>

* Bonferroni corrections showed significant differences among the conditions for each task (counting, number line estimation, block counting, numerical magnitude comparison, & numerical identification respectively):
  T1: integrated condition vs. observing physical activity ($p = .026$), and control condition ($p \leq .001$)
  T2: integrated condition vs. observing physical activity ($p \leq .001$), non-integrated ($p \leq .001$), and control condition ($p \leq .001$)
  T3: no significant differences
  T4: integrated condition vs. observing physical activity ($p = .009$), non-integrated ($p = .003$), and control condition ($p = .002$)
  T5: integrated condition vs. control condition ($p = .044$).
Completion time

An ANOVA was run on the total time needed to complete the math test at the pre-test, showing no significant differences among the conditions, $F(3, 116) = 2.43, p = .069$ (integrated condition, $M = 308.28, SD = 80.06$, observing condition, $M = 311.61, SD = 73.64$, non-integrated condition, $M = 351.90, SD = 62.27$, control condition, $M = 326.64, SD = 59.08$).²

A multilevel analysis was used to examine the effects of conditions on the time children needed to complete the math tests. Repeated measures multilevel modeling was used to take account of the variability between schools. Children’s completion time (at the pre-test, post-test, and delayed test) was set as level-one units, children as level-two units, and childcare centres as level-three units. Adjusting for clustering for childcare centre, condition was the independent variable, completion time at the pre-test, post-test, and delayed test as the dependent variable. Results revealed that the there was no significant effect of condition on completion time, $F(3, 129.77) = 1.74, p = .160$. Finally, the change in completion time over time varied significantly across children, $\text{var}(u_t) = 4.64, p \leq .001$. It took more time to children to

² A multilevel model analysis was performed, adjusting for clustering for childcare centre, with condition as independent variable, performance at the post-test, and delayed test as the dependent variables, and completion time at the post-test and at the delayed test as the covariate. Controlling for completion time, results revealed significant main effects of time of testing, $F(1, 229.67) = 38.53, p \leq .001$, and condition, $F(3, 308.87) = 7.97, p \leq .001$. Accounting for multiple testing, Bonferroni corrections demonstrated that the integrated condition ($M = 37.96, SE = 2.02$) performed better than the observing physical activity condition ($M = 25.81, SE = 2.07, 95\% \text{ CI} [4.36 – 19.28], p \leq .001$), control condition ($M = 22.47, SE = 2.15, 95\% \text{ CI} [7.55 – 23.42], p \leq .001$), and non-integrated condition ($M = 28.08, SE = 2.11, 95\% \text{ CI} [1.30 – 16.99], p = .013$). The non-integrated condition did not significantly differ from the observing physical activity (95\% CI $[-4.94 – 10.95], p = .999$), and control condition (95\% CI $[-1.76 – 14.43], p = .227$). The pairwise comparison between the observing physical activity and control condition was not significant (95\% CI $[-19.93 – -4.37], p = .999$).
complete the pre-test ($M = 323.97, SD = 70.98$) than the immediate post-test ($M = 263.83, SD = 52.22, p \leq .001$) and the delayed test ($M = 242.83, SD = 49.06, p \leq .001$).

Table 5.7 presents the means and standard deviations of completion time per condition and time of testing.

| Table 5.7. Means and Standard Deviations for Completion Time as a Function of Condition. |
|---------------------------------|-----------------|-----------------|
|                                | Pre-test        | Post-test       | Delayed test    |
|                                | $M (SD)$        | $M (SD)$        | $M (SD)$        |
| Integrated Condition           | 308.28 (80.06)  | 270.10 (49.13)  | 256.78 (52.91)  |
| Observing Condition            | 311.61 (73.64)  | 246.07 (35.79)  | 234.23 (44.66)  |
| Non-integrated Condition       | 351.89 (62.27)  | 274.41 (63.76)  | 222.79 (24.09)  |
| Control Condition              | 326.64 (59.08)  | 265.18 (54.90)  | 257.37 (60.43)  |

**Interest ratings for instructional method**

Correlations revealed that children’s interest rating at the post-test was significantly correlated with children’s total post-test ratings for instructional methods ($r = .26, p = .005$). Also, the interest ratings at the delayed test were positively correlated with children’s performance at the total delayed test scores ($r = .30, p \leq .001$). However, further examination of these correlations per condition revealed that the interest ratings at the post-test were positively correlated with children’s performance at the post-test in the control condition ($r = .40, p = .033$), but in none of the other conditions (integrated condition, post-test, $r = .03, p = .875$, delayed test, $r = .16, p = .378$; observing physical activity condition, post-test, $r = .11,$
A multilevel model analysis was performed, adjusting for clustering for childcare centre, with condition as independent variable, performance at the post-test, and delayed test as the dependent variables, and children’s interest ratings at the post-test and at the delayed test as the covariates. Results revealed that the main effects of condition, $F(3, 215.39) < 1, p = .614$, children’s interest, $F(1, 205.06) = 3.74, p = .054$, and the interaction between condition and interest, $F(1, 205.12) = 1.16, p = .322$, on math performance were not significant. Finally, the change in math performance over time varied significantly across children, var(u) = .87, $p \leq .001$.

A mixed ANOVA was run to assess children’s interest across the conditions, measured at two moments, directly after the end (immediate post-test) and six weeks after the intervention (delayed post-test). The analysis revealed main effects of condition, $F(1, 101) = 17.94, p \leq .001, \eta^2_p = .33$, and of time of testing, $F(1, 111) = 6.59, p = .012, \eta^2_p = .06$. The interaction between condition and time of testing was not significant, $F(3, 111) < 1, p = .999$. With regard to the main effect of condition, post-hoc comparisons revealed that children in the integrated condition ($M = 4.59, SE = .13, 95\% CI 4.34 - 4.84$) enjoyed playing this game more than children in the observing condition ($M = 3.41, SE = .13, 95\% CI [3.16 - 3.67]$) and control condition ($M = 3.74, SE = .13, 95\% CI [3.48 - 4.00]$, both $ps \leq .001$). Also, children in the non-integrated condition ($M = 4.32, SE = .13, 95\% CI [4.07 - 4.57]$) enjoyed the game more than children in the observing condition ($p \leq .001$) and control condition ($p = .002$). However, the integrated and non-integrated condition ($p = .128$) as well as the observing condition and control condition ($p = .076$) did not differ in terms of how much children enjoyed playing the game.
Physical activity outcomes

An ANOVA was performed to assess the differences in physical activity
counts across the conditions, with average counts per minute as dependent variable,
and condition as independent variable. Results showed a significant effect of
condition on the counts per minute, $F(3, 366) = 28.46, p \leq .001, \eta^2_p = .19$. Post hoc
comparisons with Gabriel correction revealed that physical activity counts did not
differ between the physical activity conditions (integrated condition, $M = 1228.33, SE$
$= 65.65, 95% CI [1099.23 - 1357.44]; non-integrated condition, $M = 1008.64, SE =$
$70.13, 95% CI [3870.73 - 1146.56], p = .128$), and between the sedentary conditions
(observing condition, $M = 584.87, SE = 63.41, 95% CI [460.18 - 709.55]; control
condition, $M = 462.17, SE = 70.55, 95% CI [323.44 - 600.91], p = .728$). However,
children in the integrated and non-integrated conditions had higher activity counts per
minute than children in the observing condition and control condition (all $ps \leq .001$).

An ANOVA was also performed on the time spent in moderate- to vigorous-
intensity physical activity (MVPA). It revealed a significant effect of condition, $F(3,$
$366) = 31.99, p \leq .001, \eta^2_p = .21$. Post hoc comparisons showed that the time spent in
MVPA did not differ between the integrated ($M = 1.86, SE = .09, 95% CI [1.68 -$
$2.04]$) and the non-integrated condition ($M = 1.85, SE = .09, 95% CI [1.66 - 2.04], p =$
$.917$), as well as between the observing ($M = 1.03, SE = .09, 95% CI [.86 -1.02]$) and
control condition ($M = .83, SD = .10, 95% CI [.64 - 1.03], p = 134$). However,
children in the integrated and non-integrated condition spent more time in MVPA
than children in the observing and control condition (all $ps \leq .001$).
5.5 Discussion

This study evaluated the effectiveness of integrating physical activities with preschool children’s arithmetic skills acquisition. The theoretical frameworks of embodied cognition, the evolutionary upgrade of cognitive load theory, and the mirror neuron system were the underlying theories for this study. Particular emphasis can be placed on the specific characteristics of the different conditions (integrated physical activity, non-integrated physical activity, observing physical activity and control condition). More specifically, it can be concluded that the overall math scores confirmed the first hypothesis. The integrated condition outperformed all other conditions measured at the three time points of testing (pre-test, post-test, and delayed test). Consistent with previous research, classroom-based physical activity programs (Donnelly & Lambourne, 2011; Mahar et al., 2006; Vazou & Smiley-Oyen, 2014) and task-relevant movements (Fischer et al., 2011; Ruiter et al., 2015; Shoval, 2011) attest positive effects on math learning. A closer look at the math outcomes obtained per each task revealed that the integrated condition exerted the largest effects in the number line estimation and numerical magnitude comparison task. This outcome is in compliance with existing literature on the effects of number line training on understanding and learning of mathematical concepts (Fischer et al., 2011; Link et al., 2013). More specifically, the primary locus of the learning gains can be placed at the embodied spatialisation of numbers, meaning that each number on the number line represented a structured path of magnitudes which children could follow by moving along (see e.g., Núñez, & Marghetis, 2015). The mathematical concepts taught through the physical activities were grounded in the body, spatial systems, and situated actions (Lakoff & Núñez, 2000; Nathan et al., 2014). Consequently, children were able to connect the numeracy knowledge with real-world observations while the
body-based actions relevant to the task (i.e., grounding actions) enhanced children’s mathematical insights (Nathan et al., 2014). The physical manipulation and experience during learning exposed children to multiple modalities (visuospatial, auditory, temporal, and kinaesthetic cues), helping them to construct rich mental representations of the numerical magnitudes (Ramani & Siegler, 2008). These mental representations may have facilitated memory encoding, recall, and retrieval (Madan & Singhal, 2012). Overall, these results reveal the advantage of the embodiment effect, stating that the congruency of the sensorimotor information and knowledge to-be-learnt can enhance learning (Lindgren & Johnson-Glenberg, 2013).

Consistent with this study, a great body of research has looked at the role of gestures to support mathematics learning (for a systematic review see, Agostinho, Ginns, Tindall-Ford, Mavilidi, & Paas, 2016). This research has focused on the effectiveness of including actions on physical objects during maths instruction compared to gestures (Novack et al., 2014), the superiority of task-relevant versus task-irrelevant gestures (Brooks & Goldin-Meadow 2016), and performing compared to observing gestures (Goldin-Meadow et al., 2012). In line with this research, the current study holds promise for performing task-relevant movements that involve object manipulation (i.e., blocks of numbers). Taking into account the evidence of the existence of a mirror neuron system in learning, this study included a condition in which children observed their peers’ movements. Although empirical studies using subtle forms of movements (i.e., gestures) have provided evidence for the effectiveness of action observation for learning maths in children (Cook, Duffy, & Fenn, 2013; Cook & Goldin-Meadow, 2006), the outcomes of this study showed that observing movements did not contribute to children’s learning. Children in the observing physical activity condition had lower math performance than children in the
two physical activity groups (integrated and non-integrated), and the same performance as the children in the control group, rejecting the second hypothesis. The study of Ruiter et al. (2015) also did not find any additional effects of observing over making movements on learning, when a mirror was used in order for children to be able to watch their own actions.

Several possible explanations can be given for the lack of an effect of movement observation on learning: in the body of research supporting the positive effects of observing movements, gestures are produced by the teachers and observed by children (Singer & Goldin-Meadow, 2005). In this study, children observed movements from their peers. In other studies, the relevant actions were integrated into a student-directed lesson, in which the actions (or gestures) were part of ostensive communication and understanding directed at the learner. This means that attention was paid to ensure that the gestures would be performed correctly. In the current study, the learner was merely a bystander, with movements chosen by the instructor and not by the learner, thereby eliminating the possibility of adopting a different movement that could also assist children’s learning. Also, the whole-body movements in the form of physical activities might have been more complex to observe and relate to cognitive tasks than hand gestures, especially when they present even small variations from child to child (focus on one adult teacher vs. many children at the same time acting slightly differently).

Finally, children in this age group are sensitive to peer pressure and comparison, making them more likely to conform with their peers’ behaviours (Haun & Domasello, 2011). Children seemed to be enthusiastic about the idea of being physically active. Not allowing children in the observation group to perform
movements while watching their peers performing them, could have reduced their interest and in turn, their engagement, and academic performance in the numerical task. This explanation is supported by children’s responses on the interest scale regarding the instructional method they were enrolled. Interest ratings were the highest in the integrated and non-integrated condition, followed by the observing physical activity and control condition. Confirming the fourth hypothesis, children showed higher interest ratings in the active learning conditions than in the sedentary traditional classroom condition. The collaborative aspect of learning occurring in the active conditions might also have contributed to the higher interest scores. Research indicates that cooperative learning can improve social skills, motivation and reach higher performance (Johnson & Johnson, 1999; Shoval, 2011). However, no direct associations were found in this study between children’s performance and interest ratings, which makes us cautious about further interpretations. Future research should attempt to isolate the effects of active and group-based learning on children’s interest and academic performance.

Further exploring the math outcomes for each task, the integrated condition performed better than the observing physical activity and control condition on the counting task, and better than the control condition on the numerical identification task. However, no significant differences among the conditions were observed in the block counting task. This task consisted only of two items, which was possibly not enough to accurately distinguish children’s ability to count the blocks shown to them. Future research should focus on examining the role of movements that can promote recall of specific mathematical content or tasks (such as movements related to multiplication, division, etc.).
Moreover, despite the research evidence for the positive effects of physical activity on cognition and academic achievement in children (e.g., Khan & Hillman, 2014), Hypothesis 3, in which children in the non-integrated condition would outperform children in the control condition, was not confirmed. Possibly, the exercise dosage was too low to have acute effects on cognition and achievement. Physical activity so far revealed a potential to show improvements on children’s and youth’s cognitive performance. However, there are substantial differences in the mechanisms underlying the effects of effortful and prolonged bouts of physical activity on cognition and those of cognitively engaging movements of low intensity and duration. For example, negligible effects of low-intensity and short physical activity tasks are reported in reviews on acute exercise and cognition (Tomporowski, 2003; Vazou et al., 2016). Nevertheless, the physical activity outcomes are corroborated by the findings of Mavilidi et al. (2015), with the physical activity groups (integrated and non-integrated conditions) being engaged in the same intensity levels and duration of physical activity. Being exposed to the same amount of physical activity, the integrated condition was found to be superior for learning to the non-integrated condition. At the same time, the intensity levels of physical activity were higher for the integrated and non-integrated condition, compared to the observing physical activity and control condition, confirming Hypothesis 5.

Finally, results revealed no differences across conditions in terms of how much time children needed to complete the assessments, disproving Hypothesis 6. Overall, training effects can be assumed as children needed more time to complete the pre-test, followed by the post-test, and the delayed test. The fact that some tasks like counting might have taken longer to be completed compared to other tasks such as number recognition makes us very cautious in further interpreting and generalising
these outcomes. Nonetheless, a salient finding arises here related to time and performance. Overcoming teachers’ barriers, physical activity interventions could be incorporated to the academic content as they are not competing with academic time, and can provide substantial learning benefits (Sallis et al. 1997; Ward, Saunders, Felton, Williams, Epping, Pate, 2006).

Lastly, for this study, children from 9 childcare centres were enrolled in the different conditions. This number of childcare centres is rather low for a cluster randomised control trial. An important limitation to note is related to the randomisation process. More stringent criteria should be applied in future studies, taking into account the nested nature of data from children attending the same childcare centres. Even if in this study the instruction was conducted by the researcher, children attending the same preschool centres present similarities, which should be considered. It is also important to make clearer distinctions in the design, choosing either multisite trials, or unique treatments assigned to each group.

Concluding, the importance of children’s early exposure to the “world of mathematics” is invaluable for their development of mathematical proficiency. Already during infancy, children are able to encode numbers (e.g., Cordes & Brannon, 2008; Izard et al., 2009; Xu & Spelke, 2000), whereas at preschool age they are able to acquire and improve basic number skills (such as counting, number recognition and knowledge, Geary, 1993; Jordan, Kaplan, Olah, & Locuniak, 2006). These early-acquired skills can positively affect their level of mathematical performance in later years (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Booth & Siegler, 2006, 2008), reducing the emergence of math anxiety and its associated risk of failure (Maloney & Beilock, 2012; Mavilidi, Hoogerheide, & Paas, 2014).
Getting involved in physical activity and linking motor skills to cognitive processes is particularly important for preschool children’s cognitive enhancement (Lu & Montague, 2015). Embodiment is a fundamental underpinning of cognition (Gallagher & Lindgren, 2015). Physical actions can enhance cognitive gains when their relevance is explicitly signalled to the learners (Nathan et al., 2013).

Concurrently, stimulating physical, social, emotional, and cognitive development through physical activity has been identified as an effective way to improve children's cognitive processing and academic performance (for a review see, Khan & Hillman, 2014; for meta-analyses see, Rasberry et al., 2011; Verburgh, Königs, Scherder, & Oosterlaan, 2013). In this study, condition differences emerged and children's mathematical thinking was improved after this simple and short intervention (1 hour in total). This outcome is crucial considering that the higher the initial level of mathematical performance of children entering school, the greater the rate of growth and development of their mathematical ability (Aunola et al., 2004; Siegler et al., 2012). Early childhood interventions can be influential for children’s mathematical abilities (Griffin, 2004) as well as their overall development (i.e., cognitive, emotional, social and physical; Barnett, 1998). This study presented an instructional approach with combined physical and cognitive gains in the domain of math for preschool children. The suggested type of instruction is engaging, enjoyable, can be easily applied and adjusted to places, teachers’ demands and children’s needs, ensuring children’s long-term wellbeing.
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Chapter 6

Effects of Integrating Physical Activities into a Science Lesson on Preschool Children’s Learning and Enjoyment

6.1 Abstract

This study investigated the effects of physical activities that were integrated into a science lesson on learning among preschool children. A total of 90 children from seven childcare centres ($M_{\text{age}} = 4.90, SD = .52; 45$ girls) were randomly assigned across an integrated physical activity condition including task-relevant physical activities, a non-integrated physical activity condition involving task-irrelevant physical activities, or a control condition involving the predominantly conventional sedentary style of teaching. Children learnt the names of the planets and their order, based on the distance from the sun. For both the immediate and delayed (6 weeks after the program) assessments, results showed that learning outcomes were highest in the integrated condition, and higher in the non-integrated condition than in the control condition. Children in the integrated condition scored higher on perceived enjoyment of learning than children in the control condition. Implications of integrated physical activity programs for preschool children’s health, cognition, and learning are further discussed.

**Keywords:** learning, science, preschool children, physical activity
6.2 Introduction

Young children are particularly enthusiastic about discovering the physical environment that surrounds them. Part of this interest stems from the tangible and specific ideas of concrete objects or animals – as opposed to abstract concepts – that are part of this environment. The first developmental theories of Piaget (1970) and Vygotsky (1962) emphasized the critical role of motor actions in human learning. When it comes to science learning, this is especially important as children have to abandon their beliefs or perceptions, and progress through a conceptual change in order to develop more complex representational structures (Carey, 2000). To this vein, physical experience through observation and manipulation appears to be essential for promoting young children’s novel conceptual understanding in science (Gelman & Brenneman, 2004; Zacharia, Loizou, & Papaevripidou, 2012). For example, spatial thinking, which is critical to success in STEM disciplines, can be improved by the use of symbolic representations, analogies and gestures (Uttal, Miller, & Newcombe, 2013). Intervention studies, using the theoretical framework of embodied cognition, have shown that physical experience, for example in the form of object manipulation, can embody knowledge and enhance learning of science (see e.g., Boncoddo, Dixon, & Kelley, 2010; Kontra, Lyons, Fischer, & Beilock, 2013; Lindgren & Glenberg, 2013). Similar effects have been found in the domains of language (e.g., Mavilidi, Okely, Chandler, Cliff, & Paas, 2015) and geography (Mavilidi, Okely, Chandler, & Paas, 2016), when the knowledge was embodied through movements in the form of physical activities. In this study, we aimed to follow up on these studies by investigating the effects of infusing physical activities in preschool children's science learning on learning outcomes.
Research on human movements can generally be categorised into studies including subtle movements such as gestures or studies including gross motor movements such as physical activity. Whereas the research on subtle movements mainly focuses on effects on cognition, research on physical activity mainly focuses on effects on health. The first part of this article presents the underlying theory and empirical evidence linking actions during learning (Madan & Singhal, 2012; Moreau, 2015; Pouw, Van Gog & Paas, 2014). In addition, the health and cognitive benefits of physical activity and how these benefits can be extended into education will be described (Owen et al., 2015; Sibley & Etnier, 2003).

Perception and action are closely intertwined (Gallagher, 2005; Wilson, 2002). It is believed that cognition is grounded in different ways consisting of mental simulations, situated action, and bodily states. Movements play an essential role in learning and instruction (Ayres, Marcus, Chan, & Qian, 2009). The body acquires a dominant role in cognition with a combination of perceptual, and sensorimotor experiences forming multimodal representations in memory (Barsalou, 2008; Barsalou, Simmons, Barbey, & Wilson, 2003). These representations supply alternative routes for memory retrieval, because they are enriched with motor information (Madan & Singhal, 2012; Plummer, 2009). The enactment effect was initially built upon the foundation that actions are better recalled when they are performed compared to when they are heard or read (Engelkamp & Zimmer, 1989). Through embodied learning, embodiment, which refers to the enactment of concepts using the body, ranges from neuromuscular activation of low embodiment, in which only movements of fingers are involved, to high embodiment with full body movements engaged, relying on multimodal encoding methods to elicit higher retention and transfer of learning (Lindgren & Johnson-Glenberg, 2013). Education
researchers have proposed enactive metaphors during learning through whole-body movements as a way to instigate learning in science (Gallagher & Lindgren, 2015). For instance, mixed reality environments use action-concepts congruencies where children can learn about laws of physics (e.g., gravitational force) by simulating the movements of asteroids in empty space or the orbits of planets by moving across floor-projected virtual environment, walking in a straight line, or moving faster or slower depending on children’s distance to the planets (Lindgren & Johnson-Glenberg, 2013; Lindgren & Tscholl, Wang, & Johnson, 2016). Comparing middle school students in an experimental condition, in which they were engaged in whole-body movements simulations, to a control condition using a desktop version of the simulation (i.e., movements by clicking a computer mouse), Lindgren et al. (2016) found that the learning gains as well as children’s engagement levels were more pronounced in the experimental condition. Likewise, Plummer (2009) noted significant learning gains in the development of astronomy concepts in first and second grade students, through kinesthetic learning techniques in the planetarium, whereby they performed celestial trajectories with their bodies or objects representing stars and planets.

The importance of physical experience in science learning through engagement in whole-body movements is well accepted. However, it seems important to examine whether there is a relationship between the full-body movements in the form of physical activity and cognition. Physical activity can be defined as “any bodily movement produced by the contraction of skeletal muscle that can increase energy expenditure above a certain level, whereas exercise is considered as a “sub-category of physical activity that is planned, structured, and repetitive, focusing on the improvement or maintenance of one or more components of physical fitness, physical
performance, or health” (Centre for Disease Control and Prevention, 2016). Research has gleaned insight into the association between physical activity and fitness with health benefits such as muscle and bone strengthening, better cardiometabolic health, prevention of chronic diseases (e.g., obesity, cholesterol, high blood pressure, type 2 diabetes, cardiovascular disease, cancer), reduction of depression and stress, better states of mood, and improved self-esteem and body image (Baranowski et al., 1992; Janssen & LeBlanc, 2010; Penedo & Dahn, 2005; Sothern, Loftin, Suskind, Udall, & Blecker, 2010; Warburton, Nicol, & Bredin, 2006; World Health Organization, 2015). Physical activity has also been related to cognitive benefits such as improved cerebral activity and enhanced brain development (e.g., better neural connections, improved blood flow and oxygenation), cognitive functioning (e.g., cognitive control, attention, and memory) and academic performance in children (Chaddock-Heyman et al., 2016; Drollette et al., 2014; Erickson, Hillman, & Kramer, 2015; Fedewa & Ahn, 2011; Hillman, Castelli, & Buck, 2005; Kamijo, Takeda, Takai, & Haramura, 2011; Khan & Hillman, 2014; Rasberry et al., 2011; Sibley & Etnier, 2003; Tomporowski, Davis, Miller, & Naglieri, 2008). It is suggested that, in order to cultivate the potential for these salient benefits to occur, it should commence in early childhood education and care settings, widely recognised as a place for holistic learning characterised by physical, social and emotional development, and determined by scaffolding of behavioural patterns (Barnett, 2008; Lu & Montague, 2016).

Intervention programs to increase physical activity levels and positively affect academic achievement have been successfully established in elementary school settings. These studies have incorporated classroom-based physical activities in the academic lessons of various learning areas such as maths, language, science, social sciences and general health (Donnelly & Lambourne, 2011; Kibbe et al., 2011; Mahar
et al. 2006; Mahar, 2011; Tarp et al., 2016). Based on these studies, Grieco, Jowers, Errisuriz, and Bartholomew (2016) focused on the dosage of physical activity intensity required to improve on-task behaviour. Results revealed that both a low dose of low-to moderate physical activity as well as a higher dose of moderate-to-vigorous physical activity can increase children’s on-task behaviour compared to traditional sedentary more lessons. The magnitude of the effects shown were similar to Mahar et al. (2006). Finally, a series of studies objectively measuring physical activity and learning outcomes in preschool children found improvements in academic performance and increase in physical activity levels during learning of foreign language vocabulary and geography combined with whole-body movements (Mavilidi et al., 2015, 2016).

The current study will assess the effects of whole-body movements on preschool children’s learning in science by objectively gauging learning and physical activity outcomes. A solar system task was chosen for preschool children as a foundational introduction in the domain of science. More complex and developed concepts such as the celestial motion (how the sun, the moon and the stars move) are considered as an acquired knowledge for children in early elementary school (Benchmarks; AAAS, 1994; Plummer, 2009).

In this study, three experimental conditions will engage children in a solar system task combined with meaningful physical activities, non-related physical activities, or without physical activities included. In the integrated condition, children will perform movements related to the learning content. In this condition, children will run starting from the position of the sun to the closest planet (i.e., Mercury). In the non-integrated condition, movements will be unrelated to the task and children
will run around the classroom for several minutes. Finally, the control condition will represent the conventional way of teaching, in which children will stay seated and observe the planets. It is expected that the conditions that include movements (integrated and non-integrated condition) will outperform the control condition (Hypothesis 1). Moreover, based on the combined embodied and physiological effects, it is assumed that the integrated condition will show the highest learning outcomes (Hypothesis 2). Finally, children in each condition will evaluate how much they enjoyed the way they learned. It is hypothesised that the integrated condition will show the highest scores for perceived enjoyment of the learning method (Hypothesis 3).

6.3 Method

6.3.1 Participants

This study was approved by the Human Research Ethics Committee of the University of Wollongong (HE15/458; Appendix P). Seven early childhood centres from the Illawara area of NSW, Australia were included in this study (See Figure 6.1). Each centre director and the child’s parents provided their written consent forms for their children’s participation in the study (Appendices Q & R). A total of 90 typically developing children (no diagnosis of mental illness, disorders, or learning difficulties) participated in this study (\(M_{\text{age}} = 4.90, SD = .52; 45\) girls; 2.3% Aboriginal, 1.1% for American, French, Indian, Indonesian, Irish, Vietnamese, Russian, Spanish, Serbian, 2.3% British, 3.4% Chinese). The existence of low income Health Care Card or pension card from Centrelink was used as an index of socioeconomic status (SES; Australian Government Department of Human Rights, 2016). The index indicated that the population of this study consisted of mainly
medium to high socioeconomic status. There were no differences among the conditions in terms of demographic characteristics (Table 6.1). Three children were excluded from the analyses because of a general reluctance to participate and 1 child due to missing data. Randomisation occurred at centre level and per condition (each centre was aligned to one/several different conditions), resulting in 30 enrolled in the integrated condition, 27 in the non-integrated condition, and 29 in the control condition. Stickers were given as a reward for children’s effort at the end of each learning and testing session.

![Flowchart](image)

*Figure 6.1. Chart flow of schools and children from enrolment and allocation.*
6.3.2 Procedure and Materials

The researcher visited the childcare centres and coordinated the learning and testing sessions. The learning sessions consisted of a solar system task (i.e., name of planets and their right order based on their distance from the sun). The learning sessions took place in small groups (max 10 children), once per week, for four weeks. The testing session occurred individually at three time points: a pre-test was administered before the first learning session to assess children’s prior knowledge, an immediate post-test directly after the end of the last learning session, and a delayed post-test 6 weeks after the last learning sessions. The two post-tests determined the knowledge children had acquired during the learning sessions.

During the learning sessions, a picture of the sun and the planets in space (on a straight line) was placed at a central point easily to be seen by all children. Also, toy planets were placed in a line on the floor in the same order, corresponding to the planets in the pictures. Children had to remember the names of the planets and their correct order starting from the planet closest to the sun, Mercury, through to the planet furthest from the sun, Neptune. The instructor began with a small introduction of the concept of space and the planets.

Children were assigned to a condition at a centre level. However, some centres were enrolled in more than one condition. In these cases, each group ran on different days with different children and at the completion of the previous group to avoid contamination of the conditions. The instructor called aloud the name of the planets in all conditions. In the integrated condition, children performed physical activities related to the learning task. Starting from the sun, they visited the first planet and then they returned back to the sun. Then, they visited the second planet, and returned back
to the sun. They did the same actions for all the planets. In the non-integrated condition, children performed physical activities unrelated to the learning task. Firstly, children ran a lap around the room. Then, they sat and listened to all the names of the planets. They followed the same process three times. In the control condition, no physical activities were involved. Children remained seated while observing the planets (the first planet was the one closer to the sun until the one furthest from the sun). During each learning session, which lasted 10 min per day for all conditions, the names of the planets were repeated three times in all conditions.

During the testing sessions, children were evaluated on their ability to recall the names of the planets and their appropriate order starting from Mercury. The cognitive tests included:

*Free-recall test:* children were asked to name any planet they could remember. Next, they were asked to place the toys planets in a straight line, starting with Mercury and finishing with Neptune.

*Cued-recall test:* children were shown pictures of four planets and were asked to name them (i.e., Venus, Mars, Earth, Uranus). Also, children were given four toy planets and were asked to place them in the right order based on their distance from the sun, starting with the planet that is closest to the sun (i.e., Mercury, Jupiter, Saturn, Neptune). Finally, children were shown four toy planets and were asked to name them (i.e., Mercury, Earth, Uranus, Neptune).

Children received one point for each correct answer. The maximum score that children could get was 28 (Appendix S). This method was based on Best, Dockrell, and Braisby's (2006) method to evaluate older children’s knowledge about the eclipse
and entities related to space. A reliability coefficient (Cronbach’s alpha) of .84 was found for the testing materials.

Physical activity was objectively assessed using accelerometers (model GT1M, Pensacola, FL). The sampling interval (epoch) was set at 1 second to best capture variability in children's activity (Cliff, Reilly, & Okely, 2009). Parents (via written consent forms) were informed that their children would wear the accelerometer during the learning sessions. Accelerometers were affixed to an elastic belt and placed by trained staff around the child's waist so that the accelerometer was at the top of their right hip at the beginning of the lesson and were removed at the end of the lesson. Accelerometers were processed using ActiLife v6.12.1 software and were recorded for the scheduled 10-min period. The time spent per lesson in various intensities was calculated using child-specific cut-points (Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006). These cut-points have been shown to be the most accurate in young children (Janssen et al., 2013). Data were reported as minutes spent in moderate-to-vigorous-intensity physical activity, and the average activity counts per minute, representing the total activity intensity during the lesson.

At the end of the immediate post-test and delayed post-test, children evaluated how much they liked the type of instruction (“Did you like this game”), and if they would like to be taught this way in the future (“Would you like to play it again in the future?”) on a 5-point Likert scale with response scores ranging from 1, “I didn’t like it all”, to 5, “I liked it a lot”, and 1, “Not at all” to 5, “I would love to”, respectively. These were supplemented with a visual scale of smiley faces ranging from 1 to 5, corresponding to the two questions. The interest ratings were computed as the average scores on these questions (Appendix T). This scale was adapted from the study of
A coefficient alpha of .85 was obtained for these questions in this study.

### 6.3.3 Statistical Analyses

A randomised controlled trial was conducted to assess the effectiveness of the suggested instructional approaches on children’s learning outcomes and children’s interest after the intervention. Physical activity outcomes were included in the analyses to confirm our basic assumption that children would be more physically active in the physical activity conditions (integrated and non-integrated), than in the sedentary control condition. To control for baseline differences in demographic characteristics among the conditions (age, gender, ethnicity, socioeconomic status), an ANOVA and Chi-Square Tests were used. Separate analyses were conducted for the learning outcomes, interest ratings for the instructional method, and physical activity outcomes. With regard to the learning outcomes, a cluster design was chosen initially since the intervention was structured in 7 childcare centres, where childcare centre was treated as a random variable with children nested in preschools and in conditions (integrated vs. non-integrated vs. control). The childcare centre, children’s ethnicity, socioeconomic status, and gender were set as the cluster units for the randomisation. Because the analyses produced similar results and none of the demographics characteristics seem to be a confounder, we chose to perform a mixed 3 (Condition: integrated physical activity, non-integrated physical activity, control) x 2 (Time of Testing: immediate post-test, delayed post-test) experimental design with repeated-measures on the latter factor, accounting for possible interaction effects. The independent variables were condition and time of testing, and the covariate was children’s pre-test scores. The same experimental design was used to look for differential effects of condition on children’s interest scores (excluding the covariate).
Finally, the differences in physical activity outcomes among the conditions were examined in two separate analyses for counts per minute, and time spent in moderate-to-vigorous intensity physical activity.

The datasets were controlled for outliers, normality of the distribution, homogeneity of variance, and sphericity (when required; Field, 2009). The analyses were performed using SPSS and STATA. The significance level was set at .05 and Eta-squared $\eta^2$ was used as an estimate of effect size, with $\eta^2 = .02$ corresponding to a small effect, $\eta^2 = .13$ corresponding to a moderate effect, and $\eta^2 = .26$ corresponding to a large effect (Cohen, 1988, 2013).

### Table 6.1. Participants’ demographics stratified by condition.

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Integrated Condition</th>
<th>Non-integrated Condition</th>
<th>Control Condition</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years (SD)</td>
<td>4.90 (.52)</td>
<td>4.96 (.51)</td>
<td>5.10 (.43)</td>
<td>4.80 (.44)</td>
<td>.118&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Gender, N boys (%)</td>
<td>49.4</td>
<td>54.8</td>
<td>40.7</td>
<td>51.7</td>
<td>.538&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ethnicity, N Australian (%)</td>
<td>74.7</td>
<td>90.3</td>
<td>70.4</td>
<td>62.1</td>
<td>.269&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Health Care Card or Pension card, N no (%)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>92</td>
<td>96.6</td>
<td>85.2</td>
<td>93.5</td>
<td>.284&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> ANOVA. <sup>b</sup> Chi-square test. <sup>c</sup> As an index of SES.
6.4 Results

Learning outcomes

An analysis of variance (ANOVA) was run before the main analysis. This analysis yielded no significant differences among the conditions in the pre-test scores, $F(2, 84) = .08, p = .922$ (integrated condition, $M = 1.58, SE = .38, 95\% CI .82 - 2.34$, non-integrated condition, $M = 1.37, SE = .41, 95\% CI .56 - 2.18$, control condition, $M = 1.55, SE = .39, 95\% CI .77 - 2.33$).

Results from the mixed ANCOVA revealed that the covariate, pre-test scores, had a significant effect on learning scores, $F(1, 82) = 12.44, p \leq .001, \eta^2_p = .13$. After controlling for the covariate, pre-test scores, there were significant main effects of condition, $F(2, 82) = 34.98, p \leq .001, \eta^2_p = .46$, and time of testing, $F(1, 82) = 16.15, p \leq .001, \eta^2_p = .17$, on learning performance. Although the interaction between time of testing and the covariate, pre-test scores, was not significant, $F(1, 82) < 1, p = .177$, the main effects were qualified by a significant interaction between condition and time of testing, $F(2, 82) = 6.17, p = .003, \eta^2_p = .13$. Post hoc comparisons with Bonferroni correction, controlling for Type I error, revealed that the integrated condition ($M = 14.05, SE = .73, 95\% CI 12.59 - 15.51$) performed better than the non-integrated ($M = 10.11, SE = .78, 95\% CI 8.56 - 11.65, p \leq .001$) and control condition ($M = 5.28, SE = .75, 95\% CI 3.79 - 6.77, p \leq .001$). Also, the non-integrated ($p \leq .001$) and control condition ($p \leq .001$) significantly differed. Table 6.2 presents descriptive statistics for science scores for all conditions during the two time points of testing.

Furthermore, pairwise comparisons with Bonferroni corrections showed that children performed better in the immediate post-test ($M = 10.71, SE = .48, 95\% CI$
9.75 - 11.67), \( p \leq .001 \) than the delayed post-test (\( M = 8.91, SE = .44, 95\% CI 8.04 - 9.79, p \leq .001 \)).

*Interest ratings for instructional method*

A mixed analysis of variance (ANOVA) was run to assess children’s interest across the conditions. The interest ratings were measured at two moments, directly after the end (immediate post-test) and six weeks after the intervention (delayed post-test). Table 6.2 presents descriptive statistics for children’s interest for the three conditions during the two time points of testing. The analysis revealed that the main effect of time of testing was not significant, \( F(1, 83) = 1.98, p = .164 \). However, there was a significant main effect of condition, \( F(2, 83) = 7.43, p \leq .001, \eta^2_p = .15 \). The interaction between condition and time of testing was not significant, \( F(2, 83) = 1.34, p = .267 \). With regard to the main effect of condition, post-hoc comparisons revealed that children in the integrated condition (\( M = 4.36, SE = .16, 95\% CI 4.05 - 4.67 \)) gave higher ratings for enjoyment of their way of learning than children in the control condition (\( M = 3.49, SE = .16, 95\% CI 3.17 - 3.81, ps \leq .001 \)) did for their specific way of learning. However, the ratings in the non-integrated condition (\( M = 3.94, SE = .17, 95\% CI 3.61 - 4.28 \)) did not differ from ratings in the integrated condition (\( p = .075 \)), and control condition (\( p = .053 \)).
Table 6.2. Means and Standard Deviations for Performance and Instruction Evaluation at the Immediate and Delayed Tests as a Function of the Condition.

<table>
<thead>
<tr>
<th>Time of testing</th>
<th>Performance M (SD)</th>
<th>Evaluation M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test scores (0-28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated condition</td>
<td>1.58 (1.67)</td>
<td></td>
</tr>
<tr>
<td>Non-integrated condition</td>
<td>1.37 (1.82)</td>
<td></td>
</tr>
<tr>
<td>Control condition</td>
<td>1.55 (2.72)</td>
<td></td>
</tr>
<tr>
<td>Immediate post-test (0-28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated condition</td>
<td>15.53 (4.91)</td>
<td>4.35 (1.05)</td>
</tr>
<tr>
<td>Non-integrated condition</td>
<td>11.07 (5.04)</td>
<td>3.98 (.91)</td>
</tr>
<tr>
<td>Control condition</td>
<td>5.52 (4.37)</td>
<td>3.67 (1.17)</td>
</tr>
<tr>
<td>Delayed post-test (0-28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated condition</td>
<td>12.63 (5.08)</td>
<td>4.37 (.82)</td>
</tr>
<tr>
<td>Non-integrated condition</td>
<td>8.97 (4.14)</td>
<td>3.91 (1.00)</td>
</tr>
<tr>
<td>Control condition</td>
<td>5.14 (3.36)</td>
<td>3.31 (.88)</td>
</tr>
</tbody>
</table>

Physical activity outcomes

An ANOVA was performed to assess the intensity levels of physical activity across the conditions, with counts per minute as dependent variable, and condition as independent variable. Results showed a significant effect of condition on counts per minute, \( F(2, 215) = 26.13, p \leq .001, \eta^2_p = .19 \). Post hoc comparisons with Hochberg corrections, controlling for different sample sizes, revealed that children in the non-integrated condition (\( M = 1117.00, SE = 53.57, 95\% CI 1011.42 - 1222.59 \)) were more physically active than children in the integrated condition (\( M = 878.23, SE = \))
53.57, 95% CI 780.85 - 975.61, \( p = .004 \)). Children in the integrated and non-integrated condition were more physically active than children in the control condition (\( M = 530.27, SE = 61.04, 95\% \text{ CI } 409.96 - 650.57, \text{ both } ps \leq .001 \)).

Moreover, an ANOVA was performed on the total time spent in moderate to vigorous physical activity (MVPA), with condition as the independent variable. Results showed that there was a significant effect of condition on time spent in MVPA, \( F(2, 215) = 40.92, p \leq .001, \eta^2_p = .27 \). Post hoc comparisons with Games-Howell corrections, controlling for unequal variances, showed that children in the non-integrated condition (\( M = 2.25, SE = .09, 95\% \text{ CI } 2.06 - 2.43 \)) spent more time in MVPA than children in the integrated condition (\( M = 1.62, SE = .09, 95\% \text{ CI } 1.46 - 1.79, p \leq .001 \)). Moreover, children in the integrated and non-integrated condition spent more time in MVPA than children in the control condition (\( M = .98, SE = .11, 95\% \text{ CI } .77 - 1.19, \text{ both } ps \leq .001 \)).

### 6.5 Discussion

The purpose of this study was to investigate the learning effects of integrating physical activities into a science lesson among preschool children. The results confirmed the hypotheses, indicating that the integrated physical activity condition, in which children embodied science knowledge through physical activities, had the highest learning outcomes, assessed by a combination of free-recall and cued-recall tests directly after and six weeks after the end of the intervention. In addition to that, the non-integrated condition, which involved task-irrelevant movement, performed better than the sedentary control condition (Hypothesis 1). The outcomes of this study reflect the effects of task-relevant whole and part-body movements on learning outcomes found in past research (Boncoddo, Dixon, & Kelley, 2010; Donnelly &
Lambourne, 2011; Gallagher & Lindgren, 2015; Mavilidi et al., 2015, 2016).

Intervention studies attest the importance of the use of body movements, specifically for science learning. For example, Kontra, Lyons, Fischer, and Beilock (2015) evaluated the importance of physical experience in science learning in college students. Through a series of studies, students learned about the vector nature of angular momentum. Firstly, during the training, they observed avatars on videos and afterwards they were paired to an action group in which they had to physically manipulate aspects of a wheel system (e.g., direction, spin, speed, size, and tilt), or an observation group in which they could observe the tilting and the path of a red laser dot on the wall. The test trials included wheels spun in the same and opposite directions to those in the training sessions. Also, the neural correlates of the learning path of the participants were recorded using functional magnetic resonance imaging (fMRI). Finally, it was examined whether the effects of action experience would remain after several days of engagement in the bicycle-wheel system. It was found that students who were able to physically manipulate the angular momentum outperformed students who only observed the same phenomena. Action experience activated their sensorimotor brain systems and fostered their understanding of the physics concepts. Moreover, Boncoddo et al. (2010) examined whether meaningful hand movements had an effect on preschool children’s learning of simple gear-system problems. Firstly, children familiarised themselves with the properties of the gears by physically manipulating toy gears and then they solved the gear-system problems on a computer. Results displayed that, when children used a force-tracing strategy (i.e., by choosing which clockwise-counterclockwise motions they had to make to solve how gears alternate turning direction), they were able to solve the gear problems faster.
The interaction between children’s movements and the gear system enabled them to acquire novel representations of physics from their own actions.

Importantly, the essential role of physical experience and linking knowledge to real-world examples during science learning is emphasised for improving spatial abilities (Hegarty & Waller, 2005), the construction of mental representations and richer cognitive schemas, memory encoding, retention and retrieval, and learning (Madan & Singhal, 2012; Zacharia, Loizou, & Papaevripidou, 2012). Mental imagery is a fundamental key element for understanding and learning of science in students (Leutner, Leopold, & Sumfleth, 2009). The explicit connections between experiences and representations as well as the high level of familiarity of the scientific concepts enhanced children’s learning (Enyedy, Danish, Delacruz, & Kumar, 2012). The dynamic imagery arising from the multimodal representations and use of analogies during science learning is consistent with the “embodied cognition” notion, advocating that people learn from the interaction of their body with their physical environment (Gallagher, 2005; Wilson, 2002). Engaging preschool children’s cognitive and motor skills is pivotal for their future development (Lu & Montague, 2015). Strong empirical evidence attests the positive associations of physical activity and exercise on cognition and academic achievement during childhood (Álvarez-Bueno et al., 2017; Hillman & Biggan, 2017; Khan & Hillman, 2014). The fact that children in the non-integrated physical activity condition had higher learning outcomes than the control condition provides proof in favor of this argument (Hypothesis 2).

Two previous studies conducted in preschool children, utilising the physiological benefits of physical activity combined with the attributes from
embodied learning, and incorporating short interventions of 10 – 20 min weekly with combined physical and cognitive activities during instruction in different learning domains, replicate the main findings found here (Mavilidi et al., 2015, 2016).

Mavilidi et al. (2015) targeted foreign language vocabulary learning conducted 15-20 min, twice per week for 4 weeks, when children were randomly assigned to four conditions: in the integrated condition, they performed physical activities related to the meaning of the words (e.g., dancing for the word “dance”). In the non-integrated condition, they were engaged in physical activities irrelevant to the meaning of the word (i.e., running for each word). In the gesturing condition, children remained seated and gestured related to the meaning of the word (e.g., rhythmic hand movements for the word “dance”). Finally, in the conventional condition, children remained seated and repeated the words with no movements involved. Results showed that the children in the integrated condition had the highest scores on free-recall and cued-recall tests, and that children in both the non-integrated and gesturing condition outperformed the children in the conventional condition on the cued-recall test.

Children’s physical activity levels were equal in the physical activity groups (integrated and non-integrated condition) but higher compared to the gesturing and conventional condition. Finally, in Mavilidi et al. (2016), children attended three learning sessions of 10 min per day while learning geography (i.e., the continents and characteristics animals living in each continent), and were randomly assigned to three experimental conditions: in the integrated condition, physical activities were linked with the information to–be-learned such as hopping like a kangaroo from Oceania; the non-integrated condition, in which physical activities were irrelevant to the information such as running around the map, and a control condition, where children remained seated and listened to the information to–be-learned. The physical activity
groups outperformed the control condition whereas children in the non-integrated condition were more physically active than children in the integrated and in the control condition. Both studies suggested that active learning through the integration of physical activities with academic content has the potential to enhance preschool children’s learning performance, with effects found when instruction was conducted in groups (Mavilidi et al., 2015) as well as individually (Mavilidi et al., 2016).

In addition, although we were expecting children in the physical activity groups (integrated and non-integrated condition) to be involved in the same levels of physical activity, this was not found to hold true in this case. This study corroborates the findings of physical activity measurements from Mavilidi et al. (2016) and can be attributed to the type and nature of the learning task. Children in the non-integrated condition in both studies had to run around (the planets and the map respectively), and consequently covered a greater distance compared to children in the integrated condition. It is possible that higher physical activity intensity levels for the integrated condition would contribute to even higher learning scores, but this needs to be examined in future research.

Nevertheless, it is likely that children did not enjoy the physical activity aspect unrelated to the task as they evaluated it the same as in the control condition, in which children remained seated and observed the planets. Conversely, they showed higher levels of enjoyment in the integrated condition as they evaluated it higher than the control condition, partly confirming Hypothesis 3. Existing literature supports that collaborative learning (Shoval, 2011) and classroom based-physical activity programs (Vazou & Smiley-Oyen, 2014) can enhance children’s motivation and enjoyment.
In summary, this is the first experiment to include objective measurements of both physical activity and learning outcomes in preschool children’s science learning. It adds to the existing body of research indicating how physical activity interventions can positively affect cognitive functioning and academic performance in children (Diamond, 2015; Diamond & Lee, 2011; Schmidt, Benzing, & Kamer, 2016; Vazou, Pesce, Lakes, & Smiley-Oyen, 2016). The effects are more pronounced when these interventions include cognitively engaging activities during learning. In the present study, children in the integrated condition seemed to have benefited from the combined embodied and physical activity effects. In addition to this, children might have benefited not only from making movements but also from observing others’ movements. In accordance with research on the “mirror neuron system”, looking at other’s actions may activate the same neurons related to these actions in the motor cortex (Rizzolatti & Craighero, 2004). The mirroring capacity can be transferred during learning of cognitive tasks including a motor component (Paas & Sweller, 2012; Van Gog, Paas, Marcus, Ayres, & Sweller, 2009). Future research should shed light on the effects of performing and observing physical activities on learning occurring in groups and/or individual sessions as well as isolating the effects of embodiment and physical activity, motivation, and cooperative learning.

Future research is also recommended to investigate the effectiveness and efficacy of classroom-based physical activity programs with different target groups such as adolescents, and different learning contents related to science, as well as the generalisability of outcomes to more complex cognitive tasks. In addition, intervention studies at larger scale and for more prolonged periods would be needed to capture the long-term effects of physical activity, related to the possible changes in body mass index and physical fitness, on preschool children’s cognition and learning, allowing
us to be more conclusive in an area of research which is currently scarce. So far, it has been shown that single bouts of physical activity (acute exercise) can provoke physiological arousal facilitating the available attentional resources and engagement of cognitive functioning whereas multiple bouts (chronic exercise) alternate morphologically brain regions responsible for learning (Best, 2012; Brisswalter, Collardeau, & René, 2002; Tomporowski et al., 2008).

Finally, this study took into account the nested nature of data as well as participants’ demographics characteristics. Although no significant differences were found among the conditions, a stricter criterion during randomisation would be advisable in future research to control for potential confounders.

In conclusion, this study places science learning in early childhood - an area where there has been little research - at the centre of attention. However, children usually face challenges with deeper understanding of concepts of science. Best, Dockrell, and Braisby (2006) assessed the knowledge of children from ages 4 to 8 years old on science and more specifically on their knowledge about the concept of eclipse and entities related to space (i.e., sun, moon, earth, planets). Their aim was to examine what children were able to understand about science and at what level their mental representations of space correspond with those of adults. It was found that children were able to acquire new words or concepts as abstract as space but not as accurately as adults. Even though children obtained knowledge about solar eclipse, the concept of lunar eclipse was more difficult for them. Nevertheless, children’s interest and knowledge in science commence well before formal schooling. This study suggests a promising, and entertaining way to promote the acquisition of fundamental concepts during science learning (i.e., the solar system), knowledge that is required by
young children when entering school (Benchmarks; AAAS, 1994; Plummer, 2009). Early exposure and familiarisation to the contents of science are the foundational basis for learning (Trundle, 2015), rendering them as the backbone for STEM learning and future related careers.

Overall, the present study suggests a promising instructional approach that has the potential to offer significant physical, psychological, and cognitive gains. Notable changes were detected only within a short intervention of 1h in total. We think that longer periods will offer even more pervasive results, but this needs to be confirmed in future research. This innovative method is easy to implement, requires little additional resources or equipment, and can be adjusted to teachers’ restrictions and demands during daily routines. At the same time, it can foster academic achievement through higher engagement and performance, while compensating for the loss in academic time that is characteristic for normal physical activity lessons that are not integrated with learning (Sallis et al. 1997; Ward et al., 2006). Notably, taking into account the increment of overweight preschool children (Ogden et al., 2006), who are less active in the childcare centres compared to their normal counterparts (Trost, Sirard, Dowda, Pfeiffer, & Pate, 2003), initiating physical activity into classroom-based programs would result in a concomitant increase in children’s daily physical activity intensity levels. In turn, infusing physical activity with learning tasks would bring preschool children closer to the suggested 3 hours per day of physical activity recommendations (Australian Government Department of Health, 2014; Tremblay et al., 2002), leading to a healthier lifestyle and well-being in the long-term.


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Chapter 7

General Discussion
7.1 Aim of thesis

A literature review and a series of intervention studies were conducted as part of this PhD thesis, which examined the effects of infusing movements in the form of physical activities into the learning process in preschool children. The learning domains used in this study were foreign language, geography, math, and science. For that purpose, a total of 425 preschool children from 41 childcare centres participated in the four experimental studies.

7.2 Main findings

Chapter 2 summarised the existing literature on the effects of movements on cognition and learning. Current research in human movements can generally be categorised into studies that include subtle movements such as gestures, and studies including gross motor movements such as physical activity. The research in gestures focuses on the effects on cognition and learning. The physical activity studies target either increasing children’s physical activity levels or decreasing children’s sedentary behaviour (mostly health-related studies), or examining the effects on health and cognition, or only on cognition. Overall, the movement actions in exercise and cognition and integrated physical activity research can largely diverge in intensity, duration, cognitive challenges and time relation between the physical and cognitive engagement. The studies chosen were classified along a double continuum of integration and relevance of the physical activity with the learning/cognitive task. It is suggested that the best way to learn especially in childhood is incorporating full-body movements in a relevant and integrated way during learning process, in the sense that the physical activities are connected with the content material or the information to be learned.
Chapter 3 described an intervention study on learning language in 115 preschool children (4-5 years) from 15 childcare centres. More specifically, it evaluated the effectiveness of integrating task-relevant movements on learning 14 Italian words. There were four conditions in this study:

The **integrated** condition consisted of task-relevant movements, or physical activities combined with the learning context. For example, children were dancing for the respective Italian word “dance”. The **non-integrated** condition included task non-relevant movements, or physical activities occurring prior to the cognitive task. In this condition, children were running for all the words. The **gesture** condition involved task-relevant gestures. In this condition, children remained seated and moved their hands rhythmically for the respective Italian word “dance”. The **control** condition represented the traditional sedentary way of teaching, in which no movements were involved. Children remained seated and looked at the static pictures of the Italian words.

The cognitive assessments included: a questionnaire completed by the parents before the beginning of the intervention, used to control for demographic information and familiarity of children with an Italian background, an assessment included during the four-week intervention period (i.e., week 2), a post-test immediate after the end of the intervention (immediate post-test), and a post-test 6 weeks after the end of the intervention with no exposure to the learning materials (delayed post-test).

It was hypothesised that the integrated condition would produce the highest learning outcomes (Hypothesis 1). Also, it was hypothesised that the non-integrated condition would be higher than the control condition (Hypothesis 2).
This study demonstrated that integrating physical activities had the highest effects on learning foreign language words. Children in the integrated condition performed the best on free-recall tests, and they also outperformed children in the gesturing and conventional conditions on cued-recall tests. Children in the non-integrated condition and the gesturing condition remembered more words than those in the conventional condition. The intensity of the physical activities was the same in the integrated and non-integrated physical activity conditions, but higher than in the gesturing and conventional conditions, which did not differ from each other.

Chapter 4 focused on the effects of infusing physical activities into a geography learning task. Participants were 87 preschool children (4-5 years) from 8 childcare centres, who had to learn the continents and a typical animal that lived there. The integrated condition consisted of task-relevant movements, or physical activities combined with the learning context. For example, children were “hopping like a kangaroo” when moving from Oceania to Europe. The non-integrated condition included task non-relevant movements, or physical activities occurring prior to the cognitive task. In this condition, children were running around the map. The control condition represented the traditional sedentary way of teaching, in which no gross motor movements were performed. Children remained seated and looked at the map and the animals on it.

The cognitive assessments included: a pre-test before the beginning of the intervention, a post-test immediate after the end of the intervention (immediate post-test), and a post-test five weeks after the end of the intervention with no exposure to the learning materials (delayed post-test).
It was hypothesised that the integrated condition would produce the highest learning outcomes (Hypothesis 1). Also, it was expected that the non-integrated condition would be higher than the control condition (Hypothesis 2). Finally, it was assumed that the physical activity conditions would be perceived as the most preferred instructional method (Hypothesis 3).

The results showed that the physical activity groups (integrated and non-integrated condition) performed better in the learning tasks than the control condition. However, there were no significant differences in learning performance between the integrated and non-integrated condition. Moreover, active lessons were perceived as more enjoyable and led to better learning performance. Finally, the non-integrated condition was the most physically active group followed by the integrated, and control condition.

In Chapter 5, we examined the effects of integrating physical activity into children's learning of numeracy skills. Participants were 120 preschool children (3.5-5 years) from 9 childcare centres. Children were trained on a number line estimation task consisted of blocks of numbers. In the integrated condition children performed task-relevant physical activities (e.g., running on the numbers), while children in the observing physical condition stayed seated, observing the physical activities performed from their peers in the integrated condition. Children in the non-integrated condition performed task non-relevant physical activities (e.g., running around the numbers). Finally, the control condition remained seated without performing or observing any physical activities.

The cognitive assessments included: a pre-test before the beginning of the intervention, a post-test immediate after the end of the intervention (immediate post-
test), and a post-test six weeks after the end of the intervention with no exposure to
the learning materials (delayed post-test).

It was hypothesised that children in the integrated condition would show the
highest learning performance on the cognitive tests compared to the other conditions
(Hypothesis 1). Moreover, we expected that children in the observing condition would
score higher than children in the control condition (Hypothesis 2). Also, we expected
that children in the non-integrated condition would perform better in the learning
tasks than children in the control condition (Hypothesis 3). Moreover, it was assumed
that the integrated condition would have the highest interest rating scales, followed by
the non-integrated condition, and the observing physical activity and control
conditions (Hypothesis 4).

The integrated condition outperformed the other conditions in learning
outcomes. More specifically, the integrated condition had the highest scores in the
number line estimation and numerical comparison tasks, performed better than
observing physical activity and control conditions in the counting task, and better than
the control condition in the numerical identification task. No differences among the
conditions were found for the block counting task. The observing physical activity
and non-integrated condition did not perform better than the control condition.
Children in the integrated condition rated higher their interest in the instructional
method compared to the observing physical activity and control condition, although
no significant differences were found between the integrated and non-integrated
condition. Finally, the integrated and non-integrated condition did not differ in terms
of physical activity compared with the observing and control condition. The two
physical activity groups (integrated and non-integrated condition) were more physically active than the sedentary groups (observing and control condition).

In Chapter 6, we studied the effects of physical experience in the form of integrated physical activities on learning science in preschool children (4-5 year old). Eighty-six children learnt the names of the planets and their order, based on the distance from the sun.

The integrated condition consisted of task-relevant movements, or physical activities combined with the learning context. For example, children starting from the sun, visited the first planet and then returned to the sun, continuing the same process with the right order from the sun for all planets. The non-integrated condition included task non-relevant movements, or physical activities occurring prior to the cognitive task. In this condition, children ran around the planets. The control condition represented the traditional sedentary way of teaching, in which no movements were involved. Children remained seated and looked at the planets.

The cognitive assessments included: a pre-test before the beginning of the intervention, a post-test immediate after the end of the intervention (immediate post-test), and a post-test six weeks after the end of the intervention with no exposure to the learning materials (delayed post-test).

It was hypothesised that the integrated condition would produce the highest learning outcomes (Hypothesis 1). Also, it was hypothesised that the non-integrated condition would be higher than the control condition (Hypothesis 2). Finally, it was hypothesised that the physical activity conditions would be perceived as the most preferred instructional method (Hypothesis 3).
Results revealed that the integrated condition had the highest learning outcomes whereas the non-integrated condition performed better than the control condition. Also, the integrated condition was perceived by children as a more enjoyable instructional method than the control condition. Finally, children in the non-integrated condition were the most physically active, followed by the integrated, and control condition.

In summary, the current literature (e.g., embodied cognition and cognitive load theories) in combination with the results from the four experimental studies suggest that physical activities can be successfully implemented into learning activities in early childhood settings in order to enhance children’s learning and promote physical activity. These results can be generalised to different learning domains such as language, geography, mathematics, and science.

7.3 Discussion

The main body of research in this thesis was based on educational psychology research, which attests to the positive effects of subtle movements (i.e. gestures, object manipulation). Embodied cognition was used as the dominating conceptual framework advocating the effectiveness of using the body in learning experiences. Also, the evolutionary upgrade of cognitive load theory showed how the human motor system (as a form of biological primary knowledge) can be used to assist learning of complex tasks (biological secondary knowledge). Finally, studies of exercise science and/or public health, varying vastly in intensity, duration of bouts or interventions revealed how cognition and learning performance can be improved by physical activity, exercise, and fitness.
Integrating physical activity into academic lessons is an innovative, promising approach to improve learning and health outcomes. Existing interventions usually target children with the primary goal to increase physical activity and as secondary outcome to increase academic performance in school-aged children (PAAC, Donnelly & Lambourne, 2011; Take 10!, Kibbe et al., 2011; Energizers, Mahar et al., 2006, Mahar, 2011; F & V, Mullender-Wijnsma et al., 2015a, b), as well as improve on-task behaviour in preschoolers (Webster, Wadsworth, & Robinson, 2015). These interventions promote physical activity throughout the school day (Carson, Castelli, Beighle, & Erwin, 2014; Salmon et al., 2011). The time in which children were involved in physical activities did not have a negative influence on academic time, which is considered a demotivating barrier from teachers’ perspectives (Sallis et al., 1997; Ward et al., 2006). These classroom-based physical activity programs were flexible and adjustable to the learning situations, and as a results as feasible to be adopted and implemented by teachers (Delk, Springer, Kelder, & Grayless, 2014). Moreover, they were cost-effective, requiring no extra resources such as teachers or materials beyong the ones that already exist in schools (Babey, Wu, & Cohen, 2014).

In contrast, few interventions in early childhood have attempted to increase physical activity by modifying the already existing daily activities (such as structured physical indoor activity, unstructured physical activity during recess), or introducing new physically activity lessons (Pate et al., 2016; Pfeiffer et al., 2013). Typically, in childcare centres, preschool children spend more time in free-choice activities (e.g., gross motor movements or imaginative play) than in teacher-directed activities (academic activities such as literacy, language development, math, art and music activities, Howes, Fuligni, Hong, Huang, & Lara-Cinisomo, 2013). In fact, around 60% of the daily routine time is spent in free-choice activities, whereas less than 20%
is spent in teacher-directed small or whole group activities (Fuligni, Howes, Huang, Soliday-Song, & Lara-Cinisomo, 2012). However, as the results of the studies presented in this thesis reveal, engaging children in activities that combine physical with cognitive activities provides enhancements to learning (Mavilidi et al., 2015, 2016, 2017).

7.4 Overview of the results

Task-relevant physical activity – working mechanisms

This PhD thesis focused on an instructional approach, which includes task-relevant physical activities during the learning process. Different explanations for the effectiveness of this approach are briefly provided:

Research has proved the positive effects of physical activity on the brain, cognition, and academic achievement (Sibley & Etnier, 2003) through several alterations in brain functions (i.e., neurogenesis, connectivity, Khan & Hillman, 2014). Concurrently, the theoretical framework of embodied cognition advocates that body and mind are inextricably bound (Barsalou, 2008; Wilson, 2002). In this sense, the cognitive processes can develop through the interactions of the bodily actions, the environment, and perception. Another theory linked to embodied cognition, is the cognitive load theory, which advocates that biological primary knowledge (movements – as inherently acquired) can be used to assist learning of secondary primary knowledge (such as maths – acquired after instruction; Paas & Sweller, 2012). As such, sensorimotor information stemming from multimodal resources (i.e., visual, auditory, kinaesthetic) can be a significant adjunct to learning, facilitating encoding, retrieval and recall performance (Lindgren & Johnson-Glenberg, 2013; Madan & Singhal, 2012). The information received from different modalities (i.e.,
visual, auditory, motor) leads to enriched mental schemas, leaving a deeper trace in the long-term memory (Madan & Singhal, 2012). Because this information is processed in different systems, working memory resources are released, eliminating cognitive overload (Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001). In accordance with the Dual Coding Theory, students who are engaging in motions and perceptions, are connecting the kinaesthetic “imagery” with visual and verbal cues (Clark & Paivio, 1991).

In all studies in this thesis, the condition that included the task-relevant physical activities had the highest performance, allowing children to spatially locate the information that they learnt. The connections of the abstract concepts with specific cues from the external environment, improved children’s spatial thinking (Uttal, Miller, & Newcombe, 2013) and led to better understanding and learning (Chandler & Tricot, 2014).

Finally, an alternative explanation for the positive effects of movements on cognition is the existence of a “mirror neuron system” which advocates that observing others’ movements can provoke the activation of the same neurons that would required to be activated for the execution of these movements in the motor cortex (Rizzolatti & Craighero, 2004). To this vein, learning cognitive tasks involving a motor component can be a significant aid for learning (Van Gog, Paas, Marcus, Ayres, & Sweller, 2009).

Overall, we argue that children in the integrated condition, incorporating task-relevant physical activity, benefited from the combined embodied and physical effects (see Chapter 2 for more details), rendering them to perform better in different learning
tasks, be more physically active, and have higher levels of enthusiasm towards this approach for learning compared to the traditional way.

7.5 Intervention strengths

The series of the intervention studies developed for the purpose of this PhD research project, led to a number of original contributions of this thesis to the field of Educational Psychology:

To the best of our knowledge, few intervention studies objectively measured both cognitive and physical activity outcomes in preschool children. Especially in early childhood, interventions have either focused on increasing physical activity (Trost, Fees, & Dzewaltowski, 2008; Pate et al., 2016; Pfeiffer et al., 2013) or cognitive development in isolation (Campbell, & Ramey, 1994; Howard, Powell, Vasseleu, Johnstone, & Melhuish, 2017; Melhuish et al., 2008) but the combination of physical with cognitive activities during learning is scarce.

A wide range of learning areas (i.e., language, geography, maths, science) was incorporated in this PhD project and is consistent with previous research conducted with older children (Donnelly & Lambourne, 2011; Kibbe et al, 2011). This variation gives the ability to generalise findings and infer about the efficacy of the suggested instructional method in early childhood settings regardless of the learning subjects.

In contrast to previous studies that mostly focused on executive functioning using generic cognitive standardised tests (e.g., Davis et al., 2007), the primary outcome measure used in the studies presented in this PhD thesis was children’s learning performance, based on children’s learning progress from pre-test to post-test. The assessments also included delayed measurements to assess the retention of the
information learnt 5-6 weeks after the end of the interventions. The physical activity outcomes were included to strengthen the learning results, as the positive effects of physical activity on cognition, academic performance, and learning are consistent (see Chapter 2). More specifically, all studies included an integrated (task-relevant physical activity) and non-integrated condition (task non-relevant physical activity). Children in these conditions were engaged at the same intensity levels of physical activity (i.e., foreign language - Chapter 3; maths - Chapter 5), or the non-integrated conditions were more physically active than the integrated condition (i.e., geography - Chapter 4; science - Chapter 5). Nevertheless, in all studies, the integrated condition showed the greatest effect on learning outcomes. Combining the results from learning and physical activity outcomes, the efficacy of the integrated approach can be confirmed, concluding that this condition had the best performance across the different learning domains. Thus, the outcomes of this research are specific and tangible, with broad educational implications for practice for teachers and educators.

The integration of physical activity has the potential to promote health in childcare centres, in compliance with the current physical activity guidelines that recommend three hours of physical activity per day for preschool children (Australian Government Department of Health, 2014). Although the interventions described above comprise short bouts of physical activity, the educators have the flexibility to increase the active lessons for longer times during the week, easily adjusting it to their needs, time and space restrictions. The importance of these interventions is that they have been tested in “real-word” environments, increasing their ecological validity. Thus, it can be concluded that physical activity interventions in childcare settings are sustainable and cost-effective. The recommended instructional approach requires minimal training, and resources, and allows the educators to have flexibility, use their
own creativity, autonomy, and imagination in how they implement the activities, making it a “good fit” to all learning environments and situations. This adaptability in implementation makes it also “user-friendly”, increasing the possibilities of adoption by other educators (Delk, Springer, Kelder, & Grayless, 2014; Vazou & Skrade, 2016), overcoming existing challenges and barriers (i.e., time constraints, lack of social and financial school support, teacher experience, self-efficacy, attitudes toward movements; Webster, Zarrett, Cook, Egan, Nesbitt, & Weaver, 2017; Webster, Russ, Vazou, & Erwin, 2015).

7.6 Limitations

Despite the effort of this series of interventions to limit weaknesses, when drawing conclusions on the reported results, a number of limitations should be considered:

All the intervention studies used the same concepts to describe the experimental conditions. These concepts refer to an integrated approach, which included task-relevant movements, and a non-integrated approach involving task non-relevant movements. For example, Study 2 (i.e., geography - Chapter 4), a pure integrated and non-integrated comparison would look at the child hopping from Oceania to Europe versus the child just hopping around. However, in the four studies, the physical activity was actually more integrated than relevant, because it was done during learning, but not relevant to the learning task. From that point of view, a more appropriate name for the conditions would be relevant and non-relevant movement conditions.

The intervention studies were all conducted in the area of Wollongong within a 20-km radius. The studies did not take into account demographic characteristics
(such as socioeconomic status, maternal and paternal education). One exception was Study 4 (see Chapter 6), which included children’s age, gender, ethnicity, and the possession or not of a Health care or pension card from Centrelink as an indication of SES (Australian Government Department of Human Rights, 2016). However, the stratification in childcare centres was random, and not based on the SES of parents. Because the data collection was conducted locally only within a specific area, one could argue that this limits the generalisability of the results. Nevertheless, it can be assumed that this area does not differ from other metropolitan areas in terms of SES.

Moreover, there was a noticeable variability in the daily routine of the childcare centres. Unlike schools, there is not a predetermined curriculum to follow. Early years educators follow the National Quality Framework for Early Childhood Education and Care (Australian Government Department of Education and Training, 2017). This framework has a goal that children should have encountered basic literacy (i.e., reading, spelling), concepts of numeracy, and science during preschool years. Consequently, it was not feasible to control children’s previous knowledge and acquired knowledge during the intervention. For this purpose, cognitive tests that evaluated children’s progress of the specific knowledge were constructed and administered by the researcher. The cognitive tests in all studies were mainly memory tasks. Possible limitations might occur with respect to the external validity of the studies. Nevertheless, pre-tests also determined children’s existing knowledge of each topic. An exception was Study 1 (Chapter 3), which entailed a foreign language in which none of the participating children had any prior knowledge, as indicated by the parents and educators. However, a limitation of this project was that no pre-test and condition interaction effects were tested in any of the studies.
Furthermore, children’s eligibility to participation was restricted to only those children who attended a minimum of two days per week. However, there were many unexpected changes, absences, or sicknesses, which resulted in fewer children than expected. In addition, each childcare centre provided a specific indoor/outdoor space (of different room/space sizes) for conducting the intervention, which was widely affected by the weather conditions. This variability in the conditions may have been a confounder in the intervention studies. Finally, another point to take into account is the variation of the total number of participating children in each childcare centre. In some childcare centres, the number of participating children was as low as 5 while in other centres it was as high as 20 children. Nevertheless, a maximum of 10 children per group was set. In addition to this, we did not perform an intention-to-treat analysis. Consequently, we did not have a clear indication on whether children, who were excluded because of a high absence rate, had different characteristics that may have influenced the study outcomes.

Importantly, for practical reasons, in all intervention studies, the randomisation was conducted at the centre level and not at the child level. Although pre-test scores were gathered to ensure that children’s knowledge in the baseline was the same across the conditions, stricter randomisation criteria and analyses taking into account the nested nature of the data were exhaustively not applied in all cases. In this sense, only the Study 3 (maths) used a multilevel model. Possibly, in the other three experimental studies (Chapters 3, 4, and 6) an underestimation of standard errors for the condition coefficients might have occurred.

Finally, it is important to mention that the childcare centres were aware of the nature of the interventions but not of the hypotheses of the study. In contrast, with the
exception of Study 1 (see Chapter 3), which included research assistants as well as the first author as main researcher, it was not possible to have assessors who were blind to the experimental conditions during the data collection. Although the researcher and assistants worked according to the systematic protocol in each study, the possibility that the researcher’s engagement, motivation and skills might have influenced the children’s motivation and learning performance cannot be excluded.

7.7 Future research

In relation to the aforementioned limitations of the intervention studies, future research should clarify some points that were not possible to be addressed in the studies reported in this thesis.

This thesis comprised of a theoretical review and four experimental studies with similar designs and different learning domains (i.e., language, geography, maths, and science). More powerful, large-scale studies are needed within the same and other learning domains, and with different types of physical activities to substantiate our claims and results about integrated physical activities. Importantly, although this research focused on specific learning domains, including measurements of general language ability or working memory capacity could benefit the current literature regarding the possible beneficial effects of physical activity for children with low working memory capacity or reading ability.

Moreover, it is advisable to follow the CONSORT statement especially in areas such as randomisation and blinding of assessors. Setting criteria that consider demographic characteristics, for example, children’s age, gender, parents’ education and socioeconomic status, as well as the nested nature of the data, are indispensable for minimising potential bias.
Furthermore, the interventions in this thesis entailed 10-20 min of physical activity, taking place once per week (apart from Study 1, in which sessions took place twice a week), for four weeks (with the exception of Study 2, which lasted 3 sessions in total). They mainly focused on the acute and delayed effects of physical activity on learning. Intervention studies lasting for longer periods and including longer bouts of physical activity are necessary to shed light on the longer or chronic effects of physical activity on learning, accompanied by possible changes in body mass index and physical fitness (Best, 2010, 2012; Brisswalter, Collardeau, & René, 2002; Tomporowski et al., 2008), and bringing them closer to the Physical Activity guidelines for this age group (Australian Government, Department of Health, 2009). Likewise, these studies should also assess children’s learning performance throughout the duration of the intervention, providing information regarding children’s developmental progress and well as transfer or learning, and retention.

Finally, the four experimental studies described in this thesis led to a recommendation to integrate physical activities during the learning process of preschool children, both when activities are conducted in groups (Studies 1, 3, & 4) and individually (Study 2). These physical activities should furthermore be meaningfully related to the learning task, in which the role of the body acquires a dominant role for learning (embodiment; Barsalou, 2008). This new instructional approach was welcomed by children, and perceived as more enjoyable compared to the conservative sedentary way of learning. In the future, it is essential to isolate the effects of embodiment, children’s motivation and engagement, collaborative or individual instruction, and novelty, on learning. In addition to this, the current focus of this PhD thesis was preschool years. Future studies should try to identify similar
effects of task relevant physical activities on different age groups and target groups, taking into account different levels of task complexity.

7.8 Implications for educational practice

Early childhood educators are strongly encouraged to add short and simple physical activities to their existing lessons. The physical activities should be related to the learning content. It is recommended to use these active lessons at least once per week for 15 min per day, emphasising learning mechanisms such as memorisation and repetition in a healthier and more entertaining way. Physically active academic lessons have the potential to increase children’s academic achievement, motivation and engagement, as well as their physical activity intensity levels.

7.9 Conclusions

The focus of this thesis was the design, development, implementation, and evaluation of an innovative instructional approach, which combines cognitive and physical activities during learning. Cornerstone in this approach is the factor of embodiment, setting the interaction between the body and the environment as fundamental, integrated with physical activity.

The results from four experimental studies and a theoretical review revealed that the recommended approach is feasible, acceptable and potentially efficacious and more effective than the traditional approaches currently in use. This type of stealth intervention (Robinson, 2010) was able to increase children’s learning performance regarding their language, geography, maths, and science knowledge. At the same time, children enjoyed the active lessons more than the traditional way while they were more physically active as well.
The findings of this PhD thesis reinforce that early childhood settings are the right place to instigate fundamental changes to promote children’s cognitive and physical development with longer-lasting benefits for young children.
References


Chapter 8

Appendices
Appendix A

Experimental Study 1 (Language – Chapter 3): Human Ethics Approval

APPROVAL after review
In reply please quote: HE14/252
Further Enquiries Phone: 4221 3388

4 July 2014

Ms Myrto Mavilidi
Faculty of Social Sciences
University of Wollongong
Northfields Ave
WOLLONGONG 2522

Dear Ms Mavilidi

Thank you for your letter responding to the HREC review letter. I am pleased to advise that the Human Research Ethics application referred to below has been approved.

Please note: the Committee has requested that you please provide emails of support from the remaining early childhood centres when they become available.

Ethics Number: HE14/252
Project Title: The effects of embodied and physical activities on learning words in a foreign language in pre-school children
Researchers: Ms Myrto Mavilidi, Professor Tony Okely, Professor Fred Paas, Professor Paul Chandler
Approval Date: 3 July 2014
Expiry Date: 2 July 2015
Approved Documents:

- P1S Ver 2 (C1) 01-07-14 - participant information sheet
- P1S Ver 2 (C2) 01-07-14 - participant information sheet
- P1S Ver 2 (C3) 01-07-14 - participant information sheet
- P1S Ver 2 (C4) 01-07-14 - participant information sheet
- CF Ver 2 (C1) 01-07-14 - Consent Form
- CF Ver 2 (C2) 01-07-14 - Consent Form
- CF Ver 2 (C3) 01-07-14 - Consent Form
- CF Ver 2 (C4) 01-07-14 - Consent Form

The University of Wollongong/Illawarra Shoalhaven Local Health District Social Sciences

HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research. The HREC has reviewed the research proposal for compliance with the National Statement and approval of this project is conditional upon your continuing compliance with this document.

Ethics Unit, Research Services Office
University of Wollongong NSW 2522 Australia
Telephone (02) 4221 5396 Facsimile (02) 4221 4338
Email: rso-ethics@uow.edu.au Web: www.uow.edu.au
A condition of approval by the HREC is the submission of a progress report annually and a final report on completion of your project. The progress report template is available at http://www.uow.edu.au/research/rso/ethics/UOW009385.html. This report must be completed, signed by the appropriate Head of School, and returned to the Research Services Office prior to the expiry date.

As evidence of continuing compliance, the Human Research Ethics Committee also requires that researchers immediately report:

- proposed changes to the protocol including changes to investigators involved
- serious or unexpected adverse effects on participants
- unforeseen events that might affect continued ethical acceptability of the project.

Please note that approvals are granted for a twelve month period. Further extension will be considered on receipt of a progress report prior to expiry date.

If you have any queries regarding the HREC review process, please contact the Ethics Unit on phone 4221 3386 or email rso-ethics@uow.edu.au

Yours sincerely

[Redacted]

Professor Kathleen Clapham
Chair, Social Sciences
Human Research Ethics Committee

cc: Professor Tony Okely, Professor Fred Paas, Professor Paul Chandler
Appendix B

Experimental Study 1 (Language – Chapter 3): Parents’ Information Sheet (Conditions 1-4)

Parents’ Information Sheet – Condition 1

Dear Parent/Carer,

Full details about the project, its purpose, the researchers involved and what is required of your child, should you agree for your child to be involved, are provided in this information sheet.

**What is the purpose of this study?**

This study, which is part of a PhD project, will investigate the effects of different types of physical activities on learning words in a foreign language in children aged 4-5 years.

Research suggests that physical activity can facilitate academic learning. However, little is known about how preschool children’s learning can benefit from integrating physical activities into the formal learning process. Given early childhood is an important period in the acquisition and learning of new skills, it is important to understand factors that enhance cognitive development.

This is the first known study to examine the specific effects of physical activities on learning Italian vocabulary in preschool children.

**What we are asking your child to do?**

The childcare service that your child attends has agreed to be involved in this study. Your child has the opportunity to participate in this study, because (s)he attends childcare at least three times per week for four weeks and is between four and five years of age.

This study will involve your child in several sessions to learn words from a foreign (Italian) language. Children will be involved in physical activities for about 7 minutes each day on three days. The sessions will involve several activities, such as walking, running, dancing, jumping, hopping, balancing, kicking, crawling, catching, and throwing. All activities are age-appropriate and will not cause harm to your child. A researcher from the University of Wollongong will teach your child the 21 words in total for about 7 minutes per day, three times per week, for four weeks, and afterwards will assess your child’s ability to memorize the words.
Whereas, the learning of Italian words will take place in groups, the assessments will be on an individual basis. Both in the learning and testing phase, the children will be facilitated in a fun and age appropriate, non-threatening manner.

All children will be wearing an accelerometer during the data collection to measure their physical activity. Finally, training and testing sessions will be videotaped to allow a more accurate assessment of what has occurred in each session,

**What are the benefits and risks involved in this study?**
This study will benefit your child’s childcare service by providing information about whether the positive effects of physical activity on learning can be applied to preschool children. The results from the study will be presented to the educators at your child’s service and they, along with interested parents/carers will have an opportunity to discuss the findings and ways in which current practices may be modified to improve physical activity and learning.

There are no risks associated with this study.

**Participation in the study**
Your child is free to discontinue participation at any time. Discontinuation of your child’s involvement will not jeopardise your or your child’s current or future relationship with the childcare centre and the University of Wollongong.

**What will happen to the information that you provide?**
All the results will be de-identified. Information collected during this study will be kept strictly confidential and be stored in a locked office. Data from cognitive tasks and physical activity measurements may be used in publications such as papers, conference presentations and grant applications, however your child’s identity will be kept strictly confidential.

**Who is conducting the study?**
- Professor Paul Chandler, Executive Director of Early Start, Pro Vice Chancellor, University of Wollongong
- Professor Tony Okely, Professorial Fellow, Early Start Research Institute, University of Wollongong
- Professor Fred Paas, Research Fellow, Early Start Research Institute, University of Wollongong, & Professor of Educational Psychology, Institute of Psychology, Erasmus University Rotterdam, The Netherlands
- MSc Myrto Mavilidi, PhD Student, Early Start Research Institute, University of Wollongong

We are asking you to consent to your child participating in this study by completing the attached consent form and returning it to the Director of your service on your child’s as soon as possible of attendance.

Kind Regards,
Myrto Mavilidi  
Telephone: (61 2) 4221 4951  

Early Start Research Institute  
Faculty of Education  
University of Wollongong  
mfm351@uowmail.edu.au  

If you have any questions regarding the study, please contact Myrto Mavilidi (mfm351@uowmail.edu.au). If you have any concerns or complaints regarding the way the research is or has been conducted, you can contact the Complaints Officer, Human Research Ethics Committee, University of Wollongong on (02) 4221 4457 or by email (rso-ethics@uow.edu.au).  

Your co-operation in this project will be greatly appreciated.
Dear Parent/Carer,

Full details about the project, its purpose, the researchers involved and what is required of your child, should you agree for your child to be involved, are provided in this information sheet.

**What is the purpose of this study?**

This study which is part of a PhD project will investigate the effects of different types of physical activities on learning words in a foreign language in children aged 4-5 years.

Research suggests that physical activity can facilitate academic learning. However, little is known about how preschool children’s learning can benefit from integrating physical activities into the formal learning process. Given early childhood is an important period in the acquisition and learning of new skills, it is important to understand factors that enhance cognitive development.

This is the first known study to examine the specific effects of physical activities on learning Italian vocabulary in preschool children.

**What we are asking your child to do?**

The childcare service that your child attends has agreed to be involved in this study. Your child has the opportunity to participate in this study, because (s)he attends childcare at least three times per week for four weeks and is between four and five years of age.

This study will involve your child in several sessions to learn words from a foreign (Italian) language. Children will be involved in physical activities for about 7 minutes each day on three days. The sessions will involve activities such as walking and running. All activities are age-appropriate and will not cause harm to your child. A researcher from the University of Wollongong will teach your child the 21 words in total for about 7 minutes per day, three times per week, for four weeks, and afterwards will assess your child’s ability to memorize the words.

Whereas, the learning of Italian words will take place in groups, the assessments will be on an individual basis. Both in the learning and testing phase, the children will be facilitated in a fun and age appropriate, non-threatening manner.

All children will be wearing an accelerometer during the data collection to measure their physical activity. Finally, training and testing sessions will be videotaped to allow a more accurate assessment of what has occurred in each session,
What are the benefits and risks involved in this study?
This study will benefit your child’s childcare service by providing information about whether the positive effects of physical activity on learning can be applied to preschool children. The results from the study will be presented to the educators at your child’s service and they, along with interested parents/carers will have an opportunity to discuss the findings and ways in which current practices may be modified to improve physical activity and learning.

There are no risks associated with this study.

Participation in the study
Your child is free to discontinue participation at any time. Discontinuation of your child’s involvement will not jeopardise your or your child’s current or future relationship with the childcare centre and the University of Wollongong.

What will happen to the information that you provide?
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This is the first known study to examine the specific effects of physical activities on learning Italian vocabulary in preschool children.

**What we are asking your child to do?**
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This study will involve your child in several sessions to learn words from a foreign (Italian) language. The sessions will involve several hand movements. All activities are age-appropriate and will not cause harm to your child. A researcher from the University of Wollongong will teach your child the 21 words in total for about 7 minutes per day, three times per week, for four weeks, and afterwards will assess your child’s ability to memorize the words.

Whereas, the learning of Italian words will take place in groups, the assessments will be on an individual basis. Both in the learning and testing phase, the children will be facilitated in a fun and age appropriate, non-threatening manner.
All children will be wearing an accelerometer during the data collection to measure their physical activity. Finally, training and testing sessions will be videotaped to allow a more accurate assessment of what has occurred in each session.

**What are the benefits and risks involved in this study?**

This study will benefit your child’s childcare service by providing information about whether the positive effects of physical activity on learning can be applied to preschool children. The results from the study will be presented to the educators at your child’s service and they, along with interested parents/carers will have an opportunity to discuss the findings and ways in which current practices may be modified to improve physical activity and learning.

There are no risks associated with this study.

**Participation in the study**

Your child is free to discontinue participation at any time. Discontinuation of your child’s involvement will not jeopardise your or your child’s current or future relationship with the childcare centre and the University of Wollongong.

**What will happen to the information that you provide?**

All the results will be de-identified. Information collected during this study will be kept strictly confidential and be stored in a locked office. Data from cognitive tasks and physical activity measurements may be used in publications such as papers, conference presentations and grant applications, however your child’s identity will be kept strictly confidential.

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This study will involve your child in several sessions to learn words from a foreign (Italian) language. A researcher from the University of Wollongong will teach your child the 21 words in total for about 14 minutes per day, three times per week, for four weeks, and afterwards will assess your child’s ability to memorize the words.

Whereas, the learning of Italian words will take place in groups, the assessments will be on an individual basis. Both in the learning and testing phase, the children will be facilitated in a fun and age appropriate, non-threatening manner.

All children will be wearing an accelerometer during the data collection to measure their physical activity. Finally, training and testing sessions will be videotaped to allow a more accurate assessment of what has occurred in each session,
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This study will benefit your child’s childcare service by providing information about whether the positive effects of physical activity on learning can be applied to preschool children. The results from the study will be presented to the educators at your child’s service and they, along with interested parents/carers will have an opportunity to discuss the findings and ways in which current practices may be modified to improve physical activity and learning.

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- Professor Fred Paas, Research Fellow, Early Start Research Institute, University of Wollongong, & Professor of Educational Psychology, Institute of Psychology, Erasmus University Rotterdam, The Netherlands
- MSc Myrto Mavilidi, PhD Student, Early Start Research Institute, University of Wollongong

We are asking you to consent to your child participating in this study by completing the attached consent form and returning it to the Director of your service on your child’s as soon as possible of attendance.

Kind Regards,

Myrto Mavilidi
Telephone: (61 2) 4221 4951
Early Start Research Institute
Faculty of Education
University of Wollongong
mfm351@uowmail.edu.au
If you have any questions regarding the study, please contact Myrto Mavilidi (mfm351@uowmai.edu.au). If you have any concerns or complaints regarding the way the research is or has been conducted, you can contact the Complaints Officer, Human Research Ethics Committee, University of Wollongong on (02) 4221 4457 or by email (rso-ethics@uow.edu.au).

Your co-operation in this project will be greatly appreciated.
Appendix C

Experimental Study 1 (Language – Chapter 3): Consent Form for Parents (Conditions 1-4)

Consent Form for Parents – condition 1

University of Wollongong

Effects of Physical Activities on Learning a Foreign Language in Preschool Children.

Consent form for parents/carers on behalf of their child (C1)

I have been given information about the PhD research study entitled: “Effects of physical activities on learning a foreign language in preschool children”.

I understand that if I consent for my child to participate (s)he will be asked to:

- Perform several activities such as walking, running, dancing, jumping, hopping, galloping, kicking, throwing, and catching during the program.
- Participate in this program as part of their daily routine at childcare.
- Learn vocabulary words in a foreign (Italian) language and assess their ability to recall these words.
- Wear an accelerometer during the learning sessions

Moreover, the learning and training sessions will be videotaped for study purposes and I will be asked to complete a survey to provide information about my child’s age and sleeping habits, and my own educational level and current employment.

I have been advised of the potential risks and burdens associated with this study. I understand that my child’s participation is voluntary, I have been invited to participate, and assured that my child is free to withdraw from the study at any time. Withdrawal from the study will not affect my relationship or that of my child’s, with our childcare service or with the University of Wollongong.
now or in the future. Furthermore, I understand that the information provided may be used in papers, conferences presentations or future grant applications.

If I have any enquiries about the study, I can contact Myrto Mavilidi (mfm351@uowmail.edu.au) or if I have any concerns or complaints regarding the way the research is or has been conducted, I can contact the Complaints Officer, Human Research Ethics Committee, University of Wollongong on +61 2 42214457. Or by email on (rso-ethics@uow.edu.au).

By signing below I am indicating my consent for my child to participate in this study as it has been described to me in the information sheet and in discussion with Myrto Mavilidi.
Can you please return this form on your child’s next day of attendance.

Your co-operation in this study will be greatly appreciated.

CONSENT

I (your name) ___________________________________
agree for my child (child’s full name) _________________
to take part in the study entitled
“Effects of physical activities on learning a foreign language in preschool children.”

Parent/Carer Surname:  ___________________________
Parent/Carer Given name:  ___________________________
Child’s Date of Birth: _____________________________(dd/mm/yyyy)
Sex of the Child: _____________________________(boy/girl)
Postcode:  _____________________________
Signature:  _____________________________
Date:  _____________________________
Name of Childcare Service: _____________________________.
Consent form for parents/carers on behalf of their child (C2)

I have been given information about the PhD research study entitled: “Effects of physical activities on learning a foreign language in preschool children”.

I understand that if I consent for my child to participate (s)he will be asked to:

- Perform several activities such as walking and running during the program.
- Participate in this program as part of their daily routine at childcare.
- Learn vocabulary words in a foreign (Italian) language and assess their ability to recall these words.
- Wear an accelerometer during the learning sessions

Moreover, the learning and training sessions will be videotaped for study purposes and I will be asked to complete a survey to provide information about my child’s age and sleeping habits, and my own educational level and current employment.

I have been advised of the potential risks and burdens associated with this study. I understand that my child’s participation is voluntary, I have been invited to participate, and assured that my child is free to withdraw from the study at any time. Withdrawal from the study will not affect my relationship or that of my child’s, with our childcare service or with the University of Wollongong now or in the future. Furthermore, I understand that the information provided may be used in papers, conferences presentations or future grant applications.
If I have any enquiries about the study, I can contact Myrto Mavilidi \( \text{mfm351@uowmail.edu.au} \) or if I have any concerns or complaints regarding the way the research is or has been conducted, I can contact the Complaints Officer, Human Research Ethics Committee, University of Wollongong on +61 2 42214457. Or by email on \( \text{rso-ethics@uow.edu.au} \).

By signing below I am indicating my consent for my child to participate in this study as it has been described to me in the information sheet and in discussion with Myrto Mavilidi. Can you please return this form on your child’s next day of attendance.

Your co-operation in this study will be greatly appreciated.

CONSENT

I (your name) __________________________

agree for my child (child’s full name) __________________________

to take part in the study entitled

“Effects of physical activities on learning a foreign language in preschool children.”

Parent/Carer Surname:  __________________________

Parent/Carer Given name:  __________________________

Child’s Date of Birth: __________________________ (dd/mm/yyyy)

Sex of the Child: __________________________ (boy/girl)

Postcode:  __________________________

Signature:  __________________________

Date:  __________________________

Name of Childcare Service: __________________________.
Effects of Physical Activities on Learning a Foreign Language in Preschool Children.

Consent form for parents/carers on behalf of their child (C3)

I have been given information about the PhD research study entitled: “Effects of physical activities on learning a foreign language in preschool children”.

I understand that if I consent for my child to participate (s)he will be asked to:

- Perform several hand movements during the program.
- Participate in this program as part of their daily routine at childcare.
- Learn vocabulary words in a foreign (Italian) language and assess their ability to recall these words.
- Wear an accelerometer during the learning sessions

Moreover, the learning and training sessions will be videotaped for study purposes and I will be asked to complete a survey to provide information about my child’s age and sleeping habits, and my own educational level and current employment.

I have been advised of the potential risks and burdens associated with this study. I understand that my child’s participation is voluntary, I have been invited to participate, and assured that my child is free to withdraw from the study at any time. Withdrawal from the study will not affect my relationship or that of my child's, with our childcare service or with the University of Wollongong now or in the future. Furthermore, I understand that the information provided may be used in papers, conferences presentations or future grant applications.

If I have any enquires about the study, I can contact Myrto Mavilidi (mfm351@uowmail.edu.au) or if I have any concerns or complaints regarding the way the research is or has been conducted, I
can contact the Complaints Officer, Human Research Ethics Committee, University of Wollongong on +61 2 42214457. Or by email on (rso-ethics@uow.edu.au).

By signing below I am indicating my consent for my child to participate in this study as it has been described to me in the information sheet and in discussion with Myrto Mavilidi. Can you please return this form on your child's next day of attendance.

Your co-operation in this study will be greatly appreciated.

CONSENT

I (your name) ____________________________
agree for my child (child’s full name) ____________________________
to take part in the study entitled
“Effects of physical activities on learning a foreign language in preschool children.”

Parent/Carer Surname:  ____________________________
Parent/Carer Given name:  ____________________________
Child’s Date of Birth: ____________________________(dd/mm/yyyy)
Sex of the Child: ____________________________ (boy/girl)
Postcode:  ____________________________
Signature:  ____________________________
Date:  ____________________________
Name of Childcare Service: ____________________________.
Effects of Physical Activities on Learning a Foreign Language in Preschool Children.

Consent form for parents/carers on behalf of their child (C4)

I have been given information about the PhD research study entitled: “Effects of physical activities on learning a foreign language in preschool children”.

I understand that if I consent for my child to participate (s)he will be asked to:

- Participate in this program as part of their daily routine at childcare.
- Learn vocabulary words in a foreign (Italian) language and assess their ability to recall these words.
- Wear an accelerometer during the learning sessions

Moreover, the learning and training sessions will be videotaped for study purposes and I will be asked to complete a survey to provide information about my child’s age and sleeping habits, and my own educational level and current employment.

I have been advised of the potential risks and burdens associated with this study. I understand that my child’s participation is voluntary, I have been invited to participate, and assured that my child is free to withdraw from the study at any time. Withdrawal from the study will not affect my relationship or that of my child’s, with our childcare service or with the University of Wollongong now or in the future. Furthermore, I understand that the information provided may be used in papers, conferences presentations or future grant applications.

If I have any enquires about the study, I can contact Myrto Mavilidi (mfm351@uowmail.edu.au) or if I have any concerns or complaints regarding the way the research is or has been conducted, I can contact the Complaints Officer, Human Research Ethics Committee, University of Wollongong on +61 2 42214457. Or by email on (rso-ethics@uow.edu.au).
By signing below I am indicating my consent for my child to participate in this study as it has been described to me in the information sheet and in discussion with Myrto Mavilidi. Can you please return this form on your child’s next day of attendance.

Your co-operation in this study will be greatly appreciated.

CONSENT

I (your name) ____________________________
agree for my child (child’s full name) ____________________________
to take part in the study entitled
“Effects of physical activities on learning a foreign language in preschool children.”

Parent/Carer Surname:  ____________________________
Parent/Carer Given name:  ____________________________
Child’s Date of Birth: ____________________________(dd/mm/yyyy)
Sex of the Child: ____________________________ (boy/girl)
Postcode:  ____________________________
Signature:  ____________________________
Date:  ____________________________
Name of Childcare Service: ____________________________
Appendix D

Experimental Study 1 (Language - Chapter 3): Parents’ Survey

Effects of Physical Activities on Learning a Foreign Language in Preschool Children

Survey for Parents

Dear parent, Thank you for participating in this study. Please answer the following questions.

1. Your full name (first name then surname):
   ____________________________________________

2. Your child’s full name. If you have more than one child over the age of 1 at childcare, please write the names of each of your children:
   ____________________________________________

3. Childs date of birth (DD/MM/YYYY): ___-___-___

4. Your date of birth (DD/MM/YYYY): ___-____-___

5. What is your sex? (please tick one) □ 1 Male □ 2 Female

6. Postcode of residence:__________

7. What is the main language you speak at home? (please tick one)
   □ 1 English
   □ 2 Other (please specify) _______________________

8. What is your **highest** level of schooling? (please tick one only)
   □ 1 No formal qualifications
   □ 2 Year 10 or equivalent (e.g. School Certificate)
   □ 3 Year 12 or equivalent (e.g. Higher School Certificate)
   □ 4 Trade/apprenticeship/certificate (e.g. hairdresser, chef, plumber)
   □ 5 Diploma (e.g. Business/Accounting)
   □ 6 University degree
   □ 7 Post-graduate qualification (e.g. Graduate Diploma, Masters, PhD)

9. Are you currently: *(Please tick one)*
   □ 1 Employed full time
   □ 2 Employed part time
   □ 3 Home-duties full time
☐ 4 A student  
☐ 5 Unemployed  
☐ 6 Other (please specify) _______________________

10. What is your current marital status?  
☐ 1 Single  ☐ 2 Married  ☐ 3 Divorced  
☐ 4 Separated  ☐ 5 Widowed

11. Do you or your partner have a Health Care Card or Pension Card (from Centrelink)? (Please tick one)  
☐ 1 Yes  ☐ 2 No

12. How many hours per night does your preschool child usually sleep at the moment? (Please write the number)  
_____________________hours

13. How many hours does your preschool child usually sleep/nap for during the day at the moment? (Please write the number. If your preschool child does not usually have a daytime nap, please write '0'.)  
_____________________hours

Thinking about the last month, which of the following indoor LEISURE activities does your preschool child USUALLY do during a typical WEEK? For this question, please think about the time your child is not at preschool or childcare.  
Please circle either ‘Yes’ or ‘No’ for each item.  
For items you have circled ‘Yes’, please write the TOTAL time your preschool child participates in the activity for the WHOLE working/school week (that is, Monday to Friday). Please also write the TOTAL time your preschool child participates in the activity for the WHOLE weekend (that is, Saturday & Sunday). If you circle ‘Yes’ for an activity and your child only participates in that activity during either the working/ school week or the weekend, please write '0' in the TOTAL hours column for the period they do not do that activity.  
Here is an example
During a typical WEEK what leisure activities does your preschool child usually do?

<table>
<thead>
<tr>
<th>Activity</th>
<th>Does your preschool child usually do this activity? (please circle ONE answer for each)</th>
<th>TOTAL hours/minutes Monday-Friday</th>
<th>TOTAL hours/minutes Saturday &amp; Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV/videos/DVDs</td>
<td>Yes₁, No₂</td>
<td>15hrs</td>
<td>6hrs 30mins</td>
</tr>
<tr>
<td>Playstation®, Nintendo®, X-Box®, Gameboy®, computer games</td>
<td>Yes₁, No₂</td>
<td>0</td>
<td>2hrs 0mins</td>
</tr>
</tbody>
</table>

During a typical WEEK what leisure activities does your preschool child usually do?

<table>
<thead>
<tr>
<th>Activity</th>
<th>Does your preschool child usually do this activity? (please circle ONE answer for each)</th>
<th>TOTAL hours/minutes Monday-Friday</th>
<th>TOTAL hours/minutes Saturday &amp; Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. TV/videos/DVDs</td>
<td>Yes₁, No₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Playstation®, Nintendo®, X-Box®, Gameboy®, computer games</td>
<td>Yes₁, No₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Wii®, Eye Toy</td>
<td>Yes₁, No₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Computer / internet (excluding games)</td>
<td>Yes₁, No₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. Quiet play (e.g. Lego®, books, train set, dolls, board games, craft)</td>
<td>Yes₁, No₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. Imaginary games (e.g. dress ups, imitating TV characters)</td>
<td>Yes₁, No₂</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thank you very much for taking the time to complete this survey – Please return when your child next attends childcare.
Appendix E

Experimental Study 1 (Language - Chapter 3): Testing Material for Cued-recall Test
Appendix F

Experimental Study 1 (Language - Chapter 3): Effects of Integrated Physical Exercises and Gestures on Preschool Children’s Foreign Language Vocabulary Learning. 
*Educational Psychology Review, 27, 413-436.*
Appendix G

Experimental Study 2 (Geography – Chapter 4): Human Ethics Approval

03 July 2015

Ms Myrto Mavlidil
School of Education
Faculty of Social Sciences

Dear Ms Mavlidil,

Thank you for your response dated 26 June 2015 to the HREC review of the application detailed below. I am pleased to advise that the application has been approved.

Ethics Number: HE15/196

Project Title: Integrating physical activities on learning geography in preschool children

Researchers: Ms Myrto Mavlidil, Professor Tony Okeley, Professor Fred Paas, Professor Paul Chandler

Documents Approved: Initial Ethics Application

- Response to Reviews 26/6/15
- Letter of Support from Big Fat Smile 26/6/15
- Information Sheet for Parents/Carers V3 20/6/15
- Response to Reviews 13/6/15
- Letter of Invitation for the Directors of the Childcare Centres received 13/6/15
- Information Sheet for Parents/Carers (C1-2) V1 27/4/15
- Information Sheet for Parents/Carers (C3) V1 27/4/15
- Consent form for parents/carers on behalf of their child (C1-2) V1 27/4/15
- Consent form for parents/carers on behalf of their child (C3) V1 27/4/15

Approval Date: 02 July 2015

Expiry Date: 01 July 2016
The University of Wollongong/Ilawarra Shoalhaven Local Health District Social Sciences HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research. The HREC has reviewed the research proposal for compliance with the National Statement and approval of this project is conditional upon your continuing compliance with this document.

Approval by the HREC is for a twelve month period. Further extension will be considered on receipt of a progress report prior to expiry date. Continuing approval requires:

- The submission of a progress report annually and on completion of your project. The progress report template is available at http://www.uow.edu.au/research/ethics/human/index.html. This report must be completed, signed by the researchers and the appropriate Head of Unit, and returned to the Research Services Office prior to the expiry date.
- Approval by the HREC of any proposed changes to the protocol including changes to investigators involved
- Immediate report of serious or unexpected adverse effects on participants
- Immediate report of unforeseen events that might affect continued ethical acceptability of the project.

If you have any queries regarding the HREC review process, please contact the Ethics Unit on phone 4221 3386 or email rso-ethics@uow.edu.au.

Yours sincerely

[Signature]

Associate Professor Melanie Randle
Chair, UOW Social Sciences
Human Research Ethics Committee
Appendix H

Experimental Study 2 (Geography – Chapter 4): Parents’ Information Sheet

University of Wollongong

Integrating physical activities on learning geography in preschool children

Information Sheet for Parents/Carers

Dear Parent/Carer,

Full details about the project, its purpose, the researchers involved and what is required of your child, should you agree for your child to be involved, are provided in this information sheet.

What is the purpose of this study?
This study, which is part of a PhD project, will investigate the effects of different types of physical activities on learning a geography task in children aged 4-5 years.

Research suggests that physical activity can facilitate academic learning. However, little is known about how preschool children’s learning can benefit from integrating physical activities into the formal learning process. Given early childhood is an important period in the acquisition and learning of new skills, it is important to understand factors that enhance cognitive development.

This is the first known study to examine the specific effects of physical activities on learning geography in preschool children.

What we are asking your child to do?
The childcare service that your child attends has agreed to be involved in this study. Your child has the opportunity to participate in this study, because (s)he attends childcare at least two times per week for one week and is between four and five years of age.

This study will involve your child in two sessions to learn a geography task. Children will either be involved in physical activities or will stay seated for about 15 minutes each day on two days. The sessions will involve several activities, such as walking, running, and jumping. Children will be randomly allocated to the physical activities or sitting sessions. All activities are age-appropriate and will not cause harm to your child. A researcher from the University of Wollongong will teach your child the geography task (the continents and characteristic animals living in each continent) for about 15 minutes per day, two times per week, for one week. The researchers will assess your child’s ability to memorize the continents and the characteristic animals (before and after the learning sessions).

The learning sessions and the assessments of the geography task will be on an individual basis. Both in the learning and testing phase, the children will be facilitated in a fun and age appropriate, non-threatening manner.

All children will be wearing an accelerometer during the data collection to measure their physical activity. The accelerometer is an instrument that will measure your child’s intensity of physical activity. It will be attached to a belt and be placed on the right hip.
What are the benefits and risks involved in this study?
This study will benefit your child’s childcare service by providing information about whether the positive effects of physical activity on learning can be applied to preschool children. The results from the study will be disseminated through presentations during staff meetings to the educators at your child’s service and they, along with interested parents/careers will have an opportunity to discuss the findings and ways in which current practices may be modified to improve physical activity and learning.
There are no risks associated with this study.

Participation in the study
Your child is free to discontinue participation at any time. Discontinuation of your child’s involvement will not jeopardise your or your child’s current or future relationship with the childcare centre and the University of Wollongong. You can indicate withdrawal from the study, either directly contacting the researcher or through your child’s educator.

What will happen to the information that you provide?
All the results will be de-identified. Information collected during this study will be kept strictly confidential and be stored in a locked office. Data from cognitive tasks and physical activity measurements may be used in publications such as papers, conference presentations and grant applications, however your child’s identity will be kept strictly confidential.

Who is conducting the study?
- Professor Paul Chandler, Executive Director of Early Start, Pro Vice Chancellor, University of Wollongong
- Professor Tony Okely, Professorial Fellow, Early Start Research Institute, University of Wollongong
- Professor Fred Paas, Research Fellow, Early Start Research Institute, University of Wollongong, & Professor of Educational Psychology, Institute of Psychology, Erasmus University Rotterdam, The Netherlands
- MSc Myrto Mavilidi, PhD Student, Early Start Research Institute, University of Wollongong

We are asking you to consent to your child participating in this study by completing the attached consent form and returning it to the Director of your service on your child’s as soon as possible of attendance.

Kind Regards,

Myrto Mavilidi
Telephone: (61 2) 4239 2278
Early Start Research Institute
Faculty of Education
University of Wollongong
mfm351@uowmail.edu.au

If you have any questions regarding the study, please contact Myrto Mavilidi (mfm351@uowmail.edu.au) or if you any concerns or complaints regarding the way the research is or has been conducted, you can contact the Ethics Unit, Research Services Office University of Wollongong NSW 2522 Australia Telephone (02) 4221 3386 Facsimile (02) 4221 4338 Email: reso-ethics@uow.edu.au Web: www.uow.edu.au.

Your co-operation in this project will be greatly appreciated.
Appendix I

Experimental Study 2 (Geography – Chapter 4): Consent Form for Parents

---

University of Wollongong

Integrating physical activities on learning geography in preschool children

Consent form for parents/carers on behalf of their child

I have been given information about the PhD research study entitled: “Integrating physical activities on learning geography in preschool children”.

I understand that if I consent for my child to participate (s)he will be asked to:

- Perform several activities such as walking, running, and jumping during the program
- Participate in this program as part of their daily routine at childcare
- Learn a geography task (the continents and characteristic animals living in each continent) and assess their ability to recall this information (before and after the learning sessions)
- Wear an accelerometer during the learning sessions

I have been advised of the potential risks and burdens associated with this study. I understand that my child’s participation is voluntary, I have been invited to participate, and assured that my child is free to withdraw from the study at any time. Withdrawal from the study will not affect my relationship or that of my child’s, with our childcare service or with the University of Wollongong now or in the future. Furthermore, I understand that the information provided may be used in papers, conferences presentations or future grant applications.

If I have any enquiries about the study, I can contact Myrto Mavilidi (mfm351@uowmail.edu.au) or if I have any concerns or complaints regarding the way the research is or has been conducted, I can contact the Complaints Officer, Human Research Ethics Committee, University of Wollongong on +61 2 42214457. Or by email on (hro-ethics@uow.edu.au).

By signing below I am indicating my consent for my child to participate in this study as it has been described to me in the information sheet and in discussion with Myrto Mavilidi. Can you please return this form at your earliest convenience.

Your co-operation in this study will be greatly appreciated.
CONSENT

I (your name) ____________________________
agree for my child (child's full name) ____________________________
to take part in the study entitled
"Integrating physical activities on learning geography in preschool children."
Parent/Carer Surname: ____________________________
Parent/Carer Given name: ____________________________
Child's Date of Birth: ____________________________ (mm/yyyy)
Sex of the Child: ____________________________ (boy/girl)
Postcode: ____________________________
Signature: ____________________________
Date: ____________________________
Name of Childcare Service: ____________________________.
Appendix J

Experimental Study 2 (Geography – Chapter 4): Testing Material

 PARTICIPANT’S TESTING SHEET

Name:
Childcare centre:
Accelerometer ID:

<table>
<thead>
<tr>
<th>Date (L 1):</th>
<th>Date (L 2):</th>
<th>Date (L 3):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Starting time:
Finish Time:

Pre-test

<table>
<thead>
<tr>
<th>Continents</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>0 1</td>
</tr>
<tr>
<td>Asia</td>
<td>0 1</td>
</tr>
<tr>
<td>Africa</td>
<td>0 1</td>
</tr>
<tr>
<td>America</td>
<td>0 1</td>
</tr>
<tr>
<td>Oceania</td>
<td>0 1</td>
</tr>
<tr>
<td>Antarctica</td>
<td>0 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Continent</th>
<th>Animal</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>Fox</td>
<td>0 1</td>
</tr>
<tr>
<td>Asia</td>
<td>Panda bear</td>
<td>0 1</td>
</tr>
<tr>
<td>Africa</td>
<td>Giraffe</td>
<td>0 1</td>
</tr>
<tr>
<td>America</td>
<td>Bear</td>
<td>0 1</td>
</tr>
<tr>
<td>Oceania/Australia</td>
<td>Kangaroo</td>
<td>0 1</td>
</tr>
<tr>
<td>Antarctica</td>
<td>Penguin</td>
<td>0 1</td>
</tr>
</tbody>
</table>

Post-test

Name the continents

<table>
<thead>
<tr>
<th>Continents</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>0 1</td>
</tr>
<tr>
<td>Asia</td>
<td>0 1</td>
</tr>
<tr>
<td>Africa</td>
<td>0 1</td>
</tr>
<tr>
<td>America</td>
<td>0 1</td>
</tr>
<tr>
<td>Oceania</td>
<td>0 1</td>
</tr>
<tr>
<td>Antarctica</td>
<td>0 1</td>
</tr>
</tbody>
</table>

Place the animals on the map

<table>
<thead>
<tr>
<th>Animal</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fox</td>
<td>0 1</td>
</tr>
<tr>
<td>Panda bear</td>
<td>0 1</td>
</tr>
<tr>
<td>Giraffe</td>
<td>0 1</td>
</tr>
<tr>
<td>Bear</td>
<td>0 1</td>
</tr>
<tr>
<td>Kangaroo</td>
<td>0 1</td>
</tr>
<tr>
<td>Penguin</td>
<td>0 1</td>
</tr>
</tbody>
</table>

Match animals with continents

<table>
<thead>
<tr>
<th>Continents - Animal</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe - fox</td>
<td>0 1</td>
</tr>
<tr>
<td>Asia - panda</td>
<td>0 1</td>
</tr>
<tr>
<td>Africa - giraffe</td>
<td>0 1</td>
</tr>
<tr>
<td>America - bear</td>
<td>0 1</td>
</tr>
<tr>
<td>Oceania – kangaroo</td>
<td>0 1</td>
</tr>
<tr>
<td>Antarctica - penguin</td>
<td>0 1</td>
</tr>
</tbody>
</table>
Walk on the map

<table>
<thead>
<tr>
<th>Question</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk from the continent of the fox, to the continent of the bear</td>
<td>0 1</td>
</tr>
<tr>
<td>Walk from the continent of the bear, to the continent of the giraffe</td>
<td>0 1</td>
</tr>
<tr>
<td>Walk from the continent of the giraffe, to the continent of the kangaroo</td>
<td>0 1</td>
</tr>
<tr>
<td>Walk from Africa to America</td>
<td>0 1</td>
</tr>
<tr>
<td>Walk from America to Antarctica</td>
<td>0 1</td>
</tr>
<tr>
<td>Walk from Antarctica to Asia</td>
<td>0 1</td>
</tr>
</tbody>
</table>

Evaluation

Did you like this game?

Would you like to play this game again in the future?
Appendix K

Appendix L

Experimental Study 3 (Maths – Chapter 4): Human Ethics Approval

14 September 2015

Ms Myrto Mavilidi
Faculty of Social Sciences
University of Wollongong

Dear Ms Mavilidi

Thank you for your response dated 7 September 2015 to the HREC review of the application detailed below. I am pleased to advise that the application has been approved.

Ethics Number: HE14/287

Project Title: Integrating physical activities in the teaching of maths in preschool children

Researchers: Ms Myrto Mavilidi, Professor Anthony Okely, Professor Fred Paas, Professor Paul Chandler

Documents reviewed/approved:
- Initial application
- Math test, Pre-test – Post-test
- Participant Information Sheet for Parents/Carers, V2, 05/08/2015
- Consent form for parents/carers on behalf of their child, V2, 05/08/2015
- Letter of support from Kim Bertino, KU, 28/07/2015

Approval Date: 11 September 2015

Expiry Date: 10 September 2016

The University of Wollongong/Illawarra Shoalhaven Local Health District Social Sciences HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research. The HREC has reviewed the research proposal for compliance with the National Statement and approval of this project is conditional upon your continuing compliance with this document.

Approval by the HREC is for a twelve month period. Further extension will be considered on receipt of a progress report prior to expiry date. Continuing approval requires:

- The submission of a progress report annually and on completion of your project. The progress report template is available at http://www.uow.edu.au/research/ethics/human/index.html. This report must be completed, signed by the researchers and the appropriate Head of Unit, and returned to the Research Services Office prior to the expiry date.
- Approval by the HREC of any proposed changes to the protocol including changes to investigators involved
- Immediate report of serious or unexpected adverse effects on participants
- Immediate report of unforeseen events that might affect continued ethical acceptability of the project.
If you have any queries regarding the HREC review process, please contact the Ethics Unit on phone 4221 3386 or email rso-ethics@uow.edu.au.

Yours sincerely

[Name redacted]

Associate Professor Melanie Randle
Chair, UOW Social Sciences Human Research Ethics Committee
Appendix M

Experimental Study 3 (Maths – Chapter 4): Parents’ Information Sheet

Dear Parent/Carer,

Full details about the project, its purpose, the researchers involved and what is required of your child, should you agree for your child to be involved, are provided in this information sheet.

What is the purpose of this study?
This study, which is part of a PhD project, will investigate the effects of different types of physical activities on learning maths in children aged 3-5 years.

Research suggests that physical activity can facilitate academic learning. However, little is known about how preschool children’s learning can benefit from integrating physical activities into the formal learning process. Given early childhood is an important period in the acquisition and learning of new skills, it is important to understand factors that enhance cognitive development.

This is the first known study to examine the specific effects of physical activities on learning maths in preschool children.

What we are asking your child to do?
The childcare service that your child attends has agreed to be involved in this study. Your child has the opportunity to participate in this study, because (s)he attends childcare at least once per week and is between four and five years of age. The participation in this study is voluntary.

This study will involve your child in one learning session per week, for 4 weeks learning about addition and subtraction. Children will either be involved in physical activities or will stay seated for about 15 minutes each day on two days. All Children at your child’s centre will be randomly allocated to one out of three groups: two physical activities or one sitting group. In all groups children will be taught exactly the same. In the physical activity groups, children will be involved in several activities, such as walking, running, and jumping. All activities are age-appropriate and will not cause harm to your child. A researcher from the University of Wollongong will teach your child the numbers and simple addition problems for about 15 minutes per day, once per week, for four weeks. The researchers will assess your child’s ability to make simple addition and subtraction problems (before and after the learning sessions).

The learning sessions will be in groups and the assessments of the math task will be on an individual basis. Both in the learning and testing phase, the children will be facilitated in a fun and age appropriate, non-threatening manner.

All children will be wearing an accelerometer during each learning session to measure their physical activity. The accelerometer is an instrument that will measure your child’s intensity of physical activity. It will be attached to a belt and be placed on the right hip.
What are the benefits and risks involved in this study?
This study will benefit your child’s childcare service by providing information about whether the positive effects of physical activity on learning can be applied to preschool children. The results from the study will be disseminated through presentations during staff meetings to the educators at your child’s service and they, along with interested parents/carers will have an opportunity to discuss the findings and ways in which current practices may be modified to improve physical activity and learning.
There are no risks associated with this study.

Participation in the study
Your child is free to discontinue participation at any time. Discontinuation of your child’s involvement will not jeopardise your or your child’s current or future relationship with the childcare centre and the University of Wollongong. You can indicate withdrawal from the study at any moment, either directly contacting the researcher or though your child’s educator. Children who are not willing to participate will not be included in the study and will follow their usual daily routine.

What will happen to the information that you provide?
All the results will be de-identified. Information collected during this study will be kept strictly confidential and be stored in a locked office at the University of Wollongong. Data from cognitive tasks and physical activity measurements may be used in publications such as papers, conference presentations and grant applications, however your child’s identity will be kept strictly confidential.

Who is conducting the study?
- Professor Paul Chandler, Executive Director of Early Start, Pro Vice Chancellor, University of Wollongong
- Professor Tony Okely, Professorial Fellow, Early Start Research Institute, University of Wollongong
- Professor Fred Paas, Research Fellow, Early Start Research Institute, University of Wollongong, & Professor of Educational Psychology, Institute of Psychology, Erasmus University Rotterdam, The Netherlands
- Ms Myrto Mavilidi, MSc, PhD Candidate, Early Start Research Institute, University of Wollongong

We are asking you to consent to your child participating in this study by completing the attached consent form and returning it to the Director of your service on your child’s as soon as possible of attendance.

Kind Regards,

Myrto Mavilidi
Telephone: (61 2) 4239 2278

Early Start Research Institute
Faculty of Education
University of Wollongong
mfm351@uowmail.edu.au

If you have any questions regarding the study, please contact Myrto Mavilidi (mfm351@uowmail.edu.au). If you have any concerns or complaints regarding the way the research is or has been conducted, you can contact the Ethics Unit, Research Services Office University of Wollongong NSW 2522 Australia Telephone (02) 4221 3386 Facsimile (02) 4221 4338 Email: rs-o-ethics@uow.edu.au Web: www.uow.edu.au.

Your co-operation in this project will be greatly appreciated.
Appendix N

Experimental Study 3 (Maths – Chapter 4): Consent Form for Parents

Integrating physical activities on learning maths in preschool children

Consent form for parents/carers on behalf of their child
I have been given information about the PhD research study entitled: “Integrating physical activities on learning maths in preschool children”.

I understand that if I consent for my child to participate (s)he may be asked to:

- Perform several activities such as walking, running, and jumping during the program
- Participate in this program as part of their daily routine at childcare
- Learn a maths task and assess their ability to execute simple math calculations (before and after the learning sessions)
- Wear an accelerometer during the learning sessions

I have been advised of the potential risks and burdens associated with this study. I understand that my child’s participation is voluntary, I have been invited to participate, and assured that my child is free to withdraw from the study at any time. Withdrawal from the study will not affect my relationship or that of my child's, with our childcare service or with the University of Wollongong now or in the future. Furthermore, I understand that the information provided may be used in papers, conferences presentations or future grant applications.

If I have any enquires about the study, I can contact Myrto Mavilidi (mfm351@uowmail.edu.au) or if I have any concerns or complaints regarding the way the research is or has been conducted, I can contact the Complaints Officer, Human Research Ethics Committee, University of Wollongong on +61 2 42214457. Or by email on (rso-ethics@uow.edu.au).
By signing below I am indicating my consent for my child to participate in this study as it has been described to me in the information sheet and in discussion with Myrto Mavilidi. Can you please return this form at your earliest convenience.

Your co-operation in this study will be greatly appreciated.

CONSENT

I (your name) ____________________________
agree for my child (child's full name) ____________________________
to take part in the study entitled

"Integrating physical activities on learning maths in preschool children."

Parent/Carer Surname: ____________________________
Parent/Carer Given name: ____________________________
Child's Month and Year of Birth: ____________________________ (mm/yyyy)
Sex of the Child: ____________________________ (boy/girl)
Postcode: ____________________________
Signature: ____________________________
Date: ____________________________
Name of Childcare Service: ____________________________
Appendix O

Experimental Study 3 (Maths – Chapter 4): Testing Material

Participant Testing Sheet

Name:  
Childcare centre:  
Condition:  
Accelerometer no:  
Dates of teaching:  
Starting & Finishing time:  

Dates of testing:  
Pre-test – immediate test – delayed test

Assessments

Start time  
Stop time  
**Counting** / 40

1 – 20: 
20 – 1:

Start time  
Stop time  
**Number line estimation** 
(Placing the numbers 2, 5, 9, 10, 14, 16, 19 in the number line 1-20) / 7

Start time  
Stop time  
**Correspondence with numbers-blocks** / 2

Start time  
Stop time  
**Numerical Magnitude Comparison** / 6

4 vs. 7
5 vs. 8
12 vs. 17

4 vs. 9
13 vs. 18
2 vs. 6
Evaluation

Did you like this game?

Would you like to play this game again in the future?
Appendix P

Experimental Study 3 (Maths – Chapter 5): Immediate and delayed effects of integrating physical activity into preschool children’s learning of numeracy skills. *Journal of Experimental Child Psychology, 166, 502-519.*
Introduction

The power of human movements during the first stages of young children's learning was addressed early by the developmental theories of Piaget (1968; concept of reflective abstraction) and Vygotsky (1967; make-believe play and imagination). Researchers within the field of educational psychology have been showing increased research interest in examining effects of gestures or subtle motor movements on learning. In addition, recent research attests to the physiological, cognitive, and academic benefits of physical activity in childhood learning activities (Sibley & Etnier, 2003; Tomporowski, Davis, Miller, & Naglieri, 2008). However, this research mostly targeted primary school children (e.g., math: Mahar, 2011; Ruitter, Loyens, & Paas, 2015). Only a few studies have been conducted during early childhood in different domains such as language (Mavili, Okely, Chandler, Cliff, & Paas, 2015), geography (Mavili, Okely, Chandler, & Paas, 2016), and science (Donnelly & Lambourne, 2011; Mavili, Okely, Chandler, & Paas, 2017). This study investigated the effects of integrated physical and cognitive activities on preschool children's learning of numeracy skills.

The theoretical frameworks of embodied and grounded cognition lay the foundation for research into the relation between the human motor system and cognition. These approaches assume that perception and action are closely intertwined (Barsalou, 2003). According to Wilson (2002), people learn from the interaction between their body and the physical environment. It is argued that cognitive processes are grounded in action and perception, whereas mental representations are grounded in different modalities (i.e., perceptual, motor, verbal, visual, auditory; Barsalou, 2008). Body, language, and the external resources from the environment can contribute to the construction of conceptual maps and foster the transition from perceptual facts to symbolic representations (Vitale, Swart, & Black, 2014). In conjunction with the theoretical framework of embodied cognition, the evolutionary perspective of cognitive load theory recognizes the significant role of the human motor system in working memory capacity during complex learning (Paas & Sweller, 2012). According to this perspective, humans have evolved to effortlessly acquire biologically primary knowledge such as human movement and speaking one's native language. This means that this type of knowledge does not impose a load on working memory and can be acquired automatically without formal instruction. In contrast, we have not evolved to effortlessly acquire biologically secondary knowledge such as reading and mathematics. Based on these ideas, Paas and Sweller (2012) argued that human movement as a form of primary biological knowledge can be used to assist the learning of mathematics as a form of biologically secondary knowledge. In line with these ideas, research has shown that connecting action and perception during instruction can be a way to promote memory consolidation, retrieval, and long-lasting learning (Barsalou, Simmons, Barbey, & Wilson, 2003; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; Madan & Singhal, 2012; Paas & Sweller, 2012; Ping & Goldin-Meadow, 2010).

There is growing evidence that some aspects of mathematical knowledge can be enhanced from the interactions with the physical, social, cultural, and semiotic worlds (Alibali & Nathan, 2012). Linking abstract mathematical knowledge with sensorimotor metaphors, stemming from the human body and its imaginary motion (i.e., grounding actions), can help in transforming it into tangible events or situations with which young children are familiar. For example, numbers placed in a number line can be seen as an ordered path of magnitudes that one can move along (see, e.g., Núñez & Marghetis, 2015). The studies of Fischer, Moeller, Bientzle, Cress, and Nuerk (2011) and Link, Moeller, Huber, Fischer, and Nuerk (2013) found improvements in young children's counting principles from 0 to 10 (p < .05, ES = .88, with no effects for the 0–20 scale) and spatial numerical representation (p < .02, ES = .89, with no effects for single-digit and two-digit sums, nonsymbolic number comparison, and place value understanding) after walking on a number line. In the first study, kindergarten children either made steps to the left for smaller numbers and to the right for larger ones while walking on a dance mat or performed the same numerical task without the movements on a tablet PC. In the second study, first-grade children either performed task-specific full-body movements while walking on a number line or received number line training without the body experiences. Finally, Ruitter et al. (2015) examined first-grade children's learning of two-digit numbers by making steps on a ruler mounted across the floor either while watching their movements in a mirror (or not) or in a control condition without movements. In the movement conditions, children made small, medium, and large
steps representing different number units of 1, 5, and 10, respectively. Results showed that learning the process of number building was better in the conditions with movements, but observing one's own movements in the mirror did not have an additional benefit.

Applying the idea of embodied learning to geometry, forming geometrical shapes through body movements can help second and third graders to better understand geometrical concepts such as learning about the angles compared with conventional methods (Shoval, 2011). Similarly, Smith, King, and Hoyle (2014) found that students' understanding of angle and angle measurement was facilitated when the task combined both body-based and abstract visual representations of the angles.

In addition, Hu, Ginns, and Bobis (2014, 2015) showed that 9- to 12-year-old students who had traced information shown in geometry worked-out examples with their index finger achieved higher learning outcomes than children who only studied the worked examples. Lastly, Agostinho et al. (2015) found that third- and fourth-grade students who traced temperature line graphs on an iPad with their index finger during the learning phase performed better on transfer test tasks than students who only looked at the same information.

Nevertheless, the study of Ruijer et al. (2015) found no additional effects of observing movements on mathematics learning. These findings reflect an existing ambiguity in the literature regarding the role of observing others' movements in perception and learning. Learning by observing others has been explained by the existence of the "mirror neuron system," a neural system in the motor cortex area of the brain, which is automatically activated when observing others' actions and, consequently, can support mental simulation and imitation of these actions (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Rizzolatti & Craighero, 2004). Van Gog, Paas, Marcus, Ayres, and Sweller (2009; see also Paas & Sweller, 2012) suggested that this mirroring capacity of the human brain can be exploited during the learning of cognitive tasks involving a motor component. Cook, Duffy, and Fenn's (2013) study argued toward this notion. The authors found that second- to fourth-grade students learned better to solve mathematical equations (i.e., equivalence problems) and maintained this knowledge longer when they observed the instructor's gestures while verbally explaining to them the process of how to solve the problems compared with training consisting of verbal explanation only. The study of Cook and Goldin-Meadow (2006) also looked at the effects of observing others' movements on learning. When students observed instructors' gestures during training, they were able to reproduce their own gestures similar to the observed gestures. The produced gestures entailed information about the underlying problem-solving strategy required for the specific mathematical tasks (Cook & Goldin-Meadow, 2006).

Moving toward a different area of research, substantial empirical work has shown that purposeful engagement of the motor system in the form of physical activity during instruction (e.g., mathematics) enhances cognition and learning. In general, physical activity can be defined as "any bodily movement produced by the contraction of skeletal muscle that can increase energy expenditure above a certain level." (Centers for Disease Control and Prevention, n.d.). It has been associated with positive health outcomes (e.g., reduction and prevention of obesity, diabetes, cardiovascular diseases, cancer, conditions of stress, anxiety, and depression; Hills, King, & Armstrong, 2007; Must & Tybor, 2005; Warburton, Nicol, & Bredin, 2006). Importantly, physical activity (e.g., aerobics, martial arts, yoga) and fitness have been found to improve the physical condition, along with brain activity, executive function skills, and cognitive performance, in children (Buck, Hillman, & Castelli, 2008; Chaddock et al., 2010; Diamond & Lee, 2011; Hillman, Buck, Themanson, Pontefex, & Castelli, 2009). Importantly, core executive functions such as attention, shifting, inhibitory control, working memory, and self-regulation, used in cognitive processes such as problem solving, reasoning, and planning, are fundamental for the emergent mathematical ability in children (Blair & Razza, 2007; Bull, Espy, & Wiebe, 2008; Bull & Scerif, 2001; Espy et al., 2004).

Studies attempting to induce physical activity during learning have reported positive effects, as well as no adverse effects, on primary school children's academic achievement (i.e., math). For instance, Mahar et al. (2006) and Mahar (2011) showed better learning about space orientation for fourth-grade students, who had lined up around the perimeter of the room and moved over, under, around, or through different objects each time or moved steps forward to represent inches, feet, or yards, than students in a conventional control group without movements (p < .017; ES = .49). Donnelly and Lambourne (2011) completed a randomized controlled trial in 24 elementary schools examining the effects of integrating physical activities on academic achievement in reading, math,
spelling, science, history, geography, language, and the arts. Of the 24 schools, 10 followed traditional sedentary classes and 14 included classroom-based physical activity. The classroom-based physical activities in math, for example, included running, hopping, and skipping while counting laps, forming different shapes, or learning about fractions. Results revealed significant improvements in academic scores, especially in math. However, after 3 years, the group differences in academic achievement observed at the baseline were not significant anymore (Donnelly et al., 2017). Finally, Mullender-Wijnsma et al. (2016) compared second- and third-grade students’ performance between physically active academic lessons (20–30 min of physical activity, three times per week, for 22 weeks) and usual classroom activities without physical activity. After 2 years, children in the active lessons group showed higher learning gains on mathematics ($p < .001, ES = .42$), mathematics speed test ($p < .001, ES = .42$), and spelling ($p < .001, ES = .45$), than children in the control group. However, no significant gains were found for the reading test.

The current study

Synthesizing the theoretical and empirical work on embodied cognition, the evolutionary account of cognitive load theory, and the mirror–neuron system, this study investigated the effects of performing or observing movements on young children’s mathematics learning. The study focused on a new instructional approach for active learning in which task-relevant physical activity is meaningfully integrated during mathematics instruction.

Preschool children were selected as an age group in which research in this domain has been relatively scarce. Children’s numeracy skills were compared across four conditions involving task-relevant physical activity (performing integrated physical activity condition), observing movements from integrated condition (observing integrated physical activity condition), task nonrelevent physical activity (performing nonintegrated physical activity condition), and the conventional way of learning (control condition).

We hypothesized that children in the integrated condition would show the highest learning performance on the cognitive tests compared with the other conditions (Hypothesis 1). Because of the “mirror neuron system” theory, we expected that children in the observing integrated physical activity condition would score higher than children in the control condition (Hypothesis 2). In addition, we expected that children in the performing nonintegrated physical activity condition would perform better in the learning tasks than children in the control condition (Hypothesis 3). Children’s interest regarding the instructional method they were assigned was also examined. It was hypothesized that children in the instructional conditions with physical activity (performing integrated and nonintegrated physical activity conditions) would give higher interest ratings than children in the conventional conditions without physical activity (observing integrated physical activity and control conditions; Hypothesis 4). In terms of physical activity, it was expected that the intensity levels of physical activity would be higher for the two active conditions (performing integrated and nonintegrated physical activity conditions) than the sedentary conditions (observing integrated physical activity and control conditions; Hypothesis 5). If the active conditions are exposed to the same duration and intensity of physical activity, any observed learning effect would then be attributable to the relevance of the movements with the learning task. Similarly, if the sedentary conditions produce similar levels of physical activity, improvements in learning would arise from the observation of peers’ movement during learning. Finally, children’s completion time of each assessment (pretest, immediate posttest, and delayed test) was measured. It was expected that children in the performing integrated physical activity condition would complete the tests faster because they would have been engaged in deeper processing and better understanding of the mathematical concepts during the learning phase (Hypothesis 6).

Method

Participants

Participants were 120 preschool children ($M_{age} = 4.70$ years, $SD = 0.49$; 57 girls) recruited from nine child-care centers. These centers were randomly assigned to the experimental conditions, which
resulted in four centers in the performing integrated physical activity and observing integrated physical activity conditions, two in the performing nonintegrated condition, and three in the control condition. A further randomization was performed to assign children to the performing and observing integrated physical activity conditions, which occurred simultaneously at the same preschool centers. The study was approved by the human research ethics committee of the University of Wollongong (HE15/287). Parents completed a written consent form for their children's participation in the research. Five participants were excluded from the analysis due to missing data, resulting in 30 children enrolled in the performing integrated physical activity condition, 29 in the observing integrated physical activity condition, 29 in the performing nonintegrated physical activity condition, and 27 in the control condition. Children received stickers as a reward for their participation in the activities.

Procedure

The lead author visited the child-care centers and was the instructor of the learning sessions throughout the intervention for all conditions to ensure the consistency of the teaching materials. Foam blocks of numbers from 1 to 20 were placed on the floor, shaping a straight line (see Fig. 1). Children performed the cognitive tasks to learn about the numeric symbols (i.e., Arabic digits) and to improve their counting skills from 1 to 20.

The intervention consisted of the cognitive tasks, which were the same for all conditions, and the physical activity tasks, which differed across the conditions. The assessments took place at three time points.

Cognitive tasks

In each learning session, children performed two counting skill tasks; first they counted from 1 to 20 (Task 1), and then they counted backward from 20 to 1 (Task 2). Next, children pointed to written numerals (shown in the foam blocks) in response to the teacher calling out number words (Task 3:

![Image](image_url)

Fig. 1. Child performing physical activities on the number line.
ranging from 1 to 10; Task 4: ranging from 10 to 20; Task 5: ranging from 1 to 20). The learning sessions included different numbers each time, the order of which was counterbalanced across the weeks.

Physical activity tasks

Children were assigned to one of the four conditions. In the performing integrated physical activity condition, children performed physical activity related to the learning task. They ran, jumped, and stepped each time on one number while counting (Task 1) or walked backward (Task 2). For the third task, children ran on the right side when numbers were increasing (e.g., from 2 to 8) and ran on the left side when numbers were decreasing (e.g., from 10 to 5). For the last two tasks, children ran forward when numbers were increasing and ran backward when numbers were decreasing. More specifically, children counted a number on each step when they moved forward (1–20) and backward (20–1). In the observing integrated physical activity condition, children observed their peers’ movements in the performing integrated physical activity condition. They remained seated, counted, and looked at the numbers (Tasks 1–5) on the number line. In the performing nonintegrated physical activity condition, children performed physical activity unrelated to the learning task. They performed the cognitive tasks (Tasks 1–5), separating them with running laps around in the room for 1 min. In the control condition, no physical activity was involved. Children remained seated, counted, and looked at the numbers (Tasks 1–5) on the number line. Children’s intensity levels of physical activity during the learning sessions were recorded to control for children’s physical activity levels across the conditions. The learning sessions occurred once per week and lasted 15 min per day for 4 weeks (adding to 1 h in total). The learning activities were conducted in small groups (maximum of 10 children). All children in each group participated in the activities concurrently. For example, children in the performing and observing integrated physical activity conditions were counting the numbers from 1 to 20 at the same time.

Assessments

The assessments took place individually directly before (pretest) and after the intervention (immediate posttest) and 5 weeks after the intervention (delayed posttest). The material used was the same across the three points of measurement. Children’s completion time of each assessment was recorded. Finally, at the end of the posttest assessments, children were asked to rate their interest in the instructional method to which they were assigned.

Materials

Math outcome measures

The assessments, adapted from Ramani and Siegler (2008), consisted of a pretest, an immediate posttest, and a delayed posttest. The pretest determined children’s prior knowledge, whereas the immediate posttest and delayed posttest revealed the intervention effect on children’s understanding and performance of numbers. More specifically, cognitive tests consisted of the following:

Counting: Children counted from 1 to 20 and from 20 to 1. The correct answer was given up to the point of the first error. For example, if a child counted “1, 2, 3, 5,” he or she received 3 points.

Number line estimation: Children needed to locate the numbers 2, 5, 9, 10, 14, 16, and 19 on the number line where only the number 1 was placed at the beginning and the number 20 was placed at the end. The rest of the numbers were missing.

Block counting: Children needed to count a pile of blocks consisting of 5 and 6 blocks, respectively.

Numerical magnitude comparison: Children needed to choose which number was bigger between sets of two digits (4 vs. 9, 5 vs. 8, 19 vs. 17, 6 vs. 9, 13 vs. 18, 4 vs. 7, and 9 vs. 6).

Numerical identification: Children were shown three different numbers at a time, and they needed to choose the correct number matching to the verbal instructions. This process was repeated three times for the numbers 14, 7, and 8, respectively. Finally, children were shown three numbers (in the order of 9, 11, and 16) and were asked to recognize and read aloud the numbers shown.
The total score of the correct answers that children could get was 61, receiving 1 point for each correct answer. A reliability coefficient (Cronbach’s alpha) of .89 was found for the testing materials.

**Instruction evaluation**

At the end of the immediate posttest and delayed posttest, children evaluated the instructional method in which they were enrolled by indicating their preference on a 5-point Likert scale with semantic anchors (expressed as smiley faces) ranging from 1 (“I didn’t like it at all”) to 5 (“I liked it a lot”) and from 1 (“Not at all”) to 5 (“I would love to”). Specifically, children were asked how much they liked the type of instruction (“Did you like this game?”) and whether they would like to be taught this way in the future (“Would you like to play it again in the future?”). This scale was adapted from the studies of Mavilić, Okely, Chandler, and Paas (2016, 2017). A coefficient alpha of .75 was obtained for these questions in this study.

**Physical activity measure.** During the learning sessions, children’s physical activity was measured using an ActiGraph accelerometer (model GT1M, Pensacola, FL) worn around the waist on an elastic belt with the accelerometer positioned over the anterior aspect of the right hip. Accelerometers are instruments designed to measure time-specific acceleration used for physical activity assessments. ActiGraphs have established utility, validity, and reliability in children aged 3–5 years (Cliff, Reilly, & Okely, 2009). Parents were informed via participant information sheets that children would wear accelerometers during the learning sessions. An accelerometer was placed on each child by the researcher at the beginning of the learning session and was removed at the end. Accelerometer data were processed using ActiLife version 6.12.1 software and were recorded for the scheduled 10-min time period. Only activity during lesson times was recorded. The epoch length was set at 1-s intervals, a time that is recommended for use in preschool children, and age-appropriate cut-points were used to define intensity of activity (Pate, Almeida, McVey, Pfeiffer, & Dowda, 2006). The magnitude of the recorded accelerations over an epoch was measured in activity counts as an estimate of total physical activity data (Cliff et al., 2009). Cut-points were set at <625 counts/15 s for sedentary behavior and at ≥420 counts/15 s for moderate- to vigorous-intensity physical activities. These cut-points have been shown to be the most accurate in young children (Janssen et al., 2013). Data were reported as minutes spent in moderate- to vigorous-intensity physical activity (MVPA) and the average activity counts per minute, representing the average intensity activity during the lesson.

**Completion time.** Children’s total response time was calculated (measured in seconds), aggregating the time of completion needed for every question separately during the three assessments (pretest, immediate posttest, and delayed posttest).

**Statistical analyses**

This study was a cluster-randomized controlled trial. Separate analyses were conducted for performance (learning outcomes and completion time), interest ratings for the instructional method, and physical activity outcomes. In regard to the learning outcomes, to examine whether contextual factors (i.e., child-care center, age, and gender) and pretest scores could predict math performance, a hierarchical regression analysis was conducted, with child-care center, gender, and age entered as predictors in Step 1, pretest scores entered in Step 2, and condition entered in Step 3.

A cluster design was chosen because the intervention was implemented in nine child-care centers, where the child-care center was treated as a random variable with children nested in centers and in conditions (performing integrated vs. nonintegrated physical activity vs. observing integrated physical activity vs. control). The child-care center was set as the cluster unit for the randomization. Condition was used as the independent variable, and performance and completion times at the pretest, immediate posttest, and delayed posttest were used as dependent variables. Children’s interest ratings for the instructional method they were taught were included as a covariate. Finally, a separate analysis was performed for the physical activity outcomes, with condition as the independent variable and counts per minute and time spent in MVPA as dependent variables.
Analyses were completed using SPSS. The significance level was set at .05 (Field, 2009). Hedges’ $g$ and eta-squared were used as estimators of effect size, with $g = 0.20$ corresponding to a small effect, $g = 0.50$ to a medium effect, and $g = 0.80$ to a large effect and with $\eta^2 = .02$ corresponding to a small effect, $\eta^2 = .13$ to a moderate effect, and $\eta^2 = .25$ to a large effect (Cohen, 1988, 2013; Hedges, 2007).

Results

Performance

Learning outcomes

A hierarchical regression analysis was conducted to determine whether contextual factors (i.e., child-care center) and pretest scores classes could predict math performance for the immediate and delayed posttests. The new models with the extra predictors significantly improved our ability to predict performance in the immediate posttest. Results showed that child-care center, children’s age, and children’s gender did not significantly predict math performance for the immediate and delayed posttests, whereas pretest scores and condition were significant predictors of performance (immediate and delayed) posttests (Tables 1-4).

A univariate analysis of variance (ANOVA) was performed for the main analysis. This analysis yielded no significant differences among the conditions on the pretest scores. $F(3,116) = 2.06$, $p = .110$ (performing integrated physical activity condition: $M = 27.72$, $SD = 10.83$; observing integrated physical activity condition: $M = 24.03$, $SD = 10.57$; performing nonintegrated physical activity condition: $M = 23.34$, $SD = 12.69$; control condition: $M = 20.57$, $SD = 10.95$).

A multilevel analysis was used to examine the effects of the intervention at the pretest, posttest, and delayed test and to examine the effects of the intervention for math performance. Repeated-measures multilevel modeling was used to take account of the variability between schools. Children’s performance (at the pretest, posttest, and delayed test) was set as Level 1 units, children as Level 2 units, and child-care centers as Level 3 units (Table 5). Adjusting for clustering for child-care center, results revealed that there was a significant effect of condition on math performance.

| Table 1 | Correlations for immediate posttest. |
|---|---|---|---|---|---|
| 1. Child-care center | -.02 | .15 | -.13 | -.09 | -.04 |
| 2. Age | -.07 | .22 | .31 | .36 |
| 3. Gender | .17 | .17 | .08 |
| 4. Condition | -.21 | .49 | .81 |
| 5. Pretest scores | | | |
| 6. Immediate posttest | | | |

<table>
<thead>
<tr>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
</table>

$p < .05.

$p \leq .001$.

| Table 2 | Correlations for delayed posttest. |
|---|---|---|---|---|---|
| 1. Child-care center | .36 | .14 | -.48 | .82 | -.07 |
| 2. Age | -.06 | -.23 | .33 | .36 |
| 3. Gender | .16 | .21 | .14 |
| 4. Condition | -.25 | .48 | .82 |
| 5. Pretest scores | | | | |
| 6. Delayed posttest | | | | |
### Table 3
Hierarchical regression analysis for immediate posttest.

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Standardized β</th>
<th>T</th>
<th>R²</th>
<th>R² change</th>
<th>F change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Child-care center</td>
<td>-.05</td>
<td>-0.56</td>
<td>.14</td>
<td>.14</td>
<td>6.15</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>.37</td>
<td>4.15</td>
<td>.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>.12</td>
<td>1.23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Child-care center</td>
<td>.05</td>
<td>0.86</td>
<td>.68</td>
<td>.53</td>
<td>179.12</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>.11</td>
<td>1.19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>-.05</td>
<td>-0.90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pretest scores</td>
<td>.79</td>
<td>13.38</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Child-care center</td>
<td>-.01</td>
<td>-0.28</td>
<td>.79</td>
<td>.09</td>
<td>42.51</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>.06</td>
<td>1.28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>.02</td>
<td>0.48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pretest scores</td>
<td>.72</td>
<td>13.93</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Condition</td>
<td>-.33</td>
<td>-6.52</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** p ≤ .01.

### Table 4
Hierarchical regression analysis for delayed posttest.

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Standardized β</th>
<th>T</th>
<th>R²</th>
<th>R² change</th>
<th>F change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Child-care center</td>
<td>.09</td>
<td>1.07</td>
<td>.16</td>
<td>.16</td>
<td>7.16</td>
</tr>
<tr>
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<td>Age</td>
<td>.37</td>
<td>4.22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>.17</td>
<td>1.95</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Child-care center</td>
<td>.02</td>
<td>0.42</td>
<td>.69</td>
<td>.53</td>
<td>186.32</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>.09</td>
<td>1.56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>-.03</td>
<td>-0.44</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pretest scores</td>
<td>.80</td>
<td>13.66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Child-care center</td>
<td>-.04</td>
<td>-0.86</td>
<td>.76</td>
<td>.03</td>
<td>33.49</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>.05</td>
<td>1.06</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>.05</td>
<td>0.97</td>
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<tr>
<td></td>
<td>Pretest scores</td>
<td>.72</td>
<td>13.31</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Condition</td>
<td>-.30</td>
<td>-5.79</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*: p < .05.

**: p ≤ .01.

### Table 5
Means (and standard deviations) for total math scores as a function of condition for each child-care center.

<table>
<thead>
<tr>
<th>Child-care center</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Delayed test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performing integrated physical activity condition:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>28.33 (11.69)</td>
<td>43.83 (7.23)</td>
<td>42.00 (8.48)</td>
</tr>
<tr>
<td>2</td>
<td>29.45 (9.40)</td>
<td>43.18 (12.88)</td>
<td>46.90 (11.51)</td>
</tr>
<tr>
<td>3</td>
<td>26.83 (12.60)</td>
<td>36.08 (14.05)</td>
<td>38.63 (10.60)</td>
</tr>
<tr>
<td>4</td>
<td>22.33 (7.57)</td>
<td>28.33 (16.01)</td>
<td>30.50 (19.09)</td>
</tr>
<tr>
<td><strong>Observing integrated physical activity condition:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>34.00 (3.39)</td>
<td>36.20 (9.17)</td>
<td>36.80 (10.18)</td>
</tr>
<tr>
<td>2</td>
<td>34.77 (10.48)</td>
<td>26.61 (11.60)</td>
<td>31.09 (11.55)</td>
</tr>
<tr>
<td>3</td>
<td>24.75 (10.37)</td>
<td>24.75 (10.24)</td>
<td>28.75 (10.71)</td>
</tr>
<tr>
<td><strong>Performing nonintegrated physical activity condition:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>22.66 (13.05)</td>
<td>31.00 (15.17)</td>
<td>30.53 (14.61)</td>
</tr>
<tr>
<td>6</td>
<td>24.00 (12.87)</td>
<td>28.78 (13.80)</td>
<td>30.28 (13.09)</td>
</tr>
<tr>
<td><strong>Control condition:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>24.71 (7.29)</td>
<td>23.57 (8.56)</td>
<td>25.00 (10.03)</td>
</tr>
<tr>
<td>8</td>
<td>23.86 (12.31)</td>
<td>28.66 (14.74)</td>
<td>28.44 (12.58)</td>
</tr>
<tr>
<td>9</td>
<td>15.38 (8.50)</td>
<td>18.27 (9.31)</td>
<td>18.91 (11.02)</td>
</tr>
</tbody>
</table>
Accounting for multiple testing, Bonferroni corrections demonstrated that the performing integrated physical activity condition (M = 35.25, SE = 1.97) performed better than the observing integrated physical activity condition (M = 25.83, SE = 2.00), 95% confidence interval (CI) [1.90, 15.92], p = .006, g = .82, control condition (M = 22.07, SE = 2.09), 95% CI [5.48, 20.87], p ≤ .001, g = 1.14, and performing nonintegrated physical activity condition (M = 27.23, SE = 2.06), 95% CI [0.38, 15.64], p = .034, g = .61. The performing nonintegrated condition did not significantly differ from the observing integrated physical activity condition, 95% CI [−6.28, 9.08], p = .999, and control condition, 95% CI [−2.70, 13.04], p = .485. The observing integrated physical activity and control conditions were not significant, 95% CI [−3.98, 11.52], p = .959. Finally, the change in math performance over time varied significantly across children, \( \text{var}(u_i) = 0.76, p \leq .001 \).

To explore how learning performance differed for each task, further multilevel modeling analyses, adjusting for clustering for child-care center, were conducted with condition as the independent variable and performances on the pretest, immediate posttest, and delayed posttest as dependent variables. The results, including the means and standard deviations for each task, are presented in Table 6.

**Completion time**

An ANOVA was run on the total time needed to complete the math test at the pretest, showing no significant differences among the conditions. \( F(3, 116) = 2.43, p = .069 \) (performing integrated physical activity condition: \( M = 308.28, SD = 80.06 \); observing integrated physical activity condition: \( M = 311.61, SD = 73.64 \); performing nonintegrated physical activity condition: \( M = 351.90, SD = 62.27 \); control condition: \( M = 326.84, SD = 59.08 \))\(^1\).

A multilevel analysis was used to examine the effects of conditions on the time children needed to complete the math tests. Repeated-measures multilevel modeling was used to take account of the variability between schools. Children's completion time (at the pretest, posttest, and delayed test) was set as Level 1 units, children as Level 2 units, and child-care center as Level 3 units. Adjusting for clustering for child-care center, condition was the independent variable and completion times at the pretest, posttest, and delayed test were the dependent variables. Results revealed that there was no significant effect of condition on completion time, \( F(3, 125.77) = 1.74, p = .150 \). Finally, the change in completion time over time varied significantly across children, \( \text{var}(u_i) = 4.64, p \leq .001 \). It took more time for children to complete the pretest \( (M = 323.97, SD = 70.98) \) than to complete the immediate posttest \( (M = 283.83, SD = 52.22, p \leq .001) \) and the delayed test \( (M = 242.83, SD = 40.06, p \leq .001) \). Table 7 presents the means and standard deviations of completion time per condition and time of testing.

**Interest ratings for instructional method**

Correlations revealed that children's interest rating at the posttest was significantly correlated with children's total posttest scores \( (r = .26, p = .005) \). In addition, the interest ratings at the delayed test were positively correlated with children's performance at the total delayed test scores \( (r = .30, p \leq .001) \). However, further examination of these correlations per condition revealed that the interest ratings at the posttest were positively correlated with children's performance at the posttest in the control condition \( (r = .40, p = .033) \) but in none of the other conditions (performing integrated physical activity condition: posttest, \( r = .03, p = .875 \); delayed test, \( r = .16, p = .378 \); observing integrated physical activity condition: posttest, \( r = .01, p = .987 \); delayed test, \( r = .08, p = .486 \)).

\(^1\) A multilevel model analysis was performed, adjusting for clustering for child-care center, with condition as the independent variable, performance at the posttest and delayed test as the dependent variables, and completion time as the covariate. Controlling for completion time, results revealed significant main effects of time of testing. \( F(1, 229.67) = 38.53, p \leq .001 \), and condition, \( F(3, 308.87) = 7.07, p \leq .001 \). Accounting for multiple testing, Bonferroni corrections demonstrated that the performing integrated physical activity condition \( (M = 37.96, SE = 2.02) \) performed better than the observing integrated physical activity condition \( (M = 25.61, SE = 2.07) \), 95% CI [4.36, 19.28], \( p \leq .001 \), control condition \( (M = 22.47, SE = 2.15) \), 95% CI [7.55, 23.42], \( p \leq .001 \), and performing nonintegrated physical activity condition \( (M = 28.08, SE = 2.11) \), 95% CI [11.30, 18.99], \( p = .013 \). The performing nonintegrated physical activity condition did not significantly differ from the observing physical activity condition, 95% CI [−4.84, 10.65], \( p = .999 \), and control condition, 95% CI [−1.76, 1.43], \( p = .227 \). The observing integrated physical activity and control conditions were not significant, 95% CI [−19.93, 4.37], \( p = .099 \).
Table 6
Means (and standard deviations) for overall math scores (at three time points: pretest, immediate posttest, and delayed posttest) as a function of condition per task.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Task 3</th>
<th>Task 4</th>
<th>Task 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performing integrated physical activity condition</td>
<td>24.14</td>
<td>1.90</td>
<td>1.69</td>
<td>4.43</td>
<td>4.07</td>
</tr>
<tr>
<td>(10.03)</td>
<td>(2.31)</td>
<td>(0.63)</td>
<td>(1.44)</td>
<td>(1.53)</td>
<td></td>
</tr>
<tr>
<td>Observing integrated physical activity condition</td>
<td>17.47</td>
<td>0.25</td>
<td>1.46</td>
<td>3.52</td>
<td>3.05</td>
</tr>
<tr>
<td>(9.26)</td>
<td>(0.60)</td>
<td>(0.76)</td>
<td>(1.78)</td>
<td>(1.80)</td>
<td></td>
</tr>
<tr>
<td>Performing nonintegrated physical activity condition</td>
<td>19.72</td>
<td>0.03</td>
<td>1.85</td>
<td>3.42</td>
<td>3.10</td>
</tr>
<tr>
<td>(11.27)</td>
<td>(0.36)</td>
<td>(0.86)</td>
<td>(1.83)</td>
<td>(1.94)</td>
<td></td>
</tr>
<tr>
<td>Control condition</td>
<td>14.53</td>
<td>0.01</td>
<td>1.95</td>
<td>3.24</td>
<td>2.89</td>
</tr>
<tr>
<td>(8.43)</td>
<td>(0.10)</td>
<td>(0.81)</td>
<td>(1.59)</td>
<td>(2.07)</td>
<td></td>
</tr>
</tbody>
</table>

Note. Bonferroni corrections showed significant differences among the conditions for each task (counting, number line estimation, block counting, numerical magnitude comparison, and numerical identification, respectively):  
Task 1: Performing integrated physical activity condition vs. observing integrated physical activity condition ($p = .026$) and control condition ($p \leq .001$).  
Task 2: Performing integrated physical activity condition vs. observing integrated physical activity condition ($p \leq .001$), performing nonintegrated physical activity condition ($p \leq .001$), and control condition ($p \leq .001$).  
Task 3: No significant differences.  
Task 4: Performing integrated physical activity condition vs. observing integrated physical activity condition ($p = .009$), performing nonintegrated physical activity condition ($p = .003$), and control condition ($p = .002$).  
Task 5: Performing integrated physical activity condition vs. control condition ($p = .044$).

physical activity condition: posttest, $r = .11$, $p = .557$, delayed test, $r = .13$, $p = .475$; performing nonintegrated physical activity condition: posttest, $r = .25$, $p = .185$, delayed test, $r = .05$, $p = .773$.

A multilevel model analysis was performed, adjusting for clustering for child-care center, with condition as the independent variable, math performance as the dependent variable, and children's
Table 7
Manns (and standard deviations) for completion time as a function of condition.

<table>
<thead>
<tr>
<th></th>
<th>Pretor</th>
<th>Postest</th>
<th>Delay test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performing integrated physical activity condition</td>
<td>308.28 (80.06)</td>
<td>270.10 (49.13)</td>
<td>256.78 (52.91)</td>
</tr>
<tr>
<td>Observing integrated physical activity condition</td>
<td>311.61 (73.64)</td>
<td>246.07 (35.79)</td>
<td>234.23 (44.00)</td>
</tr>
<tr>
<td>Performing nonintegrated physical activity condition</td>
<td>351.89 (62.27)</td>
<td>274.41 (63.70)</td>
<td>222.79 (24.09)</td>
</tr>
<tr>
<td>Control condition</td>
<td>326.64 (59.08)</td>
<td>265.18 (54.90)</td>
<td>257.37 (60.43)</td>
</tr>
</tbody>
</table>

interest ratings at the posttest and delayed test as the covariates. Results revealed that the main effects of condition, $F(3,215.39) < 1, p = .614$, children's interest, $F(1,205.86) = 3.74, p = .054$, and the interaction between condition and interest, $F(2,205.12) = .116, p = .322$, on math performance were not significant. Finally, the change in math performance over time varied significantly across children, $\text{var}(\mu_i) = 0.87, p \leq .001$.

A mixed ANOVA was run to assess children's interest across the conditions measured at two moments: directly after the end (immediate postest) and 6 weeks after the intervention (delayed postest). The analysis revealed main effects of condition, $F(3,111) = 17.94, p < .001, \eta^2 = .33$, and time of testing, $F(1,111) = 6.59, p = .012, \eta^2 = .06$. The interaction between condition and time of testing was not significant, $F(3,111) = 1.47, p = .217$. With regard to the main effect of condition, post hoc comparisons revealed that children in the performing integrated physical activity condition ($M = 4.59, SE = 0.13, 95\% CI [4.24, 4.94]$) enjoyed playing this game more than those in the observing integrated physical activity condition ($M = 3.41, SE = 0.13, 95\% CI [3.13, 3.69]$) and control condition ($M = 3.74, SE = 0.13, 95\% CI [3.48, 4.00]$), both $p < .001$. In addition, children in the performing nonintegrated physical activity condition ($M = 4.32, SE = 0.13, 95\% CI [4.07, 4.57]$) enjoyed the game more than those in the observing integrated physical activity condition ($p < .001$) and control condition ($p = .002$). However, the performing integrated and nonintegrated physical activity condition ($M = 128$) as well as the observing integrated physical activity condition and control condition ($p = .076$) did not differ in terms of how much children enjoyed playing the game.

Physical activity outcomes

An ANOVA was performed to assess the differences in physical activity counts across the conditions, with average counts per minute as the dependent variable and condition as the independent variable. Results showed a significant effect of condition on the counts per minute, $F(3,366) = 28.46, p < .001, \eta^2 = .42$. Post hoc comparisons with Gabriel correction revealed that physical activity counts did not differ between the physical activity conditions (performing integrated physical activity condition: $M = 1228.33, SE = 65.65, 95\% CI [1096.23, 1357.44]$; performing nonintegrated physical activity condition: $M = 1098.64, SE = 70.13, 95\% CI [987.73, 1165.56]$), $p = .128$, and between the sedentary conditions (observing integrated physical activity condition: $M = 584.87, SE = 63.41, 95\% CI [480.18, 780.55]$; control condition: $M = 462.17, SE = 70.55, 95\% CI [322.44, 600.91]$), $p = .728$. However, children in the performing integrated and nonintegrated physical activity conditions had higher activity counts per minute than children in the observing condition and control conditions (all $p < .001$).

An ANOVA was also performed on the time spent in MVPA. It revealed a significant effect of condition, $F(3,366) = 31.93, p < .001, \eta^2 = .21$. Post hoc comparisons showed that the time spent in MVPA did not differ between the performing integrated physical activity condition ($M = 1.86, SE = 0.09, 95\% CI [1.78, 2.04]$) and the performing nonintegrated physical activity condition ($M = 1.85, SE = 0.09, 95\% CI [1.66, 2.04]$), $p = .917$, as well as between the observing integrated physical activity condition ($M = 1.03, SE = 0.09, 95\% CI [0.86, 1.02]$) and the control condition ($M = 1.03, SD = 1.0, 95\% CI [0.64, 1.03]$), $p = .774$. However, children in the performing integrated and nonintegrated physical activity conditions spent more time in MVPA than children in the observing integrated physical activity and control conditions (all $p < .001$).
Discussion

This study evaluated the effectiveness of integrating physical activities with preschool children's arithmetic skills acquisition. For this purpose, four conditions were created, including a performing integrated physical activity condition, which was compared with a performing non-integrated physical activity condition, an observing integrated physical activity condition, and a sedentary control condition. In the performing integrated physical activity condition, children performed physical activities (such as running and stepping on blocks of numbers) while learning cognitive activities. In the performing non-integrated physical activity condition, children performed the same cognitive task but performed the physical activities separately (e.g., first counting and then running). The observing integrated physical activity condition occurred at the same time and place as the performing integrated physical activity condition, where children were seated and watched their peers from the integrated condition performing the physical activity. Finally, in the control condition, no physical activity was involved, corresponding to the conventional way of teaching in which children stay seated and listen to the instructor.

It can be concluded that the overall math scores confirmed the first hypothesis. The performing integrated physical activity condition outperformed all other conditions measured at the three time points of testing (prettest, posttest, and delayed test). Consistent with previous research, classroom-based physical activity programs (Donnelly & Lambourne, 2011; Mahar et al., 2006; Vazou & Smiley-Cylen, 2014) and task-relevant movements (Fischer et al., 2011; Rutter et al., 2015; Shoval, 2011) show positive effects on math learning. A closer look at the math outcomes obtained for each task revealed that the performing integrated physical activity condition exerted the largest effects in the number line estimation and numerical magnitude comparison tasks. This outcome is in accord with existing literature on the effects of number line training on understanding and learning of mathematical concepts (Fischer et al., 2011; Link et al., 2013). More specifically, the primary locus of the learning gains can be placed at the embodied spatialization of numbers, meaning that together the numbers on the number line represented a structured path of magnitudes that children could follow by moving along (see e.g., Núñez & Marghetis, 2015). The mathematical concepts taught through the physical activities were grounded in the body, spatial systems and situated actions (Lakoff & Núñez, 2000; Nathan et al., 2014). Consequently, children were able to connect the numeracy knowledge with real-world observations while the body-based actions relevant to the task (i.e., grounding actions) enhanced children's mathematical insights (Nathan et al., 2014). The physical manipulation and experience during learning exposed children to multiple modalities (visuospatial, auditory, temporal, and kinesthetic cues), helping them to construct rich mental representations of the numerical magnitudes (Ramani & Siegler, 2008). These mental representations may have facilitated memory encoding, recall, and retrieval (Madan & Singhal, 2012). Overall, these results reveal the advantage of the embodiment effect, stating that the congruency of the sensorimotor information and knowledge to be learned can enhance learning (Lindgren & Johnson-Glenberg, 2013).

Consistent with this study, a great body of research has looked at the role of gestures to support mathematics learning (for a systematic review, see Agostinho, Ginns, Tindall-Ford, Mavili, & Paas, 2016). This research has focused on the effectiveness of including actions on physical objects during math instruction compared with gestures (Novack, Congdon, Hemani-Lopez, & Goldin-Meadow, 2014), the superiority of task-relevant versus task-irrelevant gestures (Brooks & Goldin-Meadow, 2016), and performing gestures compared with observing gestures (Goldin-Meadow et al., 2012). In line with this research, the current study holds promise for performing task-relevant movements that involve object manipulation (i.e., blocks of numbers). Taking into account the evidence of the existence of a mirror neuron system in learning, this study included a condition in which children observed their peers' movements. Although empirical studies using subtle forms of movements (i.e., gestures) have provided evidence for the effectiveness of action observation for learning math in children (Cook & Goldin-Meadow, 2006; Cook et al., 2013), the outcomes of this study showed that observing movements did not contribute to children's learning. Children in the observing integrated physical activity condition had lower math performance than children in the two performing physical activity groups (integrated and nonintegrated) and had the same performance as children in the
control group, rejecting the second hypothesis. The study of Ruiter et al. (2015) also did not find any additional effects of observing over making movements on learning when a mirror was used in order for children to be able to watch their own actions.

Several possible explanations can be given for the lack of an effect of movement observation on learning. In the body of research supporting the positive effects of observing movements, gestures are produced by teachers and observed by children. In this study, children observed movements from their peers. In other studies, the relevant actions were integrated into a student-directed lesson in which the actions (or gestures) were part of ostensive communication and understanding directed at the learner. This means that attention was paid to ensure that the gestures would be performed correctly. In the current study, the learner was merely a bystander, with movements chosen by the instructor and not by the learner, thereby eliminating the possibility of adopting a different movement that could also assist children’s learning. In addition, the whole-body movements in the form of physical activities might have been more complex to observe and relate to cognitive tasks than hand gestures, especially when they present even small variations from child to child (focus on one adult teacher vs. many children at the same time acting slightly differently).

Finally, children in this age group are sensitive to peer pressure and comparison, making them more likely to conform with their peers’ behaviors (Haun & Tomasello, 2011). Children seemed to be enthusiastic about the idea of being physically active. Not allowing children in the observing physical activity group to perform movements while watching their peers performing them could have reduced their interest and, in turn, their engagement and academic performance in the numerical task. This explanation is supported by children’s responses on the interest scale regarding the instructional method in which they were enrolled. Interest ratings were the highest in the performing integrated and nonintegrated physical activity conditions, followed by the observing integrated physical activity and control conditions. Confirming the fourth hypothesis, children showed higher interest ratings in the active learning conditions than in the sedentary traditional classroom condition. The collaborative aspect of learning occurring in the active conditions might also have contributed to the higher interest scores. Research indicates that cooperative learning can improve social skills, increase motivation, and reach higher performance (Johnson & Johnson, 1999; Shoval, 2011). However, no direct associations were found in this study between children’s performance and interest ratings, which makes us cautious about further interpretations. Future research should attempt to isolate the effects of active and group-based learning on children’s interest and academic performance.

Further exploring the math outcomes for each task, the performing integrated physical activity condition performed better than the observing integrated physical activity and control conditions on the counting task and performed better than the control condition on the numerical identification task. However, no significant differences among the conditions were observed on the block counting task. This task consisted of only two items, which were possibly not enough to accurately distinguish children’s ability to count the blocks shown to them. Future research should focus on examining the role of movements that can promote recall of specific mathematical content or tasks (such as movements related to multiplication, division, etc.).

Moreover, despite the research evidence for the positive effects of physical activity on cognition and academic achievement in children (e.g., Khan & Hillman, 2014), the third hypothesis, in which children in the performing nonintegrated physical activity condition would outperform children in the control condition, was not confirmed. It is possible that the exercise dosage was too low to have acute effects on cognition and achievement. Nevertheless, the physical activity outcomes are corroborated by the findings of Mavili et al. (2015), with the physical activity groups (performing integrated and nonintegrated physical activity conditions) being engaged in the same intensity levels and duration of physical activity. Being exposed to the same amount of physical activity, the integrated condition was found to be superior for learning to the nonintegrated condition. At the same time, the intensity levels of physical activity were higher for the performing integrated and nonintegrated conditions compared with the observing integrated physical activity and control conditions, confirming the fifth hypothesis.

Finally, results revealed no differences across conditions in terms of how much time children needed to complete the assessments, disproving the sixth hypothesis. Overall, training effects can be assumed because children needed more time to complete the pretest, followed by the posttest
and the delayed test. The fact that some tasks, such as counting, might have taken longer to be completed compared with other tasks, such as number recognition, makes us very cautious in further interpreting and generalizing these outcomes. Nonetheless, a salient finding arises here related to time and performance. Overcoming teachers’ barriers, physical activity interventions could be incorporated into the academic content because they are not competing with academic time and can provide substantial learning benefits (Sallis et al., 1997; Ward et al., 2006).

Lastly, for this study, children from nine child-care centers were enrolled in the various conditions. This number of child-care centers is rather low for a cluster-randomized control trial. An important limitation to note is related to the randomization process. More stringent criteria should be applied in future studies, taking into account the nested nature of data from children attending the same child-care centers. Even if in this study the instruction was conducted by the researcher, children attending the same preschool centers present similarities that should be considered. It is also important to make clearer distinctions in the design, choosing either multisite trials or unique treatments assigned to each group.

In conclusion, the importance of children’s early exposure to the “world of mathematics” is invaluable for their development of mathematical proficiency. Already during infancy, children are able to encode numbers (e.g., Cordes & Brannon, 2008; Izard, Sann, Spelke, & Streri, 2009; Xu & Spelke, 2000), whereas at preschool age they are able to acquire and improve basic number skills (such as counting number recognition, and knowledge: Geary, 1993; Jordan, Kaplan, Nabors Olaá, & Locuniak, 2006). These early acquired skills can positively affect their level of mathematical performance during later years (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Booth & Siegler, 2006, 2008), reducing the emergence of math anxiety and its associated risk of failure (Maloney & Belson, 2012; Mavilidi, Hoogerheide, & Paas, 2014).

Getting involved in physical activity and linking motor skills to cognitive processes is particularly important for preschool children’s cognitive enhancement (Lu & Montague, 2015). Embedding is a fundamental underpinning of cognition (Gallagher & Lindgren, 2015). Physical actions can enhance cognitive gains when their relevance is explicitly signaled to the learners (Nathan et al., 2013). Concurrently, stimulating physical, social, emotional, and cognitive development through physical activity has been identified as an effective way to improve children’s cognitive processing and academic performance (for a review, see Khan & Hillman, 2014; for meta-analyses, see Rasberry et al., 2011; Verburgh, König, Scherder, & Oosterlaan, 2013). In this study, condition differences emerged and children’s mathematical thinking was improved after this simple and short intervention (1 h in total). This outcome is crucial considering that the higher the initial level of mathematical performance of children entering school, the greater the rate of growth and development of their mathematical ability (Aunola et al., 2004; Siegler et al., 2012). Early childhood interventions can be influential for children’s mathematical abilities (Griffin, 2004) as well as their overall development (i.e., cognitive, emotional, social, and physical; Barnett, 1998). This study presented an instructional approach with combined physical and cognitive gains in the domain of math for preschool children. The suggested type of instruction is engaging and enjoyable, and it can be easily applied and adjusted to places, teachers’ demands, and children’s needs, ensuring children’s long-term well-being.

References


Appendix Q

Experimental Study 4 (Science – Chapter 6): Human Ethics Approval

21 January 2016

Ms Myrto Mavili
Faculty of Social Sciences
University Of Wollongong
NSW 2522

Dear Ms Mavili

Thank you for your letter responding to the HREC review letter. I am pleased to advise that the Human Research Ethics application referred to below has been approved.

Ethics Number: HE15/458
Project Title: Integrating physical activities on learning science in preschool children
Researchers: Ms Myrto Mavili, Professor Tony Okley, Professor Fred Paas, Professor Paul Chandler

Documents Approved:
- Initial Ethics Application
- Response dated 14/01/2016
- Response dated 04/01/2016
- Information Sheet for Parents/Careers V2 - 23/12/2015
- Consent Form for Parents/Careers on behalf of their child V1 - 12/11/2015
- Supporting emails from KCPK Director for KU

Approval Date: 20 January 2016
Study Expiry Date: 19 January 2017

The University of Wollongong/Ilawarre Shoalhaven Local Health District Social Sciences HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research. The HREC has reviewed the research proposal for compliance with the National Statement and approval of this project is conditional upon your continuing compliance with this document.

A condition of approval by the HREC is the submission of a progress report annually and a final report on completion of your project. The progress report template is available at http://www.uow.edu.au/research/rsa/ethics/UOW009385.html. This report must be completed, signed by the appropriate Head of School, and returned to the Research Services Office prior to the expiry date.
As evidence of continuing compliance, the Human Research Ethics Committee also requires that researchers immediately report:

- proposed changes to the protocol including changes to investigators involved
- serious or unexpected adverse effects on participants
- unforeseen events that might affect continued ethical acceptability of the project.

Please note that approvals are granted for a twelve month period. Further extension will be considered on receipt of a progress report prior to expiry date.

If you have any queries regarding the HREC review process, please contact the Ethics Unit on phone 4221 3386 or email rso-ethics@uow.edu.au.

Yours sincerely

[Redacted]

Associate Professor Melanie Randle
Chair, Social Sciences
Human Research Ethics Committee

cc: Professor Tony Okley, Professor Fred Paas, Professor Paul Chandler
Appendix R

Experimental Study 4 (Science – Chapter 6): Parents’ Information Sheet

Integrating physical activities on learning Science in preschool children

Information Sheet for Parents/Carers

Dear Parent/Carer,

Full details about the project, its purpose, the researchers involved and what is required of your child, should you agree for your child to be involved, are provided in this information sheet.

What is the purpose of this study?
This study, which is part of a PhD project, will investigate the effects of different types of physical activities on learning science in children aged 4-5 years.

Research suggests that physical activity can facilitate academic learning. However, little is known about how preschool children’s learning can benefit from integrating physical activities into the formal learning process. Given early childhood is an important period in the acquisition and learning of new skills, it is important to understand factors that enhance cognitive development.

This is the first known study to examine the specific effects of physical activities on learning science in preschool children.

What we are asking your child to do?
The childcare service that your child attends has agreed to be involved in this study. Your child has the opportunity to participate in this study, because (s)he attends childcare at least two times per week and is between four and five years of age. The participation in this study is voluntary.

This study will involve your child in one learning session per week, for 6 weeks learning about the planets and their position relative to the sun. Children will either be involved in physical activities or will stay seated for about 15 minutes each day. All Children at your child’s centre will be randomly allocated to one out of three groups: two physical activities or one sitting group. In all groups children will be taught exactly the same. In the physical activity groups, children will be involved in several activities, such as walking, running, and jumping. All activities are age-appropriate and will not cause harm to your child. A researcher from the University of Wollongong will teach your child the planets for about 15 minutes per day, one time per week, for six weeks. The researchers will assess your child’s ability to recall the name of the planets and their position relative to the sun (before and after the learning sessions).

The learning sessions will be in groups and the assessments of the science task will be on an individual basis. Both in the learning and testing phase, the children will be facilitated in a fun and age appropriate, non-threatening manner.

All children will be wearing an accelerometer during each learning session (for 15 minutes per day/1 per week for 6 weeks) to measure their physical activity. The accelerometer is an instrument that will measure your child’s intensity of physical activity. It will be attached to a belt and be placed on the right hip.
What are the benefits and risks involved in this study?
This study will benefit your child’s childcare service by providing information about whether the positive effects of physical activity on learning can be applied to preschool children. The results from the study will be disseminated through presentations during staff meetings to the educators at your child’s service and they, along with interested parents/carers will have an opportunity to discuss the findings and ways in which current practices may be modified to improve physical activity and learning.
There are no risks associated with this study.

Participation in the study
The participation in this study is voluntary. Your child is free to discontinue participation at any time. Discontinuation of your child’s involvement will not jeopardise your or your child’s current or future relationship with the childcare centre and the University of Wollongong. You can indicate withdrawal from the study at any moment, either directly contacting the researcher or though your child’s educator. Children who are not willing to participate will not be included in the study and will follow their usual daily routine.

What will happen to the information that you provide?
All the results will be de-identified. Information collected during this study will be kept strictly confidential and be stored in a locked office at the University of Wollongong. Data from cognitive tasks and physical activity measurements may be used in publications such as papers, conference presentations and grant applications, however your child’s identity will be kept strictly confidential.

Who is conducting the study?
- Professor Paul Chandler, Executive Director of Early Start, Pro Vice Chancellor, University of Wollongong
- Professor Tony Okely, Professorial Fellow, Early Start Research Institute, University of Wollongong
- Professor Fred Paas, Research Fellow, Early Start Research Institute, University of Wollongong, & Professor of Educational Psychology, Institute of Psychology, Erasmus University Rotterdam, The Netherlands
- Ms Myrto Mavilidi, MSc, PhD Candidate, Early Start Research Institute, University of Wollongong

We are asking you to consent to your child participating in this study by completing the attached consent form and returning it to the Director of your service on your child’s as soon as possible of attendance.

Kind Regards,

Myrto Mavilidi
Telephone: (61 2) 4239 2278

Early Start Research Institute
Faculty of Education
University of Wollongong
mfm351@uowmail.edu.au

If you have any questions regarding the study, please contact Myrto Mavilidi (mfm351@uowmail.edu.au). If you have any concerns or complaints regarding the way the research is or has been conducted, you can contact the Ethics Unit, Research Services Office University of Wollongong NSW 2522 Australia Telephone (02) 4221 3386 Facsimile (02) 4221 4338 Email: rso-ethics@uow.edu.au Web: www.uow.edu.au.

Your co-operation in this project will be greatly appreciated.
Appendix S

Experimental Study 4 (Science – Chapter 6): Consent Form for Parents

Integrating physical activities on learning science in preschool children

Consent form for parents/carers on behalf of their child

I have been given information about the PhD research study entitled: “Integrating physical activities on learning science in preschool children”.

I understand that if I consent for my child to participate (s)he may be asked to:

- Perform several activities such as walking, running, and jumping during the program
- Participate in this program as part of their daily routine at childcare
- Learn a science task (about the planet system and the position of the planets relative to the sun) and assess their ability to recall the name of the planets and their position relative to their sun (before and after the learning sessions)
- Wear an accelerometer during the learning sessions

I have been advised of the potential risks and burdens associated with this study. I understand that my child’s participation is voluntary, I have been invited to participate, and assured that my child is free to withdraw from the study at any time. Withdrawal from the study will not affect my relationship or that of my child’s, with our childcare service or with the University of Wollongong now or in the future. Furthermore, I understand that the information provided may be used in papers, conferences presentations or future grant applications.

If I have any enquires about the study, I can contact Myrto Mavilidi (mfm351@uowmail.edu.au) or if I have any concerns or complaints regarding the way the research is or has been conducted, I can contact the Complaints Officer, Human Research Ethics Committee, University of Wollongong on +61 2 42214457. Or by email on (rso-ethics@uow.edu.au).
By signing below I am indicating my consent for my child to participate in this study as it has been described to me in the information sheet and in discussion with Myrto Mavilidi. Can you please return this form at your earliest convenience.

Your co-operation in this study will be greatly appreciated.

CONSENT

I (your name) ____________________________
agree for my child (child’s full name) ____________________________
to take part in the study entitled

“Integrating physical activities on learning science in preschool children.”

Parent/Carer Surname:  ___________________________________
Parent/Carer Given name:  ___________________________________
Child’s Month and Year of Birth: _____________________________(mm/yyyy)
Sex of the Child: ___________________________________(boy/girl)
Postcode:  ___________________________________
Signature:  ___________________________________
Date:  ___________________________________
Name of Childcare Service:___________________________________________
Appendix T

Experimental Study 4 (Science – Chapter 6): Testing Material

Participant Testing Sheet

Name:
Childcare centre:
Condition:
Accelerometer no:
Dates of teaching:
Dates of testing:
Pre-test – immediate test – delayed test

Assessments

[Free-recall test]
Name the planets:

[Blank Space] / 9

Name the planets starting from the one that is closest to the sun:

[Blank Space] / 9

[Cued-recall test]
Identifying the planets (see pictures and name them):

Venus
Mars
Earth
Uranus

Place the planets in the right order:

Mercury
Jupiter
Saturn
Neptune

/ 4

/ 4
Identifying the planets (name the planets placed on the floor):

- Mercury
- Earth
- Uranus
- Neptune

Evaluation

Did you like this game?

Would you like to play this game again in the future?
Appendix U

Experimental Study 4 (Science – Chapter 6): Effects of integrating physical activities into a science lesson on preschool children’s learning and enjoyment. *Applied Cognitive Psychology, 31*, 281-290.
Appendix V

List of Publications


Appendix W

Authors' Contribution

1. Myrto Mavilidi and Margina Ruiter wrote the manuscript and contributed to the development of the original concept. Sofie Loyens, Anthony Okely, Paul Chandler, & Fred Paas contributed to the development of the original concept, supervised drafting of the manuscript and reviewed it for important intellectual content.

2. Myrto Mavilidi wrote the manuscript, conducted the data collection, analysis and interpretation, and contributed to the development of the original concept and experimental design. Dylan Cliff contributed to the analysis of accelerometry. Anthony Okely, Paul Chandler, & Fred Paas contributed to the development of the original concept and experimental design, supervised drafting of the manuscript, and reviewed it for important intellectual content.

3. Myrto Mavilidi wrote the manuscript, conducted the data collection, analysis and interpretation, and contributed to the development of the original concept and experimental design. Anthony Okely, Paul Chandler, & Fred Paas contributed to the development of the original concept and experimental design, supervised drafting of the manuscript, and reviewed it for important intellectual content.

4. Myrto Mavilidi wrote the manuscript, conducted the data collection, analysis and interpretation, and contributed to the development of the original concept and experimental design. Sidsel Louise Domaset provided helpful input. Anthony Okely, Paul Chandler, & Fred Paas contributed to the development of the original concept and experimental design, supervised drafting of the manuscript, and reviewed it for important intellectual content.

5. Myrto Mavilidi wrote the manuscript, conducted the data collection, analysis and interpretation, and contributed to the development of the original concept and experimental design. Anthony Okely, Paul Chandler, & Fred Paas contributed to the development of the original concept and experimental design, supervised drafting of the manuscript, and reviewed it for important intellectual content.