Enhancing participation and performance in physical activity through primary level physical education- The role of physical literacy.

By Susan Giblin

A thesis submitted in partial fulfilment for the requirements for the degree of Doctor of Philosophy at the University of Central Lancashire

August 2016

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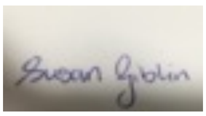
Signature of Candidate 

Type of Award	**PhD**
School	**School of Sport & Wellbeing**

Abstract

Physical literacy is a multifaceted conceptual model that purports to describe the physical, psychological and behavioural skills needed to sustain a lifetime of physical activity engagement. Physical Literacy is commonly deployed as a guiding framework in schools and educational policy, however, despite physical education provision and policy stipulation, obesity has reached epidemic levels and sedentary lifestyles prevail. In fact, children often graduate to second level education without a complete physical skill set. Thus the objective of this thesis was to investigate the reasons underpinning inadequate physical development, despite its suggested importance. A number of critical reviews of the literature were undertaken to understand the efficacy of physical education models and practices. Notably, the prominence of the 'just let them play' approach to PE appears to limit the transfer of evidence based practice to physical education. Whilst aiming to deliver a psychosocially appealing 'fun' PE class, an undefined, unstructured and un-assessed curricula prevails in primary level physical education. This lack of accountability is in stark contrast to the stringent requirements for other curricular subjects. Based on the critical review, a number of complex movement skills that include a cognitive element whereby individuals must interpret and respond to movement demands were found to be important for high level physical ability. These seemingly essential movement skills were; interceptive timing, object manipulation, rhythm and sequencing, locomotion and agility, balance and spatial awareness.

Further examination of PE assessment methods showed that the lack of comparative study and standardisation may have arisen from inappropriate tools to measure complex physical skill development. As a result, basic movement skills have taken precedence in physical development research and practice. Combined with basic movement learning, fitness and transient activity measures are readily deployed that offer little insight into the physical competencies that research have shown to be important for engagement and progression in sport and physical activity throughout the lifespan. In order to triangulate the findings from the literary review, quasi-qualitative research was undertaken. A sample of qualified and currently practicing generalist primary school teachers were surveyed. The findings from the survey show that whilst teachers reported each of the essential movement competencies as being of equal and high importance to developing physically literate children, a minority used structured teaching approaches during their physical education lessons. There was no standardisation between methods of delivery (i.e. in some school generalist teachers provided game-based activity and in others sports coaches offered sports-specific skill education). Despite acknowledging the importance of acquiring a broad-base of comprehensive athletic ability, none of the study participants reported engaging in formal skill assessment. Furthermore, those who did use assessment (28%) relied on subjective, unsystematic observation.

To begin to address this substantial gap in the research and practice, an exergaming based movement assessment was proposed and developed. Exergaming provides a practical and user-friendly solution to measuring complex movement tasks, assessments can be designed by experts, deployed by teachers and scored automatically. The essential movement tasks were programmed via Microsoft Kinect, a number of pilot studies were undertaken to refine the assessment tasks. Furthermore a validation of the Microsoft Kinect for measuring complex movement skills was undertaken. Firstly, a critical review of the literature was undertaken, then a single case comparative study was completed using a industry standard motion capture system to establish the accuracy of the Microsoft Kinect for measuring gross motor tasks. Based on the positive findings, the Physical Literacy exergame test was deployed for large scale investigation in primary school settings. 317 children aged between 4-11 years were tested using the Physical Literacy exergame tasks. Reliability was established using test-retest investigation. Further PL exergame scores were compared against teachers' observational ratings and already validated (although inappropriate for complex skill assessment) movement battery. The results showed that the Physical Literacy exergame was a valid and reliable. The teachers' observational rating correlated well with the Physical Literacy exergame and poorly with the movement battery. Although further research is clearly required to test the assessment methods in other populations and longitudinally to measure progression in PE, this initial investigation provides a base upon which to develop a robust, objective and valid assessment of Physical Literacy movement skills.

Overall, this thesis provides a number of evidence-based studies to address the requirements and methods through which physical skills are developed and assessed in primary school children. With practical requirements at the fore, this work serves to aid teachers and educators in delivering a standardised, evidence based curricula of comprehensive physical education. Additionally, the thesis raises questions about the adequacy of existing theory, policy and practices that lack the empirical validation and offers a useful insight into how this might be rectified in the future.

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Acknowledgements

Sincerest thanks to my Director of Studies, Professor Dave Collins for his support, guidance and patience throughout the PhD process and thanks to my extended supervisory team at UCLan, Prof. Jim Richards, Dr.Áine MacNamara and Dr. Chris Button, Mr. Gavin Kennedy at the University of Otago. Finally, thanks to my family and colleagues for their continual encouragement.

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Giblin, S., Collins, D., & Button, C. (2014). Physical literacy: importance, assessment and future directions. Sports Medicine, 44(9), 1177-1184.

Giblin, S., Collins, D., MacNamara, A., & Kiely, J. (2014). “Deliberate Preparation” as an Evidence-Based Focus for Primary Physical Education.Quest, 66(4), 385-395.

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CHAPTER 1

Introduction

There is a substantial amount of scientific research suggesting the physical and psychological health benefits associated with living a physically active life-style (Lubans, Morgan, Cliff et al., 2010). Furthermore, sedentary behaviour has been identified as the fourth leader in global-mortality (Castelli, Barcelona & Bryant, 2015). Consequently, Governments world-wide prioritise policies, finances and resources in healthcare, education and sports sectors to increase mass participation in physical activity (PA). Physical Education (PE) is an ubiquitous and important resource for developing PA habits that has remained a proclaimed priority in education systems (Ford, Collins, Baily et al., 2012; Lubans , Morgan, Cliffe et al., 2010).

Despite the proclaimed importance of PE, standardisation of PE delivery has not been achieved to date (Dyson, Placek, Graber et al., 2011). Despite research evidencing the benefit of specialist teacher-lead PE classes (Lander, Barnett, Brown & Telford, 2014; Miller, Christensen, Eather, et al., 2015), in many countries National curricular delivery is the responsibility of generalist educators (e.g. Ireland, UK, New Zealand). Additionally, in contrast to other curricular subjects, formal PE assessment does not take place at primary school level (Dyson et al., 2011). The lack of standardisation has contributed to limited physical skill levels being achieved by children on cessation of formal primary level education (Lubans et al., 2012). Thus the primary objective of this thesis is to examine the promotion of physical skill development through Physical Literacy based primary level education. In this introductory Chapter, the definition, origins, operationalisation and delivery of PE are discussed. From there, the content and structure of the thesis are described.

1.0 PE Definition

Semantics have been a source of complication in the process of standardising the promotion of PA through PE. PA has been defined as a behaviour produced by skeletal muscles to expend energy (Castelli et al., 2015). More formally, exercise involves planned movement. More recently, public health and education policies have adopted the term Physical Literacy as the desired outcome of learning in PE across nations (e.g. US, Canada, Northern Ireland), (Castelli et al., 2015, Whitehead, 2001). Physical Literacy (here after PL) has been suggested to present a broader conceptualisation of the physical, psychological and behavioural concomitants required for sustaining physical activity throughout the life span. The shift in focus from 'physically educated' to 'physically literate' is underpinned by an understanding that the term literacy is multifaceted, and in a general educational context requires evidence-based pedagogical strategy to be successful (Castelli et al., 2015). In the context of the National Standards for PE (USA) the expectation is that a quality PE program, delivered by certified teachers will lead to refined motor skills, understanding of the benefits of PA, attainment of physical fitness and sustained engagement in PA. Notably, to differentiate between 'educated' and 'literate' the emphasis in PL is individual orientated, self-regulated and continually monitored process to maximise individuals' potential (not simply meet basic, generic curricular criteria). Self-regulated learners have opportunities to acquire and refine skills through experience and have the opportunity to deploy their skills in new and different contexts. Furthermore, self-regulated learners are motivated to engage with experiences, to reflect and to feedback. Thus self-regulation in a PE context equips children with the psychobehavioural skills needed to engage in a range of sports and PAs.

As children develop at different rates, to meet the goals of PL and also standards-based education, previously accepted criterion-based assessment require critical consideration: Assessment of PL requires progress to be measured against individuals' previous scores, not peer comparison. Such individual-orientated assessments are needed to provide appropriate feedback and benchmark progress for individuals in pursuit of their potential.

Clearly PL is a multifaceted concept that requires careful design, delivery and assessment to be successful. As discussed by Corbin (2016), the PL concept has received considerable attention in recent times. Notably there has been debate around 'traditional' and 'new' approaches to PE whereby 'traditional' approaches focused on education *of* physical skill, 'new' PE approaches (including PL) purported to deliver education *through* physical with a holistic focus on child development. This holistic approach is encompassed in Whitehead's conceptual work focused on PL as a philosophy. Since then it's initial conceptualisation, PL has been adopted by many insititutes and policies where definitions and objectives of PL have been shaped to fit the objectives of the institution or intervention. Currently, there is little empirical evidence to support a single method, definition or operationalization of PL education. To identify appropriate methods of PL assessment and delivery, operationalisation is required.

1.1 Operationalisation of PL

PL is sustained in formal education throughout the world on the promise of improving physical, psychological and behavioural development of children. From a physical and physiological perspective, increased activity levels have been shown to improve cardio-vascular fitness, improve osteogenic activity and reduce the risk of comorbitities associated with sedentary lifestyles and over-weight status (e.g. diabetes). In addition to fitness gains, essential movement skills appear to play a mediating role in PA engagement and subsequent attainment of health associated benefits.

More specifically, motor coordination as been reported in research to correlate positively with academic achievement, physical, psychological and behavioural outcomes (Lopes, Santos, Pereira et al., 2012). Notably, although research has been produced to evidence the cognitive benefits of PA and motor skill development in an academic context, the research is highly confounded and correlational. Furthermore, the promotion of PL as a vehicle for improving academic output is contradictory to the holistic, whole-person importance of PL attainment. Whilst the cognitive benefits of PA engagement are not in question, surely optimal physical, psychological and behavioural development merits investment without necessitating additional curricular justification (i.e. improving academic output). Perhaps (and as discussed in Chapters 2 & 3) the inclusion of academic outcomes is reflective of a limited methods for evidencing progression in facets of PL.

Importantly,coordination levels in children negatively correlates with sedentary behaviours throughout life. Additionally, sedentary behaviour influenced health outcomes *independent* of PA level and coordination level related to PA and sedentary behaviours inversely and directly respectively (Pesce, Crova, Cereatti et al., 2009; Fong, Lee, Chan et al., 2011). The difficulties encountered by children due to poor motor coordination perpetuate decreased PA participation and as a consequence further decrease motor coordination level compared to children with normal motor development (Pesce et al., 2009; Fong et al., 2011). Thus motor coordination appears to be an important determinant of PA engagement.

In addition to physical factors, psychological skills play a key role in PL. Individuals possessing high autonomous motivation, demonstrate higher levels of moderate to vigorous activity during class, persist in mastering skills and enjoy PE more than individuals reporting lower levels of autonomous (controlled) motivation (Aelterman, Vansteenkiste, VanKeer et al., 2012). Developmentally and instructionally appropriate lessons where students have the opportunity to decide how to deploy their skills in response to various environmental constraints (e.g., task level, instructional authority, recognition, peer grouping, evaluation, and time) and importantly, increases motivation to display physical skill competence and perceived competence compared to 'free-play' or 'low autonomy' activities in pre-school children (Silva and Stevens 2002; Lawford, Ramey, Rose-Krasnor et al., 2012; Aelterman et al., 2012). Thus as discussed further in Chapter 2, it is important to provide early *structured* PE classes that allow children to experience success (and sometimes failure), set goals, make decisions and endorse PA through self-reflection on their experiences.

Notably, the behaviours required for attaining expertise are transferable across domains of excellence. For example, developing persistence, motivation and decision-making skills in motoric endeavours can be deployed by individuals to pursue excellence in other aspects of life (e.g., music, academia, business). A learning environment that is structured to foster autonomously motivated children could provide education *through* physical skills development and *of* the physical skill development. This thrust offers a robust argument in favour of PE's contribution to meeting broader educational agendas, particularly at primary level where research evidences that children learn optimally through perception and interaction with their physical environment (Newell, 2011). A key question of this thesis therefore is how early experiences in PE and physical activity should be structured in order to provide young people with the foundations in physical, psychological and behavioural skills needed for life-long PA participation.

1.2 PE in Practice?

For the purposes of this thesis, PE in Ireland is the main focus. Like many countries, Ireland's PE at primary school level is delivered by a generalist classroom teacher. An EU study (Eurydice Network) reported Ireland as third worst (of 36 countries) with reporting a 'consistently low' PE curriculum. At primary level, Irish school children have an average of 37 hours of PE a year, compared with 108 in France. In secondary school, less than 5 per cent of the school year is given over to PE, with about 45 hours allocated to PE, compared with 76 in the UK and 90 in Portugal. Furthermore a quarter of Irish children are overweight or obese and four out of five are not getting enough exercise.

1.2.1 Origins of PE in Ireland

Following the establishment of the Free State in 1922, the time for PE was cut from an hour to half an hour in the National Programme of Primary Schools and was no longer obligatory after 1926 (Duffy, 1977). There were no major developments in PE in the Irish primary schools until the 1971 Primary Curriculum was published and PE was included. The 1971 Curriculum placed emphasis on the areas of movement, games and athletics. Movement was subdivided into educational gymnastics and dance (Duffy, 1977). Clearly, movement was seen by the curriculum planners as pertinent to the PE programme, unfortunately, lack of structured programmes, lack of in service and confusion among teachers about how it *could* or *should* be taught led to game-based PE predominating (Runai & Carr, 2009).

The Revised Primary School Curriculum was introduced in 1999. The 1999 curriculum refers to children learning *through* the medium of movement. The goal for teachers was stipulated to allow children to improve personal and social development, physical growth and motor development. The recommendations were that schools introduce a broad-based curriculum that reflects children's abilities and school resources. Generalist primary teachers were considered the best suited for teaching PE, primarily to remain congruent with the rest of curriculum delivery (INTO, 2009). However, in contrast to the rest of the curriculum, formal assessment of PE was not stipulated. According to a 2005 INTO Curriculum Survey, only 93% of respondents stated that they taught PE to their classes (INTO, 2009). Despite the importance of specific PL assessment and benchmarking to successful curricular implementation, assessment remains unstandardised and often absent in PE.

1.3 PE Limitations

Whilst the importance of PE for social, motoric and cognitive development is widely acknowledged (INTO, 2007), the extent to which PE has become primarily focused on tackling the obesity epidemic must be considered. A focus on obesity reduction has resulted in a short-term, transient orientation of PE that ultimately fails to deliver the more holistic outcomes of developing competent, confident children who possess a comprehensive skill set to pursue physical endeavours later in life. In fact the substantial decrease in PA and sports engagement noted when transitioning to secondary education suggests that holistic outcomes of primary level PE are *not* being sufficiently met.

The World Health Organisation has termed a ‘global epidemic’ of obesity, consequently investment in PE at all levels has taken place: ‘In the long-term, investment in PE in Ireland makes sound financial sense in the light of the looming healthcare bill from an increasingly unhealthy and inactive population (Joint Oireachtas Report on the Status of Physical Education, 2005)’. As a result, policies have almost exclusively focused on improving PE in schools (Yancey, Fielding, Flores et al., 2007). However, increased PE requirements generally translate to more minutes of PE and do not appear to alter obesity levels or increase PA (Cawley, Meyerhoefer, & Newhouse, 2006).

Understanding the determinants of PA is an important first step in establishing *if* policies aimed *only* at increasing PA levels can be useful levers in reducing overall obesity levels or indeed promoting PE outcomes (Cawley et al., 2006). Unfortunately, policy formulation based on empirical evidence showing the impact of time spent in PA on robust motor skill learning is limited.Without sufficient assessment methods, understanding best-practice in PE curricula design has been impeded. As outlined in the Primary School Curriculum: Physical Education (1999), ‘..assessment in physical education informs teaching and learning by providing information on what children have learned and how they learn. Assessment has a formative role to play in the planning of PE lessons. Pupils can be assessed on their achievements and their readiness to progress to a new activity in order to plan further learning activities. Assessment also indicates areas of learning difficulty for the child. Early diagnosis and remediation of these difficulties can enhance the child’s confidence in approaching new skills. Assessment is helpful when grouping children so that maximum activity for each child is encouraged. Diagnostic assessment is particularly useful in physical education for the child with special needs’.

Teacher observation is the most consistently used form of assessment in physical education. According to research carried out by Drewett and O'Leary (2006) only 50% of participants in the research claimed to have read the section on assessment in the physical education curriculum, 43% rarely/never assessed in PE and only 7% claimed to have a policy statement on what should be assessed in PE. Just over 25% of participants felt confident in assessing PE in general (Drewett & O'Leary, 2006).

1.7 Summary

Clearly, PE is an important curricular subject. The funding and resources are presently in place to deliver optimal motor development for children, regardless of socioeconomic status or exposure to sports and exercise activities. It seems pertinent that the appropriateness of curricular content and effectiveness of PE interventions is a major consideration for governing bodies and teachers. Unfortunately, it appears that there is presently a disconnect between the purported importance of PE and practical application in primary schools. Notably, assessment and standardisation of PE is distinctly lacking. For PE to be optimised, empirical evidence and assessment is required. Thus the purpose of this thesis is to investigate the promotion of evidence based PE in primary schools. Specifically, this project will investigate motor skill assessment in PE as a potential vehicle for providing an empirical evidence-base in PE.

1.8 Objectives of the thesis:

The main objectives of this thesis are to:

- Critically examine the evidence base for the promotion of PE.
- Examine methods of assessment used in PE.

- Develop an empirical tool for measuring movement skills in PE.
- Undertake initial validation testing using the movement assessment.

1.9 Methods:

Objective 1: A literature-based study was undertaken to critically examine the evidence base underpinning physical education and specifically PL education. Based on the review, a number of limitations in the promotion of PL education were evident. Most notably, there was a lack of empirical and objective methods for engaging in assessment and monitoring of PL skills.

Objective 2: A mixed methods approach was undertaken to fulfill objectives 2 and 3. Following on from the first critical review (objective 1), a second systematic review was undertaken with a specific focus on the empirical assessment of PL skills. The objective was to identify potential platforms for improving empirical assessment for primary level education. To triangulate the findings from the literature review, a survey was developed and deployed to gather information from primary level teachers currently teaching in state institutes of education. The survey required teachers to provide information about their beliefs about the importance of PE and PL skill development. Furthermore, information about teachers' current practices for teaching and testing PL were examined. Finally, qualitative information about the requirements for improving the provision of PL education was gathered.

Objective 3: Based on the findings from the literary reviews and the teacher survey, a potential PL tool was developed using exergaming technology. The tool went through a number of iterative development phases including user testing and initial pilot testing.

Objective 4: Based on the initial user test, the PL tool was further refined and then deployed for reliability and validity testing in primary schools. Teacher ratings and validated movement assessments were used comparatively to establish construct validity of the PL measure. Test-retest reliability was established. Based on the results of this validation phase, conclusions and future progressions were derived.

1.10 Thesis Structure:

Chapter 2: Current models of PL education are discussed in Chapter 2. Comparatively, the scientific evidence base for long-term physical skill development and activity engagement is examined against the current practices and models used in PE. In doing so, the requirements for comprehensive PE are highlighted. The evidence for physical skill development being of primary importance in the education of life long skills is presented.

Chapter 3: In Chapter 3, methods of assessing effectiveness in PE are examined, both from a theoretical and applied perspective. A critical review of current movement assessments is undertaken. Suggestions for future development of objective assessments are made in light of the requirements for comprehensive, empirically based PL education.

Chapter 4: The potential of exergaming to provide a platform for a PL assessment is discussed in Chapter 4. Firstly, the origin and application of exergaming are examined. Then tests/tasks for measuring PL skills using exergaming technology are considered.

Chapter 5: The design of PL assessment tasks are discussed in Chapter 5. Firstly, the teacher survey study methods and procedures are described. Secondly, the results are compiled with the literature review findings to provide triangulation for the content and requirements for assessing PL learning in primary education. The key skills that appear to be essential for acquiring life-long physical skills are discussed and methods of assessing each skill using exergaming technology are described.

Chapter 6: Test development and pilot testing are presented in Chapter 6. The results of each stage of testing are presented to demonstrate the iterative processes undertaken to refine the PL tool. Testing procedures used to establish appropriate task design and progression within tasks are discussed to support the procedures of testing used in the main investigation (i.e. rate of learning, number of trials to asymptote etc.)

Chapter 7: Building on Chapter 4, Chapter 7 comprises of a critical review of the literature that was undertaken to investigate an appropriate motion capture platform that could be used to measure movement skills in PE. The industry standard marker-based systems are discussed and compared and contrasted against computer vision based methods for measuring dynamic movements. The benefits and limitations of both approaches are discussed in detail. A single case comparative study examining the accuracy of the markerless motion capture device and a lab-based marker system is presented. Finally, future potential for optimising the output of the markerless motion capture devices is discussed in the context of future directions for research.

Chapter 8: In Chapter 8, the main investigations undertaken to validate the assessment tool are discussed. Validity and reliability of the test was established using a number of different methods. Finally, test-retest reliability was established using repeated measures of the test administered during consecutive weeks.A range of validity procedures were undertaken to address one of the noted limitations of research examining physical movement assessments that fail to report the construct or criterion validity or inter/intra rater reliability.

Chapter 9: The results of the project are critically discussed in Chapter 9. The findings, limitations and potential future directions are presented. Primarily, refinements of the tool are discussed and then potential future applications of the measurement methods beyond the bounds of physical education are presented.

1.11 Conclusion

There is a substantial amount of scientific research suggesting the physical and psychological health benefits of a physically active life-style. PE is a ubiquitous and important resource for developing PA habit (Ford et al., 2012; Lubans et al., 2010). Unfortunately, it appears that there is presently a disconnect between the purported importance of PE and practical application in primary schools. Thus the purpose of this thesis is to investigate the promotion of evidence-based PE in primary schools.

As a crucial requirement for the work produced to undergo peer review, I would like to draw the reader's attention to the List of Publications included before this introductory Chapter. The list outlines the already existing peer reviewed publication output, on-going submission, and personal dissemination of findings and ideas.

Reflecting the publication direction and format consistency, this thesis has been written following guidelines of the American Psychological Association (APA 6th edition). Furthermore, to provide context and understanding, I would like to draw the readers attention to the DVD attached in Appendix 6. This DVD provide a demonstration of the PL tool software. Finally, in consideration of the need for research to be ethical, approval was granted from the university's ethics committee to carry out the work intended within all following chapters (Appendix 2).

CHAPTER 2

What is needed? Optimum preparation for life-long physical activity

2.1 Introduction

The purpose of this first literature based study was to identify factors important for developing physical literacy. The literature review encompassed the available research from motor development, physical education and physical activity domains. To source relevant available literature, electronic databases (Science Direct, PsychInfo, Wiley) were searched using the terms 'motor-skill' OR 'movement skills' OR 'motor-development' OR 'motor learning' OR 'physical literacy' OR 'physical education'. Furthermore, the literature was compared and contrasted with current programmes and policy that are purported to promote physical activity engagement and physical literacy attainment. In this Chapter, Deliberate Preparation is presented as a model through which Physical Literacy, and specifically essential movement skills could be taught in primary education settings.

2.1.1 Current practices in PE and PA promotion

Recent research in the UK suggests that nearly half of children leave school without the basic movement skills required to engage successfully in sport and physical activity (Griffith, Cortina Borja & Sera, 2013). A key question therefore is how early experiences in sport and physical activity should be structured in order to provide young people with the foundation for life-long physical activity (LPA) participation. Perhaps as a backlash to the demands placed on young children in (some) organised sport (Hancock, Alder & Cote, 2013), and reflective of the dreading of the "disappearance of childhood" (Postman, 1994), there is a growing advocacy for a play approach, with an emphasis on psychosocial rather than psychomotor development, to dominate early years participation. A common concern amongst adults is that children no longer play the way previous generations did and this, perhaps nostalgic, observation has led to calls for opportunities for children to engage in spontaneous and self-directed play. Unlike coach-led approaches aimed at instruction and the transmission of knowledge, "play curricula" are seen as child-centered and developmentally appropriate. However, the extent to which this foundation provides an effective basis for prolonged engagement in sport and physical activity is notably unsupported. The play approach appears to be built on a general presumption that movement skills and physical literacy develop naturally as a consequence of age, maturation, general movement experiences and self-discovery. However, a substantial body of research (e.g., Giblin, Button & Collins., 2014, Robinson & Goodway, 2009. Stodden, Goodway & Lagendorfer et al., 2008) highlights how structured instruction and feedback are required to ensure that essential movement skills (EMS) develop appropriately, particularly during early childhood. Importantly, EMS incorporates not just the actual competence to perform physical skills but also the psychological and behavioural skills to engage in physical activity. Notably, the interaction between actual competence and perceived competence predicts future engagement in physical activity more accurately than either alone (e.g., Barnett, Morgan, Van Burden et al., 2008). A focus on the quality of experience, rather than a misplaced emphasis on (ill-defined) play experiences should be the focus of early interventions.

Deliberate Play, described as activities engaged in during childhood that are inherently enjoyable and different from organised sport and adult-led practices, is promoted as an important precursor for long-term engagement in sport and physical activity (cf. Côté. 1999). However, the deliberate play paradigm is often misinterpreted. Allowing children to play without appropriate feedback, instruction or organisation is unlikely to result in the learning (i.e., actual and perceived competence) required to ensure prolonged engagement; children need to be supported, guided, and encouraged through a range of developmentally appropriate tasks to facilitate acquisition of, and confidence in, the skills needed for proactive and enthusiastic participation. Furthermore, the contention (Côté & Hancock, 2014) that deliberate play can make unique contributions to skill development through implicit learning certainly requires more evidence before it can be adopted with any certainty. Although children's EMS develop with age, it is important that versatile skill practice situations are provided to promote and reinforce these skills. Specifically, it is far from proven that skill levels *naturally* reach the levels which encourage or facilitate participation (Giblin et al., 2014b). In the same way that children need to learn the ABCs before learning how to read and write, they need to learn EMS before they can become skilful and confident in playing sports and other physical activities (Goodway & Savage, 2001). Acquiring and refining EMS during early childhood enables children to engage in physical activity with competence and confidence (Giblin et al., 2014a; Goodway & Savage 2001) – the essential precursors for long-term engagement. Indeed, the relationship between proficient motor skills and physical activity has been demonstrated in several cross-sectional studies (Lubans, Morgan, Cliff et al., 2010; Stodden, Goodway, Lagendorfer et al., 2008). As such, there is considerable evidence to support the teaching of EMS through age-appropriate activities within a sequential curriculum. Like reading, writing, and maths, EMS experiences need to be planned, taught, learned, reinforced, and assessed (Robinson & Goodway, 2009). This will inevitably employ some fun, as with the teaching of anything at this age, but the benefits are unlikely to spontaneously occur in an unstructured play environment. Therefore the importance of a supportive, learning environment that fosters these essential precursors of long-term engagement is crucial.

This is also more than just time accumulated in physical activity. Significant research suggests that time spent in physical activity alone is not enough to generate positive changes in children's EMS (Fisher, Reilly, Kelly et al., 2005). Instead, skill specific experiences are needed although careful consideration of the appropriateness of this experience is the vital element. The extant literature suggests that the sensitive learning period for the development of EMS is between two and seven years of age (Gallahue & Cleland-Donnelly, 2007). Reflecting this, providing young children with a broad experience in a supportive environment gives them the best chance to become successful movers – as such, it is important to recognise that children do not acquire these skills automatically as a result of the maturation process but instead it is facilitated through instruction and practice (e.g., Martin, Redistill & Hastie, 2009). EMS cannot be expected to naturally "emerge" during early childhood, at least to the level of competence needed for them to act as building blocks for later engagement, whether the individual is focused on participation or higher level performance (cf. Collins, Bailey, Ford et al., 2012). Recent research (Belanger, Sebastian, Barnett et al., 2015) suggests that type and consistency of participation during childhood is related to adult physical activity participation. Specifically, prolonged participation in organised team sports and running during childhood was shown to positively correlated to adult physical activity participation with no relationship apparent between fitness or dance activities during childhood and adult physical activity participation. Although speculative, it may be that participation in organised sports and running equipped young people with the EMS required to maintain participation through adult years, whereas the "daily dose" and participation motives associated with fitness and dance activities may not have the same long-lasting effects. The need for further research notwithstanding it seems likely that without appropriate foundations in organised sport, many children will not attain sufficient competence in EMS to be motorically competent as adults.

Clearly, the question that must be addressed is how to ensure the optimum development of EMS. For example, environmental considerations, such as the equipment used, previous experience, and instruction, may influence motor development with EMS proposed to emerge within a dynamic system consisting of a specific task, performed by a learner with given characteristics, in a particular environment. As such, a range of factors interact with the learner to influence motor skill development. A number of studies (e.g., Hamilton, Goodway & Haubenstricker, 1999) have found that disadvantaged children demonstrated developmental delays in EMS, suggesting that these delays indicated the lack of environmental support in which the children were raised and further questioning the automatic growth assumption espoused by many of the 'let them play' camp. Given these data, it is important to examine the role of intervention programs, including quality physical education and sport instruction during early childhood, in ensuring the development of EMS across populations. Notably, a range of empirical evidence supports this approach with (Kelly, Reuschlein & Haubenstricker, 1989), amongst others (Hamilton et al., 1999), reporting that typical preschool children demonstrated qualitative performance gains in six fundamental motor skills from pretest to post-test as a result of two 5-week instructional units consisting of direct instruction. In contrast, the control group, who engaged in well-equipped free play, made no significant gains in motor skill development. The solution seems obvious; for students to learn the EMS required for long-term engagement in physical activity, quality interventions using effective instruction must be implemented (Graham, Holt-Hales & Parker, 2001). However, the key consideration is that young children demonstrate various levels of motor skill competence primarily because of differences in experience. These differences are the result of many factors including immediate environment, presence of structured physical education, socioeconomic status, parental influences, climate, etc. Consideration, and exploitation, of these factors within well-structured and appropriately delivered educational systems should ensure that all (or at least as many as possible) are equipped with the skills needed to maintain their involvement in physical activity and sport, especially as these perceptions of competence play an increasingly important role in adolescence. This is an important consideration because, although there is evidence showing that four- to seven-year-old children's fundamental movement skills and physical activity are only weakly interrelated (Raudsepp & Pall, 2006), studies have shown that childhood motor skill proficiency influences adolescent physical activity and fitness (Barnett et al., 2008). Therefore, the ability to perform a variety of EMS, and the confidence in this ability, effectively increases the likelihood of children's participation in different physical activities throughout their lives (Haywood & Getchell, 2009).

Unfortunately, policy formulation, particularly in childhood physical activity promotion, has to date been predominated by two disparate perspectives. The first, psychosocially focused idea (deliberate play; Côté & Hancock, 2014) suggests a distinct focus on developing the psycho-social facets (fun, enjoyment, play) almost exclusively, with little guidance derived from neuroscience or motor development theory. Whilst the value of developing intrinsic motivation for being physically active is not in question, I argue that the sole focus on the psychosocial factors of physical development when unaccompanied by a sufficient level of physical skill learning is a limited approach. For example, play models suggest that unstructured activities are optimal for increasing activity and engagement during early childhood- however, for children lacking basic movement competence the experience of playing can frequently result in frustration or failure. Although self-exploration and internally generated feedback is an important part of skill acquisition, from a motor-learning stance even self-exploration, solution generation and feedback interpretation requires careful curricular design and delivery consideration (even if not directly provided by adults) to ensure that appropriate movement information is acquired (cf. Posner & Snyder, 1975) or even to experience the positive psychosocial benefits typically associated with play (cf. Kennedy-Behr, Rodger & Mickan, 2014). More specifically, whilst basic movements emerge before the age of four surely the aim of physical education should be to provide more advanced physical skill learning (i.e., object manipulation, interceptive timing, spatial awareness, rhythm and sequencing). In the absence of sufficient procedural knowledge during learning phases, the level, progression and adaptation of movement skills is likely to be impeded.

The second, physiological or fitness perspective places an increasing emphasis on the fitness levels of children, presumably with the assumption that greater fitness at young ages will in some way translate into a lifelong fitness habit (cf. UK Active's Generation Inactive report). Once again, but equally concerning, this premise is promoted without evidence.

2.1.2 Deliberate Preparation – equipping for lifelong physical activity

So, what is the answer? Unstructured play in the early years is unlikely to afford sufficient opportunities to develop competence and confidence and it therefore follows that children should be provided with early experiences to develop a broad range of fundamental skills as these facilitate both successful early involvement in sport (a prerequisite for prolonged engagement), as well as subsequent development either at elite levels or for personal accomplishment and progression (Collins et al., 2012).

Accordingly, lifelong participation in physical activity can derive from a robust foundation of psychomotor skills and that, for students to learn these skills, quality programs using effective instruction must be provided (Graham et al., 2001). This approach to physical activity promotion is called “Deliberate Preparation” (Giblin et al., 2014). Appropriate and well-founded generic athletic skills (e.g., locomotion, balance, strength) allow flexible movement of individuals between levels and domains of PA involvement (Collins et al., 2012).

The Deliberate Preparation approach proposes that structured physical skill development during the early years could provide a situated learning environment for students to acquire Physical Literacy. Given this, and building on the relationship between enjoyment, self-determination, and perceived competence discussed previously, the conditions of children’s sport involvement should focus on improving physical skill competence rather than short-term “activity quotas” or “just letting them play”. Unfortunately, and as discussed in more depth later (Chapter 3), in the absence of effective assessment tools there is little data on how or if such interventions work (Bardid et al., 2015).

2.3 Implications of non-standardised PE

A lack of empirical-based evidence for best practices in PE has lead to a divided approach to delivering PE within education systems. For example in the UK education system, a lack of policy stipulation leaves financial allocation at the discretion of individual institutions to invest in various options; for example, towards either specialised teacher training, *or* to employ external coaches and increase extracurricular games activities. The latter options present methods of programme delivery that have limited the effectiveness of previous interventions (Busseri & Rose-Krasnor, 2010; Busseri &Rose-Krasnor, 2009) that focusses on "activity today" approaches rather than education of LPA skills. However, research findings evidence that effective delivery of an integrative PE programme is underpinned by a *unified* system: one to which all educators, school sports and clubs can subscribe (Collins, Martindale & Snowerby, 2010; Jess &Collins, 2003; MacNamara, Collins, Bailey et al., 2011). The lack of empirical evidence could be due to insufficiencies of measurement tools available to test and track physical skill development. As a result, although substantial, the extant literature-base about effective skill-learning in PE remains correlational.

Evidence-based practice is imperative to ensuring the *efficiency* and *effectiveness* of interventions designed to promote population health (Bouffard &Reid, 2012). Governing policy in medicine, nursing, psychology, physiotherapy, and education is informed by scientific "gold-standard" protocols that optimise service provision (Leng, Baillie, & Raj, 2008). However, discrepancy appears between the research findings, policy and practice in PA promotion throughout the UK (Collins et al., 2010; Bailey, Morely & Dismore, 2009; Collins et al., 2012, Côté, Lidor & Hackfort, 2009) and similar trends prevail globally. For example almost half (49.1%)

the respondents agreed that evidence (for effective interventions) does not have major influence on decisions in PA policy in Australia (Bellew, Bauman & Brown 2010).

Development of EMS is dynamic and non-linear (Simonton, 2001, Memmert, Baker, & Bertsch, 2010) and there are multiple pathways that individuals may take as they attain Physical Literacy (e.g. sport, PA) (Ford et al., 2012, Memmert et al., 2010, Pankhurst & Collins, 2013). For present purposes, consider how multiple pathways could be catered for within a development model. PA promotion should enable individuals to seamlessly move across a participation-performance *continuum*; engaging in a physically active life at any age or level (Collins et al., 2010, Collins et al., 2012, Jess & Collins, 2003; MacNamara et al., 2011, Pankhurst& Collins, 2013). Accordingly, it is crucial for development systems to offer maximum flexibility, enabling movement across the Participation-Performance-Excellence (PPE) continuum at any age (Collins et al., 2012, Collins et al., 2010, MacNamara et al., 2011).

The focus on *quantity* in lieu of *quality* to regulate curricular content (i.e. a goal of time-spent engaging in PA) in PE seems to grate with policy in other educational realms (Scottish Executive, 2014). An exemplar parallel might be to seek to optimise literacy simply through high volume, facilitated reading (regardless of content or nature of challenge) rather than through delivery of a carefully designed, progressively challenging, validated and reviewed programme of study.

So what can be done to improve the specificity of policies that govern PE practices to provide a unified development system for PA participation? The remainder of this chapter aims to examine the current evidence base, to source explanation for the absence of empirically justified, unified policy, and to further operationalise a model that depicts the life-long skills required for dynamic engagement in the PA through PE.

2.4 Deliberate Preparation - The centrality of movement skills

A proficient foundation of fundamental motor skills is essential for developing physical literacy. Appropriate and well-founded generic athletic skills (e.g. locomotion, balance, strength) allow flexible movement of individuals between levels and domains of PA involvement (Bompa, 2000; Seifert, Button, & Davids, 2013; Collins et al,. 2012; Goodway & Branta, 2003; Starkes & Ericsson, 2003; Tucker & Collins, 2012). In addition to basic movement skills, motor coordination influences PA engagement in later life, high levels of motor coordination in childhood correlate positively with physical, psychological and behavioural outcomes measured in adolescence and later life (Lopes et al., 2012, Stodden et al., 2008). Concurrently, motor coordination levels in children negatively correlates with sedentary behaviours throughout life. Furthermore, sedentary behaviour influenced health outcomes *independent* of PA level and coordination level relate to PA and sedentary behaviours inversely and directly respectively.

Specifically, children with poor motor-coordination struggle with tasks of daily living, participate in less PA, have higher BMI and are at higher risk of cardiovascular disease than individuals with typical motor coordination development (Fong, Lee, Chan et al., 2011). These difficulties encountered by children due to poor motor coordination perpetuate decreased PA participation and decrease motor coordination level compared to children with normal motor development (Fong et al., 2011). Poor motor coordination also negatively effects physical health across the life span; children, adolescents and adults with poor coordination have lower physical fitness, increased adiposity, poor cholesterol profiles (low HDL and higher LDL) compared with their age-matched counterparts who possess normal coordination (Cantwell et al., 2008) . Finally, motor-coordination level in children directly correlates with time spent in extracurricular PA, diversity of PAs, engagement in PA (as measured by time spent in moderate to vigorous activity) during school based PE, self-rated enjoyment of PA and perceptions of ability (Fong et al., 2011). In short, motor coordination appears to be, at least, a 'strong contender' as a causative factor in PA.

There are also broader implications of poor coordination. Poor motor coordination is often coupled with poor academic achievement and cognitive deficits (Kirby & Sugden, 2007). Notably, lower motor coordination level corresponds with lower attention control and planning functions of cognition. Notably, the development of these cognitive functions during childhood can be improved through specialist-led training in PA (Best, 2012; Klingberg, Fernell, Olsen et al., 2005; Pesce, Crova, Marchetti et al., 2013). Accordingly, physical, psychological and cognitive benefits of PA participation are optimised when cognitive challenge is incorporated into PE lessons at a level that reflects the individual's motor coordination ability (Pesce et al., 2013). Children with poor coordination benefit from PAs that do not include additional cognitive demands; however, children with higher level coordination benefit more from PAs with enhanced cognitive challenge (Pesce et al., 2013). The cognitive ability to assess the environment and adapt motor skills to satisfy the demands of novel movement tasks or environments (executive functioning) provides increased opportunities to explore and display mastery in a wide range of PAs (sport, dance, exercise etc.; Seifert et al., 2011; Seifert, Button, & Davids, 2013, Wright, Holmes, & Smith, 2011).

Development of motor coordination in children requires the identification, optimisation and assessment of movement competence that account for individual differences. For example, gender, genetics, anthropometrics, physical skill level, task and environmental constraints influence coordination (Tucker &Collins, 2012). Further investigations that include empirical measures of motor coordination, sensitive to individual differences and applicable to longitudinal research, are required to enhance the evidence base beyond the cross-sectional, correlational information currently available (Lopes et al., 2012). Unfortunately, however, studies to date vary extensively in content and methodology, resulting limiting comparisons between studies to identify optimal practices.

In addition, the only empirically validated measures of physical competence (i.e., coordinative skill rather than fitness) are designed to identify motor impairment (the bottom 5% of the population) (Lubans et al., 2010). Tests often aggregate skill score in spite of the fact that different components of motor coordination influence over all coordination to varying extents. For example, gross motor coordination skills accounted for 40% of variance on discriminant measures used to diagnose dysfunctional coordination development, but fine motor and flexibility scores do not differentiate between ability levels to a similar extent (Shoemaker et al., 2012, Hands, 2013). Thus, there is an apparent lack of informative diagnostic tools capable of discriminating between movement qualities within the "normal" range and, consequently, little guidance available in relation to best developmental practice for motor-coordination.

What work has been done on the evaluation of normal motor ability has been largely related to checks for age-appropriate development. For example, the McCarron Assessment of Neuromuscular Development (MAND; Brantner, Piek & Smith, 2009) offers a norm related marker of coordination on ten broad tasks against expected averages at six monthly intervals. Interestingly, these coordination measures appear to hold some external validity; for example, scores showing close correlations with performance on novel but age-appropriate fundamental skills (Brantner et al., 2009). These are promising directions but more work is clearly needed, particularly to establish societally specific norm values and representative tests as a basis for developing an accountable motor skill curriculum. The assessment of movement and motor coordination will be discussed greater depth in Chapter 3.

2.4.1 Deliberate Preparation - Perceived motor skill competence

PE programmes require psychological and psycho-social components that cater for varying motivations, beliefs and abilities for PA engagement (Collins et al., 2010, Fairclough, Hilland & Stratton, 2012). There is significant evidence supporting the influence of early PE experiences on PA behaviours and perceptions of ability in later life (Aelterman et al., 2012; Bailey & Morly, 2006; Berry, Abernethy,& Côté, 2008; Bompa, 2000; Fairclough et al., 2012 Kirk 2005; Lawford et al., 2012; Lopes et al., 2012; Lubans et al., 2010). Individuals with high perception of competence are more likely to persist and master skills (Horn & Harris, 1996; Goodway & Rudisill, 1997; Goodway & Branta, 2003). Notably, the interaction between actual competence and perceived competence predicts future engagement in PA more accurately than the level of competence (actual or perceived). For example, individuals who either under or overestimated their actual level experienced less positive PA involvement than those accurately perceiving their ability, irrespective of level (Aelterman et al., 2012). In this regard, developmental psychology has provided significant considerations for PE. Specifically, studies evidencing that children's perception of their physical competence are high irrespective of skill level and that the mediating influence of differences between actual and perceived competence is not apparent before the age of eight (Goodway &Rudisill, 1997). Therefore, developing a proficient physical skill level to match children's high perception before the discrepancy becomes a mediating factor on their experience of PE could enhance future PA engagement. Specifically, low movement skill competence is associated with lower level of engagement in PA during late childhood and adolescence. Low PA participation increases the risk of obesity, decreases motivation and increases negative self-perception that could perpetuate further decrements in PA throughout life (Stodden & Goodway, 2007); again, this highlights the importance of *early* and well-structured education in physical skills. Studies examining models for developing youth PA participation have provided substantial insight into the concomitants that inform students' perceptions of physical ability and experience of PE. Notably, children with high perceptions of their ability and who believe that PE is worthwhile engage in more extra-curricular PA (Fairclough et al., 2012; Stodden et al., 2008). Of course, it is acknowledged that conceptual models are largely based on correlational research. Thus, once again, further experimental and longitudinal research is necessary to test the veracity of models linking physical competence, psychological mediators and PA participation later in life.

2.4.2 Deliberate Preparation -Psycho-behavioural factors

An important objective of school PE programs is to develop children who have the skills, knowledge, positive attitudes and confidence to enjoy a physically active lifestyle beyond the cessation of formal PE. Accordingly, an increasing body of research has explored the identification, development, and application of psycho-behavioural skills needed to control, exploit, or simply to cope with the varied challenges and demands faced by individuals as they pursue personal objectives in PA and PE (Collins et al., 2012; Collins et al., 2010, Fairclough et al. 2009; MacNamara et al., 2011;Whitehead, 2010).

Behavioural characteristics, such as grit (Duckworth & Quinn, 2009) e.g., goal setting, imagery, reflection) appear to play a crucial role in the realisation of potential by enabling individuals to invest the requisite time to practice, avoid distractions, and stay committed to pursuing excellence in any domain. These behaviours are even more crucial when the significant challenges of prolonged engagement in PA are considered. Indeed, such skills have already been shown to be vital in weight control in the crucial transition to adolescence (Duckworth, Tsukayama & Geier, 2010; Tsukayama et al., 2010). Young people must have the skills (e.g., coping skills, self-efficacy) to overcome associated risk factors (e.g., competing demands, lack of positive reinforcement) and steer a passage through the everyday stressors they encounter such as social and peer pressures. In essence, these psycho-behavioural skills act as a buffer against risk factors and contribute to a young person's ability to make appropriate choices about their physical activity involvement. Studies have validated the importance of student beliefs and behaviours in PE (Fairclough et al., 2012) and demonstrated the effectiveness of autonomy supportive teacher-student interactions (particularly for females) and self-determined motivations for increasing engagement in PE lessons.

Individuals possessing high autonomous motivation, demonstrate higher levels of moderate to vigorous activity during class, persist in mastering skills and enjoy PE more than individuals reporting lower levels of autonomous (controlled) motivation (Aelterman et al., 2012). Developmentally and instructionally appropriate lessons, that provide students with an opportunity to decide how to deploy their skills in response to various environmental constraints (e.g., task level, instructional authority, recognition, peer grouping, evaluation, and time), increases motivation to display physical skill competence and perceived competence when compared to "free-play" or "low autonomy" activities in pre-school children (Lawford et al., 2012; Aelterman et al., 2012). Thus, it is important to provide early *structured* PE classes that allow children to experience success (and sometimes failure), set goals, make decisions and endorse PA through self-reflection on their experiences

Notably, the behaviours required for attaining expertise are transferable across domains of excellence. For example, developing persistence, motivation and decision-making skills in motoric endeavours can be deployed by individuals to pursue excellence in other aspects of life (e.g., music, academia, business). Accordingly, a learning environment that is structured to foster autonomously motivated children could provide education *through* the physical and *of* the physical. This thrust offers a robust argument in favour of PE, particularly at primary level where research evidences that children learn optimally through perception and interaction with their physical environment (Newell, 2011). Deliberate Preparation proposes that structured physical skill development could provide a situated learning environment for students to acquire the behavioural and psychological skills that improve physical ability, perception of ability and increase appreciation of the importance of leading a physically active life (Fairclough et al., 2012). Extant models of PE (e.g. Physical Literacy - Whitehead, 2007) depict integrative development pathways for physical, psychological, psycho-social and behavioural correlates of PA. However, I suggest that a more prescriptive physical development and content-specific model (Deliberate Preparation) could provide an empirical basis for examining the development of skills required to lead a physically active life.

2.5 Benefits of Deliberate Preparation

The benefits of integrative development in PE and the limitations of focusing exclusively on physical or psychological skills is acknowledged in PE theory (Whitehead, 2001), youth participation in PA models (Dishman, Motl, Sallis et al., 2005) and action research (MacNamara et al., 2011; Jess & Collins, 2003; Collins et al., 2010; Collins et al., 2012). Although consistent in the salience of integrative physical development, conceptualisations of PA promotion vary widely in content and structure.

For example, Welk's (1999) Physical Activity in Youth Promotion model primarily focuses on the psycho-social concomitants of participation. In contrast, physical movement skills take precedence in other research Stodden et al., (2008) and Whitehead (2001). Consequently, rather than continuing the proliferation of theory formulation in research, it is proposed to proceed with a scientifically grounded action-based approach (e.g. Deliberate Preparation) that prioritises *quality* physical skill acquisition in PE at primary level. In addition, whilst Deliberate Preparation places emphasis on motor skill development, 'fitness today' approaches for increasing moderate to vigorous PA levels are also a necessary part of the strategy to combat the obesity epidemic among school age children, even though the relative contribution of current rather than preparation for future activity awaits clarification. Notably, however, PE interventions targeting solely transient fitness improvements through increments in intensity of current fitness based activity warrant caution, considering the life-long impact of negative experiences in PE, particularly for individuals with lower physical competence (Cardinal, Yan & Cardinal, 2013). A limition of the Cardinal paper is that it examined the negative impact of experiences in sport and PA on attitudes and beliefs towards PE later in life in an American collegiate cohort, thus the findings may not be generalisable to experience in education institutes on other continents. However, caution is warranted; negative experiences during poorly desinged fitness or game based PE may influence future beliefs and behaviours. While some programs designed to improve motoric competence have failed to impact fitness levels or engage children in sufficient moderate to vigorous PA levels (Lonsdale, Rozanstak, Perata et al., 2013), surely both can be achieved through well designed PE delivery.

To continue progress with practical implementation of evidence-based PE, there are a number of barriers that need to be removed. Without comparative examination between developmental strategies, the generation of scientifically supported guidelines to inform curricula from research findings is clearly limited (Ramey &Rose-Krasnor, 2012; Busseri & Rose-Krasnor 2010; Busseri & Rose-Krasnor 2009).

2.5.1 Factors limiting the standardisation deliberate preparation – movement assessments

As outlined above, holistic development (e.g. deliberate preparation) of physical skills is required to promote lifelong physical activity. Reflecting this contention, the UK, Canada, Australia and New Zealand have recently pioneered large scale initiatives in education, community and public health settings to promote participation and performance in physical activities (PA) through PL.

Given the perceived importance of PL for improving PA engagement, however, it is unfortunate that current models used to operationalise this important concept currently lack an accepted governing standard and vary in interpretation across the globe. Without comparative data to generate evidence for best-practice in developing PL skills, policies can only offer vague guidelines (Giblin, 2014b). If PL is as important as claimed (Whitehead, 2001), then a robust empirical evidence base would seem long overdue.

Echoing the arguments for valid, reliable tests of motor coordination ability reported across sub-disciplines of exercise and movement sciences, a valid measurement of physical movement competence is required to test the application of Deliberate Preparation and other conceptual models in PE (eg. PL). For example, objective measurements that meet the demands of large scale assessment will facilitate longitudinal investigations of the effect of PE programmes on PA habits in later life (Tucker & Collins, 2012; Collins et al., 2012; Lubans et al., 2010; MacNamara et al., 2011). Substantial longitudinal and experimental research is required to examine if structured physical skill development models (Deliberate Preparation) provide a comprehensive PE that translates to enhanced PA habits later in life.

Accordingly, now a critical consideration of the evaluation of PL is presented, in order to examine options for enhancing the evidence base.

2.5.2 Movement assessment variation

As iterated above, one reason for the contradicting research findings appears to be the wide variety of assessment tools employed to test the physical skill component of programmes designed to promote life-long physical activity. In the absence of a 'gold standard', the variation in methods for assessing interventions has arguably impeded the development of further longitudinal studies and led to interventions that encompass a broad variety of definitions and objectives (Giblin, 2014b). These issues are summarised through exemplar different PA programmes across the world in Table 1.

Intervention	*Objective*	*Setting*	*Assessment*	*Assessment limitations*
CS4L (Canada Sports 4 Life)	Develop physical literacy through sport and athleticism based on stages of Long Term Athlete Development model	Sports clubs & community	Physical Literacy Assessment for Youth (PLAY)	Time/resource intensive Instruction and demonstration based movement assessment
Skills 4 Sport (Northern Ireland)	Learning key movement skills leading to development of sport specific skills	Sports club & community	McCarron Assessment of Neuromuscular Development (MAND)	MAND is not suitable for assessing motor skill longitudinally due to gender, age and cultural factors mediating the validity of psychometric properties.
Start to Move (UK)	Primary schools based interventions for training teachers/ coaches to deliver PL education	Schools	Provides guidelines and training to for teachers and coaches to assess movement skills based on fundamental.	Measures fundamental movements separately. Instruction and demonstration based movement assessment.
Basic Moves (Scotland)	Basic/ fundamental movement development	Sports club & community	Test of Gross Motor Development TGMD	Summative score provided for overall skill level based on a dichotomous 'successful' or 'unsuccessful' rating of movement skills tested separately.
Kiwi Sport (New Zealand)	To develop fundamental movement skills and progress to educating modified sports specific skills	Sports club	Non-standardised ('invented') games used to test fundamental and combined motor skill level marked on rubric form for upper/ lower/body skills	Non-comparative data due to lack of standardised assessment
Nike Designed to Move (USA)	Universal programme to promote fundamental movement skills	Schools, sports club and community	Provides a database for club, community, education systems to report effectiveness.	No standardised method of assessing skill learning. Provides limited comparative data.

Table 2.1: Physical Literacy interventions and outcome assessments from 2010-2015

Whitehead's (2001, 2010) model describes the behavioural, psychological and physical components that encompass PL: Although distinct, the components of PL are inter-linked i.e. physical skills are required to utilise psychological and behavioural concomitants of PL. Notably, however, while the psychological and behavioural components have achieved some consistency of understanding, the physical component remains obfuscated by the variety of measurements used in its operationalisation. Explicit focus on physicality is a feature of Whitehead's (2001) original ideas, which categorised PL movement skills into three movement capacities (i.e. fundamental, combined and complex movement capacities). However, the exact balance of physical capacities required to attain *proficient* PL has yet to be clearly expressed. A summary of generally accepted physical movement capacities is shown in Table 2.

Simple movement capacities	**Combined movement capacities**	**Complex movement capacities**
Core stability	Poise (both balance and core stability)	Bilateral coordination
Balance	Fluency (coordination, balance and proprioception)	Inter-limb coordination
Coordination	Precision (accurate placement of the body and core stability)	Hand–eye coordination
Flexibility Speed variation	Dexterity (coordination, accurate placement and flexibility)	Control of acceleration/ deceleration
Control Proprioception Power	Equilibrium (balance, core stability and movement control)	Turning and twisting Rhythmic movement

Table 2.2: Summary of physical movement capacities (Murdoch & Whitehead, 2010)

2.5.3 What we need to measure?

A primary point is that, in the absence of evidence based guidance, programmes to provide PL education may focus (potentially erroneously) on developing *simple* movements. At first sight the attention to simple movement capacities seems sensible. Well-founded generic athletic abilities (e.g. balance, locomotion, strength) underpin almost all physical pursuits (Whitehead, 2010). Developing fundamental movement competence is imperative to perceived competence and confidence that is associated with improving and increasing PA and correlates with physical fitness levels in adolescents and adulthood (Lubans et al., 2010). Whilst basic movement skills are undoubtedly imperative, however, their role in PL education requires consideration *if* the objective is to promote higher order motoric competence. For example, neither balance (static, reactive or proactive) nor strength shows statistically significant correlations to functional performance tests (e.g. timed 'up and go') (Muehlbauer, Besemer, Wehrle et al., 2013)

Combining basic movements is essential to engage in advanced physical experiences in a variety of domains. For example, Seifert and colleagues (2013) show that adaptability and variation in combinations of motor patterns enable individuals to display mastery in previously learned movements and gain new movement knowledge from executing motor skills in a variety of *novel* combinations. Furthermore, some skills seem to be more indicative of robust change behavioural change. For example, research has shown that object manipulation and gross motor coordination skills are more predictive of PA engagement and skill level during adolescence and later in life. In contrast, locomotor ability was not indicative of future physical activity behaviours. Similarly, perception of motor competence was more closely associated with object manipulation skill level. Thus clearly the relative importance of skills is an important consideration for the delivery, design and assessment of PL education.

The point here is that the current popular emphasis on fundamental skills may not be appropriate for realisation of the benefits claimed for PL. As such, PE programmes, guided ideally by evidence, should be ensuring the development of more sophisticated elements of motor coordination (i.e. column 3 in table 2). Of course, the veracity of such suggestions awaits the development of more accurate measures of PL.

2.6 Conclusion

As outlined above, the adhoc approach to delivering PE could be due to a lack of appropriate methods of evidencing effectiveness. To understand the limitations of presently available assessments used in PE a review of outcome measure used in both research and practice was conducted. In the following chapter the findings of the review are discussed and the benefits, limitations or movement assessments are contrasted against the requirement for assessing motor coordination in primary level education settings.

CHAPTER 3

What do we need to know Movement assessments

3.1 Introduction

As discussed in Chapter 2, the importance of integrative PE that focuses on providing quality experiences within which children can learn *complex* movement skills seems to be acknowledged in research but not reflected in practice. A potential reason for this discrepancy between research-base and implementation could be a lack of appropriate methods for measuring effectiveness of physical skill learning. Therefore, the purpose of this Chapter is to consider the methods for measuring movement that are currently used in research, education and sports/PA settings. To source relevant available literature, electronic databases (Science Direct, PsychInfo, Wiley) were searched using the terms 'motor-skill' OR 'movement skills' AND 'physical literacy' OR 'physical education' AND 'assessment' OR 'evaluation'. Abstracts were examined and relevant articles were further examined if they included a measure of physical skill competence used to test physical ability in children.

The requirements for assessing the skills that are imperative to sustaining PA engagement across the lifespan are discussed. Then, the requirements are compared and contrasted to the skills currently measured today to identify potential improvements in assessment. In doing so, the content required to develop a more robust assessment of physical skill learning is presented.

3.1.1 Evaluating Essential Movement Skills (EMS)

In addition to the lack of comparative data due to non-standardised testing, skill learning 'confounds' the external validity of action-based longitudinal PL research to date (Hands, Larkin, Rose, 2013). In the context of PL, assessment should test self-regulated execution of gross motor coordination in a range of tasks to measure individuals' strengths/weaknesses, including specific evidence of learning and skill progression to track development over time. However, movement assessment batteries most commonly used in research were designed to test for motor development impairment (Schoemaker, Niemeijer, Flapper, et al., 2012) . Thus, these typically focus on the basic requirements for reproducing simple movement components.

Assessment batteries use either 'product' or 'process' focused methods to examine movement skills. Product focused measures offer objective information indicating the time taken or the number of trials an individual needs to successfully complete a predetermined task (such as the Movement Assessment Battery for Children: "M-ABC"). Such tests constrain movement to set time, space and procedural parameters. Product focussed assessments have been criticised for lacking the sensitivity required to detect individual differences in movement abilities considering the idiosyncratic nature of optimal motor pattern execution (Brisson & Alain, 1996).

Process orientated assessments examine movement quality and provide valuable movement data: however, reliability confounds are present due to the influence of assessor experience and subjectivity on test scores. Also, environmental constraints influence testing procedures (equipment used) and the performance of the individuals being assessed (e.g. assessor relations, noise, audience observation etc.). Despite their clinical origin, these movement analysis procedures are increasingly adopted in education and sports settings as a general assessment of motor ability by coaches, teachers and researchers. In order to illustrate the nature of some of these tests an overview of the applications, weaknesses and structure is provided.

3.1.2 M-ABC

The Movement Assessment Battery for Children is designed to test children with movement difficulties (Henderson & Sugden, 1992). The test includes test procedures, a checklist for teachers and guidelines for interventions to address deficiencies identified using the test (Henderson & Sugden, 1992). The MABC was preceded by the Test of Motor Impairment, and both utilise normative data from the USA, Canada and UK. The normative data used in the most current MABC version is derived from an American cohort. The MABC takes 20-25 minutes per child to administer and is designed for use in children aged 4-12 years. The test comprises of 32 items divided in to 4 sets. The first set of items are labeled age band one and are designed for 4-6 year olds. The second set (age band 2) are designed for 7-8 year olds. The third set (age band 3) are designed for 9-10 year olds and the final set are designed for 11 year olds. Each age band includes three hand-based items. Two items that require throwing and catching of a small ball and three static and dynamic balance items. A noted limitation of the test is the absence of integrating these skill components. Measuring skills in isolation is not indicative of the skills necessary for use in PA or sports. During sport and activity, movements are complex and require flexible adaptation and combination of a range of movement competencies.

The MABC can be scored in a number of ways. Raw scores for the task are recorded and these raw scores are then converted to scaled scores to assess the child's ability in relation to a standardised sample. The transformation of scores can be done on an individual basis for each skill subset or as an aggregated total. Again, a noted limitation of this approach is the failure to address the relative importance of each skill subset. The sensitivity afforded through the scoring of the MABC is questionable; the recommendations made in the MABC manual are that children whose scores fall in the bottom 5th percentile of the standardised norm values have a motor deficiency and that those scoring within the 10-15th percentiles have a degree of difficulty that may require additional monitoring. Thus discrimination of higher ability children is not catered for in this test.

3.1.3 Koperkordinations Test fur Kinder

The Koperkordinations Test fur Kinder (KTK) was standardised in Germany and focuses exclusively on gross motor coordination (Kiphard and Schilling, 1974). The KTK takes 15-20 minutes per child to administer. The test is designed for children aged 5-15 years. The KTK includes a set of four movement tasks that were selected to differentiate between normal and deficient movement performance. Each movement task is loaded on a factor called total body coordination. The four test tasks are:

1. Walking backwards on a balance beam - the number of successful trials are recorded.
2. Hopping for height - the child hops single leg over a foam barrier. Height can be increased as required. Time taken is recorded.
3. Jumping sideways as fast as possible requires the child to make 15 consecutive jumps sideways and time taken is recorded.
4. Moving sideways on boxes requires the child stand on a box, holding a second box. The child places the second box in front of the first and moves on to it. The child then takes the first box and transfers it up and over. The sequence is repeated and number of successful trials are recorded.

Similar to the scoring of the MABC, the KTK can be scored in a number of different ways, for example, the raw scores are recorded and scaled scores are recorded. The test provides norm values for children at yearly intervals. For three of the four tasks different norm values are presented for boys and girls. Norm values for three different standardised groups are provided (normal, learning disabled and 'brain dysfunction'). Percentile scores are provided for 15th and 3rd percentiles. Again, limitations of testing movement ability in this way include the discrete measurement of movement tasks, the time and resource constraints and importantly the orientation of the test to differentiate between normal and pathological movement not to evidence skill learning.

3.1.4 TGMD-2

The TGMD-2 has become widely used throughout research for assessing the effectiveness of physical development programmes. In fact, this was one of the main objectives behind developing the shorter, process orientated assessment. The TGMD-2 purports to measure the movement skills that are required for normal motor development. As outlined in the TMGD2 manual, and researched in developmental psychology, motor developmental level is associated with cognitive and social development. As well as showing lower cognitive function, children with poor motor skills are often subjected to negative experience when engaging in physical activity and negative peer evaluation. Often, the outcome of poor physical competence and negative peer comparison is poor perceived competence and decreased self esteem. Thus the TGMD-2 was designed to detect those with poor movement competence in order to provide PE teachers with a method of tracking children's development. The inclusion of process orientated outcomes differentiates the TGMD-2 from other movement assessments that rely solely on performance outcomes. Ulrich (1998) reports that the inclusion of process orientated factors provides information about how a child moves that can be incorporated in to the formation of individualised educational programmes to address specific element of physical development on an individual level. Whilst the premise of individualised assessments that provide information about movement quality is not in question, arguably, the TGMD-2 is limited in the amount of information that can be garnered from the scoring system deployed in the test. Children are marked on twelve skills encompassing the locomotor and object control skills that are pertinent to everyday movement (i.e. transportation of centre of gravity, sending/receiving a ball). The skill is marked by observation on a rather dichotomous scale of 1- 0, able, not able, according to a list of criteria per task (e.g. arms bent and lifted at waist level).

3.2 General limitations of movement batteries

The validity, reliability and sensitivity of applying battery assessments to test movement are limited without considering the contextual inferences of the test (Larsen & Quennerstedt, 2012). In the context of an appropriate movement-based PL assessment, the current batteries have a number of limitations. For example, the Test of Gross Motor Development 2nd edition (TGMD-2) provides a summative score for the performance of separate motor skills: The individual receives a score of 1 if the skill is completed and 0 if not. This seems a rather 'black and white' but contrastingly subjective evaluation of a surely continuous variable! The TGMD-2 also constricts movement skills to a specific context i.e., a skill level deemed fundamental for normal motor development. Skills considered fundamental to PL development should surely include more complexity and sophistication.

3.2.1 Prescribed movement tasks

It is arguable that the predetermined movement tasks constrain the assessment of skill to very specific movements, rather than reflecting the ability to adapt, transfer and deploy self organised skills to meet a movement goal. This ability is an essential parameter, widely researched in motor skill learning and motor development, that appears to be largely ignored in the production of movement assessments for learning. For a movement test to measure motor skill learning, the parameters identified as indicative of skill learning are speed and accuracy; a shift in the speed accuracy profile of skill execution improves with increased skill level. The improvement reflects changes in movement representations that are associated with practice and consolidation. Although the understanding of the operating mechanisms underpinning the changes in motor execution associated with learning require further investigation. What is known about motor skill learning shows that improvements of skill are dependent on skill type. For example, changes in the 'selection' phase of skill execution are associated with learning in serial reaction time tasks (e.g. interception). For discrete sequence production tasks (pattern recognition), a combination of selection and execution learning takes place, whilst most movement skill learning requires improvement in both selection and execution neural networks. Unfortunately, movement assessments that are highly prescriptive and measure single execution of movement skills fail to test a persons ability to interpret a movement task and self select appropriate skills from their repertoire to meet the demands and then the level of success with which they deploy their movement skills. Further the amount of 'learning' that can be demonstrated in highly prescriptive tests is questionable considering the evidence that shows expertise in movement is acquired and developed in a nonlinear and idiosyncratic manner (Seifert, Button & Davids, 2012).

The context of movement ability remains constrained by set tasks and performance criteria throughout a number of battery tests. The M-ABC focuses on measuring balance, manual dexterity and ball skills using quantitative outcomes of trials completed within set boundaries. Take, for example, the object manipulation task, which provides information about an individuals' ability to throw a tennis ball in a certain predefined way (overhand). Notably, however, it does not depict a generalisable motor ability (i.e. the motoric competence required to adapt movement skills and throw an oval-shaped ball underhand). As highlighted earlier, these tests were originally intended for use in clinical setting as a discriminative measure to characterise motor *deficiency* (Deitz, Kartin & Kopp, 2007).

Movement assessments predominantly involve skill-instruction guidelines or a demonstration by the tester prior to assessment (Janssen, Diekema, van Dolder et al., 2012). As such, these tools provide results that *may* be more indicative of a demonstrator's expertise and/or a child's mimicry skills than the individual's knowledge, level and understanding of movement skills. This is not to say that reproducing a demonstrated movement is not an important component of PL; however, it is also not representative of an individual's ability to interpret task demands and select appropriate movements from their repertoire of motor competence in response.

3.2.2 Subjective bias

Secondly, the amount of test error is inflated by subjective bias, the amount of variation present between scores can be substantially influenced by rater experience. The extent to which the TGMD-2 measure an individual ability to coordinate motor skills, rather than simply reproduce a gross motor movement is questionable. Reliable methods to test coordinative ability are paramount to assessing PL.

3.2.3 Ecological considerations

There are also a number of pragmatic issues associated with the various tests. For example, the time requirements to perform individual assessment compromises practical application in schools settings. The M-ABC takes 20-25 minutes to test per individual and requires administration in a separate room (Cools, Martelaer, Vandaele et al., 2010). Additionally, norm-based movement tests lack the flexibility required to monitor individual-specific progress in motor skill learning that varies as a function of age, gender and cultural factors (Hands, Larkin & rose, 2013, Larson & Quennnerstedt, 2012, Venetsanou, Kambas, Aggeloussis et al., 2009). As a cross-cultural example, the McCarron Assessment of Neuromuscular Development is a norm-based assessment originating from the US that has limited validity when used to test movement ability of Australian cohorts (Hands et al., 2013).

3.2.4 Weighting of movement constructs

The validity of assessments is further contested by a lack of consideration for the *relative* importance of factors contributing to physical proficiency. Reflecting earlier comments, whilst developing a fundamental base of movement skills is essential, proficiency in combined and complex movement capacities are surely more imperative to becoming physically literate. Attaining sufficient competence in basic movements provides individuals with the motivation and perceived ability to participate and progress in PA (Stodden et al., 2008, Lopes, Santos, Pereira et al., 2012). However, some movement skills impact on future progression and participation in PA to a greater extent than others. Gross motor-coordination accounted for 40% of the variance detected on discriminant tests used on children with and without motor impairment (Schoemaker, et al., 2012), whereas individual scores for flexibility, fine motor skills or locomotion did not show any significant relation to future levels of PA (Lopes, et al., 2012) or overall scores of motor ability (Schoemaker et al., 2012) . However, motor skill assessments often aggregate components together in an unweighted total; i.e. each factor is treated as important as the next, even though some components are measured more often and, therefore, make a bigger contribution. Additionally, motor skill assessments typically require individual administration, demonstration and equipment making them challenging to implement in practical settings. As an example, the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) (Deitz et al., 2007) is an individually administered, norm-based measure of fine and gross motor skills used to assess skill development. Finally but no less important, all of the evaluations which I have reviewed fail to test an individuals' ability to evaluate a task, then combine and adapt motor skills to novel environments, clearly a major expected feature of those presumed to be high in PL (Whitehead, 2010).

3.3 Quantity-based methods used to evaluate PE

In the absence of ecologically valid movement assessments for use in education of physical activity interventions, a number of other methods for measuring effectiveness in practical settings have prevailed. For example, amount of time spend engaging in physical activity is a common metric used to examine whether PE or a PA intervention has been successful. The premise being that following a period of successful PE, amount of time spent in PA will increase. Typically either self report or objective based methods such as accelerometers are used. Self-report of PA engagement has obvious subjective limitations and the quality of data extrapolated from such review of PE or PA programmes are questionable. To reduce subjective bias, objective methods used to measure time spent in PA have been introduced. Accelerometer measure the amount of time spent moving. Noted limitations of such devices include the ability too falsify movement. Equally movement recording is constrained to the number of times the centre of mass oscillates (deemed representative of stepping motion). The type or intensity of movement is not taken in to consideration. Importantly, the use of quantity based measure of PE or PA provide no quality information of movement skill proficiency.

3.3.1 Weight and Motor Coordination

BMI and anthropometrics is an inverse association between adiposity and motor coordination, i.e., overweight and particularly obese children display markedly poorer performance and are less competent in motor tasks requiring support, propulsion, or movement of a great proportion of body mass compared with their normal weight counterparts. For example, D'Hondt and colleagues (2013) investigated the short-term change in the level of gross motor coordination according to children's weight status, and concluded that participants in the normal weight group showed more progress than their overweight/obese peers, who demonstrated significantly poorer performances.

BMI is the most common anthropometric measure used in studies relating to adiposity status and motor coordination. BMI is a suboptimal marker of body fat because it does not distinguish fat from lean tissue or bone; therefore, classifying people as overweight or obese based on their BMI alone may lead to significant misclassification.

3.3.2 Implications of limited PL evaluation

The empirical evidence base supporting PL depicts contradictory findings that, I suggest, reflect either a flawed construct of PL or, more likely, inappropriate use or interpretation of movement data. If the primary objective of PL education is *life-long* physical activity (facilitated by physical proficiency), not immediate fitness gains, the outcomes of PL development initiatives should reflect these aims. Clearly, the behavioural, psychological and physical components of PL are (theoretically and practically) distinct *but interlinking* constructs. Integrating evaluation of the constructs should provide a more accurate assessment of an individual's PL ability. Therefore, as iterated in our earlier arguments, an *appropriate* physical skill evaluation is required to meet the objective of integrated monitoring in *all* parameters of PL education.

Researchers have addressed the need for standardisation and clarification between measuring tools that report the same objective but which, confusingly, provide different information (Logan, Robinson Rudisill et al., 2010). Process-focussed qualitative movement tests that provide standard definitions and descriptions to guide the tester and reduce subjective bias have also been developed (Janssen, Diekenna, van Dolder et al., 2012). However, important movement capacities have often been omitted from qualitative measurements due to difficulties in observing certain characteristics (e.g., movement fluency). A possible caveat of including complex movement skills in evaluations is increased measurement error that reduces test reliability. Careful refinement will be required to produce reliable assessments of complex movement skills. Nonetheless, it is suggested that such efforts must be made in order to generate a valid and meaningful tool.

In short, research is required to establish appropriate procedures for testing movement ability that provide empirical monitoring on micro (individual) or macro (intervention) levels. This, in turn, should generate valid, reliable measures that reduce demands on resources without compromising the quality of data measured.

3.4 Requirements for enhancing PL Evaluation

Currently, the movement battery assessments used do not coherently link test outcomes to the objectives of PL education as conceptualised by Whitehead (2007, 2001). Specifically, the movement capacities that demonstrate deep and meaningful learning of physical skills are neglected. Some assessment batteries use facilitate assessor ease but provide limited information that lacks objectivity and largely focuses on basic movement abilities. Ecologically viable and objective measures are required to produce an empirical evidence base.

3.4.1 New directions in movement assessment

As a new direction, and in order to address these various issues, I suggest that movement assessments which use commercially popular motion capture systems (e.g., Microsoft Kinect, Nintendo Wii, etc.) could provide a potential solution. exergaming is a portmanteau of exercise and gaming used to describe video games that require physical body movement to engage in gaming activity. The exergaming phenomenon has become a recent focus of research in physical health, leisure (Best, 2012, 2013, Sheehan & Katz, 2010, 2011, 2013, Biddies & Irwin, 2010) and clinical (Klingberg, Fernell, Olsen et al., 2005) contexts, albeit with mixed results. These issues notwithstanding, however, the exergaming technological platform may provide objective, accessible and sensitive methods of monitoring learning in the context of becoming physically literate, even if their potential as exercise stimuli is more limited. Furthermore adopting similar methods to assess movement in PE could potentially provide an ecologically valid, and child friendly/accepted measure to test the effectiveness of PL programmes. The rapidly increasing popularity of exergaming across the globe could provide a means of assessing and tracking motor learning that can be used comparatively across nations to establish an evidence-based protocol for designing and delivering quality PL education. Clearly, incorporating the assessment of physical skills in to a game format is optimal for learning. Notably, one of the key tenets of Teaching Games for Understanding is to create a self-rewarding environment for individuals to learn (Vernakadis et al., 2012); poor performance on a 'gamified' assessment could result in autonomously regulated incentive to improve and progress in the game. Therefore, the negative connotation with poor performance in tests and (potentially) confidence thwarting peer comparisons that are often associated with traditional forms of assessment could be negated. Exergaming in education originally received mixed reviews (Sheehan & Katz, 2010, Vernadakis et al., 2012). Concerns about the validity of employing video-game technology to promote real-life physical activity was debated, similarly the ability for exergames to induce sufficiently demanding physical engagement to meet the recommended requirements for health related benefits of physical activity engagement. However, a recent study has highlighted interesting developments in the application of exergaming technology for the assessment of movement in education settings (Reynolds, Thornton, Ley et al., 2014): Statistically significant correlations were observed between the Movement Assessment Battery for Children 2nd edition (MABC-2) balance and exergaming sprint and target kick performance. In this study children who scored better in real life gross motor movement tasks performed better in most related exergaming activities. This suggests current exergaming technology has advanced to a point where body movement unencumbered by a physical or remote game device-tether can extract movements resembling real life tasks, translate them into game play and reward proficient movers with higher in-game performance. It is noted that benefit gained in an exergaming environment by more proficient movers was a result of either their more proficient movement, or a greater ability to adapt to the exergame. Thus further validation research is required to establish the correlations between real-life movement ability and exergame movement evaluation.

3.4.2 Progress in assessment standardisation

The Centre for exergaming Research Canada (CERC) and CS4L have recognised the potential of exergaming technology to provide enhanced education, compliance, motivation and commitment to PE compared to traditional PE models, (Sheehan & Katz, 2010, 2013). However, the impact of exergames on PA levels and fitness vary depending on game design and PA parameters measured. For example, studies found that exergames designed to improve movement skills (e.g., balance) or using upper-limb only movement induced light-moderate PA levels (Sheehan & Katz, 2013, Biddies & Irwin, 2010). In contrast, exergames designed to engage whole-body movements (Dance, Dance Revolution) resulted in moderate-vigorous activity levels, energy expenditure and heart rate increases equal to traditional PA engagement (running) (Biddiss & Irwin, 2010). Exergames also improved functional fitness in overweight children (Biddiss & Irwin, 2010), although increased traditional PA and exergaming PA correlated with increased sedentary behaviour and no significant differences in overall activity levels compared to control groups (Sun, 2013).

In addition to the physical component, exergaming impacts the psychological and behavioural aspects of PL: 'On-line' visual feedback provides the opportunity for intrinsic task correction to facilitate motor-skill learning (Olivier, Hay & Bard, 2007). Motivation and enjoyment of PA participation increased through exergaming interventions compared to traditional PA particularly in 'at risk' populations (Sun, 2013, Biddiss & Irwin, 2010).

Given these mixed outcomes, the effectiveness of exergames as a means of increasing PA clearly requires further research. However, as stated above, the use of exergame technology could provide an appropriate method for assessing movement competence. Low-cost motion capture devices used in PE could enhance the quality of movement testing procedures, provide individualised, detailed feedback and allow longitudinal data-gathering to monitor motor-skill development. Exergames currently used in education evaluate markers of physical fitness (BMI) or simple movement capacities (balance, postural stability) (Olivier et al., 2007). Exergame technology provides scope for testing (and teaching) all PL parameters (behavioural, psychological and physical) across a range of levels (fundamental-advanced). Clearly, further longitudinal research is required to establish the optimal design of exergames used to educate and evaluate PL skills.

3.5 Conclusion

Adequate physical movement assessments could provide a more robust evidence-base to support the PL construct. Combining the advances in understanding in neuroscience underpinning physical skill learning and expertise with exergaming technology could provide accessible, appropriate methods for both teaching and monitoring PL education.

Some progress is evident. The current standardisation of monitoring methods (Keegen, Keegan, Daley et al., 2013) shows progressions in optimising evidence-based PL education. However, further development within PL education using exergaming programmes could improve the measurement of movement skills that reflect skill learning in *all* PL parameters and provide valid and comparable empirical data to assess effectiveness in PL education. Further research is required to examine the effectiveness of exergaming applications for providing meaningful skill learning that reflects PL objectives. Such empirical evidence is required to test the validity of both PL and exergaming for providing optimal physical education.

In the following Chapter (4) the concept of exergaming used in education is examined in more detail. A specific focus on the use of exergaming technology to measure movement skills, with a specific focus on the key physical requirements for becoming physically literate i.e. motor coordination are considered.

CHAPTER 4

Exergaming Potential

4.1 Introduction

As suggested in Chapters 2 & 3, exergaming technology could provide a platform upon which to build and validate an objective PL assessment tool. The purpose of this chapter is to investigate the origins and applications of gaming technology in educational settings. Furthermore, the potential of exergaming technology for enhancing PE assessments in primary school settings is considered.

Notably, as discussed in Chapter 3, the main limitations in current movement assessments are heavy time/expertise requirements and the lack of valuable quality information/feedback important movement factors such as motor coordination. Computer vision technology could offer an objective, resource-efficient method of delivering appropriate movement evaluations by primary school teachers. The application of computer vision in gaming technology is presented as a potential for delivering PE assessments in primary school settings. To present the argument for exergaming technology in PE, factors of PE assessment (e.g. movement factors, learning), PE experience (e.g. enjoyment, perceived competence, autonomous regulation and teacher confidence) and exergaming (e.g. benefits, limitations) and are considered in the context of gaming approaches used in education.

4.2 Exergames and PE assessments

Computer vision involves the automatic extraction and analyses of useful information from an image or a series of images. Derived from machine vision, computer vision replicates the function of the human eyes and brain to make visual sense of the world. Computer vision uses hardware (e.g. cameras, computers) and software (algorithmic extraction) to provide information about the world presented in the field of view. Exergaming technology has emerged that includes computer vision functionality specifically tracking human movement (i.e. Microsoft Kinect). Exergaming is a portmanteau of exercise and gaming used to describe hardware and software that incorporates human movement and natural user interaction to control and interact in computer games.

It has been suggested that exergames could offer a positive buffer to the negative affiliation of sedentary activity associated with computer gaming as a pass-time. However, research showing the impact of exergames on activity levels and sedentary behaviour is contrasting. Some studies show that exergames promote activity during gaming to a greater extent than traditional computer games. Unfortunately, studies do not show the transfer of exergaming tasks to real-life activity, or indeed contrast the activity level sustained during exergaming compared with traditional physical activity or sport. Exergames utilise hardware such as platforms (e.g. Dance Dance Revolution) or remote control tethers (e.g. wii) that allow the player to input information using body movement and gestures. The Microsoft Kinect has progressed exergaming motion capture to provide a tether-less experience that requires no platform or external control i.e. a natural user interface between the human and digital realms. The Kinect camera simply tracks a human shape that is presented in front of the device, allowing marker-less interaction.

The capacity of the Microsoft Kinect offers scope for the development of cost-effective motion capture systems and warrants further consideration: Motion capture (the process of recording the movement of objects or people) to date has been used in military, entertainment, sports, medical applications. In the domain of human movement and biomechanics, motion capture has largely involved the use of marker-based camera systems (e.g. Vicon or Qualysis). Indeed, motion capture and analyses using marker based systems has become the reference standard for understanding and tracking human movement. Largely used in clinical settings, human motion capture plays a prominent role in rehabilitation environments. However, a limitation of the clinical application of motion capture is the resource, expense and expertise requirements. The use of motion capture systems is thus often restricted to research and clinical settings. The proliferation of lower cost motion capture systems (e.g. Microsoft Kinect) provides a method of transferring movement tracking and analyses to wider populations. Although in preliminary stages, low-cost marker-less motion capture as a method of measuring movement function offers optimism for future development and progression of PE-based movement assessments:

4.2.1 Gamified tests for education

From an educational perspective, one of the key tenets of Teaching Games for Understanding is to create a self-rewarding environment for individuals to learn (Vernakadis et al., 2012). A gamified movement test could provide student with crucial feedback and incentive to improve the physical skills in PE. Unfortunately, PE has suffered from a lack of objective and standardised assessment (as discussed in Chapter 3). A potential limiter for applying assessment in PE (as highlighted in teacher reports discussed in Chapter 5) is fear of demotivating children or encouraging negative self perceptions amongst peers. However, well designed games could provide appropriate assessment methods as well as encouraging fun, enjoyment and competition.

Gaming methods have been used effectively as an auxiliary motor learning tool in the classroom. For example, a school for students with special needs ‘De Ruimte’ in

Holland, uses Microsoft Kinect for rehabbing students' motor skills in special needs education. The school claims that improving students' motor skills is part of increasing autonomy and citizenship inside and outside school situations. Students who participated in this project experienced dynamic balance and physical fitness problems. According to the school, learning by using Kinect results not only on the improvement of students' motor skills and their motivation, but also appeared to ensure a longer attention span. Therefore, incorporating the assessment of physical skills in to an exergame format could provide a positive testing method for use in the classroom.

4.2.2 Games in Education - what has been done so far?

Serious games initiatives (Jenkins, 2006) have focused on using games to provide deeper learning in the context of an enjoyable experience. Serious education games can include complexity to extend beyond knowledge acquisition by providing enriched learning opportunities that require exploration, problem-solving and incidental learning. Additionally, children's play is inextricably linked with learning. One of the main mediums for play in childhood is through physical exploration. Thus physical gaming experiences could provide educational, enjoyable experiences that engage children while exercising, experimenting and expanding their physical skills.

Exergaming in education originally received mixed reviews (Sheehan & Katz, 2010, Vernadakis et al., 2012). Concerns about the validity of employing video-game technology to promote real-life physical activity was debated. Similarly, the ability for exergames to induce sufficiently demanding physical engagement to meet the recommended requirements for health related benefits of physical activity engagement was challenged. However, a recent study has highlighted interesting developments in the application of exergaming technology for the assessment of movement in education settings (Reynolds, Thornton, Ley et al., 2014): Statistically significant correlations were observed between the Movement Assessment Battery for Children 2nd edition (MABC-2) balance and exergaming sprint and target kick performance. In this study, children who scored better in real life gross motor movement tasks performed better in most related exergaming activities. This suggests current exergaming technology has advanced to a point where body movement, unencumbered by a physical or remote game device-tether, can extract movements resembling real life tasks, translate them into game play and reward proficient movers with higher in-game performance. It is noted that benefit gained in an exergaming environment by more proficient movers was a result of either their more proficient movement, or a greater ability to adapt to the exergame. Thus, further validation research is required to establish the correlations between real-life movement ability and exergame movement evaluation.

According to Hsu and colleagues (2013), Kinect as a teaching tool has the ability to enhance classroom interaction and increase the opportunities for student participation, since it supports the idea that the pedagogical strategies should encourage student participation in interaction with contents via body movements, gestures and voice without the use of a keyboard or mouse. Progress has been made in investigating the potential for the application of low cost motion capture in assessing movement (discussed in greater detail in Chapter 6). For exergames to be accepted and integrated by educational bodies, however, further empirical evidence is required. Additional rationale for inclusion in formal education settings must substantiate exergames utility beyond the bounds of increased motivation and enjoyment often associated with any novel applications. Thus the extent to which exergames could provide a useful tool for education in primary schools (specifically for PE) is now considered in further detail.

4.3 Teacher influence in PE:

The use of exergaming could be particularly pertinent for education systems where formal qualifications in PE are not requisite and physical curricula are taught by generalist teachers (e.g. primary level education through-out the UK and Ireland). The pre-prescribed goals determined by the game parameters could provide a more enriched learning experience for students compared to traditional teaching methods. For example, the design of gaming parameters can pedagogically draw upon expertise from multidisciplinary professionals including teachers, movement specialists, sports coaches, and cognitive and educational psychologists. Exergame media could ensure appropriate PE lesson structure, a key factor in motor skill development, where it is necessary to gain proficient, correct movement patterns to avoid increased incidence of movement dysfunction or negative psychosocial implications of poorly conducted PE classes.

The predetermined prescription of PE tasks through appropriately designed exergames could also reduce the often constrained or negative influence of teacher-experience and perception of sport and exercise on children's experience of PE: Teacher confidence has an impact on students' perceptions and enjoyment of PE and plays an important role in shaping the beliefs and attitudes towards physical activity and level of engagement during childhood and later in life. Furthermore, teachers' beliefs, attitudes to physical activity and personal sport experience have been found to influence the quality of PE experiences they provide in the classroom (Morgan & Bourke, 2008). Generalist primary school teachers can be influenced by amount of training, quality of training and their own person preferences for sports in PE. Thus, to ensure that children are provided with standardised, quality assured PE, teachers require appropriate tools for teaching and testing to aid their provision of comprehensive PE.

Additionally, consider the responsibility placed on teachers without specific PE qualifications by government policies implemented internationally (e.g., Australia, New Zealand, Ireland, UK) where primary level physical education is provided by generalist primary teachers. Studies conducted in New Zealand (Constantinides, Montalvo & Silverman, 2013), examining the quality and content of PE provision by specialist and non-specialist teachers in elementary schools, showed distinct differences in the quality of PE experienced during specialist and non-specialist led classes. Non-specialist teachers engaged children in less than half the amount of appropriate tasks during a specific motor-skill development lesson compared to specialist lead classes. As such, monitoring the quality of PE provided to children is imperative for generalist teacher-lead PE to ensure that positive attitudes and adept motor skills are sufficiently developed according to the individual requirements of each child.

As mentioned above, exergaming technology could provide a method of transfer expertise from movement science and neuromotor development (i.e. specialist) domains to the generalist primary school teacher's classroom. Teacher training has been found to be more pertinent than confidence or experience of movement skill testing/learning (Lander, Bartnett, Brown, Telford, 2014). PE teachers (n=168) were included in the Australian study only half (49.6%) had received more than several FMS lectures/ tutorials during their degree. Many (69.9%) had undertaken no more than four hours of professional development in Functional Movement Screen (FMS) since finishing their degree. Most (97.9%) did assess the FMS proficiency of their students. However, of those that did, the assessment quality was variable: 43.8% did not use the 'ideal' assessment tool, and only just over half (56.2%) assessed regularly enough. Neither years of experience nor confidence level influenced assessment practices. However, the more training a teacher had in FMS, the more likely they were to use the ideal assessment frequency (t = 4.16; p = 0.000) and processes (t = 1.54; p = 0.002) (Lander, Bartnett, Brown, Telford, 2014).

4.3.1 Capacity to programme difficult to teach/test tasks

In the absence of evidence based guidance, PL programmes have focused on the fundamental movements as described in previous chapters. Whilst basic movement skills are undoubtedly imperative, their *fundamental* role in PL education requires consideration if the objective is to promote higher order motoric competence, arguably the essential component for lifelong physical activity. For example, neither balance (static, reactive or proactive) nor strength show statistically significant correlations to functional performance tests (e.g. timed 'up and go'). Combining basic movements is essential to engage in advanced physical experiences in a variety of domains. For example, Seifert, Wattebled, L'Hermette, Bideault, Herault and Davids (2013) show that adaptability and variation in combinations of motor patterns enable individuals to display mastery in previously learned movements and gain new movement knowledge from executing motor skills in a variety of *novel* combinations.   The point here is that the current popular emphasis on fundamental skills may not be appropriate for realisation of the benefits claimed for PL. As such, PE programmes, guided ideally by evidence, should be ensuring the development of more sophisticated elements of motor coordination. As described in Chapters 2 & 3, motor coordination appears to be an important facet of developing motor proficiency: Motor coordination is a stable and predictive marker of physical ability. Individuals processing high motor coordination level during childhood demonstrate high coordination during adolescence (Dardouri, Selmi, Sassi, Gharbi et al., 2013). The trend is continuous for medium and low coordination levels. Selecting a *stable* marker for measurement is important considering that unstable factors are heavily influenced by training and previous experience, thus potentially confound the inferences from studies examining learning outcomes from PE interventions.

Technology is available to gather the data, input and process the variables in real time using carefully designed movement patterns and coordinative ability tasks: Exergame testing using software based programmes where children must interpret and respond to affordances presented in the virtual environment could provide a measure of the subtle interactional dynamics that influence movement during sport. Notably during multi-agent team sports, individual's action goals are always linked and in some way shared with others (Meerhoff & Poel, 2014). Therefore the movement behaviour of individuals cannot be conceptualised independently of affordances (players/ environmental). Simulation-based movement assessments could provide a more accurate depiction of a child's ability to interact in physical activity and sports setting by incorporating visual behaviours (i.e. scanning) and perceptual coupling between an individual and virtual environments presented on screen.

4.4 Psychology and Exergame technology

Self-determination theories and flow states are commonly used to explain desirable affective, cognitive, psychological and physical experiences in sports and exercise research, describing intrinsically motivating experiences that have been used to explain how players enjoy gaming experiences: The game-flow model (Sweetser & Wyeth, 2004) describes a state of higher order pleasure that is dependent on eight factors (concentration, challenge, skills, control, clear goal, feedback, immersion and social interaction). The game flow model also depicts the mediation of flow experience by game elements. Clearly there is overlap between serious gaming experiences and flow experienced when engaging in physical activity and exercise.

Such states are often difficult to replicate in physical education or sports training, however, due to the negative impact of social evaluation, presentation anxiety, and fear of failure or low perceived competence (Sweetser & Wyeth, 2004). Engaging with digital games has been shown to increase self-esteem and decrease self-consciousness through altering perceived reality when immersed in the game that results in loss of self-consciousness, distortion of time, intrinsic enjoyment and sense of control (Sweetser & Wyeth, 2004). Thus, digital gaming offers a medium for individuals to experience activities that are often considered rare in real-life activities. This offers additional pedagogical advantages for inclusive education; for example, there is evidence to support the use of exergames for providing opportunities to individuals with cognitive and motor developmental disorders to experience mastery in physical endeavours that are viewed as socially acceptable by their peers (Kliingberg et al., 2005).

Additionally, the gaming experience offers opportunities for individuals across all spectrums of ability to explore and experiment with skills that may be impeded by low-perceptions of competence when partaking in real-life activities (Fong & Tsang, 2012). Essentially, exergaming could provide opportunities to experience and learn skills that are often difficult to teach or coach using traditional models in physical education and sports environments: thus meeting one of the key tenets of PL education where individuals gain experience of complex movement skill in a range of environments, mediums and scenarios.

4.4.1 Exergaming and ability levels

Initial studies that tested cognitive function post exergaming compared to traditional methods of aerobic exercise found that a single bout of exergaming did not enhance cognitive function post exercise. The study compared the effect of whole body, aerobic treadmill exercise with a number of exergaming and digital gaming devices on cognitive control immediately post exercise. The findings showed that cognitive functioning was *not* enhanced using exergames compared to aerobic exercise or seated games. This is, however, in contrast to outcomes evidencing the benefit of gaming and exergaming on executive functions (Klingberg et al., 2005). One possible explanation for the contrasting results could be that the exergames incorporated in one of the studies were not comparable with the exercise task; i.e. they did not involve gross whole body exertion. Further, the cognitive demands of engaging in exergaming, digital gaming and exercise were not measured during task performance. Therefore, it is possible that the exergaming conditions depleted their self-regulatory capacity to control cognition to a greater extent the aerobic exercise condition prior to testing. The raised arousal state measured in the seated game compared to the rest condition would support this contention. This study also focused on one aspect of cognitive performance (control), gaming could have varying effects on other aspects of cognitive performance (e.g. cognitive flexibility). In this regard, research has demonstrated the enhanced executive functioning capacity resulting from exergaming interventions with individuals of impaired and normal cognitive development (Klingberg et al., 2005) across a wide demographic. However, the studies did not compare the resultant enhanced cognitive functions to traditional exercise training.

4.4.2 Perceived control, engagement and enjoyment

Interface between players and the exergames involves motion capture devices that transmit movement information from the player allowing the individual to interact with virtual environment on screen. Two forms of motion capture hardware devices facilitate the input of information from the individual to the software; infrared and depth sensors: Infrared motion capture involves information being recorded by a remote device (handheld, dance-mat etc.) and transmitted to a receptor. There are a number of limitations to the use of such devices for optimally educating physical literacy skills: for example, Exergames that require the use of external hardware (e.g. dance mat, balance board, hand-held control) often place constrains on movement patterns used to complete gaming task (e.g. balance board, ski simulators, Dance mats). Furthermore, using external hardware devices often negates the necessity for player to engage fully with the physical activity. Often the exergame tasks can be completed without deploying gross motor movement or exerting physical competencies at a level that is sufficiently demanding to incur physiological changes or increase physical activity levels significantly (Sallis, 2011). For example, using the ‘wii fit’ balance board requires a change in pressure to transmit data and can be achieved with minimal physical exertion from a seated position (Vander Schee & Boyles, 2010, Sallis, 2011). A review of enjoyment ratings for serious games evidenced that frustration due to controlling requirements was one of the main negative factors influencing the gamer’s experience. The review was conducted using an experienced adult gamer and non-pc controlled Serious Games. From an educational perspective for children, the additional demands of external controlling devices may negatively influence their experience of exergames. Thus, advocacy is offered for the use of games that employ depth-sensor technology that allow individuals to interact with the exergame without the need for external controlling devices allow greater immersion, require substantial physical engagement and may decrease the risk of frustrations resulting from additional demands of external control devices to transfer action-information.

Games that involve limited challenge, progression or that involve predictable measures of skill level provide initial motivation, largely due to novelty of the experience. With repeated exposure, however, motivation level decreases over time. Furthermore, advanced complexity and diverse decision making associated with educational content of Serious Games often ameliorates lesser quality graphics (Kline, 2004). Thus, for the purposes of gaming in education, it could be argued that well-designed content of games should take precedence over graphics and other factors that are considered of primary importance in entertainment games.

More specifically for the purpose of PE games, research has examined the impact of movement factors on motivation and experience during gaming, (Pasch et.al., 2009): Four movement factors (mimicry of movement, natural control, physical challenge and proprioceptive feedback) were found to influence immersion in the gaming experience. Immersive experiences correlate with flow state that are intrinsically motivating. Thus, incorporating movement tasks that are challenging and conducive to immersion with a stimulating auditory input and simple graphic stimulus could provide appropriate game experience that does not require costly graphic and design components commonly associated with games developed for the leisure industry. In fact, simple graphic representation is optimal for younger or lower skill level gamers to understand and focus without distracting or distorting the content with superfluous or task irrelevant information that could inhibit task relevant information processing (Jenkins, 2006).

Another important property of gaming to be considered in PL learning contexts is micro-control: Micro-influence refers to elements that an individual can control, affecting movement and action. For example, direct control of an avatar, indirectly controlling other gaming characters by instruction, or the ability to manipulate and control multiple elements progressively to accomplish a task. Human learning studies show that the space within which individuals feel they exert immediate micro control correlates positively with the feeling of embodied power (Ritterfeld, Cody & Vorderer, 2009). Gaming provides experiences of embodiment that expand the space for individuals to experience micro-control over movement elements that are not within their immediate personal environment.

In summary, gaming encourages individuals to think strategically and allows problem solving skills to develop as more challenging scenarios are presented with progressive levels of accomplishment. Additionally, the immediate provision of feedback promotes recognition that can be gratifying and motivating when either positive *or* negative: Individuals can recognise and evaluate where errors occurred and problem solve to overcome the errors, additionally when expectations are met, advantage is awarded in the form of increased challenge and complexity. Ultimately, exergames as PE assessments could provide children with opportunities to experience and develop the psychological skills that have been found to be important for progressing in sport, activities and pursuing expertise in general (MacNamara & Collins, 2011).

4.5 Exergames Outcomes

Researchers have started to address some of the pedagogical issues required to assess the effect of exergames incorporated in formal education: For example one study examined the longitudinal effect of a Dance Dance Revolution intervention on BMI, cardiorespiratory fitness and math and reading scores, integrating both physical and academic facets of exergaming in the study outcomes (Pope, Chen, Pasco & Gao, 2016). The intervention tracked scores over a one year period and results showed positive outcomes for using exergaming from an educational perspective. The study also confirmed previous research evidencing the generalisable nature of cognitive skills gained from serious gaming. To examine the effect of exergames used to promote formal PL education, outcome variables that correlate with skill learning *within* PL education need to be assessed (i.e. the testing the ability to process movement information and apply movement skills to solve problems in physical pursuits). Additionally, the longitudinal studies to date have examined the effect of exergaming for improving physical activity and fitness in schools compared to no physical education. Thus, further research is required to examine whether long term exergaming interventions can enrich outcomes of physical education to a greater extent than tradition PE programmes

Although physical fitness is undoubtedly a desired goal of PL education, the validity of using *only* physical fitness parameters is limited for PE where the objective is to promote acquire knowledge that can be used throughout life, *not* to induce transient physical or behavioural changes. Notably, exergames did not succeed in increasing physical activity level as shown by measures of energy expenditure when games involved low intensity activity (xbox Kinect bowling). In contrast, however, games that involved high intensity activities (xbox Kinect 200m sprint) succeeded in raising heart rate to a sufficient level to induce positive vascular adaptations (Sallis, 2011). Another study examined rate of perceived exertion and heart rate reached during structured and unstructured exergaming (wii-fit). The findings showed that children exerted more energy during structured gaming and were more likely to play passively in unstructured environments. The researchers suggest that the *structured* environment acted as an additional external motivator for children to engage more actively in the activity. In similar fashion, Gao (2013) showed that a single 30 minute exergame session delivered to 8-14 year olds in increased situational motivation and that this predicted physical activity enjoyment and intensity; however the impact of exergames on motivation decreases over time. Further to the motivational implication, therefore, delivering exergaming in a structured way but across a limited time span could provide a standardised game development procedure that optimises the benefits and reduces the risks of exergaming activities.

Clearly, the lack of *standardised* outcomes that specifically measure physical skill development in exergaming interventions is a limitation. A number of recent studies have started to address this issue. Large scale initiatives (e.g. Centre for Exergaming Research Canada) showed that exergames successfully met learning objectives of teaching basic physical movement skills (balance control). However, results were not statistically significant compared to traditional methods used to teach movement skills in PE. The intervention had limited transfer to large scale application. The programme required a purpose built exergaming facility comprising of eight different gaming modalities in a primary school. Clearly, such interventions are not designed for those who are most at risk of decreased engagement in sport and exercise (i.e. of a lower socioeconomic status). The intervention also required additional equipment to test students' balance, while offering valuable information, further applied research involving equipment and evaluation methods that can feasibly be used by teachers would be beneficial: The ecological impracticalities clearly limit the application of traditional assessment methods in PE settings, proliferating the problem through cumbersome exergaming set-ups is unlikely to improve frequency of application in classrooms. Exergames *could* be used efficiently in a classroom set-up, requiring minimal space, equipment or training, thus a primary objective of PE exergames should be to provide a modality that can be easily integrated and deployed in to normal school environments, without necessitating additional dedicated rooms or excessive financial investments.

Exergames used in accessible, cost effective environments could therefore enhance the positive impact of exergaming for improving physical and psychological status of children. However, and as noted by Ennis, the lack of supporting evidence for the use of exergaming in formal physical education settings could be due to inappropriate conceptualisations of exergaming education (Ennis, 2013). To date, motivational, leisure, health or fitness paradigms have framed research designs and offered inconclusive information about the effectiveness of exergames as a modality to promote physical *activity* in children. Preliminary findings indicate, however, that adopting a serious exergame approach could provide enhanced PE for children to learn physical, psychological and behavioural skills necessary to lead a physically active life. Clearly, further investigation that examines the effect of exer-games from an education (serious gaming) perspective is required to progress the application of exergames used in PE.

4.6 PE Exergames Requirements

To achieve the aim of examining the impact of appropriate PE exergames, it is important to consider what sorts of tasks and challenges will be required**.** The ability to 'read' the environment and adapt motor skills to coordinate movement patterns which optimally satisfy the demands of novel movement tasks or environments is a key component a motor skill proficiency that is conducive to progression and transfer in a wide range of physical experiences (sport, dance, exercise etc.). The theoretical support underpinning the importance of 'reading' skills (complex movement capacities) needed to acquire high level PL is well established and derived from a strong base in neuroscience: For example, movement-based training that is sufficiently demanding to require close attention to movement execution has been shown to cause positive plastic changes within the motor cortex that facilitate an enhanced clarity of communication between cortex and activated musculature and elicits adaptations at the level of the brain, the spinal cord, and at the neuro-muscular junctions (Pesce, 2013). Such robust, multi-level changes are conducive to developing the competence required for assessing environmental and task constraints, adapting and executing complex motor patterns accordingly to meet movement demands for a wide range of movement activities (Seifert, Button, & Davids, 2013). Similarly, evidence from other areas of neuroscience support the efficacy of executive functioning training for improving cognitive skill learning: Executive function training has been effective in improving information processing, pattern recognition and memory in individuals with cognitive disorders (ADHD) (Klingberg, 2005). In summary, complex exergame challenges that require advanced movement-problem solving could induce robust learning that promotes both cognitive and physical development.

In addition to the neuro-scientific requirements for gaining knowledge and learning skill proficiency, gaining an understanding, appreciation and behavioural concomitants is required to successfully apply proficient physical skills. The evidence base suggests that implicit learning of psychological and behavioural skills through physical skills provide robust education that is conducive to optimal development across the three distinct but interlinked components of physical literacy. Therefore, designing optimally challenging movement component of exergames could provide appropriate sources of feedback, motivation and opportunity for trial, error and mastery required to sustain a physically active lifestyle. Table 4.1 below shows potential exergame tasks that could test the skills required for attaining PL.

Educational exergames also require specific attention to the empirical evidence of learning provided. Firstly, for validating exergames as appropriate assessments, secondly for evaluating individual ability (learning) and finally for monitoring progress (individual and inter-programme). A range of exergame tasks that could provide objective learning assessments in complex movement skills for PE are shown Table 4.1. Note; the level of difficulty across tasks that are required to cater for the ranges of ability level present in primary schools. Equally, task progression is important to track learning and improvement. For example, within a task, the number of trials required to achieve asymptote could be used as a marker of learning rate. In addition to absolute level, the rate of change over

4.7 Exergame Research

The inability to produce comparative data is a noted limitation of motor coordination and physical literacy research to date (Lopes et al., 2015). An exergame based assessment could be used in a PE context to assimilate data and compare physical development curricula across time and between cultures/nations. This could also aid in the development of standardised best-practice for developing physically active individuals.

The main limitations associated with traditional movement assessments from an ecological perspective include the time and resource requirements. Many assessments require individual administration and take up to 25 minutes to administer. Exergames could speed up the process of movement assessments by negating the need for demonstration and providing a combined assessment of multiple movement components in a single assessment. Furthermore, the use of technology means that test information is passively recorded and analysed by the programme, reducing the demands placed on generalist teachers to observe and report on movement performance. The automated process also ensures objectivity and reduces time constraints for inputting, analysing and exporting test results. Additionally, having predetermined tasks, outcomes and scores that are automatically run by the exergame further reduces the requirements on teachers to compute scores. Thus, exergames could promote increased frequency of assessment in PE. Additionally, exergames allow for quality movement information to be gathered. Currently, assessment methods include dichotomous present/not present assessments of skill. An exergame could present useful skill information about the processes used to execute movement providing teachers with additional quality information that they could use to optimise feedback and instruction provided to children during motor skill lessons.

In addition to the logistical limitation of traditional movement assessment, the nature of assessment currently undertaken requires consideration from a primary level education perspective: Video analysis and checklist formats are typically used in movement assessments. Video recording presents obvious ethical considerations in primary school settings. Furthermore, from a movement assessment perspective, limitations of video are also noted. Video recording only permits movement to be recorded in a single plane of motion; most usually requiring the presence of a global (environmental) point of reference (e.g., striking object or field target) to conduct an analysis. As such, utilising a global co-ordinate system (GCS) in only one plane of motion prevents a functional representation of complex movement skills and the coordinative dynamics employed by an individual. Factors associated with perspective error must also be accounted for each time data are collected (Payton, 2008). Consequently, this makes inter-test comparisons less reliable since there is a constant need for global reference(s).

Practically, the use of exergame could broaden the scope for international longitudinal research. There is a strong case for the integration of general movement tests in a software program that could be standardised and deployed across nations, reducing the need for standard procedures and assessment protocols to be translated and adapted to reflect the needs of different cultures/languages etc. An exergaming software package that automatically exports data via the internet to promote larger scale comparative studies by enabling remote data collection.

4.8 Exergames for learning

The use of exergaming has the potential to encompass all physical, psychological and behavioural components of PL development under a 'serious games' paradigm. Modern theories of learning espouse that experiences requiring individuals to think in-action and on-action (reflection) are most beneficial to developing understanding and learning skills. Gaming encourages individuals to think strategically and allows problem solving skills to develop as more challenging scenarios are presented with progressive levels of accomplishment. Research examining the effectiveness of game-based PE has shown positive results in developing movement skills compared to traditional PE (e.g.PLUNGE, Miller, Christensen, Eather et al.,2015). Additionally, the immediate provision of feedback promotes recognition that can be gratifying and motivating when positive or negative; individuals can recognise and evaluate where errors occurred resulting problem solving to overcome errors, additionally when expectations are met, advantage is awarded in the form of increased challenge and complexity. PL-based exergames provide a platform upon which individuals can learn behavioural and psychological skills through physical skills. For example, although the rules and goals of an exergame are pre-determined, the personal meaning derived individually from interacting with the game is self-regulated (e.g. gamers choose to deploy different strategies to meet the movement goal).

4.9 Limitations

It is acknowledged that there are still numerous barriers to be negotiated before exergaming can be considered as a potential alternative to movement assessment batteries to monitor movement competency on a large scale. In practical terms, the accuracy and sensitivity of commercial exergaming equipment requires rigorous testing against accepted motion analysis systems. Furthermore, the limited accessibility and acceptance of such technologies in certain countries and communities also needs to be considered as a socio-cultural constraint. Finally, one may also raise ethical concerns about the promotion of exergaming as the 'saviour' in the face of decreasing levels of physical activity and increasing childhood obesity (Fong & Tsang, 2012). The immediacy of the obesity epidemic necessitates PE that increases moderate to vigorous PA levels and physical fitness presently. It is suggested that appropriately designed PE could, indeed, *should* combine moderate to vigorous PA with life-long physical skill learning. Alongside consideration of these barriers, the 'potential versus the actual' benefits of exergaming needs to be verified (Sallis, 2011).

Although many positive health outcomes are emerging from the exergaming research in rehabilitation settings, the negative implication of increased exergaming engagement should also be considered. The incidence of 'wii-tennis shoulder' and other repetitive strain injuries resulting from addictively pursuing exergame activities are noted in the literature (Jones & Hamming, 2009). Furthermore, it is postulated that physical inhibitors to exercise (limited strength/ endurance for example) are not considered during exergames to the same extent as during regular physical exercise (Jones & Hamming, 2009). Thus the necessity for warm up, rest and recovery is often negated. Coupled with the addictive nature of gaming, this can lead to increased incidence of strain related injuries (Eley, 2010). However, appropriate design and structured delivery of exergames in education settings could ameliorate these negative concomitants. Additionally, the use of hardware-free games that do not require external devices for controlling the interface should reduce the risk further. Notably, device-free games that can simulate proprioceptive feedback to that more reflective of real-life physical movement without the kinaesthetic alterations of handheld controllers or balance board may also be useful. The counter-position that these may not have functional equivalence to the kinaesthetic feedback from equipment/environments encountered in real world sports and exercises is also important to note

In addition to the possible negative associations of exergaming engagement, the limitations of the exergaming modalities require attention: Motion capture capacity of th Microsoft Kinect for example, has been found to vary in accuracy (up to ten degrees) depending on the movements/joints being analysed. For the purposes of primary physical education, where gross motor development plays a prominent role and measures of effectiveness can utilise performance outcomes such as time taken, accuracy of movement within a bandwidth, the Kinect technologies provide sufficient capabilities. A lack of tactile/kinaesthetic feedback during manual dexterity or interceptive tasks using the marker-less Kinect system is not optimal for skill learning, however. Notably, some exergaming systems (e.g. wii) include vibration/kinaesthetic feedback via external hardware (remote/balance board). To ensure optimal object manipulation skill/haptic exploration the inclusion of hand-held accelerometer/inertial devices requires consideration.

Combined with the technological considerations, research design has limited the evidence base underpinning exergaming application: Research conducted in the rehabilitation sphere has included numerous studies from cerebral palsy, motor-dysfunction, developmental coordination disorder stroke and athletic injury rehab. However, the research studies suffer from a lack of congruence between implementation and monitoring of rehabilitation programmes. Further standardisation of research procedures is required to produce comparative data to assess the efficacy of Kinect for use in clinical or home rehab settings. However, it is noted that where discrete measures of joint position, displacement and range of motion are required, for example in clinical rehab, the efficacy of the Kinect might not be sufficient.

As discussed, there are noted limitations arising from the technology, the application and the research of exergaming. However, and as noted by Staiano & Calvert (2011), exergames motivate participants, expend energy, promote social interaction, cognitive function and *could* become one of the most popular, engaging and health-promoting homework assignments of the twenty-first century. Taking a critical consideration of both the limitations and benefits of exergaming research (in education and rehab) that is available, further standardisation of exergaming research is required to proceed an empirical evidence base for its application.

4.10 Conclusion

The purpose of this chapter was to examine the origins of exergames and to review the research available on the application of exergames in education and in the assessment of movement (in rehab or clinical). Evidently, the application of exergames could provide a vehicle for assessing movement competency in primary education that encompasses the psychological, behavioural and physical facets of PL education. Furthermore, the benefits for gathering and assimilating data through exergame platforms could aid in the provision of longitudinal and comparative research that is currently lacking in the realm of physical activity and physical education research. However, research to date has largely been limited by the focus on fitness and enjoyment measures of exergames compared to traditional exercise or PE. Exergaming research that includes *appropriate* measures of complex movement skill development could provide essential empirical evidence needed to understand optimal physical development pathways. A sample of exergame tasks designed to measure essential movement skills are described in Table 4.1. Clearly, more long-term research examining PE games designed based on the theoretical evidence underpinning physical skill development is required.

Coordination Characteristic	PL Skills Involved	Description	Evaluation of Learning
Interceptive timing e.g. Basketball, tennis, baseball, cricket	Visual perception timing Control Unimanual & bimanual coordination Limb dominance Ballistic power	A bouncing ball is projected across the screen in front of the participant. The participant has to 'strike' the virtual ball inside a highlighted target zone on the screen using their hand/s. Each hand is tested separately and two hands together to measure bimanual co-ordination and hand dominance. Spatio-temporal coordination in interceptive actions between hand and ball are measured.	Varying level of difficulty in ball speed, size of target zone, predictability of bounce. Motion sensors used to detect the movements of the punching limb/s. Measuring coupling of hand motion to lateral ball position, occurrence of peak hand acceleration relative to target zone, resultant velocity/direction of ball following impact, etc.
Object manipulation e.g. Archery	Visual-perception Hand-eye coordination Control Precision timing Fine motor skill	Pick up different sized balls and put them in a container using a virtual crane controlled by the participants' actual hand movements testing the spatio-temporal accuracy of the movement of the crane to the balls, and the co-ordination between opening and closing of the virtual 'claw'	Variations in ball size. Timing and accuracy of trapping ball. Timing and accuracy of ball placement.
Locomotion and agility e.g. Gymnastics, athletics	Visual-perception Kinesthetic awareness Postural control Gross motor adaptation	Task requires quiet standing with feet together; standing shifting weight from one foot to the other as if making a step; normal walking; and walking with changes in direction, level change (squat). Motion analysis sensors monitor movements of the head, top and bottom of spine, hips, knees, ankles and feet.	Increased stability of centre of mass within base of support. Decreased time to achieve centre of mass stability changing base of support.
Rhythm and sequencing e.g. rugby, soccer, hockey, dance	Perception of rhythm Timing Intralimb coordination Stability of bimanual coordination	Learn a number of simple to complex rhythms/patterns and reproduce them with a bimanual tapping movement	Accuracy of pattern repetition. Accuracy of recall with decreased feedback/ auditory occlusion Time/number of trials taken to achieve task.
Spatial awareness and balance e.g. ice-skating, skiing, diving, gymnastics, track & field events	Visual perception Kinesthetic integration Imagery Planning Postural control Stability	Adopt and hold different spatial configurations of their body and limbs to suit expanding apertures on the screen. Hence the task is somewhat akin to a version of 'Human Tetris'. Sensory organisation and postural stability will be assessed via composite performance measurements .	Time taken to achieve shape. Accuracy of movement. Increased speed of transition between shapes. Increased complexity of shapes.

Table 4.1: Potential exergame tasks to measure physical literacy

CHAPTER 5

Test Design

5.1 Introduction

As outlined in chapters 2, 3 & 4, exergaming could provide a solution to testing movement competence in PE. From a pedagogical view point, however, the objective of the thesis was to understand the promotion of physical education in primary settings. So, whilst the literature reviews discussed in Chapters 2 and 3 highlighted key factors of motor development that need to be measured, it is important to identify what from theory has translated in to practice. One noted limitation of research to date is the dichotomy between theoretical science and contextualised scientific applications: In order to produce robust research, scientists strive to produce research that is underpinned by generality. However, especially in the sports and education domain, research requires context. Thus for understanding how PE is taught and how learning in PE is measured, an applied context and perspective is required. Therefore the objective of this chapter is to present the qualitative research undertaken to examine assessment methods used by teacher in primary PE settings from an applied perspective.

5.2 PL models and motor development theory

Whitehead's (2001) original work categorised PL movement skills into three movement capacities (i.e. fundamental, combined and complex movement capacities). Each movement capacity requires structured education to provide appropriate experience in a variety of movement domains (e.g., rhythmic, artistic, technological) and environments (e.g., geographical, socio-cultural, climatic). Each movement capacity is now discussed in further detail in the following paragraphs with a specific focus on the relative importance each has in mediating PA experiences and influencing future levels of PA participation and performance.

5.2.1 Fundamental Movement Capacities.

Appropriate and well-founded generic athletic abilities allow flexible movement of individuals between levels and domains of PA involvement. This is a key factor for promoting either participation or performance in PA, considering that the pathways taken to attain excellence in either are highly idiosyncratic. Further to the requirement for progressing movement skills, proficiency in fundamental movement capacities are imperative for preventing digression from, or indeed cessation of PA (Goodway & Branta, 2003; Lawford et al., 2012; Lubans, Morgan, Cliff, Barnett, & Okely, 2010).

5.2.2 Combined Movement Capacities.

Proficiency in fundamental movement capacities are salient, however combining and adapting basic movements is essential to engage in more enriched physical experiences across the variety of domains necessary for genuine involvement. Combined movement capacities enable individuals to display mastery in previously learned movements and gain new movement knowledge from executing individual fundamental capacities in a variety of novel combinations (Whitehead, 2007; 2010). This allows individuals to gain the movement competencies required to seek more challenging physical experiences, for example PAs that involve different physical mediums (e.g. in water, on ice etc.). Additionally, combining fundamental movement capacities is required to experience movement in artistic and expressive forms (e.g. rhythm, dance).

With regard to the combination of fundamental skill elements, early specialstion in sports specific movement skills often accompanies competitive level engagement in PA. This often correlates with early cessation of physical pursuits, possibly due to insufficient general movement abilities to combine and adapt to the requirements for other activities (Collins et al., 2012). Similarly, insufficient skills or experience in combining fundamental movements could impede progression in specialised sports when the task requirements change according to level of competition or age (e.g. junior to senior level) or even as a result of growth or injury-related changes (Newell, 2011; Pankhurst & Collins, 2013). A proficient, practised and well-developed ability in combining movement skills will enable individuals to experience a spectrum of participation levels in sports or PAs and promote performance should they choose to refine their skills in a specialist domain (MacNamara et al., 2011).

5.2.3 Complex Movement Capacities.

The ability to 'read' the environment and adapt motor skills to coordinate movement patterns which optimally satisfy the demands of novel movement tasks or environments is also a key component. This crucial motor skill proficiency is conducive to progression and transfer in a wide range of physical experiences (sport, dance, exercise etc.). The theoretical support underpinning the importance of 'reading' skills (complex movement capacities) needed to acquire high level PL is well established

(Seifert et al., 2011; Seifert, Button, & Davids, 2013) and derived from a strong base in neuroscience (Wright, Holmes, & Smith, 2011): For example, movement-based training that is sufficiently demanding to require close attention to movement execution has been shown to cause positive plastic changes within the motor cortex that facilitates an enhanced clarity of communication between cortex and activated musculature and elicits adaptations at the level of the brain, the spinal cord, and at the neuro-muscular junctions (Seifert et al., 2013; Starkes & Ericsson, 2003; Tucker & Collins, 2012). Such robust, multi-level changes allow individuals to assess environmental and task constraints, adapt and execute complex motor patterns accordingly to meet movement demands for a wide range of movement activities (Seifert et al., 2013). The resultant enhanced executive functioning capacity positively correlates with expert motor skill performance (Maxwell, Masters, & Eves, 2003). A summary of the fundamental, combined and complex movement skills considered important to attaining PL as described by Whitehead (2001) are listed in Table 5.1 below.

Fundamental movement skills	*Combined Movement skills*	*Complex Movement Skills*
Core stability	Poise (both balance and core stability)	Bilateral coordination
Balance	Fluency (coordination, balance and proprioception)	Inter-limb coordination
Coordination	Precision (accurate placement of the body and core stability)	Hand–eye coordination
Flexibility Speed variation	Dexterity (coordination, accurate placement and flexibility)	Control of acceleration/ deceleration
Control Proprioception Power	Equilibrium (balance, core stability and movement control)	Turning and twisting Rhythmic movement

Table 5.1: Summary of Physical Parameters needed to attain Physical Literacy (Whitehead, 2001)

Using *appropriate* methods to test a sample of complex movement capacities could provide a composite measure of fundamental, combined and complex motor ability (e.g. evaluating the execution of coordinated gross motor patterns in response to stimuli, movement-pattern recall).

In short, components that research has shown to correlate with higher skill level and participation in sports and physical activity require assessment and weighting in tests. Additionally, these components represent factors that are largely absent for currently available movement assessments that are commonly deployed to assess PL.

5.3 Qualitative investigation of the practices used for teaching and testing PL skills in primary school

Despite limited empirical evidence, it is evident that development models such as Physical Literacy (PL) play an important role in physical education and physical activity promotion (Whitehead, 2010). The UK, Canada, Australia and New Zealand have pioneered large scale initiatives in education, community and public health settings to promote physical activity engagement. Whitehead's model describes the behavioural, psychological and physical components that encompass PL: Although distinct, the components of PL are inter-linked i.e. physical skills are required to utilise psychological and behavioural concomitants of PL. Notably, however, while the psychological and behavioural components have achieved some consistency of understanding, the physical component remains obfuscated by the variety of measurements used in its operationalisation. Explicit focus on physicality is a feature of Whitehead's original ideas, which categorised PL movement skills into three movement capacities (i.e. fundamental, combined and complex movement capacities as described above). However, the relative importance of physical competencies for PE has yet to be clearly expressed.

Clearly, the factors limiting PE from a research perspective (discussed in Chapters 2 & 3) i.e. lack of standardisation and limited empirical evidence need to be addressed. Furthermore, the practical application of PE in the classroom needs to be understood. Unfortunately, the discrepancy between policy and practice in the domain of physical activity is often substantial. Therefore, it is necessary to understand the extent to which theory is transferred to teaching practice. Additionally, teachers' beliefs, attitudes to physical activity and personal sport experience have been found to influence the quality of PE experiences they provide in the classroom (Morgan & Bourke, 2008). Thus, understanding teachers' perceptions of PE and current practices in school settings is an imperative precursor to standardising PE practices and optimising the transfer of evidence based practice to teaching in primary level PE.

So what should constitute quality primary level physical education and how could it be monitored? Motor development theories suggest that gross motor coordination, developed through appropriate instruction and structured feedback, is conducive to optimal motor skill learning. Conversely, a large proportion of current education and activity promotion policy supports unstructured 'play' that is largely orientated towards developing psychosocial correlates of physical activity. These contrasting viewpoints warrant attention, especially considering the implications of inappropriate physical development. Thus it is imperative that further investigation in to best practice for physical development is considered.

Accordingly, the aim of the current study was to examine teachers' perceptions of physical development in PE; more specifically, to establish what teachers consider the key movement competencies in education to be, their main objectives of delivering the PE curriculum, and finally, what evaluation methods they use to track the effectiveness of PE lessons. The extant evidence pertaining to physical development, in conjunction with teachers' self-reports, is used to compare and contrast scientific best-practices against reported experiences. This comparison forms the basis for identifying potential mechanisms for improving PE monitoring in primary schools.

Method

Participants

Teachers were recruited from Irish primary schools (4 years to 12 years education) via formal email requests. To ensure a stratified sample, recruitment included schools from different regions throughout Ireland. Socio-economic factors influence physical development practices and experiences; thus, a sample including participants from different locations was elected to obtain research finding that were generalisable to a broad demographic. The inclusion criteria included a formal qualification in education (PE or primary) and currently teaching within state institutes of education. 36 participants (22 female, 14 male), 38% from rural institutions and 62% urban primary schools, reflecting demographic stratification in Ireland (CSO Town & Country Profile 1, Census, 2011) completed the surveys. Teachers' mean experience was nine years (SD +/- 4.5 years). All participants had completed a Bachelor's degree in Education (B.Ed.). One teacher had completed an additional post-graduate qualification specialising in PE.

Instrumentation

As an essential first step in the development of the survey, an extensive literature review was carried out to identify the key aspects of physical development. More comprehensive review of the issue can be found in Giblin et al. (2014). For present purposes,consider how key factors of holistic PE, although theoretically distinct (physical, psychological and behavioural) components are inextricably interlinked.

Motor development research shows that physical movement skills play a central role in developing competence and confidence to engage in PE and physical activity. However, with limited empirical evidence the centrality of movement competence to PE remains under researched. Drawing on research evidence from other cohorts; movement competence plays a pertinent role in differentiating between engagement and ability, gross motor coordination skills are high amongst elite level individuals across a range of sports (Seifert,Wattebled, L'Hermette et al, 2013). Similarly, gross motor coordination differentiates between levels of physical activity participation (Stodden, Goodway & Lagendorfer, 2008). Unfortunately, as a result of limited empirical evidence to demonstrate optimal content, delivery and monitoring procedures for PE teachers has been impeded.

Motor development theories suggest that gross motor coordination (developed through appropriate instruction and structured feedback) is conducive to optimal motor skill development and a stable marker throughout childhood and adolescence (Muehlbauer, Besemer, Wehrle, 2013). Motor coordination influences physical activity engagement in later life, with childhood movement proficiency correlating positively with academic achievement, physical, psychological and behavioural outcomes measured in adolescence and later life Seifert et al 2013). Concurrently, motor coordination levels in children negatively correlate with sedentary behaviours throughout life. Additionally, sedentary behaviour influences health outcomes independent of the current physical activity level. Children with poor motor-coordination struggle with tasks of daily living, participate in less physical activity, have higher BMI and are at higher risk of cardiovascular disease than individuals with typical levels (Hands, Larkin & Rose, 2013). Furthermore, it seems that the difficulties encountered by children due to poor motor coordination perpetuate decreased participation in physical activities and thus, negatively impact physical health throughout the lifespan. Children, adolescents and adults with poor coordination have lower physical fitness, increased adiposity, and poor blood lipid profiles (low HDL and higher LDL) compared with their age-matched counterparts who possess normal coordination (Cools, Martelaer, Vandal et al, 2010). Thus, movement competencies that contribute to gross motor coordination appear to play an important part in holistic physical development.

From recent review (Giblin et al, 2014), the main movement skills considered integral to physical development are as follows: Object manipulation, interceptive timing, rhythm and sequencing, locomotion and agility, spatial awareness and balance:

Survey design & development

The five factors of movement identified as being key factors of developing physical competence were, for the purposes of this study defined as follows:

Interceptive timing: Anticipation of the speed, direction and trajectory of a ball and coordinating motor patterns to ensure that the bat/racket/limb arrives at the point of interception with appropriate speed, force and direction (Weissensteiner, Abernathy & Farrow, 2011).

Object manipulation: The use of limb movements and systematic force to move an object (e.g. bat, racket etc.) (Mah & Mussa-Ivaldi, 2003).

Locomotion and agility: The ability to maintain a stable centre of mass when walking, running, jumping, changing direction and various speed (Jambor, 1990).

Spatial awareness and balance: Balance is the ability to maintain a stable centre of mass. Spatial awareness is an understanding of how much space the body occupies and how the body can move in space (Frost, Worthiam & Reifel, 2001).

Rhythm and sequencing: An awareness of the relationship between movement and time (temporal awareness). Sequencing movement events uses a form of rhythm or pattern that reflects temporal awareness (Frost, 1992; Gallahue, 1989; Jambor, 1990).

Examples of sports and activities that required each of the five movement skills were provided to further ensure congruence in participant meaning and understanding of the movement skills in question. The combination of quantitative and qualitative data was chosen to allow the identification of trends and inclusion of individual specific information and examples from the teachers' experience.

Reflecting good practice in the design of such instruments (MacNamara & Collins, 2011), the survey was distributed and reviewed by two physical education specialists, who acted as an expert panel. The specialists included in the panel were experienced researchers in physical education. Furthermore, both specialists had practical experience of physical skill development in children in the UK, USA and New Zealand. Feedback provided from the panel on content order, semantics and presentation of information was used to refine the questionnaire prior to participant completion. In addition, a sample of participants (n = 6, 3 male, 3 female) were interviewed after completing the questionnaire. The objective of the interview was to ensure understanding of the questionnaire content. No significant changes to the content were made following this step. For full survey see Appendix.

Procedures

The research protocol was approved by the University ethics committee. Participants received information about the research project and instructions for completion of the questionnaire. All participants completed an informed consent process prior to the intervention.

For questions utilising a Likert scale response, 1-5 was chosen, 1 indicating low importance/ability/confidence and 5 indicating high. Teachers were asked to rate the importance of each factor on a Likert scale of 1-5 reflecting the contribution of the factor to overall physical ability. Teachers were then asked to describe how they taught and evaluated each skill using a qualitative open response. Teachers were asked to indicate the average physical ability of students on commencing and finishing education. The range of physical abilities was indicated using a -5 to +5 rating (extremely below expected physical ability for the age cohort – extremely above expected ability for the age cohort).

Finally, teacher confidence has an impact on students' perceptions and enjoyment of PE and plays an important role in shaping the beliefs and attitudes towards physical activity and level of engagement during childhood and later in life. Therefore a rating of teacher confidence, again using a Likert scale of 1-5, in teaching specific motor skill parameters (e.g. spatial awareness, interceptive timing etc.) were included to examine teachers' confidence as well as understanding of the requirements for delivering comprehensive PL lessons across the span of primary education (4-12 years).

Data Analysis

Quantitative analyses were completed using SPSS (version 21) and Microsoft Excel. The data gathered showed normal distribution and agreement, demonstrating saturation (Guest, Bunce & Johnson, 2006). That is additional information with further survey examination was not achieved and further coding of the data was not feasible (Guest et al., 2006). Thus a larger sample size was not pursued.A quasi-statistical approach was used to analyse qualitative data. With the qualitative data, Braun and Clarke's (2006) guidelines were deployed for thematic analysis. Thus the teachers responses were read and re-read to ensure familiarity with the content. From there, initial codes were generated then further themes were examined. This thematic analysis was employed to assess information about teachers' self reports about PE importance, PE objectives, lesson content, assessment procedures and lesson delivery.

5.3.2 Results

PE Objective	Mean	Std. Deviation
Achievement	3.00	0.00
Motivation	3.00	0.81
Physical and psychological health	3.29	1.38
Competition	3.50	0.71
Obesity & fitness	3.50	1.64

Table 5.2: PE Objectives – Mean and SD Rankings of PE objectives by teachers

Skills	Importance of physical skill component (1-5 Likert)	Confidence in ability to teach PL skills (1-5 Likert)	% Teachers engaging in PL evaluation	% Structured PL skill development lesson content
Object manipulation	4.0	3.4	28%	20%
Locomotion& agility	3.9	3.2	14%	93%
Rhythm& sequencing	4.0	3.6	21%	86%
Spatial awareness	4.2	3.8	17%	58%
Interceptive timing	4.5	3.6	7%	0%

Table 5.3: Teachers' Self-Reported Knowledge, Importance and Practices in Movement Development

Education Stage	Ability Range	Ability Average
Entry	-1 - +3	+2
Exit	+3- +5	+3

Table 5.4. Perceived Student Ability across Primary Level PE

5.3.3 Discussion

PE provision in primary schools

In contrast to extensive applied research showing the the delivery of PE is optimised through a unified systems to which all stakeholders can subscribe (Collins, Martingale, Button & Snowerby, 2010) the results from the present study showed that differences exist in the delivery of PE in primary schools. For example, teachers reported that PE was provided by both external sports coaches and by generalist teachers. Furthermore, the majority of teachers had no specialised training in PE delivery beyond the standard requirements for B. Ed completion. Three teachers reported having completed foundation level certification in coaching for Gaelic games (n = 2) or soccer (n = 1). One teacher had specialised in PE during her Masters dissertation. All other teachers had Bachelor of Education qualifications. Less than a third reported completing continuing professional development in PE. An average of 35 mins of PE was provided to students per week. Again, according to research (Miller, Christensen, Eather & Sproule, 2015) structure PE delivery by teachers who have received specialised training. Clearly, there is a gap between best-practices derived from applied research and actual delivery of PE in primary education.

Objectives of Physical Education

Notably, reflecting prevalence of the unstructured ‘play’ approach to physical activity engagement (MacNamara et al., 2015), teachers reported the predominant objectives of PE at primary school level to be psychosocial skill development and transient fitness improvements. From a psychosocial perspective, all participants reported that promoting mental health and positive attitudes, team spirit and sportsmanship towards physical activity as the objectives of the PE curriculum. In terms of transient physical activity and fitness, increasing fitness levels and providing broad game-based experience were reported as objectives of the PE curriculum by all teachers. A summary of the objectives as reported by the teachers in this study are presented in Table 1.

Notably, only one teacher referred to developing skills needed for ‘life-long activity engagement’ as being an objective of PE. Whilst I acknowledge the immediacy of increasing fitness and enjoyment, equipping children with the necessary complex movement skills is required to reinforce positive attitudes and gain competence through experiences in PE/PA across the life-span *should* be an essential component of comprehensive PE. Increased activity, without sufficient physical ability could in fact promote the *opposite* of the intended goals of sportsmanship, team spirit, increased engagement. In fact, engaging in increased PA without sufficient movement competency can emphasise deficiency and increase the risk of negative peer comparison. Again, the importance of sportsmanship, teamwork, psychological and physical fitness are not being questioned here; rather, I am highlighting how a sufficiently broad base of physical skills are required first to achieve these aims through engagement in physical pursuits.

Importance of Physical Movement Skill Components

Notably, whilst psychosocial and behavioural skills formed an important part of the Physical Literacy construct that informs PA and PE intervention and curricular design (Whitehead, 2007), movement competence was central to the holistic paradigm presented in Whitehead's work . The importance of movement competence was supported by teachers responses in this study. Teachers rated the five physical skill capacities derived from research as important (see Table 2). Clearly, the results support the literature showing that teachers currently working in primary education have an up-to-date knowledge of the importance of movement skills for the development of physically active lifestyles. There was no distinct difference in the importance ratings associated with any movement capacity demonstrating teachers' understanding of the importance of breadth in physical movement skill learning as shown by the ubiquitously high average rating for physical skills (see Table 2). Further, all teachers reported a moderate to good level of confidence in their own ability to teach each physical skill category. However, the centrality of movement skills was not reflected in the reported objectives of PE curricula that were discussed in the preceding section. Some potential causes of this discrepancy is discussed in more detail later.

Lesson content

A substantial body of research (e.g., Giblin, Button & Collins., Miller, Eather, Christenson t al., 2015, 2014, Robinson & Goodway, 2009, Stodden, Goodway &

Lagendorfer et al., 2008) highlights how structured instruction and feedback are required to ensure that skills are developed optimally. However, in the present study teachers reported that unstructured play-based activity predominates in their PE classes. Furthermore, contradictory findings were evident in terms of the knowledge implementation Teachers rated physical skills as highly important. Similarly, teachers rated high levels of confidence in teaching PL skills. Notably, however, the content and design of the PE lessons did not reflect optimal physical skill development (i.e. structured and progressive content). The majority of teachers reported their lessons for teaching physical skills consisted of unstructured game play.These discrepancies are highlighted in Table 2.

Evaluation methods

The themes generated for PE assessment were dichotomised in to 'observational assessment' and 'no assessment'. Less than one third of participants reported using testing methods to monitor ability level in PE. Observation was reported exclusively by teachers as the only method of assessment used in PE. I acknowledge here that the use of the word 'test' in the questionnaire may have been a limiting factor. A potential negative association with testing and outcome orientation with in PE may have been against the goals and/or ethos of PE development considering the large proportion of teachers reporting enjoyment as a primary goal of PE. As such, 'testing' may have seemed counterintuitive to fostering fun and promoting enjoyment. It is plausible that teachers do not engage in assessment for fear of the negative repercussions of 'failure' or performance monitoring, although no such concerns or issues emerged during the pilot testing of the survey instrument.

These hypothesised concerns notwithstanding, assessment is an important source or formative information for teachers. Furthermore, to become self-regulated learners, children engaging in sport and activity require adequate self-evaluation and attribution skills. By providing an environment where children can learn, reflect, succeed and sometimes fail, students can gain the psychological skills and behaviours required to negotiate barriers to maintaining or progressing within physical activity and sport when encountered (Collins & MacNamara, 2013). Experience of achievement is a powerful tool for building positive self-perception and motivation. Thus, rather than avoiding assessment for fear of discouragement, more attention should be drawn to the valuable repercussions of well-designed evaluation. A lack of availability of practical or appropriate assessments for PE, or indeed a lack of understanding of how to assess each skill, could be the cause of the results reported. Namely, that only 28% of teachers engaged in informal observation based assessment during PE with figures much lower for other skills.

Student ability

As children develop at different rates, to meet the goals of PL and also standards-based education, previously accepted criterion-based assessment require critical consideration: Assessment of physical skills requires progress to be measured against individuals' previous scores, not peer comparison. Such individual-orientated assessments are needed to provide appropriate feedback and benchmark progress for individuals in pursuit of their potential. In the present study, teachers reported that, typically, the average ability level and range of students' ability varied widely on entry to primary education (see Table 5.3). Evidently, teachers are required to meet the needs of many differing levels of students. Further general PE class provision without consideration for the range of needs and abilities within the class cohort could mean that individuals on either periphery of the competence spectrum do not receive appropriate support, thus impeding personal physical skill development. Positively, the range of ability decreased by the time students exited primary education. Although the lowest ability level increased, however, the highest ability level did not vary as prominently as the lowest from entry level to exit. A potential explanation for this is the almost exclusive focus on time-spent being active *rather* than on developing specific movement competence. Children with lower level movement skills are shown to gain more benefit from increased time spent being physically active than children with higher level movement ability (Capio et al., 2014), perhaps on the basis that this something is better than their previously experienced nothing. The result could be indicative of the extant focus on FMS development. Again, this benefits lower-level movers to a greater extent than students who have already acquired basic competence in movement skills prior to engaging in formal primary PE. Whatever is happening, however, I would highlight that, in the absence of a focus on measurement, teachers, other educationalists and administrators are flying blind with respect to whether *appropriate* levels of competence (i.e. those necessary for a longer term physical activity commitment) are being achieve

Importance and evaluation of movement competencies

The present study adopted an inductive phenomenological approach to investigating whether facets of PL development identified from theory and research were understood and employed in practice by generalist primary school teachers. Notably, teachers involved in this study did acknowledge the importance of each of the movement skill categories that correspond to the scientific evidence base. Additionally, teachers showed average or above (3+) confidence in their ability to teach the range of movement competencies. Less positively, whilst teachers demonstrated knowledge of the importance of PL skill development, practical implementation in terms of appropriately structured lesson content did not reflect evidence based best practice (i.e. unstructured play and/or fundamental movement skill focus). Whilst I acknowledge the importance of fun and enjoyment of engagement in physical activity, high usage of game play negates the substantial motor development research evidence that suggests structured practice and appropriate structure and feedback is required for optimal skill-learning (Capio, Sit, Eguia, et al., 2014). Furthermore, recently, PL programmes have tended to focus on fundamental movements that can be measured using existing movement batteries. However, I suggest that this focus on fundamental movement is flawed; indeed, more a matter of convenience rather than robust science. Fundamental Movement Skills (FMS) involving locomotive (run, jump, hop) and object manipulation (catch/kick) have been identified as being basic requirements to progress in a broad range of physical activities and sports (Whitehead, 2010). Furthermore, FMS competence in childhood is associated with increase PA behaviours in adolescents and later in life (Stodden et al., 2008). Largely, however, these basic movement skills (balance, locomotion etc.) develop before children commence school. Consequently, I would argue that developing higher-order movement skills *should* be priority in a comprehensive programme of PE. For example, gross motor coordination, interceptive timing, dynamic balance and spatial awareness are associated with higher level of physical competence, lower BMI and engagement in a wide-variety of activity and sports. Unfortunately, to date, the teaching and testing of movements skills in physical activity and education domains has focused predominantly on FMS, potentially due to the validated measures for assessing these skills.

Notably, the majority of teachers reported that they did not engage in *any* assessment of skill learning during PE. To emphasise the implication of this finding, consider a parallel in another subject domain, for example literacy or numeracy skills not being assessed at all throughout the duration of primary education, such that student arrive at secondary level (12 years of age) having no formal record of their ability level. I suggest that such a situation would be untenable and would ask why this is *not* the case with PE?

Object manipulation was the skill that teachers reported assessing the most (28%); however, assessment relied heavily on unsystematic *observation* to assess student ability. Attempts to standardise observational assessment methods through check-list style movement batteries are evident in clinical and therapeutic movement contexts. Even when standardised, however, (and note that no standardised or systematic observation-based methods were reported by teachers in this study) the validity of observational assessments are questionable in the context of an *appropriate* PL assessment, For example, the Test of Gross Motor Development 2nd edition (TGMD-2) provides a summative score for the performance of separate motor skills. The individual receives a score of 1 if the skill is completed and 0 if not. Surely, student ability level (of any skill) *must* be a continuous variable rather than a dichotomous 'can' or 'can't' categorisation?! The TGMD-2 also constricts movement skills to a specific context i.e., a skill level deemed fundamental for normal motor development. Skills considered fundamental to physical development should surely include more complexity and sophistication. Notably, however, movement assessments do not test a generalisable motor ability. Further, these tests were originally intended for use in clinical setting as a discriminative measure to characterise motor *deficiency*.

In addition to the clear disconnect with education systems that stipulate standardised and evidenced based assessments for rigorous monitoring of curricula and student progression skill application across subjects, the lack of testing procedures in PE impedes the provision of feedback to students, promotes demotivation, poor physical development, low perceived confidence and cessation of engagement in PE by secondary level. Equally crucial, but from a management perspective, there is no way of evaluating the increasing number of initiatives promoted for children of this age (e.g., Start to Move, UK and Skills 4 Sport, NI) except for clinically orientated, inappropriate movement assessments or ratings of fun.

Again, I wonder if this situation would be permitted in the case of a reading or maths initiative. Similar unstandardised, or indeed absent, methods of tracking student skill learning in other educational domains would not be tolerated. Clearly, an assessment of general physical ability, unbiased by sports specific knowledge, fear of failure, or subjective observation bias could enhance the sense of achievement accrued through physical skill learning, regardless of individual skill level. A test that promotes perceptions of accomplishment should ideally be enjoyable but, most essentially, valid for tracking learning in movement skills that are associated with comprehensive PL curricula. In summary, such a test is a necessary precursor to enhancing and standardising the provision of PL education at primary level. Accordingly, the aim of this study was to gather data from teachers in primary mainstream education about the factors most relevant to PE, how they are taught and how they are tested in school settings.

Challenges facing generalist teachers

Clearly, generalist primary school teachers are tasked with challenging requirements to deliver optimal physical, psychological and behavioural development to a wide range of ages and abilities, often within a packed curriculum and to a large number of children. Without standardised curricula or standardised methods for assessment, structuring and guiding development to meet the individual needs of each pupil appears to be non-existent. Furthermore, the lack of standardisation in PE assessment could contribute to the 'optional' approach that is often evident in PE environments whereby children (facilitated by parents) opt out of PE class. Similar approaches would not be acceptable in other standardised, assessed subject domains for fear of children falling behind. Practical resources for teachers are a necessary step in addressing the standardisation of PE delivery. In the following section, potential options for practically assessing movement skills in classroom settings are considered.

A potential solution

The assessment of movement skills has progressed with recent proliferation of motion capture devices. Motion capture (optical or mechanical) devices have been widely used in lab-based and clinical assessments of human movements. These devices could provide objective, quality movement assessment in applied settings. To date, external to clinical or laboratory settings, motion capture has been predominantly used in the elite sporting domain where resources, expertise and finances are available to aid in monitoring performance, injury prevention and movement rehabilitation. The use of motion capture has become more wide-spread with the proliferation of low cost systems in the entertainment industry. Exergames use motion capture systems to increase physical activities. Exergames have been adopted in health care, rehabilitation and exercise settings where professionals can use the system to track the quality of movement rehabilitation or exercise prescription completed by patients/clients (Best, 2013, Wheat & Choppin, 2013, Galna, Barry, Jackson et al., 2014).

Exergaming in education originally received mixed reviews (Sheehan & Katz, 2010, Sallis, 2011). Concerns about the validity of employing video-game technology to promote real-life physical activity was debated, similarly the ability of exergames to induce sufficiently demanding physical engagement to meet the recommended requirements for health related benefits of physical activity engagement (Sallis, 2011). However, and as mentioned previously, teachers noted in survey responses that the use of 'tests' or formal assessments could compromise the enjoyment and increase pressure associated with engaging in PE. Notably, incorporating the assessment of physical skills into a game is optimal for learning. Indeed, one of the key tenets of Teaching Games for Understanding is to create a self-rewarding environment for individuals to learn (Kirk, Brooker & Braiuka, 2000); poor performance on a 'gamified' assessment could result in autonomously regulated incentive to improve and progress in the game. Therefore, the negative connotations associated with poor performance in tests and potentially confidence thwarting peer comparisons often associated with traditional forms of assessment could be negated.

Based on results from the present study, the assessment of PE in primary schools is poor and often non-existent, combined with the extant evidence-base and, the recent development in exergaming applications that predominantly focus on gross motor movements and interceptive timing demonstrate potential for providing a solution to the problems currently facing teachers in education settings. However, extensive further research is required to examine the ecological validity exergaming technology used to assess primary PL education.

5.3.4 Limitations

The present qualitative study was limited by the lack of generalisability of the findings (i.e. cohort of generalist primary teachers in Ireland). Further research is required to investigate beliefs and behaviours of PE teachers across nations who teach under differing governing policies. Equally, further focus group investigations could be beneficial to investigate the results from this study e.g. why teachers experiences a lack of confidence in or the specific barriers for deploying assessments.

5.3.5 Summary of survey study

Although the sample size of this study was limited, the saturation of results demonstrate the sample was representative of generalist primary teachers' opinion in state governed educational institutions where PE is provided by teachers without specific specialist PE qualifications. Future studies investigating difference in PE practices between generalist and specialist teachers could provide further insights in to the training and resources necessary to optimise the teaching and testing of PE provided by generalist teacher, or the addition educational requirements for providing specialised PE qualification at primary level.

The results of this study show that teachers encounter a wide range of physical abilities and require extensive knowledge, understanding and resources to implement PE programmes. Generally the content and structure of key movement skills was poor and time spent in appropriately structured physical lessons was low. Although the range of ability levels displayed by students decreased across time spent in primary school, the present study showed that average ability level only improved marginally over eight years. Clearly, higher standards of PE provision are required to ensure the skills required to sustain life-long physical activity are developed appropriately. Practical methods of movement evaluation are necessary to monitor and ensure effectiveness of PE in primary schools. The use of exergaming technology could provide a useful tool for teachers, particularly generalist primary teachers who predominantly rely on sports coaches or their own sporting experience to supplement their provision of appropriate physical development to students. Children spend substantial amount of time engaging with digital technology during leisure time - Staiano & Calvert (2011) report that exergames could become one of the most popular, engaging and health-promoting homework assignments of the twenty-first century. Further research is required to examine the ecological validity of using exergaming technology as an assessment tool in primary PL education. Similarly, additional research is required to establish content validity of PL exergaming assessments.

Based on the findings of the qualitative study (and the literature reviews), a range of exergame tasks were designed to test the movement skills considered important by both research and applied investigation. The movement skills that each task was designed to measure are detailed in Table 5.4 below.

Task design and development

As detailed previously, the relative importance of movement skills are an important consideration for developing a valid assessment of PL: Whilst gross motor coordination appears to have a pertinent impact on physical activity participation and skill level, there is currently a lack of empirical evidence to discriminate the importance of movement skills. A primary objective of PL tool development was to establish the relative contribution of each of the 5 movement components being tested to overall physical competence. As shown in Table 5.4 higher representation of interceptive timing and spatial awareness and balance were afforded in the PL tool based on the research base showing correlations with complex movement skill ability and motor expertise development and engagement in PA with the concomitant absence of readily available tools to assess these seemingly crucial components of PL development.

PL Task	Interceptive timing	Object manipulation	Locomotion & agility	Spatial awareness & balance	Rhythm & sequencing
Monster 1	✓				
Monster 2	✓				✓
Trace 1		✓			
Heading	✓			✓	
Hopscotch			✓	✓	✓
Maze			✓	✓	✓
Batting	✓	✓		✓	
Jump	✓			✓	
TOTAL	5	2	2	5	3

Table 5.4: Description of movement skill representation in each PL task

5.4 Motor learning and PL scores

Understanding conceptualisations of motor development is an important step in identifying appropriate methods of assessing progression in motor skill learning. The characterisation of motor development via age category can be misleading, motor development is age related *not* age dependant such that highly talented movers age 7 could be more capable than less competent 11 year olds. During childhood, development stage are broken up by age group whereby 0-4 years olds are toddlers whose movement capacity is independent walking. 4-7 year olds are early childhood, 7-9 middle childhood and 9-11 late childhood. For the purposes of this thesis project, assessment focuses on children age 4-7, 8-9, 10-11. Motor *learning* refers to changes that occur in skill ability to result in improved performance. Motor development is influenced by both growth and maturational factors. Growth refers to structural changes that occur (i.e. change in height, weigh, brain etc.). Equally, maturation occurs as a result of change from experience, practice etc. It has been suggested that taking part in sports or activity that requires computation or cognitive processes are inappropriate as a means of motor learning under the age of 10.

Learning involves changes in behaviour that arise from interaction with the environment that is distinct from motor development (maturation). Thus for the purposes of this thesis, motor learning, parameters of learning and evidencing learning will take precedence. Learning in motor skills can be evidence from increased accuracy and precision or decreased time taken to achieve a task goal. The relevance of timing and accuracy can vary depending on type of task and stage of learning. A combination of timing and accuracy is important to monitor skill acquisition, for example, if time decreases but accuracy also decreases, learning has not taken place, in contrast if accuracy remains stable or improves with a decrease in time taken, learning has taken place. Thus time taken to execute a movement could be considered as representing efficiency of motor processing with decrease in time taken showing an improvement of motor efficiency.

Score Feedback

The content of feedback and the subsequent impact on motor behaviour was taken in to consideration when designing the scoring system for the proposed PL tool. 'Having deliberate practices that are extrinsically motivated and focused on outcomes rather than processes an have somewhat rigid rules have detrimental effects on children's learning and motivation' (Piaget, 1962). Thus outcomes of PL testing that solely focus on achievement of tasks can have negative repercussions for children with poor motor competence. Therefore, evidencing success in the PL tasks must be rewarding, but focused on process and quality of movement rather than simply attainment of a final score. For the present PL tool, auditory and visual feedback was presented on screen to offer positive reinforcement when movement tasks demands were successfully met.

5.4.1 Measuring learning with PL tool

The relative weighting of different PL factors is an important component of test design; indeed this was shown to be an inherent weakness of several of the more established tests and checklists (Giblin, Collins & Button, 2014). Accordingly, derivation of a weighting scale has been based on three factors. Firstly, the five PL factors themselves have been developed from the extant literature on movement skills, with a particular focus on children. Secondly, the completed primary teacher survey, requesting individual opinions on the importance and weighting of the different factors. This is shown in Table 5.4 where the importance scale has been used to evolve the weightings (Table 5.5).

Finally, an expert panel of PE specialists (n=2), developed a weighting of PL skills based on their importance for sports and activities common in secondary age group children. As such, this component represents what may usefully be seen as the primary PE 'target market'. The suggested weightings, based on a combination of these data sources, are shown as the right hand column of Table 5.5. These weightings also take into account the combination of PL factors evaluated by the 8 elements of the PL test. As a result of this, estimated total loadings for each of the PL factors are as follows: Interceptive timing – 20%, Object manipulation – 10%, Locomotion and agility – 30%, Spatial awareness and balance – 32%, Rhythm and sequencing – 8%.

Task Group	**Outcomes**	**PL skills**	**Weighting (\100)**
Vertical jump	Time to complete	Locomotion & agility	10
Heading	Time divided by successful intercepts	Locomotion & agiliity Spatial awareness Interceptive timing	20
Hop scotch	Time to complete	Locomotion & agility Spatial awareness Rhythm & sequencing	20
Obstacle course	Time to complete	Locomotion & agility Spatial awareness	10
Monsters 1	Time divided by successful intercepts	Interceptive timing Spatial awareness & balance	5
Monsters 2	Time divided by successful intercepts	Interceptive timing Spatial awareness Rhythm & sequencing	10
Batting	Time divided by successful intercepts	Interceptive timing Spatial awareness & balance	15
Trace	Time to complete	Object manipulation	

Table 5.5: The eight PL elements, element weightings and the PL components tested by each

The final factor to be addressed in developing the test was to define a balanced scoring system across the elements. The definition and weighting was agreed upon by two experts in the field of motor skill and physical education. Table 5.5 reports what the outcome measures are and the relative contribution of each to overall PL skill level. To validate the weighting an initial set of norm values for each element was developed from the data gathered from 317 children during the main investigation described in Chapter 7.

5.5 Conclusion

In this chapter the process undertaken to design and develop the the content and structure of a comprehensive PL assessment were discussed. The process of test design included a theoretical review (described in chapters 2, 3 & 4), followed by a quasi qualitative study investigating the beliefs and practices of primary school teachers. The rationale for this approach was underpinned by the gap between research and practice that is often present in physical activity promotion, physical education and sports coaching. The study results show that the concepts identified as pertinent by the scientific evidence base were considered important factors in teaching physical education at primary level. However, the testing of these factors was limited. Surely, if PE is to remain considered a key facet of formal education, similar testing requirements should be in place to replicate the emphasis on learning, progression and evidencing effectiveness of curricular design and teaching in other subject domains. The teachers' survey results triangulated the findings from research, that available movement assessments or validated measures are not conducive to application in primary education environments by generalist teachers.

The latter sections of this chapter focus on defining the content and structure of a practical movement assessment that could be used in primary education by generalist teachers to test pertinent factors of PL. The task requirements, learning outcomes and weighting scale development resulted in eight tasks that comprise the first version of PL tool. The task requirements were used by a software engineer in the University of Otago to develop and pilot version of the testing tool. The development of the software was an iterative process using the Microsoft Kinect platform. The technical considerations of developing a movement assessment using low-cost motion Capture are discussed in Chapter 6. Following on from this, the initial feasibility testing of these tasks are described in Chapter 7.

CHAPTER 6

Test Development

6.1 Introduction

The objective of this chapter is to present the processes undertaken to develop the Physical Literacy (PL) assessment through a series of iterative pilot tests: Each version of the assessment and the testing procedures undertaken are described. Additionally the rationale for modifications are presented. Each pilot test was used to gather useful information about the standardised procedures needed for large scale testing. The pilot testing was conducted in Irish Primary schools. Feedback from the pilot tests was used to inform development of the testing software. During the iterative process a number of tasks were included and excluded to establish the combination of tasks that best provided assessment of key PL skills whilst also facilitating the psychosocial and practical requirements of deployment in a primary school setting (i.e. enjoyable, engaging and easy to use). Finally, the version of the PL assessment (PLV3) used in the main investigation (presented in Chapter 8) is described in this Chapter.

6.2 Kinect PL Version 1

Based on the findings from the teachers' survey (discussed in Chapter 5) and the literature based studies (presented in Chapters 2, 3 & 4), a pilot version of an exergame test to PL movement skills was developed, hereafter referred to as the 'PL Tool'. As discussed previously in Chapters 2,3 and 5, the ability to combine, select and self-organise movement is a central and crucial element of PL. The ability to deploy appropriate movements that are specific to an individual's skill set (and physical characteristics) to meet task demands is important for real-world physical activity, exercise and sport. In contrast, movement assessments often include children mimicking the 'correct' method of executing a movement skill. Consequently, the PL tool tasks provide a number of assessments during which children can deploy a variety of skills to meet a movement goal. The tasks include the five movement components found to be important to PL (Chapter 3 & 5). The five factors (locomotor skills, interceptive timing, rhythm and sequencing, object manipulation, balance and agility) were used to form a *combined* movement assessment 'game' using computer vision technology (i.e. Microsoft Kinect). The combination of factors was elected to replicate the application of movement skills in physical activity and sporting contexts (i.e. not used in isolation). To address the requirement for skill learning, the movement tasks were divided into levels with increasing difficulty. In this first version of the PL tool, scoring was based on speed and accuracy. For each task the relative importance of speed-accuracy was assessed by a panel of physical education and movement experts (n=2).

6.2.1 PLV1 tasks:

The following tasks were designed to test key facets of PL:

1. *Monsters.* The objective of this task was to hit the monster as soon as possible after it appeared on screen. Interceptive timing was the predominate skill used to complete this task. However, children also needed to deploy gross motor movement, dynamic balance and spatial awareness to ensure that they reached the monster shape in time.

2. *Tetris.* The objective was to match the shape presented on screen using whole-body movements. Balance, coordination and spatial awareness were required to successfully complete this task

3. *Target.* The objective of the task was to position body/body-part (head and hands) over the target(s). Targets are presented intermittently, firstly single targets appear and then pairs of targets are presented at various positions on the screen. Gross motor coordination, inter-limb coordination, hand-eye coordination and spatial awareness are required to successfully complete this task.

6.2.2 PLV1 Usability testing:

As discussed in Chapter 3, one of the main limitations of available movement assessments is the time, resources and expertise required to administer them. The labour-intensive process is not conducive to application in practical settings. Equally, assessment procedures often require extensive domain-specific expertise, thus potentially limiting the veracity of movement assessments deployed by generalist primary school teachers who have limited (if any) formal training in the area of motor skill evaluation. Thus a primary aim of PL tool development was to ensure that the assessment could be employed in school settings. With a packed curriculum and often limited PE hall availability, the assessment was designed with easy application within relatively confined spaces and time resources in mind, through the use of short duration, yet comprehensively designed PL movement tasks.

6.2.3 Method:

To examine the usability of the PL assessment, an initial user test was conducted using a sample of primary school children. The objective was to observe child interaction with the software, to gauge whether the task objectives were clear, the level of progression appropriate and to establish efficient methods of passive data gathering and exportation. Similarly, information about the practical aspects of test application such as space required and test duration were gathered.

Participants:

The initial alpha test was conducted on ten individuals (male and female), aged between 3 and 12. The participants were selected to provide a broad sample of ages, genders and abilities to enhance the generalisability of outcomes to typical primary populations. Participant assent and informed parental consent were attained prior to recruitment. A short physical activity readiness questionnaire was completed by the participants' parents prior to participation. Due to the age of participants (under 18) parental completion of the forms was sought to ensure accuracy and understanding.

Procedures:

Participants were provided with standardised instructions about the purpose of the game and how to play prior to each task. Trials were conducted in a clear 4x4m space, with the Kinect and screen position in clear view in front of the participant at a height of 60 cm. Participants played each task several times. The number of attempts that were required to achieve a steady score for each task were tracked for each individual as a measure of learning-rate.

6.2.4 Outcomes:

One of the main interferences during this testing was 'other person' tracking, for example, the testing took place in a school foyer, where people were occasionally moving across the background. The interference of background and foreground objects (tables/chairs etc.) limited the tracking capacity of the Kinect. Similarly, sunlight introduced infra-red interference that disrupted the Kinect tracking.

Tasks

Some interesting findings emerged form this initial pilot test in terms of task engagement. Some tasks provided more engaging than others. Specifically, the Monster and the Target tasks were most engaging. Children understood the requirements and the software accurately reflected the child's movement on screen. Successful intercepts were recorded appropriately. In contrasts, the Tetris task was less successful in both engaging and tracking individuals. Even if the child matched the shape on screen appropriately, the shape did not turn green, register a successful trial or progress to the next shape. This resulted in many children disengaging and requesting to discontinue the task. Based on these initial findings, the Monster and Target tasks were further refined and developed however Tetris was excluded from future iterations. A summary of the inclusion and exclusion criteria for PL tool tasks is provided below in Table 6.1.

Tech

In addition to task engagement there were a number of technical limitation that resulted user frustration during this initial pilot testing. Participants were easily frustrated by the latency between their actions in reality and the response of the skeletal tracking on screen. The latency on screen during this initial piloting phase reduced the validity of the data gathered. During the trial period, a number of unsuccessful tasks could have been attributed to the software delayed response rather than the child's movement ability. Improving the latency constraint is required prior to the next iteration of the PL tool.

Trials

For the Monster and Target tasks, 4-6 trials were required for scores to plateau. Notably, the Monster intercept was easy for participants to achieve high scores. Further difficulty manipulations were recommended for future iterations of the tasks. The number of trials taken to achieve asymptote was not measured during the Tetris task due to the major limitations listed above.

The score display was another limiting factor. The score was displayed on screen during PLV1. As a consequence of the display, children focused almost exclusively on the score of the previous participant and their own score. Thus, future versions required the inclusion of other feedback mechanisms, for example, auditory and visual feedback that provide more constructive information about the successful completion of tasks, rather than comparison to others' performances.

Task Inclusion	**Task Exclusion**
Measure a combination complex movement skills	Not representative of movement ability (i.e. the child can falsify scores without using controlled movement skill execution
Include flexibility for task execution and problem solving	Confusing presentation of task demands
Sufficiently challenging	Not able to discriminate between levels of ability because of insufficiently challenging difficulty level.
Promote self-regulated learning (i.e. engaging, rewarding, enjoyable)	Do not provide any additional information from another, more complex task.

Table 6.1 Task inclusion/exclusion criteria

6.3 PLV2

Following on from the initial user test, modifications were made to PLV1 to reduce the latency (RGB data display removed), the scores were removed from screen and the tasks were modified to provide more challenge (Monsters intercept provided quicker transition and multiple task interceptions simultaneously) Furthermore, non-representative tasks were removed (i.e. Tetris). Additionally, standardised environmental procedures were included in PLV2 pilot testing. Specifically, ambient sounds, background movement and clutter and lighting requirements were standardised during PLV2 testing.

Additionally, during PLV2 testing, measures of reliability were taken. Reliability was measured using test re-test for the tasks. During this pilot investigation, the number of trials required to asymptote per task were tracked similar to PLV1 testing.

6.3.1 Method:

Two groups of students were assessed over two consecutive week long periods in main stream national schools (mixed gender aged 7-8 & 9-10 years). The height, distance from the Kinect and participant clothing were standardised throughout test procedures. It should be noted that the level of control for light and noise interference with the Kinect cameras was more difficult to standardise in school settings. However, the testing environment was kept as constant as possible (with the exception of natural changes in day light, background noise etc.).

6.3.2 Procedures:

Participants

A total of 12 participants were recruited for testing. Testing took place in two primary schools in Dublin. Participants were divided according to class year grouping (1st class, 7-8 year olds n = 6 and 4th class 9-10 year olds n= 6). Participant assent and parental informed consent were completed prior to testing. A short physical activity readiness questionnaire for children was completed (by parents) prior to participation due to the participants being under the age of 18, parents were requested to complete the form to ensure accurate and complete information about the child's health status. All participants were injury free, participated in regular recreational extracurricular activity and completed 60 minutes of school based PE per week under the supervision of their class room teacher. No participant had health contraindications for physical activity participation at the time of the testing. Participants were informed that testing would involve playing a number of computer games that required them to use their body and movement to play.

PLV2 tasks:

1. *Monsters.* The objective of this task was to hit the monster as soon as possible after it appeared on screen. Interceptive timing was the predominate skill used to complete this task. However, children also needed to deploy gross motor movement, dynamic balance and spatial awareness to ensure that they reached the monster shape in time.
2. *Monsters (multiple).* Similar to the single monster intercept task, the objective of this task was to hit the monsters as soon as possible after they appeared on screen. Multiple monsters appeared at once, starting with two and progressing to four. Interceptive timing was the predominate skill used to complete this task. However, children also needed to deploy gross motor movement, dynamic balance and spatial awareness to ensure that they reached the monster shape in time.
3. *Target.* The objective of the task was to position body/body-part (head and hands) over the target(s). Targets were presented intermittently. First, single targets appear and then pairs of targets were presented at various positions on the screen. Gross motor coordination, inter-limb coordination, hand-eye coordination and spatial awareness were required to successfully complete this task.

Test

In small groups (2-3 participants) the movement tasks were explained to the students. The equipment was set-up in a typical school environment i.e. hall or large open corridor space. Students were instructed to stand at a180cm distance from the Kinect sensor. Procedures replicated those employed during the initial usability pilot test. Students completed trials of tasks (interception and target) until their scores plateau.

Re-test (5 days later)

Following the same procedures as test-day, students completed 6 trials at each task. If their score was increasing at trial 6, students repeated further trials. All students achieved score stabilisation within a further 3 trials.

Results

High test-retest reliability was found. Intraclass correlations were computed for the three tasks as (0.96), (0.94) and (0.74). Thus the tasks were considered representative and reliable for further development. Testing time was approx. 5 minutes per student.

Refinements

Tasks showed good reliability on test and retest. Scores typically plateaued by trial 6. Latency was still somewhat of an issue in this version. Accordingly, it was recommended that PLV3 reduce latency by optimising speed and graphics capabilities of the hardware and software used to run the PL assessment. Based on the effectiveness on interceptive timing and target tasks, other tasks variations for assessing PL (i.e. gross motor coordination, spatial awareness etc.) using similar tasks and constraints were developed for inclusion in PLV3. Standardising the environment improved the reliability and technical capacity of the Kinect. The duration of the test was approx. five minutes per students to complete one trial of each task.

6.4 PLV3 Pilot Test

Based on the findings from the first and second pilot tests, a range of tasks were developed. the tasks were designed to provide a combined assessment of the key PL skills that were identified from both literature and qualitative studies. Tasks that measure a combination complex movement skills, include flexibility for task execution and problem solving, are sufficiently challenging and promote self-regulated learning (i.e. engaging, rewarding, enjoyable) were PLV3.

6.4.1 Procedures:

The PL assessment software was refined based on the findings of PLV2 pilot testing. Again, PLV3 was tested in a school setting. A sample of 5 students completed pilot testing of PLV3 (test-retest) to establish reliability of the PL tool. Simultaneously, students were observationally rated for 'movement competence' during each task. 'Movement competence' was explained as confidence, ability and efficiency in completing the movement task.

6.4.2 Participants:

5 participants were recruited for the PLV3 pilot test. The participants were in 4th class in primary school. Two female and three males aged 8-10 were recruited. Participant assent and parental informed consent were completed prior to testing. As before, a short physical activity readiness questionnaire (PAR-Q) for children was completed (by parents) prior to participation. All participants were injury free, participated in regular recreational extracurricular activity and completed 60 minutes of school based PE per week under the supervision of their class room teacher. No

participant had health contraindications for physical activity participation at the time of the testing. Participants were informed that testing would involve playing a number of computer games that required them to use their body and movement to play.

6.4.3 Calibration & set up:

Tests were conducted over the two days in a primary school. The Kinect and screen were set up in a classroom with a clear 4x4m space. The lighting was standardised (using window blinds) for the duration of the testing. The Kinect was positioned at a height of 60 cms. Participants were directed to stand at a distance of 180cm from the camera to begin the calibration procedure. Calibration required the child to create a 'virtual square' by standing in four corners of the space whilst the tester recorded each of the four positions through the software application. Once the virtual square was displayed on screen, the child was directed to stand in the centre of the square and make a Y shape, reaching their hands above their head and fully extending their body. From this position, the software matched the model of the human skeleton to the shape detected, allowing the camera to estimate joint position for the 20 joints tracked by the Kinect. Calibrations screens are shown in Figures 6.1 and 6.2.

6.4.4 Task testing

Once calibration was complete, the child was taken to an introduction screen of the first task. The instructions of the task were read out to the child. Written and visual information of the requirements were also presented on screen. Verbal confirmation of understanding was sought prior to commencing the task. Each task was repeated a maximum of 9 times in succession. Initially, students completed each task 6 times, if their score was still increasing at trial 6, students repeated further trials. All students achieved score stabilisation within a further 3 trials.

Scores for each repetition of the task were recorded. Observational review of movement ability for each child were recorded simultaneously under the broad categorisations of movement competence. Each child was allocated a 1-5 rating per category for each task. The objective of observational recording was to provide a triangulation of the scores retrieved from the software application. The rationale for recording observational scores was twofold; to provide a measure of construct validity and to triangulate the information being recorded by the software. As evident from PLV1 and PLV2 pilot testing, under certain conditions (latency/light/noise interference) PL scores reflected environmental and test constraints rather than PL ability. Triangulating PLV3 scores with observational review was used as a preliminary effectiveness check for the software application functionality.

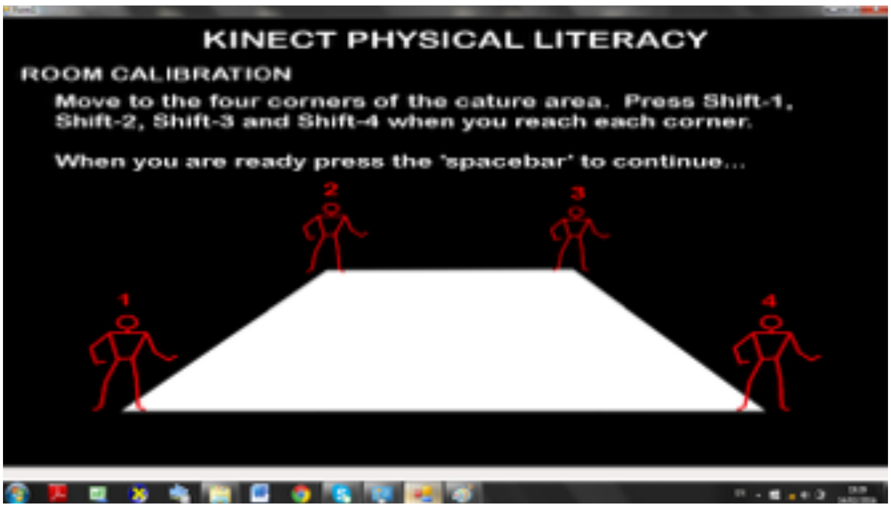

Figure 6.1: Calibration Screen 1

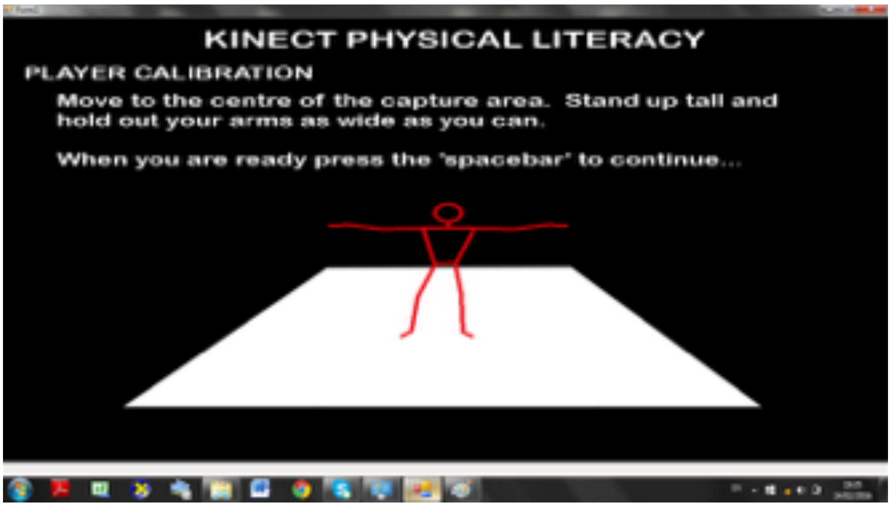

Figure 6.2: Calibration Screen

Task 1 Single monster intercept:

The first task presented was the 'single monster task' (Figure 6.3). The objective was to intercept the monster shapes as they appeared on screen. The task required the child to use hand-eye coordination, spatial awareness, balance, gross motor movement and interceptive timing to successfully complete the task. Positive outcome feedback was provided in the form of the monster immediately disappearing from the screen once intercepted successfully.

Figure 6.3: *Monsters Task instruction screen*

Task 2 Multiple monster intercept:

The second task presented to each child required the use of hand eye coordination, spatial awareness, gross motor movement, balance, speed and interceptive timing (see Figure 6.4). The task provided a progression from 'single monster intercept', thus required the application of the same facets of PL skills however under increased demands (e.g. speed and multiple shapes appearing simultaneously). The task required children to integrate information about number and position of shapes and respond appropriately to intercept as many shapes as possible under a short time frame. Positive outcome feedback was provided in the form of the monster immediately disappearing from the screen once intercepted successfully.

Figure 6.4: Monsters Task 2 instruction screen

Task 3 Heading:

The third task required the child to intercept a ball on screen using their head and to use a heading motion to direct the ball successfully to a circular target presented on screen (Figure 6.5). The round target moved position (upper corners/lower corners) of the screen. The speed of the balls presented on screen and the difficult of target position increased throughout the task. The task required the use of accurate object manipulation, interception timing, spatial awareness and balance for successful completion. The target turned green providing positive outcome feedback to participants once the ball successfully hit the target. If successful interception did not take place the target remained the same (i.e. no negative outcome feedback was presented).

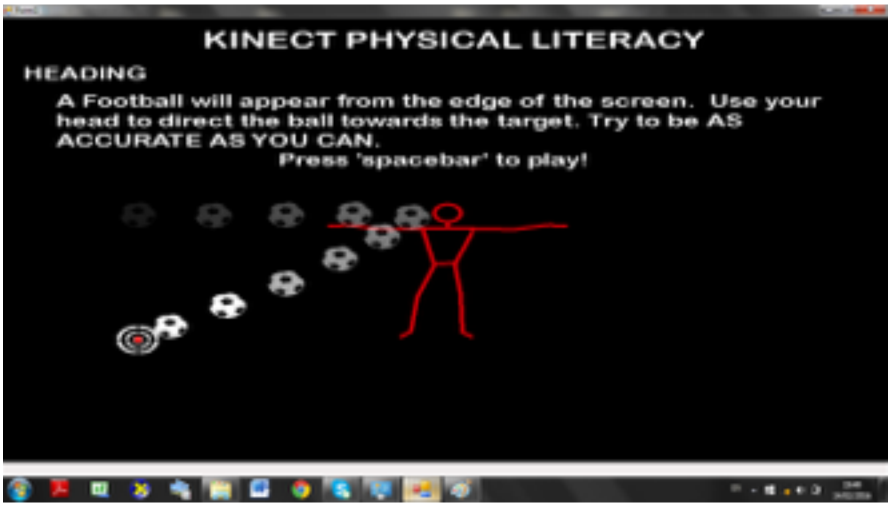

Figure 6.5: Heading Task instruction screen

Task 4 Batting:

This task required interaction with an external object. The ‘wand’ was used to emulate the demands of object manipulation required for sports such as tennis, cricket, hurling, hockey etc. The wand was calibrated prior to testing (figure 6.6). The wand was a bright coloured blue/green spherical object. The game required the child to manipulate the wand in a swinging motion to intercept ball projections presented on screen. In addition to object manipulation, this task required interceptive timing, intersegmental coordination (upper-lower limb interaction), balance and spatial awareness

Figure 6.6: Batting Task instruction screen

Task 5 Maze:

This task required the child to use gross motor movement and decision making to move from ‘start’ and ‘end’ position presented on screen. The task required additional cognitive integration and decision making whereby the child had to select and execute an appropriate motion to ensure that they arrived at the correct location as quickly as possible.

Task 6 Hop scotch:

This task required the participant to follow a pattern of squares displayed on screen (Figure 6.7). The task involved the use of double and single leg base of support, gross motor movement, visual perception and spatial awareness. Successful trials were indicated via a colour change on the square once the participant had successfully reached the highlighted square displayed on screen. Accuracy and speed were required for successful completion of this square.

Figure 6.7: HopscotchTask instruction screen

Task 7 Trace 1:

This task required interaction with an external object. The 'wand' was used to emulate the demands of fine motor coordination (Figure 6.8). Fine motor coordination ability level has been associated with academic achievement thus an important consideration for PL educational assessment. The wand was calibrated with the software prior to the task. The wand was a brightly coloured object (ball). The child was instructed to trace the line presented on screen as accurately as possible.

Task 8 Trace 2:

Similar to the demands of Trace 1, this task increased the level of difficulty of fine motor control required to successfully complete the task. Modelling and replication skills demonstrate the ability to integrate and internalise movements and sequences through observation. These skills are important for learning and interacting in physical activity and sport. The trace required the student to replicate the design presented on screen as quickly and as accurately as possible.

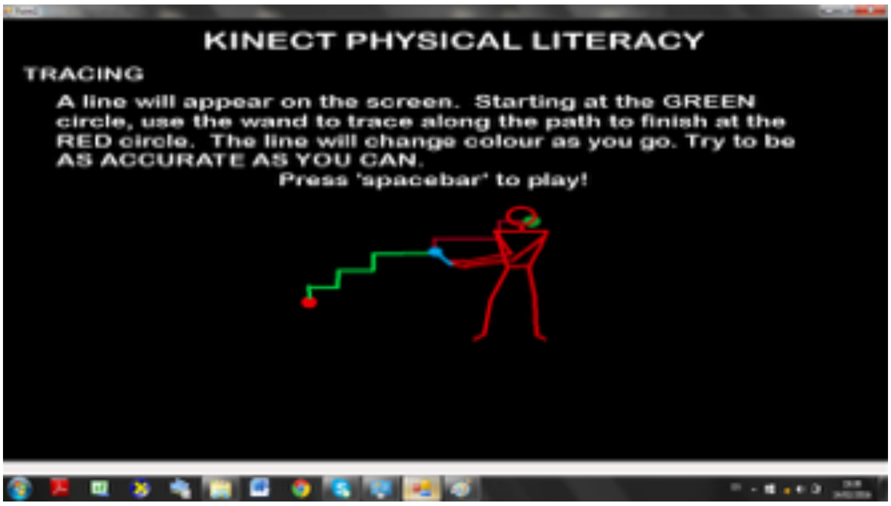

Figure 6.8: Trace Task instruction screen

Task 9 Vertical jump:

This task required the child to use their perceptual skills to assess how high they thought they could jump (see Figure 6.9). A target was positioned at the top of the screen above the child's head. The child was asked to instruct 'lower' until the target was positioned at a point the child thought they could reach with their head during jumping. The number of trials required to reach the target and the height jumped were recorded as outcome measures.

Figure 6.9: Vertical Jump Task instruction screen

6.4.5 Outcomes

Due to the strategies used by the children to achieve Task 1 & 2 (e.g. flailing arms and legs) the Monster tasks were not included in the observational analysis. Task 5 was considered too similar to Task 6 and provided no additional information about children's movement skills. Thus only Task 6 (more complex) was included for further investigation. Due to software development delays, the vertical jump task did not run as intended and therefore the results were not included for further investigation. Due to technical limitations in calibrating the wand using in the batting task, the child's hands were used to intercept the ball instead of the wand. Reliability was measured for task 2 (0.96), task 3 ICC (0.74), task 4 (0.68), task 6 ICC (0.98). Teacher observational rating of 'movement competence' resulted in high correlation with PL tool scores Task 3 (0.78). Task 4 (0.68) and Task 6 (0.73).

Thus the tool (PLV3) included for further investigation with a larger cohort of primary school children (presented in Chapter 8) included the following tasks and outcome measures described below:

<u>*Heading:*</u>

Heading task, as described in Figure 6.5, however, further feedback was provided via auditory mechanisms i.e. 'swish' sounds once the ball hit the target to provide additional positive feedback. The outcome measures were the number of successful intercepts and time taken.

<u>*Batting:*</u>

Batting, as described in Figure 6.6, requires interaction with an external object. Again additional feedback was included. The target turned green providing positive outcome feedback to participants once the ball successfully hit the target. If successful interception did not take place the target remains the same (i.e. no negative outcome feedback will be presented). Auditory bat-ball ‘clink’ sounds once the ball successfully intercepted the target were added to provide additional positive feedback. Number of successful intercepts and time taken were used as outcome measures for the tasks.

Hop scotch:

As described in Figure 6.7, this task required the participant to follow a pattern of squares displayed on screen. Feedback included a colour change and auditory cue ‘bleep’ sounds once the square was intercepted to provide additional positive feedback. If successful interception did not take place the target remained the same (i.e. no negative outcome feedback was presented). The outcome measure was time taken.

Kinect Accuracy and Technological Constraints:

For present purposes, markerless motion capture, specifically the Microsoft Kinect, provides a portable, low-cost and user friendly motion capture option for measuring movement in PE. The precision and accuracy of the system are variable depending on movement, camera placement and task constraint. In this thesis, a calibration procedure to identify the individual, body segment length and spatial information were implemented in the PL tool to ameliorate some of the inaccuracies associated with markerless motion tracking. However, the application and in-depth consideration of algorithmic correction was beyond the scope of this PhD project.

Notably, the accuracy and precision of the Kinect can be influenced by self-joint occlusion. If movements are too fast, the Kinect can miss-fit the skeletal model and reduce the accuracy of tracking throughout a dynamic movement. The Kinect toolbox (online developer resource) provides a confidence interval for each joint marker recorded by the Kinect. The confidence levels are provided on a three point scale that shows whether a joint has been confidently seen or not (0 = not seen, 1 = inferred, 2 = seen). Although beyond the scope of the study to examine the confidence intervals of joints recorded, considering this potential limitation, a positional review of the movement task was conducted to identify task components that may be less accurately tracked with the Kinect:

Batting: The cross of arms, hands and swinging motion could result in a combination of body segment misfit and joint occlusion when/if the arms swing out of view. Children who used a single hand performed better that those who deployed a typical double handed swing during the pilot study. Although a potential limiter in terms of the accuracy of tracking hand and elbow joints, the potential occlusion provided an interesting opportunity for students to use their perception and adaptation skills. For example, students who quickly figured out that intercepts where they remained square on to the screen and kept their hands visible were more successful.

Heading: The head is one of the most robust skeletal point markers of the Kinect model. A potential occlusion could occur during the heading task if the child dipped their head down or crouched parallel to their torso. The Kinect cannot fit the model in this instance as it does not recognise the shape as representative of typical humans. However, this could present similar perceptual benefits listed in batting task.

Hop scotch: The main potential limitation in this task involves travelling too far backwards during task complete. If the child moves too far back to intercept the square the skeleton can be lost or misfit in the field of view. If this is the case, the child is simply redirected in to the field of view and the skeleton is reconstructed.

6.5 Conclusion

The pilot testing showed that, with refinement and development, the test tasks were user friendly and reliable. Further testing of the PL tool tasks were required to establish validity in primary school settings. Notably, a number of tasks were considered ‘too simple’ for meaningful assessment i.e. Task 5 maze, Task 1 single monster intercept, Task 2 multiple monster intercept. Additionally, the trace tasks (Task 7 & Task 8) and the vertical jump task (Task 9) could not be included for further investigation due to software development limitations. Although beyond the scope of time constraints of this thesis project, it is suggested that the vertical jump and trace tasks are further developed to form a more comprehensive PL assessment battery. Prior to further PL test validation (discussed in Chapter 8), a critical literature review and single case-comparative study was undertaken to examine the efficacy of the Kinect for measuring movement skills. This is presented in Chapter 7.

CHAPTER 7

Technical Validation

7.0 Introduction

The purpose of this chapter is to assess the validity of the Microsoft Kinect used to track physical movement skills during a Physical Literacy (PL) assessment (described in Chapters 5 & 6). As discussed in Chapter 4, exergaming devices have been used in education and healthcare settings to promote physical activity and measure movement. The Microsoft Kinect is an exergame device which requires no external tether to transmit physical information from the user to the computer program. Additionally, the Kinect provides body segment tracking capacity to allow users to measure body segment positions. Thus, because of the Kinect's ability to track body segments in motion (albeit in limited planes of motions with three degrees of freedom) it was considered appropriate for developing the PL assessment tool due to the markerless set-up and limited equipment requirements to meet the demands of assessment in primary school settings. However, it should be noted that the accuracy and precision of the Kinect to track motion has been questioned extensively in research. Accordingly, the limitations associated with using the Kinect to track movement will now be considered critically and in more detail.

As mentioned, the limitations of Kinect for measuring movement have been acknowledged in research (Galna, 2014; Pfister, West, Bonner et al., 2015; Schmitz, Shapiro, Yang et al., 2014). For example, one noted limitation of the data stream acquired using standard Kinect SDK is the inaccuracies in planar motion identification. To investigate both the benefits and limitations of the Kinect for measuring PL tasks, a critical review of the literature was undertaken. Furthermore, a single-case comparative study was completed, assessing the accuracy of the Kinect against an industry standard marker-based motion capture system used for measuring a gross motor movement task (i.e. countermovement jump).

In this chapter, the origins of motion capture are explored. Marker-based and marker-less motion capture systems are compared and contrasted, and potential optimisations of markerless motion tracking is discussed in the context of future progressions.

7.1 Motion Capture Technology

When identifying appropriate methods of assessing human movement, the context, benefits and limitations of different motion analysis modalities is an important consideration. Movement analysis is not a new concept. In fact, the desire for increased understanding of the temporal and distance parameters of human gait date back to the mid-nineteenth century (where the Weber brothers reported the first quantitative studies of human locomotion). For the most part, contemporary study of motion has been motivated by the need to understand clinical disorders and pathologies that are characterised by subtle changes in joint and movement patterns. State-of-the-art motion capture (for clinical purposes) typically require the application of external markers to the skin that can be seen and recorded in a laboratory setting by multiple cameras (Meldrum, Shouldice, Conroy et al., 2013). Notably, marker based systems fail to meet the ecological requirements for testing motion in schools settings, however, marker-based systems offer a reference standard against which markerless systems can be assessed. For this study, a marker-based system (Vicon) was used to assess the accuracy of a Microsoft Kinect for tracking a jump motion used in a number of the PL tool tasks. In the following section, the traditional marker-based motion capture system used in this study (Vicon) is discussed. Furthermore, general technical limitations of marker-based motion capture are presented.

7.2 Marker-based camera systems

There are a number of limitations associated with marker-based systems. For example, markers placed on the skin presume a rigid position, however this presumption does not account for the dynamic nature of the skin, underlying tissue and bone. Furthermore, the behaviour of skin artefacts are considered uniform when using the maker based motion capture approach. In contrast, skin artefacts behave differently during static and dynamic motions. Additionally, the application of artefacts (i.e. placing markers on the skin) can introduce an additional extrinsic stimulus, often altering internally generated and natural movement patterns. Whilst post-processing software and techniques have advanced to ameliorate this noted limitation, the application of complex post-processing procedures is time, resource and expertise intensive.

Vicon (Oxford Metrics Group, UK) is a marker-based system that uses optoelectronic infra-red motion capture cameras. Vicon systems use passive retro-reflective markers attached to anatomical bony landmarks or segments on the human body. Light produced by infra-red stroboscopic illuminations (light emitting diodes) surrounding the camera lens are reflected by the markers and recorded. Detection of a marker by more than one camera enables its reconstruction in 3D space. Depending on the models used, post collection processing allows markers to be defined anatomically and bone segments created. Once fully applied to the motion files, anatomical segments or joints are able to be tracked and analysed using a local coordinate system defined for each body segment of interest (LCSs).

To obtain accurate marker data, Vicon systems rely on using several cameras. Camera numbers used to capture global movements have typically ranged from five to twelve so as to be able to capture dynamic motor skill executions (Fedorcik, Queen, Abbey et al., 2012; Kwon, Como, Singhal et al., 2012). Considering the substantial camera set-up requirements, studies have largely been restricted to laboratory settings. Notably, such investigation lacks representation of a primary school PE environments e.g. school hall or playing field. However, controlled lab-based indoor conditions are typical of clinical research studies (Selfe, Thewlis, Hill et al., 2011) and, whilst limited in ecological validity, they do ensure a high degree of experimental control.

In addition to lab requirements, in order to enable six degrees of freedom (DoFs) modelling, multiple markers are required to be positioned on each body segment. Without such marker positioning, 6 DoF about the joint cannot be tracked and this limits planar movement analysis. In some studies, the total number of markers used has been 42 (Meister, Ladd, Butler et al., 2011). Owing to a combination of fixed camera positions and dynamic movements, tracking multiple markers on the limbs during gross motor movements presents a challenge. Markers can become occluded from the cameras due to a change in marker orientation, and/or the positioning of other body segments (Betzler, Kratzenstein, Schweizer, Witte, & Shan, 2006). As a result of this difficulty, obtaining consistent data throughout entire dynamic movements can be unreliable, especially for high velocity joints and the upper limbs where it is more common for data to be reported only at specific task events (e.g. intercept). It should also be noted that the sampling rate of most lab-based motion capture systems is ~300Hz i.e. ten times the sampling rate of the Kinect. Again, however, this noted limitation must be weighed against the benefits of the ecological validity of the Kinect for assessing movement in primary school settings.

7.3 Marker-less motion capture

To combat the limitations of marker-based systems noted above, markerless motion capture was considered more conducive for measuring movement in a PL context. As discussed in Chapter 4, exergame modalities have grown in popularity over the last decade. The most common form of exergames use either an external tether or platform to transmit information about player's movement, or computer vision.

Tether and platform based exergames, such as the Wii, are commonly used in traditional gaming, education and rehabilitation settings. However, one of the major limitations of such devices is the ability to cheat the input. That is, when 'sprinting' using the Wii remote, instead of engaging whole-body gross motor movements, a small wrist action can be erroneously registered as meeting the movement requirements. Similarly, manipulations of force platforms can be deployed to falsify jumps. The ability to cheat may confound the engagement and interaction with the device and potentially block the exergame having the desired outcome. For example, in the context of PL, if children realise that cheating promotes higher scores, handwork, perseverance, feedback and learning may be sacrificed for quick (and erroneous) progression.

Whilst there are noted limitations of external tether-based exergames, it is also necessary to consider the benefits of external input. For example, external input devices can be used for the provision of biofeedback in the form of tactical vibration from the handheld tethered when striking a virtual ball, or from a force platform when hitting a mogul on virtual skiing. Haptic exploration, object manipulation and biofeedback are important aspects of skill learning and development that can be provided by external device input. However, the extent to which the feedback from such devices is representative of real world biomechanics has yet to be established and warrants caution.

In contrast, computer vision used to assess movement (i.e. Kinect) does not provide a source tactile feedback; however, external devices, such as a 'wand' can be tracked by the 3D depth sensing technology. Thus, the potential for tactile feedback using computer vision is possible and a potential progression that warrants further exploration (although beyond the scope of this thesis). For the present project, marker-less exergaming technology that utilised computer vision was chosen for PL tool development.

7.4 3D computer vision & depth sensing for motion analysis

Computer vision is a field that includes methods for acquiring, processing, analysing, and understanding images. Computer vision works by projecting light (of a known frequency and energy) on to a scene. The returned light, alterations in energy, shape and time taken to return, provide information about distance and depth of objects in the scene can be garnered. The Kinect uses infrared emissions and a multiple sensing camera to scan people/objects.

More specifically, the Microsoft Kinect operates like a portable 3D scanner using a structured-light approach to computer vision (the later version of Kinect uses Time of Flight computer vision). The Kinect provides depth data and RGB image data. Infrared light is emitted, the light is returned with variation in shape due to interception with objects/individuals in the field of view. The shape and speed of the returning light is recorded by the Kinect sensor. The speed and shape of light is then used to reconstruct a depth map of the field of view. The depth data is used to derive a body segment model, (using the model construction provided by the Kinect software developer kit SDK). The body segment model places joint centres and limb segments in the depth image using typical human anthropometrics to infer position within the volumetric shape created. As mentioned previously, 6 DoF are not tracked using the markerless approach. However, xyz coordinates are provided from the Kinect software relative to a calibration pose and the floor plane that assumes the individual is facing straight on to the camera during the calibration procedure. The process presents an appealing alternative to the resources intensive marker-based systems typically used to assess motion in lab-based settings.

It should be noted at this point, and will be discussed in more detail later, that there are inherent limitations of using markerless devices to track motion (e.g. accuracy, precision etc.). Thus, when considering the use of markerless or marker based systems for measuring motion, the degree of sensitivity required to track movement outcomes is an important consideration. For present purposes, the measurement of movement outcomes for PL education are not considered to involve the degree of accuracy that rehabilitation or biomechanical measurements would require. The initial movement outcomes for this project focused predominantly on performance based measures of gross motor execution (number of successful intercepts with large body segments and time to completion). Therefore, marker-less motion capture was deemed an appropriate modality measuring movement in this context.

7.5 Kinect accuracy and precision

As discussed previously in Chapter 4, within set parameters of planar motion and depth distance, Kinect *can* provide moderate-excellent reliability (Galna, 2014). Accuracy of the data varies depending on the reference comparative, with most showing error margins less than 10% for ranges of motion in the frontal and sagittal planes. Galna and colleagues (2014), examined the Kinect reliability compared to reference standard marker-based system. Results showed that the error rating and discrepancy was dependent on the type of movement task. Upper limb parameters were more reliable and accurate than lower: For example, shoulder abduction 4%, elbow flexion 6%, hip abduction 7%, knee flexion 9%. More importantly for the present purpose, results showed that Kinect measured timing of movement very accurately (low bias, 95% limits of agreement <10% of the group mean, ICCs >0.9 and Pearson's r > 0.9). Kinect had varied success measuring spatial characteristics, ranging from excellent for gross movements such as sit-to-stand (ICC = 0.98) to very poor for fine movement such as hand clasping (ICC = .012) (Galna, 2014).

Specifically examining dynamic movements, a recent study investigated the measurement of squat mechanics using Kinect, compared to Vicon (Schmitz, Boggess, Shapiro et al., 2015). Fifteen individuals participated in the study (8 male, 7 female). Marker trajectories and Kinect depth map data of the leg were collected while each subject performed a squat motion. Each set of marker trajectories calculated knee and hip angles. Absolute differences between the systems were measured at <5 deg. Peak joint angles showed high between-trial reliability with ICC > 0.9 for both systems. The peak angles calculated by the marker-based and Kinect systems were largely correlated (r > 0.55).

More specifically, examining the assessment of dynamic movement tasks that are relevant to physical development in children, Sgro and colleagues (2015) examined the effectiveness of the Kinect for measuring jump parameters associated with development in children (Sgro, Nicolosi, Schemer et al., 2015). The countermovement jump has a critical role during the development phase (Floría & Harrison, 2013). Children start jumping at 3 years old (Jensen, Phillips, & Clark, 1994), but their skills are really consolidated during early and middle childhood (Gallahue & Ozmun, 2002). For the purposes of the study, Sgro and colleagues (2015) used the coordinates of the whole body center of mass (CoM) in the medio-lateral (ML) direction (X), cephalo-caudal (CC) direction (Y), and antero-posterior (AP) direction (Z) obtained by applying the segmentation method (Winter, Patla, Prince, Ishac, & Gielo-Perczak, 1998) to the data exported. According to the Linthorne (2001) model, the parameters used for further analysis were mainly obtained from CoM vertical displacement and vertical velocity signal (as the derivative of the center of mass displacement). A fourth-order zero-lag Butterworth filter with cutoff frequencies of 20Hz was applied to clean the noise in CoM data. A descriptive analysis and t-tests were computed between all measures. The effect size was estimated with Cohen's d, and interpreted with the following criteria. Small=0.20–0.49, moderate=0.50–0.79, and large>0.80 (Cohen, 1977).The results of this research showed that the developmental levels could be effectively discriminated by knee-hip joint coordination. The height of jump was used to discriminate children with the same age in low-level and high-level groups in the jump test (Floría & Harrison, 2013). The high-level group showed significantly higher values in the parameters (e.g., peak of force in the propulsion phase, instantaneous velocity) than the low-level group. These findings also support the ability of height of jump to discriminate between performance levels in developmental stages. Heights of jump and flight time parameters seem to be the best predictors of the different performances between ability levels (Floría & Harrison, 2013).

In the study, the ground truth for both measurement systems were compared with assessments using a gold-standard inclinometer. The measures showed accuracy of < 2 degrees which is within the acceptable bandwidth of clinical variation (3-5 degrees) (Schmitz et al., 2014). The coefficient of repeatability was less than 0.51 for both systems, where 95% of the differences between two trials to be for each system (Bland and Altman, 2010). Considering all planes of motion, the limits of agreement, an interval for test–retest differences, for the markerless system (0.41 to 1.11) was comparable to that of the marker-based system (0.21 to 0.91). These results are within the range reported by other studies who have found markerless and marker-based systems to be repeatable with each other by 8.21 to 0.21 for trunk angle during a lateral reach (Clark, Pua, Fortin et al., 2012).

In another investigation, accuracy and repeatability of the Kinect system was compared with a marker-based system to assess the reproducibility of joint angle changes (Clark et al., 2012). This study assessed the concurrent validity of the Microsoft Kinect™ against a benchmark reference, a multiple-camera 3D motion analysis system, in 20 healthy subjects during three postural control tests: (i) forward reach, (ii) lateral reach, and (iii) single-leg eyes-closed standing balance. For the reach tests, the outcome measures consisted of distance reached and trunk flexion angle in the sagittal (forward reach) and coronal (lateral reach) planes. For the standing balance test the range and deviation of movement in the anatomical landmark positions for the sternum, pelvis, knee and ankle and the lateral and anterior trunk flexion angle were assessed.

Each study, and particularly dynamic movement studies, used a variety of protocols and post-processing procedures, thus comparison between studies is limited. Additionally, as outlined above, movement task demands and Kinect set-up influences the output of the skeletal movement tracking. Therefore, to ensure the veracity of the PL software and Kinect procedures used in this thesis, a single case-comparative study was undertaken in the lab to examine the accuracy between a PL tool Kinect task and a validated, marker-based system of measurement.

7.6 Marker-based and markerless motion capture for measuring jump motions.

For practical application in PE settings, the utility of state of the art biomechanical analysis is questionable. However, marker-based motion capture in a lab setting can be useful in understanding and identifying feasible methods of using markerless motion capture through comparative investigation. The purpose of this initial comparative study was to conduct a single-case examination whereby the proposed measurement method (Kinect) was compared against lab-based approaches (Vicon). A jumping task was elected for measurement due to its dynamic demands, the jump task was considered representative of gross motor tasks, using both markerless (Kinect) and marker based (Vicon) systems. Further, the jump was chosen because of its constrained nature. Other PL tasks require the participant to interpret movement demands and execute and appropriate response, thus defining the task for lab-based investigation would have been subject to tester bias and may not have represented task completion. Furthermore, the jump task was used within the heading and vertical jump tasks of our PL Tool. The centre of mass, multi-joint and level-change demands of the jump were deemed representative of the centre of mass and stabilisation requirements.

Participants

A healthy male participant was recruited to participate in the study. The participant had no current injury or injury history that was impeding participation in sport. In accordance with ethical procedures, informed consent was attained from the participant. A PAR-Q was completed prior to task completion.

Methods

A single-case comparison was completed between Vicon and Kinect. A 5 camera Vicon system was positioned in a circular fashion so that all body segments were visible to enable 3D reconstruction. Prior to testing, a calibration procedure was used to define the 3D testing volume as per the Vicon software. Calibration of the measurement volume required two calibration objects; a static L-shaped reference structure and a T-shaped wand. The L-shaped reference structure had four attached markers at set positions and of predetermined distances. The orientation of the L was such that the long side ran parallel to the length of the laboratory. Positioned in the centre of the measurement volume, the L-shaped reference structure defined the global laboratory coordinate system origin and direction of the x-, y-, and z-axes. Similarly, the wand was equipped with two markers at either top end of the T, and again at a predetermined distance. The calibration procedure was performed by dynamically moving the wand for 30 seconds around the desired volume to be calibrated, while the L-shaped reference structure remained on the floor. Standard calibration procedures were completed to ensure that the markers were visible to the camera system.

Procedures

Standardised instruction was provided to the participant and a number of familiarisation (sub maximal) jumps were completed to ensure proper technique. A qualified physiotherapist specialising in biomechanical analysis using Vicon placed the markers on the participant. A single case validation against the industry gold standard marker-based system (Vicon 250 5-camera infrared Motion Analysis System) was completed. Markers were placed as per Meldrum's model (Meldrum, 2013) on head, shoulders (Acromioclavicular joint, posterior/anterior), pelvis (ASIS, PSIS), knees (patellar, medial/lateral condyles), ankles (medial and lateral malleoli and talar joint) and sternum (supra-sternal notch line). The markers tracked multiple body segments in the sagittal, coronal and transverse planes using the calibrated anatomical system technique. The movement was captured using a Vicon system (operating at 100 Hz). The raw data was exported to Matlab/Visual 3D for processing. The movement data was filtered using a fourth order low pass Butterworth filter with a cut off frequency of 10Hz.

Kinect

Kinect RGB camera uses an 8-bit VGA resolution (640x480 pixels) while its' monochrome depth sensor has a VGA resolution of 11 bits that allows 2048 sensibility levels. The Kinect device has an approximate depth limitation from 0.7 to 6 meters. Horizontal angular field of view is 57^o and 43^o vertically. Horizontal field of view has a minimum distance around 0.8 meters and 0.63 meters in vertical, so Kinect has an approximate resolution of 1.3 millimetres per pixel.

A static Y pose was assumed, as is stipulated to calibrate joint modelling using the Kinect skeletal tracking function. A sample dynamic task was selected for system comparative purposes. The counter movement jump is a dynamic movement that is used frequently in the PL exergame tasks (heading). Furthermore, the head marker is a particularly robust marker that is easily visible by both marker based and marker less motion capture devices. The head marker is also considered a proxy measure of the centre of mass (Sgro et al., 2015). Centre of mass transition is used frequently in the PL assessment during the Hopscotch and Heading tasks. Thus, the head marker tracked during dynamic, multi-joint, gross motor movement was considered appropriate and representative of PL task requirements for this comparative study (Sgro et al., 2015).

The duration of the movement was measured as well as joint locations for specific event (head). The events were chosen to provide a representative of gross motor movements used in the PL assessment. The head was used as a proxy-measure of centre of mass position. The head is likely to be visible at all times throughout the movement measured using Kinect, thus could provide a more stable marker than the sternum/torso that may be subject to occlusion by upper limb motions etc.

Movement commencement was measured as a downward movement of the head marker by 20% of height. Jump height was measured as the difference between head marker position pre-jump and maximum head marker position height.

Data analysis

Joint angles were defined using the XYZ Cordon sequence, so that X represented flexion–extension, Y represented add–abduction, and Z represented internal–external rotation (Cole, Nigg, Ronskey et al., 1993). The precision and accuracy of measurements were assessed between both systems using Matlab. The raw data was exported to Matlab/Visual 3D for processing. The Vicon and Kinect data were coregistered using the location of the Vicon markers. The pre and post jump phases were derived from the normalised head height data as a function of time.

Normalised kinematics were exported into Matlab where joint position and displacements were plotted using data from both Polygon (Vicon software) and Kinect. Differences between the two systems were measured by tracking jump height, jump duration and head marker movement. The results of the three jumps were averaged to compute the mean and standard deviation. A p-value below 0.05 constituted significance. Data is presented pictorially in Figure 7.1 and numerically in Table 7.1

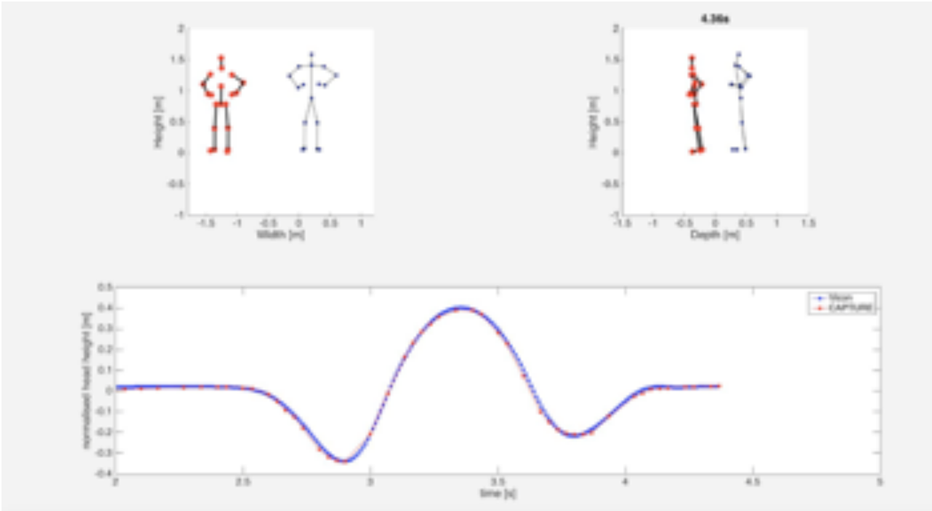

Figure 7.1. Kinect - Vicon comparison for counter movement jump curve head marker tracking.

Results

The study found high accuracy and precision between recording of jump height measured with Kinect and Vicon using the head marker as the main output. The mean jump height measured by Kinect was 36.66cm and the mean height measured by Vicon was 38.33cm as shown Figure 7.1. A T-test was performed to examine differences between the Kinect and Vicon group. No differences were found between or within groups over the three jump trials $t(4) = 1.508$, $p(0.206)$.

Trial	Kinect Jump Height (cms)	Vicon Jump Height (cms)
CMJ1	36	38
CMJ2	38	40
CMJ3	36	37
Mean	36.66	38.33
Confidence interval lower (95%)	33.79	34.53
Confidence interval upper (95%)	39.53	42.12

Table 7.1: Descriptive statistics for head height jump trials measured with Vicon and Kinect

Limitations

The initial results are promising for the accuracy and precision of the head marker used to track dynamic movements such as countermovement jump. However the single case comparative approach of this study presents limitations in the generalisability of findings. Further research with larger samples is required so as to provide accuracy and precision rating for the Kinect compared to Vicon that represents ranges of anthropometrics. The Kinect models skeletal output on typical anthropometrics therefore the accuracy and precision of atypical anthropometrics requires consideration. However, in the present study, adaptation of the skeletal model derived from Kinect was considered out of scope due to the concentration on gross motor movements. In contrast, if the outcomes required precise indications of angular motion about a joint, anthropometric correction may be warranted.

Additionally, the present case comparison does not account for the environmental factors that are known to reduce the accuracy and precision of the device (day light, background noise etc.). Thus the transference of results from the lab-based study where control for individual and environmental constraints was implemented may not be representative of the accuracy and precision of the device used in less controlled environments (i.e. school classrooms).

Discussion

The findings of the single case comparative showed that Kinect and Vicon did not differ significantly when tracking a head height during the execution of a dynamic gross motor skill. Noted limitations of measuring CMJ using Vicon were evident. The set-up of the marker-based system took 50 minutes. The marker-based system also introduced constraints on the dynamic movement. Notably, the participant was unable to place their hands on their hip as standard protocol for performing a CMJ. Similarly, knee flexion was restricted to ensure that pelvis marker models were visible. Further delays were incurred when the cameras were struggling to see the markers during the loading phase of the jump. Thus, additional adjustment was required to ensure that at least 3 cameras could identify the markers during jump phases. Furthermore, during the jump tasks, markers were displaced (i.e. fell off) necessitating setting up makers again.

The results provide support for the accuracy and precision of the Kinect for capturing dynamic movement information. Furthermore, it is clear from the review of the literature that the accuracy and precision of the Kinect is heavily impacted by task and environmental constraints, thus in the proceeding sections, potential options for optimising the Kinect output are considered.

7.7 Optimising Kinect Output

As highlighted through this Chapter, in the context of PL movements skills, acute accuracy in individual joint motions was not deemed a crucial requirement. However, consideration of potential methods for improving accuracy is warranted in the context of the environmental constraints within which testing will take place (i.e. schools). Many factors in the environment impact the accuracy and reliability of the Kinect. For example, ambient temperature, light, sound, reflective surfaces, dark or baggy clothing and fore-ground objects all limit the extent to which the Kinect can accurately infer skeletal markers. Thus, a brief summary of potential methods and future considerations for optimising the accuracy of the Kinect are now discussed to provide solutions to potential barriers of Kinect effectiveness in class room settings.

One of the main limitations of Kinect motion capture used to assess biomechanical function has largely been associated with inaccuracies in identifying joint centres. Several studies have shown that the inaccuracies are dependent on joint and motion type. Typically, joints that are covered with large tissue and muscle mass (e.g. hip) have been found to be less accurate compared to less embedded joints (e.g. elbow, knee). Furthermore, joints that possess intricate movement capacities, such as internal or external rotation as well as flexion and extension are less accurate compared to gold standard motion capture systems.

Notably, the Kinect uses a standard model to project estimated 20 joint centres on to a ‘point cloud’. The ‘point cloud’ is a representation of the volumetric information about body segments created from the Kinect depth data. The model is created, based on typical adult anthropometrics. In the context of PL, a potential limitation for tracking dynamic movements in children is the misrepresentation of limb-length parameters. The calibration procedure undertaken at the beginning of the PL tool has been used to refine the body segment identification and to ensure that the tasks are fit to the individuals’ limb and height parameters appropriately. However, the extent to which the skeletal model inferred from the Kinect (during this calibration procedure) is representative of actual body segment anthropometrics has yet to be examined against a standard reference system (i.e. marker-based system or MRI)

7.8 Potential for optimising Kinect

A number of the studies have deployed multiple Kinect set-ups to optimise the output of their low-cost skeletal tracking (Clarke et al., 2012, Choppin & Wheat, 2013). The inclusion of additional equipment and multiple Kinect cameras is not a viable option in a primary school scenario where space and technological expertise may be limited. In lieu of the inclusion of additional hardware, however, software corrections *could* provide a more applicable option for optimising the output of Kinect-based skeletal tracking and motion capture used in primary education. A number of correction procedures are described below. Although beyond the scope of this thesis to apply software corrections and post processing procedures (for example to align the Kinect data to a Local Coordinate System - LCS), the potential of such procedures warrants discussion in the context of future progressions. For example, the co-registration of Kinect data with a LCS could be useful to provide relative motion information about joint movements such as shoulder rotation movement during the interceptive timing tasks. However, the utility for the present purposes (global movements of the countermovement jump) is questionable.

7.8.1 Plane of motion correction

One noted limitation of the data stream acquired using standard Kinect SDK is the inaccuracies in planar motion identification. Unless specified and identified, the floor plane is not recognised. Implementing a floor plane identification and correction during calibration improves the accuracy and precision of the skeletal movement tracking. Notably, the impact of *not* identifying floor plane during motion tracking results in angular motion being measured in incorrect planes of motion relative to a global reference. For example, without floor plane identification, a jumping motion is measured not in the vertical plane, but in the camera's field of view i.e. the skeletal model records and outputs the movement as a jump towards the Kinect camera, not a vertical jump. The Kinect SDK provides a floor plane identification application that needs to be enabled for motion tracking applications. It is suggested that this procedure will aid in planar motion measurements, however further investigation is required to measure the accuracy of the floor plane correction through the co-registration of Kinect depth maps with a Global Coordinate System and further comparative studies are required against LCSs.

7.8.2 Skeletal joint identification

As mentioned above, motion capture systems generally measure spatial surface information in order to infer skeletal joint locations from the prior knowledge of how surface information relates to joint positions for various *typical* human anthropometrics. However, to-date it remains unclear how accurately one can estimate joint coordinates relative to the anatomically-correct joint positions. One potential limiting factor is that studies to date have largely focused on measuring the Kinect inferred skeletal parameters against joint estimations derived from marker-based systems. As noted above, limitations of marker-based camera systems include the influence of tissue artefact and skin movements, marker misplacement and marker movement or occlusion. A more robust method of joint centre assessment that provides a ground truth of joint location and limb segment volume is the use of Dynamic Fluroscopy. Unfortunately, this expensive process has limited the production of any comparative studies using Kinect to date. Magnetic Resonance Imaging (MRI) has been used to provide a true joint centre comparison to Kinect. MRI provides exact location of joint centre position without the constraint of overlaying tissue or movement. However, it is noted that MRI is limited by its' inability to perform the assessment dynamically, or in the standing anatomical neutral position. Perhaps because of these challenges, only one study to date has been conducted comparing the Kinect system to determine the localisation accuracy and precision of inferred joint positions with MRI (Zhang, Zhang & Zhuang, 2014). Going forward, the co-registration of Kinect data with MRI depth information could be used to assess correction algorithms that account for the Kinect estimation inaccuracies for a range of different populations (i.e. athletes, overweight individuals). Further research is required to produce generalisability of joint location corrections, however initial applications of this method show promising results.

Thus, *if* greater sensitivity of low-cost motion capture systems is required, correction algorithms *could* be developed and implemented to systematically correct for the error in joint centre location by co-registering depth image information and skeletal point extraction from more robust methods of establishing ground truth of joint centre and limb volume or length. Although for present purposes, the refinement and implementation of joint centre correction is beyond the scope of this project.

7.9 Summary

Although the study of human motion has clinical and lab-based origins, even systems that are currently considered 'gold standard' have a degree of error inherent in output. As such, the interpretation of comparative results can be misleading when using marker-based systems such as Vicon as the reference standard. Similarly, the comparison between marker based and markerless systems in research is often limited by the difficulty and potential for error in co-registering the joint coordinates for marker and markerless systems. Furthermore, markerless systems do not calibrate to a local coordinate system making the co-registration of joint positions tracked using separate systems difficult.

7.10 Conclusion

The theoretical basis of motion capture and various motion capture devices were discussed in this chapter. The purpose of considering historical and clinical contexts of human motion analysis was to provide a more in-depth understanding of the available types of motion capture. More specifically the benefits and limitations of using low cost, stereo vision motion capture.

Based on the available research, the Kinect device and available research was critically reviewed. From the extant evidence base, it is clear that the capacity of the Kinect varies according to the type of task (movement) being measured. The Kinect system was considered appropriate for PL assessment due to its capacity for measuring gross motor movements and proxy measures of movement performance (time taken etc.). To examine specific PL tool task set up against the industry-considered reference standard marker-based movement analysis system (Vicon), a single case comparative study was undertaken. A jumping task was elected for measurement due to its dynamic demands. The results of the study show acceptable levels of accuracy between measurements from Kinect and Vicon for gross motor movements.

Thus, based on the critical review of the literature, lab-based investigation and potential for optimisation, the tasks described in Chapter 6 were built upon the Kinect platform in collaboration with a software developer (University of Otago). The main reliability and validity testing was investigated in a large scale study conducted in primary school settings in Ireland. This main investigation is presented in Chapter 8.

CHAPTER 8

Test Validation

8.1 Introduction

The preceding Chapters have detailed the constructs that appear to be pertinent in developing PL (Chapters 2, 3, 5). In this chapter, the procedures undertaken to establish validity and reliability of the exergaming based assessment of Physical Literacy (PL) (PL tool version 3) are described. To begin, the constructs that the PL tool aimed to measure are defined. Each PL task is then categorised according to the constructs that it has been designed to measure. Typically, when validating new testing methods, tests are compared to other available tools which test the same construct. To investigate whether such validation was appropriate for this study, a comparative review of available movement assessments and the PL constructs identified as pertinent was completed (Chapter 3). Table 8.1 shows that available movement assessments do not measure the majority of PL constructs. Table 8.2 shows how each PL construct is conceptualised in the PL tool. The combination of information from Table 8.1 and 8.2 was used to determine how validation procedures should proceed.

8.2 PL test content

From Chapters 2, 3, 5 & 6 it is clear that, unfortunately, standard evaluative tests constrain movement to set requirements, task constraints and static environments. To address these limitations, assessment of individual ability to adapt movement skills, self-organise responses and modify performance are required to reflect high levels of PL skill acquisition. Within this conceptualisation, there is no expert behaviour in an absolute sense; rather, expertise is accrued as individuals satisfy unique intrinsic (skill level, maturation, experience) and extrinsic (goal, environment, knowledge) requirements.The skills identified as pertinent to PL acquisition, (through review and quasi-qualitative research, Chapters 2, 3, 4 & 5) were:

- Interceptive timing
- Object manipulation
- Locomotion and agility

- Rhythm and sequencing
- Spatial awareness & balance

These PL skills are further defined as:

1. *Interceptive timing*: Anticipation of the speed, direction and trajectory of a ball and coordinating motor patterns to ensure that the bat/racket/limb arrives at the point of interception with appropriate speed, force and direction (Weissensteiner, Abernathy & Farrow, 2011).

2. *Object manipulation*: The use of limb movements and systematic force to move an object (e.g. bat, racket etc.) (Mah & Mussa-Ivaldi, 2003).

3. *Locomotion and agility:* The ability to maintain a stable centre of mass when walking, running, jumping, changing direction and various speed (Jambor, 1990).

4. *Spatial awareness and balance*: Balance is the ability to maintain a stable centre of mass. Spatial awareness is an understanding of how much space the body occupies and how the body can move in space (Frost, Worthiam & Reifel, 2001).

5. *Rhythm and sequencing*: An awareness of the relationship between movement and time (temporal awareness). Sequencing movement events uses a form of rhythm or pattern that reflects temporal awareness (Frost, 1992; Gallahue, 1989; Jambor, 1990).

8.3 Construct weighting

The rationale behind varying the relative contribution of each task to overall PL assessment is multifactorial. Firstly, interceptive timing and spatial awareness represent skills that enable individuals to adapt and modify their movement skills repertoire to environmental task demands to meet movement goals. Other skills, such as locomotion, are considered more fundamental. Although continual refinement should take place through physical skill development, these movement skills have been largely acquired to a high level by primary school age. Similarly, rhythm and sequencing reflects cognitive and motor skills that are more indicative of computation and hierarchical paradigms of skill learning, rather than ecological dynamics skill learning that relies on responsive and adaptive interplay between the individual and the environment.

8.4 Validation

To ensure that the PL test met the criteria for assessing PL skills in primary school children, validity and reliability studies were undertaken. To do so, a cohort of primary school children and teachers were recruited for participation. The procedures of the study subcomponents are described in the following sections of this chapter. The aims of the study were:

- To examine whether the skills measured in the test reflect the skills required to attain PL (i.e. face validity).
- To examine whether the PL tool satisfied normal distribution.
- To investigate whether scoring on the PL tool correlated with scores generated from traditional methods used to assess student movement ability (i.e. teacher observation, and TGMD-2);
- To examine whether the test was reliable over multiple trials; to establish typical learning rate and norm scores for children aged 5-11 (discriminant validity).

8.4.1 Face Validity

Face validity is the extent to which a test is subjectively viewed as representing the concept it is purported to test. Thus, face validity is a measure of how relevant the test appears to individuals using it. In the context of primary school PL assessment, face validity can be seen as the extent to which teachers consider the test to represent children's movement skill. As discussed in Chapter 5, teachers typically engage in observationally based assessments to track physical ability in primary level PE. Therefore, for the purposes of this project teachers' observational ratings were compared to PL test scores to establish face validity.

8.4.2 Content validity

Content validity is the degree to which inferences can be legitimately made from measurements to the content of the construct and theory that the measurement is based on. Thus, in the context of the PL tool, content validity is the extent to which the PL tool measures constructs of PL derived from theory. For the purposes of this thesis the reviews and studies described in Chapters 2, 3 & 5 formed the basis of content validity for the PL tool used in this investigation.

8.4.3Construct validity

Typically, construct validity for a novel assessment can be established through comparison against other validated methods used to assess the same construct. However, in the case of PL, and as discussed in Chapter 2, the assessments that are available to assess movement competence in children are limited and do not replicate all of the skills required for long-term physical activity engagement. Thus, establishing PL tool construct validity against already established movement assessments was limited (and perhaps inappropriate). Table 8.1 below shows the extent to which PL movement skills are assessed in the PL tool, compared to other established movement tests. Notably, the five factors form a *combined* movement assessment PL tool. The combination of factors was elected to replicate the application of movement skills in physical activity and sporting contexts, where balance, coordination, spatial awareness, timing etc. are used in combination. Conducting correlation tests between constructs of the PL tool and other tests was considered inappropriate due to the limitations of movement assessments to assess PL constructs as outlined in Chapter 3. For comparative purposes, however, Test of Gross Motor Development Second Edition (TGMD-2) testing was conducted on a sample of students (n=40). The correlation between TGMD-2 scores, performances on the PL tool and teacher observation were then calculated.

Skill	TGMD-2	MABC-2	PL tool
Interceptive timing	Catch Kick Strike	Catch Catch single hand	Monsters 1 Monsters 2 Heading Batting
Locomotor	Skip Gallop Run Slide		Hopscotch Maze Jump
Agility		Zig-zag hop	Hopscotch Maze
Balance	Jump Hop Leap	Hop Heel-toe board walk	Jump Hopscotch
Spatial awareness			Heading Jump
Rhythm & Sequencing			Maze Monsters 2
Manual Dexterity & Fine motor		Peg turn Coin post Throw	Trace 1 Trace 2

Table 8.1: Comparing motor skills tested in standardised movement assessments and PL tool

8.4.4 Criterion validity

Criterion validity is the capacity for a test to differentiate between populations. In the case of PL, if the tool demonstrates criterion validity, the test should be able to show a significant difference in scores between those who possess a high level of movement skill and those with poor movement skills. Equally, providing ranking of PL ability across the continuum (high level - low level) is important to address the limitations of traditional movement assessments that are designed to only differentiate between motor deficiencies in typically developing populations. Motor skill learning generally refers to the neuronal changes that occur to allow an individual to perform a movement task better, faster or more accurately than before. Unfortunately, beyond this understanding there has been little scientific work to develop a precise definition of motor learning. As discussed in Chapter 5, skill learning and progression are measured in tasks according to changes in speed and accuracy. A cross sectional investigation was undertaken to gather PL scores from a range of typically developing children.

8.4.5 Reliability

Reliability is the extent to which a test can be repeated to produce the same results in different scenarios e.g. with a different tester or with the same tester on repetition of the test. Reliability is important to remove situation or tester bias and ensure the objectivity of the test results. A test-re-test reliability study was conducted using the PL tool. Test re-test reliability was measured in this study, as described below.

8.5 PL Main Test Validation

As discussed in Chapters 5 & 6, in order to reduce the constraints of assessments, where instruction and demonstration of movement processes can influence children's movement execution, PL tasks were designed to provide children with an opportunity to self-select strategies that fulfil movement task goals (Davids, Button &

Bennet, 2011). Each task was designed to pose a movement problem without prescribing how the problem should be solved (i.e. there were multiple possible solutions). Each task was presented in the form of a game (with auditory and visual feedback on performance). Please refer to the DVD attached (Appendix 6) for a demonstration of the PL tasks in action. Additionally, there was no subjective assessment of competency required by the test administrator (as is typically the case for primary school PE assessment). The skills assessed in each task and outcome measures are listed in Table 8.2. There was a ceiling on the scoring system due to a pre-determined number of trials which were presented per task (e.g. heading = 11 balls, batting = 24 balls, hopscotch = 10 squares). During PL tool development, on consultation with movement and PE experts (n=2) each task constraint was designed to include familiarity and laterality (i.e. equal right and left targets).

Notably, for the purposes of this study, three tasks were included for piloting and validation (Table 8.2 and Table 8.3). With further development of the software, it is hoped that the remainder of tasks (described in Chapter 6) will be similarly piloted and validated (although beyond the scope of this thesis).

PL Task	Outcomes	PL skills measured
Heading Lower score = better proficiency	Time to complete & number on target	Locomotion & agility Spatial awareness Vertical jump Interceptive timing
Hop scotch Lower score = better proficiency	Time to complete	Locomotion & agility Spatial awareness Rhythm & sequencing
Batting Lower score = better proficiency	Time to complete number intercepted	Interceptive timing Spatial awareness & balance

Table 8.2: PL task, outcomes and skills measured

8.5.1 Test Platform

Microsoft Kinect™

From a technological view point, as discussed in Chapter 7, Kinect was chosen as an appropriate platform upon which to develop a comprehensive PL skill assessment for use in schools. Within set parameters of planar motion and depth distance, Kinect provides moderate-excellent reliability when movement is measured repeatedly (Galna, Berry, Jackson et al., 2014). Accuracy of the data varies depending on the reference comparative. The error rating can vary from 2 - 37^{o} depending on the joint, movement and reference measurement system.

In the context of PL movements skills, acute accuracy was not deemed a crucial requirement. As such, proxy measures of movement proficiency i.e. time-taken and numbers of successful trials completed were proposed as appropriate outcome measures of PL skill assessment.

8.5.3 Study design & procedures

In order to audit the comprehensiveness of the PL battery, a review of movement assessment contents and outcomes was undertaken (Chapter 3) to ensure that the PL tool encompassed important movement factors that are already tested in validated measures, whilst also addressing noted limitations of movement assessment (Table 8.1). Although previously validated movement tests, both the M-ABC and TGMD-2 measure different movement factors (Rudd, Butson, Barnett et al., 2015) , once more highlighting the need for a more comprehensive movement assessment (Rudd et al., 2015). TGMD-2 was selected for further inclusion and comparison because the TGMD-2 was specifically designed for non-specialist application. Additionally, the TGMD-2 measures movement skill ability, in contrast, M-ABC was specifically designed to test for movement dysfunction.

Skill	Heading	Batting	Hopscotch
Interceptive timing	Head is used to hit the ball into the target	Hands are used as a 'bat' to intercept ball presented on screen.	Precise placement of feet on the squares presented.
Locomotor	Jumping, sliding, running are used to transport body to ball	Side to side translation or jumps required to intercept ball.	Jumping, hopping, running, walking is used to move from square to square
Agility	Jumping, side to side translation and centre of mass level change used.	Body repositioning in response to ball presented of screen	Jumping, hopping, running forwards, backwards, right, left
Balance	Dynamic stabilisation of centre of mass required to negotiate jumps etc.	Static balance required to engage powerful swing with rotational displacement	Dynamic stabilitsation of centre of mass is engaged for efficient transfer of the body from square to square.
Spatial awareness	Assessment of body position relative to ball	Assessment of body position and arm position relative to ball and trajectory to target	Depth perception and understanding of body position relative to virtual squares
Rhythm & Sequencing	Sequencing of gross motor movements required for successful intercept	Sequencing of swing mechanics required for successful intercept.	Recognition of timing and pattern of square presentation

Table 8.3: Skills tested by PL tool tasks

The industry standard measurement for assessing gross motor skill ability in children by a non-specialist tester, the TGMD-2 (Ulrich, 2000) was used to assess children's movement prior to completing the PL test. Further, generalist primary level teachers were asked to rate children's movement ability prior to engaging in the PL test. Teacher's rated children's ability on a scale of 1-10 (1 = extremely poor, 2 = poor, 3 = very below average, 4 = somewhat below average, 5 = average, 6 = somewhat above average, 7 = above average, 8 = very above average, 9 = excellent, 10 = exceptional). Both observational rating and TGMD-2 assessments were included due to the lack of formal, standardised assessments engaged by teachers in primary education.

8.5.4 Recruitment

Participants were recruited from a primary school in the Republic of Ireland. Ethical clearance was granted for this study by the BuSH (Built, Sport, Health) Ethics Committee of the University of Central Lancashire (UCLan). Recruitment took place via formal email to the school principal and subsequent meeting with the classroom teacher.

8.5.5 Calibration & set up:

The tests were conducted in a primary school classroom. The Kinect and screen were set up in a classroom with a clear 4 x 4m space. The lighting was standardised (using window blinds) for the duration of the testing. The Kinect was positioned at a height of 60 cms. Participants were directed to stand at a distance of 180cm from the camera to begin the calibration procedure. Calibration required the child to create a 'virtual square' by standing in four corners of the space whilst the tester recorded each of the four positions trough the software application. Once the virtual square was displayed on screen, the child was directed to stand in the centre of the square and make a Y shape, reaching their hands above their head and fully extending their body. From this position, the software matched the model of the human skeleton to the shape detected, allowing the camera to estimate joint position for the 20 joints tracked by the

Kinect.

8.5.6 Task testing

Once this calibration was complete, the child was taken to the introduction screen of the first task. The instructions of the task were read out to the child. Written and visual information of the requirements were also presented on screen. Verbal confirmation of understanding was sought prior to commencing the task. Each child completed the game 4 times. The amount of trials required was dependent on trial type and age/ability; however, on average, scores were asymptotic by trial 6. Thus trial 4 was chosen as representative of 70% children's ability after accounting for learning effects.

Heading:

The heading task required the child to intercept a ball on screen using their head and to use a heading motion to direct the ball successfully to a circular target presented on screen. The round target moved position (upper corners/lower corners) around the screen. The speed of the balls presented on screen and the difficulty of target position increased throughout the task. The task required the child to manipulate the ball trajectory accurately using the head, thus interceptive timing, spatial awareness and balance and perception is needed for successful completion. The target turned green providing positive outcome feedback to participants once the ball successfully hit the target. If successful interception did not take place, the target remained the same (i.e. no negative outcome feedback was presented). An auditory 'swish' sounded once the ball hit the target to provide additional positive feedback. The outcome measures were the number of successful intercepts and time taken.

Batting:

The batting task required interaction with an external object. The hands were used to emulate the demands of object manipulation required for sports such as tennis, cricket, hurling, hockey etc. The game required the child to use a swinging motion to intercept the balls that are presented on screen. Successful batting required interceptive timing, intersegmental coordination (upper-lower limb interaction), balance and spatial awareness. The target turned green providing positive outcome feedback to participants once the ball successfully hit the target. If successful interception did not take place the target remained the same (i.e. no negative outcome feedback were presented). Auditory bat-ball 'clink' sounds once the ball successfully intercepted the target provided additional positive feedback. The outcome measures were the number of successful intercepts and time taken.

Hop scotch:

This task required the participant to follow a pattern of squares displayed on screen. The task involved the use of double and single leg base of support, gross motor movement, visual perception and spatial awareness. Successful trials were indicated via a colour change on the square once the participant had successfully reached the highlighted square displayed on screen. Accuracy and speed were required for successful completion of this task. The target turned green providing positive outcome feedback to participants once the square had successfully been intercepted. An auditory 'bleep' sounded once the square was intercepted and provided additional positive feedback to the child. If successful interception did not take place, the target remained the same (i.e. no negative outcome feedback was presented). The outcome measure is time taken.

Participants

Participant recruitment criteria are presented in Table 8.4.

Inclusion Criteria	Exclusion Criteria
• Attending mainstream primary school • Age 5-11yrs • English speaking • Physically healthy to engage in activity	• Current or chronic history of musculoskeletal injury • Acute or chronic illness that may be exacerbated by physical activity • Visual impairments that inhibits ability to respond to task demands displayed on screen. • Special needs or learning difficulties requiring individual care.

Table 8.4: Participant inclusion & exclusion criteria

8.5.7 Teachers

Teachers were generalist primary level teachers (n = 4). Years of experience teaching ranged from 3 - 22 years with a mean of 11.75 years. All teachers had completed Bachelor of Education degrees. None had received additional specialist training or further qualification in PE.

8.5.8 Students

A total of 317 children were tested. 40 male (23) and female (17) participants aged between 5-11 years were recruited from a primary school in the Republic of Ireland, with both observational rating and TGMD-2 testing completed alongside the PL

Tool. A further 277 children (male 153 female 124 ages between 4 and 11) were recruited for the main PL test validation.

Ethical clearance was granted through the University Ethics Committee. Recruitment took place via formal email to the school principal and subsequent meeting with the classroom teacher. All students met the inclusion and exclusion criteria listed in Table 8.4. Written informed consent was obtained from the children's parents prior to participation. Verbal consent was attained from the children prior to participation.

8.5.9 TGMD-2

The TGMD-2 was completed in accordance with the standardised procedures and form available in the TGMD-2 Handbook. Object manipulation (catch, kick, throw, underarm roll, strike) and locomotor skills (run, gallop, slide, hop, leap, jump) were measured twice on each child. The ability to complete each task was marked as 0 or 1, and an overall score was calculated for each child.

8.5.10 PL test

The students were tested using the movement task. Additionally, children were rated by their teacher on each facet of movement (i.e., batting, heading, locomotor and agility). Participants were tested individually. The initial task pilot testing showed that, across age groups, scores became asymptotic at 6 trials. The trials taken to asymptote across the cohort are shown in Table 8.5.

Task	Mean, (St.dev)	95% CI
Heading	5.71 (+/- 1.53)	5.37 - 6.21
Batting	5.60(+/-1.51)	5.35 - 6.20
Hopscoth	4.79 (+/-1.55)	4.33 - 5.39

Table 8.5: Trials taken to asymptote for each task

Consequently, testing required the completion of 4 trials to represent 70% capacity of the child's PL ability. An unobstructed 4 x 4m space was set with the Kinect camera, laptop and television screen. Movement demands were presented on screen. The child began each task on an 'X' marked on the floor 2 metres from the Kinect. A calibration pose where the child stood upright with their arms stretched out to the side in a T-position was taken at the start of each task to set the skeletal representation of the child's height and position in space relative to the camera. All subsequent tasks in the Kinect software were then programmed relative to each individual's height and limb length.

8. 5.11 Teacher rating

Whilst participants were completing the PL test, their PE teacher watched them (from a lateral view point) and rated their movement form on a scale (detailed above) and using a validated observational scale as a guide (Bloom's taxonomy of motor learning) (Driscoll & Driscoll, 2005). Each teacher was briefed beforehand in the requirements of rating each child's movement ability across different movement skills. The teacher was asked to rate each child from 1-10 for interceptive skills (e.g. those used for heading), object control skills (e.g. those used for batting) and gross motor coordination skills (e.g. rhythm, locomotor, agility used for hopscotch). To calculate rater reliability, during re-test, teachers were asked to provide a second rating of children's ability per skill the following week.

8. 5.12 Reliability

A test-re-test reliability was established by testing the sample of 40 children using the PL tool children again 7 days after the initial test. The same tester completed the test and re-test and testing procedures and conditions were replicated for the re-test.

8.5.13 Data Analysis

Data processing was completed using Microsoft Excel (2010) and all data analyses were completed using SPSS (version 21). The Kolmogorov–Smirnov tests for normality and outliers were conducted. Task scores showed normal distributions. Two outliers in the hopping task scores were removed; defined as scores recorded outside +/- 2 standard deviations of the mean. Cronbach's alpha was calculated on each task score for test re-test to establish reliability ratings. Teacher reliability (0.68) for observational scores of the 40 participants was also established. Bivariate correlations were calculated to assess the relation between participants (n = 40) TGMD-2 scores and teacher ratings and between teacher ratings and PL tasks. Descriptive statistics were run on all tests to examine the distribution of scores across TGMD-2 and PL tasks. Quartile scores were computed for each task. A univariate analysis of variance (ANOVA) for each task as computed to examine differences between groups (group 1 = 4-7 years, group 2 = 7-9 years, group 3 = 9-11 years). Post hoc tests (Tukey's HSD) were performed to examine where significant differences occurred. Bonferonni corrections were applied to account for multiple analyses error.

8.5.14 Results

Test	Teacher rating correlation	95% CI
Batting	0.87	0.79 - 0.93
Heading	0.74	0.58 - 0.84
Hopscotch	0.73	0.61 - 0.83

TGMD-2	0.32	0.15 - 0.65

Table 8.6: Correlation between test and teacher rating

PL Task	ICC
Batting	0.96
Heading	0.74
Hopscotch	0.98

Table 8.7: Test re-test reliability

Age	Batting Mean (st.d)	Batting 95% CI	Heading Mean(std)	Heading 95% CI	Hopscotch Mean(sd)	Hopscotch 95% CI
4-7	6.45 (+/-1.59)	6.10 - 6.79	8.24 (+/-2.02)	7.78 - 8.68	49.89 (+/- 28.91)	44.11 - 57.35
8-9	4.91 (+/-1.16)	4.73 - 5.10	8.25 (+/-2.16)	7.89 - 8.59	37.79 (+/-16.48)	35.08 - 40.82
10-11	4.91 (+/-1.25)	4.69 -5.18	7.83 (+/- 2.91)	7.43 - 8.48	31.66 (+/- 12.75)	29.32 - 34.13

Table 8.8: Task scores across age groups

	Mean	Std. Deviation	Skewness	Kurtosis	95% CI lower	95%CI upper
Batting	5.28	1.46	0.969	1.67	5.12	5.45
Hop	38.18	17.42	1.335	2.193	36.15	39.97
Head	8.12	2.39	0.960	1.019	7.85	8.37

Table 8.9: Combined sample score descriptives

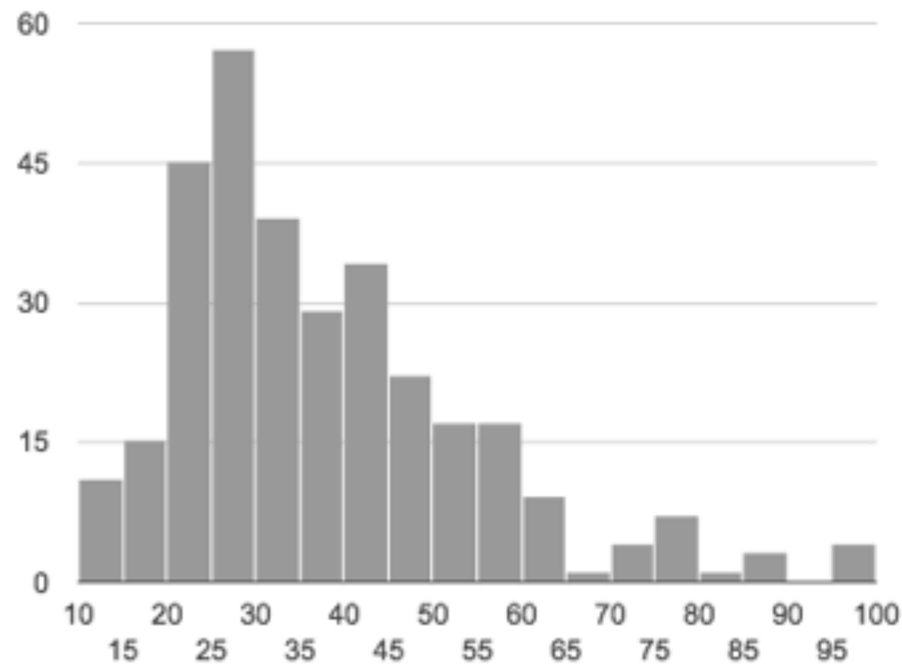

Figure 8.1: Histogram of Hopping Task scores

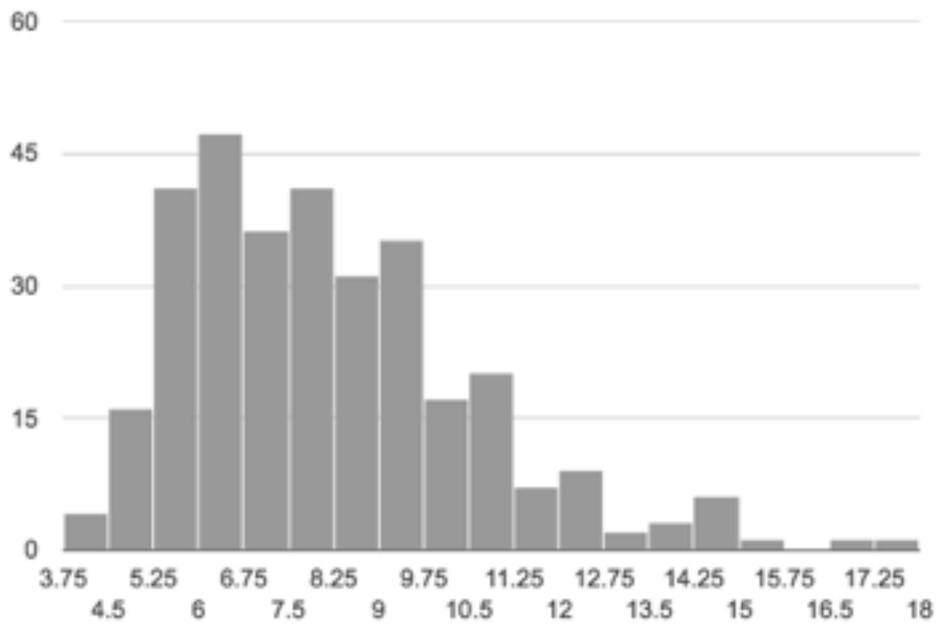

Figure 8.2: Histogram of Heading Task scores

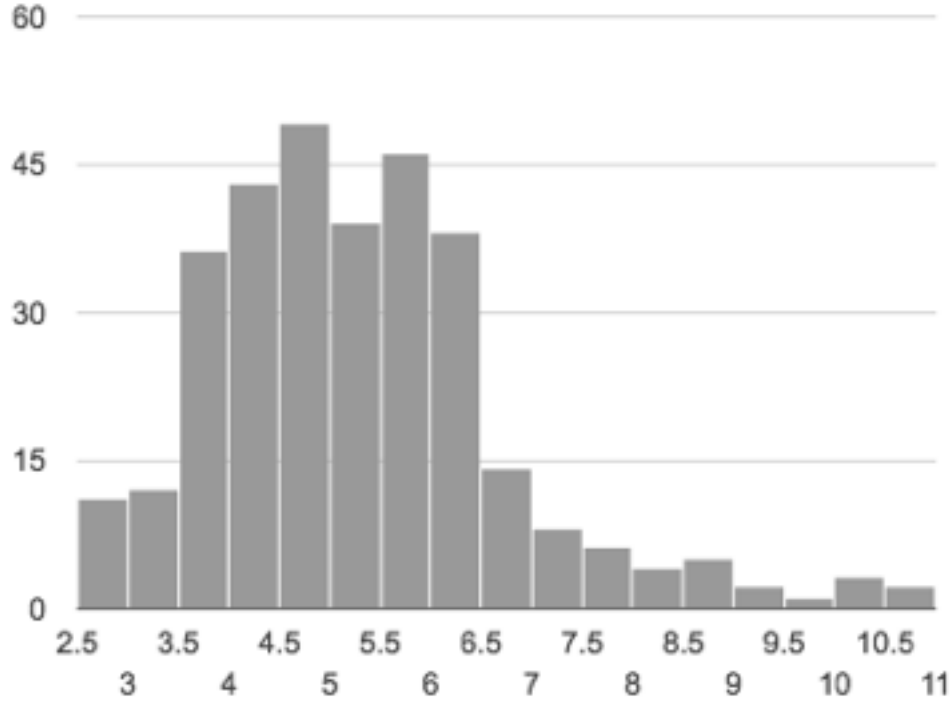

Figure 8.3 Histogram of Batting Task scores

ANOVA showed significant differences were found between group 1 (4-7 years) and groups 2 & 3 (7-9, 9-11) $F(2,316) = 20.98$, $p<.00$, η_p^2 (0.11) for the Hopscotch task. Similarly, for Batting, significant differences were found between group 1 (4-7 years) and groups 2 & 3 (7-9 and 19-11), $F(2,316)$, $= 38.71$ $p<0.00$, η_p^2 (0.19). No significant differences between any age groups were found for Heading, $F(2, 315) = 0.998$, $p = 0.371$.No other significant differences were found between Groups 2 & 3 for Batting, Heading or Hopscotch.

The teacher observational ratings correlated positively with the PL scores ($r = 0.93$). Interestingly, the TGMD-2 ratings and the teachers' observational ratings did not correlate as highly ($r = 0.32$) (see Table 8.6). High reliability coefficients were found for each of the tasks showing that the PL test was reliable and consistent (see Table 8.7).

8.6 Discussion

The development and validation of the PL tool proved promising. In particular, the hopscotch and batting tasks appear to discriminate well between levels of ability for younger age groups. The 4-7 year olds showed significantly longer completion times compared to the older cohorts for hopscotch and longer average time to achieve successful interception on the batting task. Furthermore, the level of difficulty presented in the tasks appeared appropriate for the age cohorts based on the normal distribution of scores (Figures 8.1-8.3). The tasks also showed high re-test reliability (Table 8.7), thus the test can be consistently reproduced. Additionally, the PL tool scores correlated well with teacher observational ratings whereas, in contrast, TGMD-2 scores did not correlate well with teacher's ratings. A possible explanation for teachers' observation matching more closely with the virtual reality score is that the five factors of movement competence formed *combined,* perceptual-based tasks. That is children had to deploy cognitive (e.g. perception, visual processing, timing, reaction, anticipation etc.) and motor skills (balance, coordination etc.) in combination for successful task completion. The combination of factors was elected to replicate the demands of real-life movement used during physical activity and sport (i.e. reactive and combined balance, coordination, spatial awareness, interceptive timing etc. are used in combination). Thus, it is possible that teachers are more familiar with using observational analysis in sport-specific or activity based environments (i.e. during PE lesson or games) than observationally assessing movement competence during a criterion-based test battery that requires demonstration and replication of movement tasks in isolation. This finding supports our concerns that clinical movement assessment batteries (e.g. TGMD-2) are not sensitive to the full spectrum of general movement competence (Giblin et al., 2014).

From a practical perspective, the data from the PL assessment was objectively and quickly tracked and recorded on a per child basis, taking only 5-10 minutes for a full test. Time and resources required to deploy the test were relatively small compared to cumbersome set up and preparative requirements of other tests. For example, the time requirements to perform individual assessment compromises practical application in schools settings. The M-ABC takes 20-25 minutes to test per individual and requires administration in a separate room (Cools, Martelaer, Vandaele et al., 2010).

Finally, the demonstrative requirements of other tests that rely on tester instruction and set criterion were removed. In the context of PL, assessment should test self-regulated execution of gross motor coordination in a range of tasks to measure individuals' strengths/weaknesses, including specific evidence of learning and skill progression to track development over time. However, movement assessment batteries most commonly used in research were designed to test for motor development impairment (Schoemaker, Niemeijer, Flapper, et al., 2012) . Thus, these typically focus on the basic requirements for reproducing simple movement components. Additionally, norm-based movement tests lack the flexibility required to monitor individual-specific progress in motor skill learning that varies as a function of age, gender and cultural factors (Hands, Larkin & rose, 2013, Larson & Quennnerstedt, 2012, Venetsanou, Kambas, Aggeloussis et al., 2009). As a cross-cultural example, the McCarron Assessment of Neuromuscular Development is a norm-based assessment originating from the US that has limited validity when used to test movement ability of Australian cohorts (Hands et al., 2013). In contrast, during the virtual reality PL test children were free to self-select appropriate movements to achieve the task goal, thus delivering a more individualised and less rigid form of assessment that is reflective of contemporary dynamical theories of motor performance (Chow, 2013).

However, a number of limitations of the present study warrant consideration. Firstly, although the scoring of tasks included both product (number of successful hits etc.) and movement quality (time taken, targets hit, etc.), further 'process' information to assess movement quality should be included in future research. For example, the hopscotch task used in this study relied solely on an outcome measure (i.e., duration to completion). The inclusion of process markers, for example variation in velocity curve during task completion, could enhance the information garnered from the assessment and the capacity for formative feedback from the data generated. Additionally, although all PL skills appear to contribute to overall ability, more research is required to establish the relative contribution of each outcome type (time/success etc.) to each task and also the relative contribution of each task to overall movement competence.

Notably, not all of the planned PL tasks were tested during this initial study. The rationale for prioritising the gross motor and interceptive skill components was primarily due to the limitations of current movement assessment batteries for measuring these skill components. However, it is acknowledged that the requirement for including an even more comprehensive range of PL skills (e.g. fine motor skill, perception of ability etc.). The omission of fine motor skill evaluation was twofold: Due to measurement and calibration difficulty, the extent to which the Kinect could accurately assess fine motor ability requires further investigation. The second generation of Kinect which has improved sensitivity for recognition of gestures (facial, hand signals) offers considerable promise in that regard.

Finally, the generalisability of results from this study are limited. Further examination of PL evaluation using the Kinect in other nationality cohorts is required to examine the extent to which the PL skills assessed with the tool are universal. It seems likely to me that national or even regional norms will be needed if the tool is to be fully exploited as a school based test and prescription measure.

These limitations notwithstanding, and pending further development and validation, the study provides initial empirical support for the application of virtual reality technology to PL skill assessment. The PL tool was designed to fill the gaps in movement assessment quality and address some of the major limitations of traditional, validated movement assessments. Initial results are promising, with the approach appearing to outperform ‘industry standard’ tools whilst also offering children a motivating, game-like assessment. It is hoped that this study highlights the importance of improving movement skill assessment to ensure that outcomes reflect intention of PL education and physical activity initiatives..

8.7 Conclusion

This Chapter explored the studies undertaken to examine the validity and reliability of the PL movement assessment. The PL constructs were identified and defined from literature reviews (Chapters 2 & 3) and quasi-qualitative investigation of teacher practices (Chapter 5). The PL test went through a number of iterative phases whereby test tasks were developed and tested on a sample of users in primary school settings (Chapter 6). Based on the feedback and findings of these processes, the final version of PL test was produced. The validity and reliability testing was conducted on this version of the assessment over a four week time period in 2015. The results show that the application of exergaming technology could provide a useful, objective method of assessing typically difficult to measure tasks that are imperative to physical skill development. The tasks showed normal distribution, reliability and validity compared to traditional teacher assessment methods. In addition to removing subjectivity and limitations of teacher instructed, demonstration orientated assessments, the exergame provides a platform that is naturally appealing to children. Anecdotally, the feedback from children was positive, with children expressing a desire to continue with exergame in leisure time. Thus, the negative connotations of testing with traditional methods could be reduced, with children intrinsically motivated to improve. Poor performance on the exergame test did not result in potentially self-esteem thwarting repercussions that can accompany 'failure' in other tests. Children received performance information with which they could learn and retry their skills throughout the tasks.

Although further research is clearly required to test the assessment methods in other populations and longitudinally to measure progression in PE, this initial investigation provides a base upon which to develop a robust, objective and valid assessment of PL movement skills.

The wider implications of the overall project findings and potential future directions are discussed in Chapter 9. Specifically, the application of exergame based approaches for measuring movement competency in sports and talent development environments are considered. Further, this project has solely focused on the development and assessment of PL in childhood. However, the PL concept transcends life-stages. Accordingly in Chapter 9 the implications of PL skill development in later life is discussed. In conjunction, the application of exergaming technologies in older age cohorts is discussed.

CHAPTER 9

General Discussion

Research in the UK suggests that nearly half of children leave school without the basic movement skills (Lubans et al., 2012). Furthermore, almost half of children entering second level education do not engage in sufficient levels of PA (Griffith, Cortina Borja & Sera, 2013). Thus the purpose of this thesis was to examine the promotion of physical activity (PA) through primary level Physical Education (PE). Physical Literacy (PL) is a common model used to describe the skills (physical, psychological and behavioural) needed to lead an active life. As discussed in Chapter 2, Deliberate Preparation is proposed as a practical framework that operationalises the structured delivery and content required to attain PL in primary education.

9.0 Project objectives:

The main objective of this study was to examine the promotion of PL in primary school settings. More specifically, the four main aims of the thesis were to:

- Critically examine the evidence base underpinning PE delivery.
- Examine methods of assessment used in PE.
- Develop an empirical tool for assessment in PE.
- Undertake initial validation of the assessment method.

9.1 Summary of Research:

Considering the research requirements, a mixed methods approach was required. Firstly, literature reviews were conducted to examine the evidence-base underpinning PL and PE, to examine the models that inform PE curricular design. From the literature based studies, it became clear that the delivery of PE is unstandardised. Notably, much research has focused exclusively on the psychosocial facets of PE (i.e. play-based model of PE and PA promotion). Although important, primary focus on psychosocial facets of PE and PA may be detrimental to the appropriate development of essential movement skills. Clearly a combination of psychosocial, behavioural and physical skill development is necessary to equip children with the competence to sustain a physically active lifestyle. Whilst multifaceted models exist (e.g. PL) and are commonly promoted in PE and PA, models often lack operationalisation that is needed to facilitate practical (and standardised) implementation. In Chapter 2, the Deliberate Preparation model was proposed to describe the structured delivery of appropriate movement experiences needed to attain proficiency in complex physical movement skills, psychological parameters and behavioural requirements for leading a physically active life. The benefits of integrative development in PE and the limitations of focusing exclusively on physical or psychological skills is acknowledged in PE theory (Whitehead, 2001), youth participation in PA models (Dishman, Motl, Sallis et al., 2005) and action research (MacNamara et al., 2011; Jess & Collins, 2003; Collins et al., 2010; Collins et al., 2012). Although consistent in the salience of integrative physical development, conceptualisations of PA promotion vary widely in content and structure. Consequently, rather than continuing the proliferation of theory formulation in research, it is proposed to proceed with a scientifically grounded action-based approach (e.g. Deliberate Preparation) that prioritises *quality* physical skill acquisition in PE at primary level.

From the literature, it became apparent that a lack of assessment procedures was limiting the production of empirical evidence to support PE models that prioritise quality movement skill development. Specifically, a lack of standardisation in research methods (specifically in PE assessment) has resulted in a lack of comparative research studies being produced.

Chapter 3 discussed the available assessment procedures for measuring motor skill development. The results showed that validated movement assessments originated from clinical assessment orientated towards detecting dysfunction or developmental delay and lack the complexity and sensitivity to measure skill learning in advanced motor competencies required to attain physical literacy. Furthermore, many assessments are impractical for application in primary education. In lieu of appropriate methods for evidencing effectiveness, interventions and curricula have relied on transient markers for measuring outcome of PE programmes. For example, in research, control trials often rely on measures of fitness (shuttle-test), measures of activity (accelerometers) or self-report ratings of hours spent being physically active. Such methods provide a transient marker of activity behaviour, but provide little information about skill level, movement competence or other factors associated with PA engagement later in life. Moreover, the assessment methods currently available do not meet the requirements for individualised, autonomous assessment procedures in PL education that provide comprehensive information about individual ability and progression to allow meaningful feedback for learners and teachers in guiding children to fulfil their individual potentials.

Clearly, measuring determinants of lifelong PA engagement (through valid motor skill assessment) could offer more insight in to the effectiveness of interventions, aid in the production of comparative research *and* meet the requirements for formal assessment within the standards-driven formal curriculum.

Building on the literary findings (Chapters 2 &3), Chapter 5 examined the delivery and assessment of PE from an applied perspective. Generalist primary school teachers participated in a survey to examine their behaviours, understanding and confidence in assessing PE. From the findings, it is clear that teachers agree complex motor skills play an integral role in developing PL. Notably, however, the majority of teachers failed to assess these seemingly crucial skills as part of their typical PE delivery. Teachers largely relied on unstructured play approaches to developing key motor skills. Those who did report inclusion of assessment relied solely on observational based assessment.

As discussed in Chapters 2, 3 & 5, movement competency (specifically gross motor coordination) appears to play a pertinent role in individuals' engagement in PA across a range of activity types and levels. However, these skills are under represented in validated movement assessments (Chapter 3) and in practice (Chapter 5). The key factors of motor ability were identified from the literature reviews (Chapters 2 & 3) and triangulated through qualitative information gathered from generalist primary school teachers in the survey based study (Chapter 5).

Considering the requirements for objective and ecological tools for assessing complex motor skill competence, Chapter 4 presented the results of a literary examination of exergame-based motion capture technology used in educational contexts. From the available research, the Microsoft Kinect provided an appropriate method for gathering objective movement information. The Kinect uses a markerless and tetherless approach with 3D depth sensors to track body segment positions. The device has been used in clinical and rehabilitation settings to measure movements. Furthermore, the gaming device was originally developed for gross motor movement detection and gesture recognition. Building on the potential of the Kinect for developing an objective assessment of motor competence, further review of Kinect-based research was undertaken (Chapter 7). From the literature, it is clear that measurement errors of the Kinect are environment and task dependent. Thus, a further lab-based assessment was undertaken to examine the accuracy of the Kinect against a reference standard marker-based motion capture system (Vicon) for measuring a complex motor task (i.e. counter movement jump). The results of the study showed sufficient accuracy and precision of the Kinect for measuring gross motor competence, thus further development of the PL tool using the Kinect was undertaken.

The conceptualisation and development of an exergame-based tool for assessing movement skills progressed through a number of iterative phases (described in Chapters 5 & 6). Combining the results form the literature and the qualitative study, key movement skills to be included in the assessment tool were; interceptive timing, object manipulation, spatial awareness and balance, locomotion and agility, rhythm and sequencing. The combination of skills was elected as representing the demands of skill deployment in sports and PA. Each task was defined and the relative contribution of skills included in the PL tool tasks was set to reflect the relative importance of skills based on correlations with PA level and engagement during childhood and later in life. The representation of skills within tasks and task outcome measures were established based on the research evidence and refined by a panel of experts in the field of motor skill development and PE.

Once designed, a version 1 of the PL tool was developed for pilot testing. Based on positive reliability and ecological validity from pilot testing of versions 1 & 2, the tool was further refined before version 3 of the PL tool was deployed for large scale investigation. Chapter 8 presented the main investigation procedures and results. The main investigation was conducted across three primary schools in Ireland during June 2015. During the investigation over three hundred children were tested on a range of tasks that measured their ability to read movement demands, choose appropriate methods to meet the movement goal and execute the movement accurately and efficiently.

Finally, to examine the validity and reliability of the PL tool, a large cohort study was conducted (Chapter 8).The development and validation of the PL tool proved promising.The level of difficulty presented in the tasks was appropriate for the age cohorts based on the normal distribution of scores. The tasks showed high reliability, thus the test can be consistently reproduced. Additionally, the PL tool scores correlated well with teacher ratings and in contrast TGMD-2 scores did not correlate well with teacher's ratings. This finding is in keeping with the research showing that validated movement scores (e.g. TGMD-2) do not fully represent all facets of movement competence.

From a practical perspective, data was objectively and quickly tracked and recorded on a per child basis, taking approximately 5 minutes for a full test. Time and resources required to deploy the test were further reduced compared to cumbersome set up and preparative requirements of other tests. Finally, the demonstrative requirements of other tests that rely on tester instruction and set criterion were removed. Children were free to self-select appropriate movements to achieve the task goal, thus delivering a less rigid form of assessment that is reflective of contemporary dynamical theories of motor performance (Davids et al., 2013).

In addition to the promising outcomes (discussed in Chapter 8), a number of limitations of the present study warrant consideration. The limitations of the thesis will be discussed in section 9.3 of this Chapter. First, a number of future directions for the research are presented in the next section.

9.2 Future Directions

9.2.1 Psychological factors

Notably, the present research focused exclusively on the physicality of PL. From a philosophical perspective, the movement types chosen are those suggested to promote engagement and challenge (i.e. cognitive and behavioural concomitants of PL). Furthermore, the movement tasks were presented and measured in a manner to promote self-efficacy, i.e. outcome scores were not displayed and positive visual and auditory feedback was provided when movement skill sufficiently met the demands of the task.

However, no rating of psychological skills was included in the study. There is substantial research validating measures of psychological characteristics of developing excellence (MacNamara & Collins, 2011), the inclusion of such ratings is advisable in future research. However, in-keeping with the holistic philosophical conceptualisation presented by Whitehead (2001), psychological and physical parameters are intertwined and not distinct. Thus considering methods for assessing psychological and physical skills in combination (not in isolation) is advisable.

For example, future development and research should include a measure of perceived competence such as that suggested in the vertical jump. The task requires the child to position the target on screen at a height that the child considers achievable. The child then attempts the jump task a number of times and adjusts the height according to their actual requirements. The number of attempts and time required to reach the target is used as a measure of competence i.e. if the child positions the target too high, and requires several attempts and readjustments to achieve the task, it is suggested that there is a discrepancy between the child's ability and perceived ability. As discussed in Chapter 2, up until the age of eight, all children have high perceived physical skill ability. Negative repercussions of inaccurate perceptions appear to be more detrimental to physical self concept later in life, thus ideally, actual skill level is sufficiently developed to meet the naturally high perceptions of ability before the mis-match becomes dysfunctional.

In addition to meeting the requirements for assessing children's perceptions, the self-selection and goal orientation of the task provides a means of promoting the behaviours required to pursue engagement (or indeed excellence) in physical endeavours i.e. determination, goal setting, attention and use of self-generated and externally provided feedback etc. The inclusion of rating of perceptions of competence and enjoyment could be included in future research to examine the relationship between actual and perceived competence in complex movement skills. Furthermore, specific exergame based examinations of psychological experience are warranted. Specifically, longitudinal monitoring overtime will be required to establish whether psychological correlates of exergaming are positive and if so, whether positive psychological factors associated with exergaming persist over time (beyond novelty). Similarly, assessing whether positive perceptions of ability and enjoyment transfer to 'real-world' skills and activities will advance the understanding of exergames used in education.

9.2.2 Education

In addition to examining the psychological concomitants of the PL tool, a sensible next step would be to examine the PL tool in an applied PE context to assimilate data and compare physical development curricula across time and between cultures/nations. For example, research examining the impact of game-based learning (e.g. PLUNGE, Miller, Christensen, Eather et al., 2015) compared to traditional linear education models has been produced. Presently, these research-intervention studies utilise traditional movement assessments (TGMD-2). Although validated, these movement assessments used in research studies fail to measure game-sense and complex movement skills. Such comparative research studies could benefit from an ecologically valid movement assessment. This could aid in the development of standardised best-practice for developing physically active individuals. Gaming encourages individuals to think strategically and allows problem solving skills to develop as more challenging scenarios are presented with progressive levels of accomplishment. Additionally the immediate provision of feedback promotes recognition that can be gratifying and motivating when positive or negative; individuals can recognise and evaluate where errors occurred resulting in problem solving to overcome errors, additionally when expectations are met, advantage is awarded in the form of increased challenge and complexity. PL exergame could induce individuals to learn the behavioural and psychological skills required to become physically literate while engaging in physical development. For example, although the rules and goals of an exergame are pre-determined, the personal meaning derived individually from interacting with the game is self-regulated (e.g. gamers choose to repeat skill levels or tasks that have been previously completed in order to achieve a higher standard).

The use of exergaming could be particularly pertinent for education systems where formal qualifications in PE are not requisite and physical curricula are taught by generalist teachers (e.g. primary level education through-out the UK and Ireland). The pre-prescribed task demands determined by the game parameters could provide a more enriched learning experience for students compared to traditional teaching methods. For example the design of gaming parameters can pedagogically draw upon expertise from multidisciplinary professionals including teachers, movement specialists, sports coaches, and cognitive and educational psychologists. Exergame assessments could ensure appropriate PE lesson structure, a key factor in motor skill development, where it is necessary to gain proficient, correct movement patterns to avoid increased incidence of movement dysfunction or negative psychosocial implications of poorly conducted PE classes.

Researchers have started to examine the effect of exergames incorporated in formal education: For example one study examined the longitudinal effect of Dance Dance Revolution intervention on BMI, cardiorespiratory fitness and math and reading scores. The intervention tracked scores over a one year period and the results show positive outcomes for using exergaming from an educational perspective. The study also confirms previous research evidencing the generalisable nature of cognitive skills gained from gaming. However, the results from the study may be confounded by examining the academic outcome of learning in other subjects (not PE curriculum) and transient measures of physical fitness. To examine the effect of exergames used to promote formal PE, outcome variables that correlate with skill learning within PE need to be assessed (i.e. PL tool). Additionally, the longitudinal studies to date have examined the effect of exergaming PE in schools compared to *no* PE. Thus, further research is required to examine whether long term exergaming interventions can enrich outcomes of education to a greater extent than traditional PE programmes.

9.2.3 PL tool & obesity markers

In-keeping with the requirement for PE to tackle the obesity issues facing younger generations, the inclusion of anthropometrics with PL assessment could aid the research and examine the correlations between transient measures of physical status that are often erroneously purported to be indicative of health status (e.g. body mass index). Body Mass Index, BMI, although providing little valuable information about the physical competence of an individual is unfortunately *still* monitored and reported by researchers, coaches, educators etc. Additionally research that combines physical competence and anthropometric measure may help to alter the interpretation of such transient anthropometric measures in the context of long-term PA determinants.

Clarkson, Wheat, Heller & Choppin (2015) examined the use of the Kinect to measure anthropometrics and limb segment volume compared to standardised measurement procedures. Although not directly applicable for present purposes, this study highlights the potential for the Kinect to passively gather anthropometric information about the individual. Future iterations of PL assessments could potentially gather anthropometric information *and* movement competence information about a person simultaneously.

9.2.4 Talent Identification

Another domain that could benefit from the objective assessment of complex movement ability is talent identification (TID) in sport. The predictive validity of the PL tool could be tested in a TID context to provide empirical data about the relationship between broad-base physical skill level and specialised sports skill proficiency. Sports-specific skill specialisation often predominates in talent academy environments, in spite of the research-base showing that early specialisation results in an increased risk of injury, increased risk of burnout and negative development trajectories down the line. Introducing a measure of complex, general movement competence and comparing this against specialised sports skills could provide empirical evidence of the relationship between general movement intelligence and specialised skill execution.

Notably, TID (i.e. selection of individuals to avail of enhanced training environments and development opportunities) is beginning at a young age (e.g. 9 years for English Premier League soccer). TID in soccer often involves validated physical tests (sprint speed and agility) that do not discriminate between soccer players' level based on (performance) expertise. Locomotive behaviour and visual perception skills have been used to differentiate between elite and sub-elite adult soccer players, however, when the measures are repeated with children, locomotive behaviour did not discriminate between skill level. Visual perception did differ between groups but the research is limited due to the validation of test procedures on adult cohorts, visual processing influences performance via different operating mechanisms depending on age (Savalsbergh, Haans, Kooiman & Van Kempan, 2010).

Such sports-specific measures (that offer a more prescriptive and objective measure of talent) often require sophisticated lab equipment that is not conducive to regular testing or tracking of performance (due to time, expertise or financial constraints) as a consequence, TID often relies on subjective/intuitive decisions by expert coaches. Field based assessments are often used to supplement coach decision making (e.g. agility, sprint speed, slalom dribbling, skill index). Field assessments are conducive to implementation in sporting environments, however as aforementioned, with the exception of the soccer skill index, these tests do not reflect sports-specific performance level. Field based measures often lack the sensitivity required to identify and develop talent/skill optimally, considering the idiosyncratic nature of talent/skill development.

It is essential to distinguish between variables that influence performance and those that influence development (Abbot and Collins, 2002). Biological maturation affects morphology and fitness more so than motor coordination skills (Vaeyens, Malina, Janssens et al., 2006). Recent findings showed moderate to high long-term stability in coordinative skills from childhood to adolescence (Vaeyens et al., 2006). Motor coordination is a stable and predictive marker of physical ability and activity participation. Individuals processing high motor coordination level during childhood demonstrate high coordination during adolescence (Dardouri, Selmi, Sassi, Gharbi et al., 2014). The trend is continuous for medium and low coordination levels. Other skills (speed, strength, power etc.) are less stable and less predictive of future skill level due to the influence of practice/training.

One study in gymnastics showed positive result for the predictive ability of coordination tests, as indicators of talent. One hundred gymnasts, cadets (aged 11.5 ± 0.5 yr.) and juniors (aged 13.3 ± 0.5 years), were enrolled in the study. All the tests were correlated with ranking and performance scores reached by each gymnast in the 2011, 2012, and 2013 National Championships. Coordination tests were significantly correlated to 2013 Championships scores ($p < 0.01$) and ranking ($p < 0.05$) of elite cadet athletes. Gymnasts with the best results in coordination and motor learning tests went on to achieve better competition results three years later. Notably, the best technical improvement was found in the most complex tests. These technical tests required better coordination ability, dynamic balance, multi-limb combination, and orientation than others (e.g. jumps). Jump requires improvement in several muscular abilities such as strength and stiffness, which are predictive talent indicators but not developed at this age (di Cagno et al., 2015).

Further research examining the correlation between validated sports specific indicators of high ability (e.g. soccer skill index) and general motor coordination (i.e. PL assessment) could advance knowledge and practice in the domain of TID.

9.2.5 PL through out the life span - ageing and activity.

Finally, conceptually, PL involves the competence and confidence to pursue physical activities throughout the life-course, thus PL promotion throughout *all* life stages warrants consideration: Although the focus of this thesis has been on the promotion of essential movement skills during *childhood*, the acquisition and maintenance of PL skills are important in later life stages too.

In addition to activity in childhood and adolescences, activity in older age has received much attention: With improvements in technology, science and medicine, the typical life-span is increasing. As a consequence a larger proportion of the population is reaching old age. Ageing presents challenges for healthcare systems, particularly in Western societies. One of the main initiatives to improve quality of life and reduce the health implications of ageing is *exercise*.

Ageing is characterised by a decrease in muscle mass and increase in sedentary lifestyle. In the WHO European Region, the population aged >65 years is projected to rise from 129 million in 2010 to 224 million in 2050 (WHO, 2015). As a consequence, a significant increase in old age dependency and health co-morbidities of inactivity with age is forecast e.g. 92% of individuals over the age of 65 have one or more chronic diseases including hypertension, stroke, diabetes, heart disease, lung disease and arthritis. Additionally, sarcopenia (loss of muscle mass) is associated with decreased activity levels. When muscle mass and strength decrease below a critical threshold, activities of daily living are compromised and risk of falls and fractures increase (Lee, Auyeung, Kwok et al., 2007). Low muscle mass also contributes to increased risk of developing type 2 diabetes. Muscle mass decrements are also associated with lower levels of independence (Lee et al., 2007).

PA and exercise participation is essential for healthy ageing. Exercise intervention studies observed that a combination of both aerobic and resistance training is required to combat cardiac and metabolic effects of ageing respectively. Thus equipping individuals with the skills to pursue a broad range of physical activities is an essential precursor to encouraging participation in physical activity. Equally, monitoring PL skills in later-life could provide useful information for practitioners to prescribe preventative exercise programmes to maintain health in older people.

Furthermore, exergaming technology has been proposed to encourage a holistic approach to ageing. Millington (2015) examined the use of exergaming technology in retirement homes as a means of promoting both physical and media literacies. The premise being that the technology, while encouraging physical activity and game-play within the safety of a retirement facility, also taught the older users how to use information technology. The study used qualitative methods to examine the impact of the exergame (wii bowling and golf) use with residents. Positive impacts were reported as encouraging, relatedness and activity levels.

However, the combination of hardware, software and physical actions were, in some cases, too demanding for the residents to process in combination, requiring care assistants to aid the participation. Equally, the movements (e.g. bowling) provided an opportunity to engage in games and leisure pursuits that may have been other wise not feasible due to accessibility, strength requirements etc. A number of participants in the study required physiotherapy treatment for shoulder bursitis and other musculoskeletal strains, perhaps because the movements engaged joints and musculature that had not been used by the participants in years. The introduction of exergaming *did* promote engagement and embodiment, older individuals reported striving to better their performance and a development of healthy competition and camaraderie amongst players.

Unfortunately, similar to attempts to apply commercial games in education (and PE), commercial entertainment games were used in the study. Specially designed tasks that are developed with special populations objectives in mind might be more successful. For example, PL assessment in older adults that use whole body motion, balance, safe osteogenic activities and cognitive components to integrate mind and body could prove a useful adjunct to monitoring physical health in older adults. However further robust research that provides better quality research design (than simply deploying commercial entertainment games in retirement centres) is necessary.

9.3 Limitations

As mentioned previously, there are a number of limitations of the present study. In addition to the future directions discussed in the previous sections of this Chapter, consideration should be afforded to address the noted limitations of the present study. Firstly, the movement quality information included in the outcome measures was limited. Although the scoring of PL tasks included both product (i.e. number of successful hits etc.) and a proxy measure of movement quality (i.e. time taken), incorporating additional 'process' information to assess movement quality is recommended for future research. For example, the hopscotch task used could incorporate a measure of centre of mass stabilisation during task completion to enhance the information garnered from the assessment. Further, the inclusion of kinetic information (e.g. velocity curve information for gross motor tasks) could aid in the promotion of process-based assessments that include insights about movement quality as well as performance outcome. Additionally, more research is required to establish the relative contribution of each outcome type (time/success etc.) to each task and also the relative contribution or weighting of each task to overall movement competence.

Notably, and as discussed in Chapters 6 & 8, not all of the planned PL tool tasks were tested during this initial study. The rationale for prioritising gross motor and interceptive skill components was primarily due to the limitations of current movement assessment batteries for measuring these skill components. However, I acknowledge the requirement for including a more comprehensive range of PL skills (including, perhaps, fine motor skill and perception of ability etc.). The rationale for the current omission of fine motor skill evaluation was twofold: Firstly, the extent to which general movement competence for life-long physical activity is influenced by *fine* motor ability has yet to be established. Although preliminary research evidencing a link between fine motor skills and physical health status has emerged (Gentier, D'Hondt, Schultz et al., 2013), more extensive research is required. Secondly, due to measurement and calibration difficulty, the extent to which the Kinect could accurately assess fine motor ability requires further investigation. Finally, the generalisability of results from this study is limited. Further examination using the PL tool with other nationality cohorts is required to examine the universality of PL skills and develop global standards of PL assessment.

In addition the above mentioned limitations, a number of barriers were encountered during the conduction of this research project:

9.3.1 Sample & recruitment

Firstly, the study only included a sample of Irish children. Further investigation using cohorts from other national school environments is required to produce generalisable results about the universal application of the PL tool. As aforementioned, cultural specific differences have been recorded in PE and PA research previously, the current study requires further research examination including cohorts from other countries to understand the applicability of the procedure for assessing universal PL skills.

9.3.2 Technology

Kinect hardware and software was developed for gaming purposes, thus precision and accuracy when the technology is used in other contexts has, understandably, come under critical consideration. Specifically, the proliferation of research identifying the insufficiencies of Kinect (deployed in movement assessments contexts) has acted as a barrier to credibility and trustworthiness of the technology used outside the gaming industry. A number of progressions in the technology have emerged since commencing this PhD research. Namely, Kinect V1 has been discontinued by Microsoft. Thus to continue PL tool research in the future, adaptation to the latest version of Kinect for development is required. Kinect V2 was released in 2015. Kinect V2 has a more advanced camera system and offers increased tracking capabilities. Specifically, Kinect V1 relied on structured light (SL) vision tracking. The second version of Kinect uses time of flight (ToF) cameras. Research comparing both Kinect devices used on a range of applications has shown pros and cons of each camera used for certain purposes. Kinect V2 does not suffer from the same occlusion limitations as Kinect V1. Kinect V2 has typically 5% occlusion whilst Kinect V1 has up to 20% occlusion.

9.3.3 Ambient light

As any other camera, Kinect can suffer from interference from ambient background light (i.e. infrared interference). Light can lead to over-saturation i.e. too long exposure times in relation to the objects' distance and/or reflectivity, e.g. causing problems to V1systems in detecting the returning light (Fiedler & Muller, 2013). Whilst efforts were made to limit direct sunlight in the testing space (window blinds etc.), the extent to which light saturation could be controlled for was limited. Further research that includes tracking infrared interference from external light sources could be of value in assessing the validity of task output (i.e. did the child successfully move to intercept, but the move was not tracked due to interference).

9.3.4 Measurement error correction

Both Kinect cameras (V1 & V2) suffer from error in their depth measurement. For the Kinect V1 the error is mainly due to inadequate calibration and restricted pixel resolution for estimation of the point locations in the image plane, reducing the precision of points/pixel coordination. As discussed in Chapter 7, the level of error is both task and environment dependent. Thus, it could be possible, through the standardisation of movement requirements and environmental constraints, to establish standard expected error and deploy correction methods to enhance the accuracy of the Kinect output. However, for this to be possible, more sophisticated individual-specific calibration procedures are likely to be required. For example, miss-localisation of bone depth relative to body-segment surface would require skeletal and depth information to compute the body segment length and volume information. Post-processing each frame relative to the calibration information would be necessary to to correct length and depth discrepancies that occur during fast dynamic movement. It is suggested however that, the level of accuracy afforded by more sophisticated calibration and correction procedures is beyond the level of accuracy required to measure key PL movement parameters.

9.3.5 Temperature

Kinect V1 generates less heat that Kinect V2. However, temperature stabilisation is still an important consideration for optimising the accuracy of the Kinect. For Kinect V1 a ten minute warm up phase results in more stable output and reduces error (Fiedler & Muller, 2013). A twenty minute switch on period prior to testing was included during the main investigation, however, comparison with longer or shorter duration warm up periods were not made, therefore arguably, the control and standardisation of ambient temperature for measurement may not have been optimised. However, based on Kinect recommendations, the twenty minute warm-up period used should have been sufficient. Furthermore, warm-up times were standardised between testing sessions.

9.3.6 Confounds and controls

Finally, a potential confounding factor that requires more extensive investigation is the impact of previous experience of exergaming on PL test scores. The amount of time spent playing exergames could influence score attained, however, the games were designed in such a way that they replicated general movement ability and not sports specific tasks or exergame specific tasks (thus the previous sports experience was not considered a confounding factor). Furthermore, the task requirements were intuitive and did not require additional technology or gaming knowledge to participate. Thus, it is suggested that the impact of gaming experience would be minimal. However, future research that controls for the effect of exergaming experience is warranted.

Similarly, weight and anthropometric measures were not tracked in this study. Such variables should be controlled for in future investigations.

9.4 Conclusion

The limitations discussed above notwithstanding, and pending further development and validation, the study provides initial empirical support for the application of exergaming technology to PL skill assessment. The PL tool was designed to fill the gaps in movement assessment quality and address some of the major limitations of traditional, validated movement assessments. Initial results are promising, with the approach appearing to outperform 'industry standard' tools whilst also offering children a motivating, game-like assessment. Anecdotally, almost all were enthusiastic, even given the number of repetitions required by the validation protocols. It is hoped that this study highlights the importance of improving movement skill assessment to ensure that outcomes reflect intention of PE and PA initiatives.

To conclude, the objectives of this thesis were to investigate the promotion of PA through primary level PE. The study provides initial empirical support for the application of exergaming technology to PL skill assessment. The PL tool was designed to address some of the limitations of traditional, validated movement assessments. Initial results are promising, with the approach appearing to outperform 'industry standard' tools whilst also offering children a motivating, game-like assessment.

A number of technological and methodological factors have limited this research. For example, Kinect tracking limitations, environmental interference, control factors and generalisability of the results. However the results are promising for future research and development of exergaming technology to enhance objective movement analysis in PE.

The wider implications of advancing the assessment and development of PL transcend the spectrum of physical activity participation and performance, as discussed in this Chapter. For example, the development of complex movement skill assessment provides opportunity for enhancing TID pathways in sports that currently rely on transient markers of fitness that are arguably not representative of potential. Equally, education intervention and comparative research in education could be improved with further generalisable research with the PL tool.

Finally, empirical evidence is essential to ensure evidence-based practice in PE. The limited operationalisation of PE models has resulted in descriptive, philosophically based paradigms that lack a definitive standardisation. Clearly, structured motor skill development is pertinent to long-term PA engagement. It is hoped that, in addition to the present findings, continual development of complex movement skill assessment (PL tool) can improve scientific understanding of optimal physical development. Equally, it is hoped that the ecological orientation of the research can aid in transferring scientific knowledge to practical application by providing tools for use by generalist teachers in the primary school classroom.

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Appendix 1 Ethics Approval

30th January 2014

Dave Collins and Susan Giblin

School of Sports Tourism & the Outdoors

University of Central Lancashire

Dear Dave & Susan

Re: BuSH Ethics Committee Application

Unique Reference Number: BuSH 216

The BuSH Ethics Committee has approved your proposed amendment to your application ‘Enhancing participation and performance in physical activity through primary level physical education- The role of physical literacy’.

Yours sincerely

Gill Thomson

Vice Chair

BuSH Ethics Committee

Appendix 2 Teacher Survey

Thank you for your time and feedback

Please complete sections 1, 2 and 3 in order and do not revise your answers after completion.

Section 1

The following 6 questions ask for information about you (qualifications/experience) and the provision of PE in your school.

1. What is/are your qualification(s) in teaching? __________________
2. How much PE do you teach each week? Hours________
3. Do you hold any PE specific qualifications or have you completed specialist qualifications in PE (Please list)

   ____

4. Who provides PE in your school? Please circle all appropriate :

   sports coaches   PE specialists   class teachers   other______________

5. What are the goals of the PE Curriculum taught in your school? i.e. what do you want to see leaving pupils able to do?

1.
2.
3.
4.
5.

6. What would improve PE in your school?

Section 2

Scientific research findings show that the 5 factors of movement as defined below are important for developing overall physical ability:

1. **Interceptive timing** -anticipating the speed, direction and trajectory of a ball and coordinating motor patterns to ensure that the bat/racket/limb arrives at the point of interception with appropriate speed, force and direction (Weissensteiner, Abernathy & Farrow, 2011).

2. **Object manipulation** is the use of limb movements and systematic force to move an object (e.g. batt, racket etc.) (Mah & Mussa-Ivaldi, 2003).

3. **Locomotion and agility** - the ability to maintain a stable centre of mass when walking, running, jumping, changing direction and various speed (Jambor, 1990).

4. **Spatial awareness and balance -** balance is the ability to maintain a stable centre of mass. Spatial awareness is an understanding of how much space the body occupies and how the body can move in space (Frost, Worthiam & Reifel, 2010).

5. **Rhythm and sequencing –** an awareness of the relationship between movement and time (temporal awareness). The sequence of events using a form of rhythm or pattern reflects temporal awareness (Frost, 1992; Gallahue, 1989; Jambor, 1990).

The following section (overleaf) examines each of these factors in further detail. The questions ask for information about the development of these movement skills through PE in you school. Please use the likert rating system when provided to answer the questions (1 = not at all, 3 = average, 5 = extremely).

Interceptive timing	**Example of this Factor**The skills used in like tennis or basketball or football to coordinate body movements in time to hit/catch/kick	In your own opinion, how important is this factor to overall physical development? 1 2 3 4 5	How is it taught in your school?	Do you test for students interceptive timing skills? Yes/No? If yes – how?	How confident are you teaching this factor? 1 2 3 4 5
Object manipulation	The skills used in hockey to coordinate body movements with equipment	In your own opinion, how important is this factor to overall physical development? 1 2 3 4 5	How is it taught in your school?	Do you test for students' object manipulation skills? Yes/No? If yes – how?	How confident are you teaching this factor? 1 2 3 4 5
Locomotion and agility	The ability to move quickly and smoothly such as the skills used in gymnastics.	How important is it to physical development? 1 2 3 4 5	How is it taught in your school?	Do you test for students' locomotion and agility? Yes/No? If yes – how?	How confident are you teaching this factor? 1 2 3 4 5
Rhythm and sequencing	The skills used in dance or team sports rugby to recognise and repeat complex movement patterns	How important is it to physical development? 1 2 3 4 5	How is it taught in your school?	Do you test for students' rhythm and sequencing? Yes/No? If yes – how?	How confident are you teaching this factor? 1 2 3 4 5
Spatial awareness and balance	The skills used in skating/field events to assess, maintain and adapt body position for functional movement	How important is it to physical development? 1 2 3 4 5	How is it taught in your school?	Do you test for students' spatial awareness and balance? Yes/No? If yes – how?	How confident are you teaching this factor? 1 2 3 4 5

Are there any other factors you consider important to developing physical ability? Please give details

What is it?	In your opinion, how important is this factor to overall physical ability? 1 2 3 4 5	How is it taught in your school?	How would you evaluate changes in this factor?	How confident are you in teaching this factor? 1 2 3 4 5

Section 3

For the next questions we are going to ask about average level of student ability and the range of abilities you encounter at entry (age 5) and exit (age 12) of your primary school. Average ability refers to the expected level of physical development for an individual of that age.

Using the scale, please **circle** the average ability level and **underline** the lowest and highest level, where -5 = extremely below expected physical ability and +5 = extremely above expected physical ability for their age group.

1. Please indicate the **average** (circle) level student ability and **range** (underline) of abilities you encounter at the beginning of primary education.

-5 -4 -3 -2 -1 0 1 2 3 4 5

2. Please indicate the **average** (circle) level of student ability and **range** (underline) of abilities at cessation of primary education.

-5 -4 -3 -2 -1 0 1 2 3 4 5

Appendix 3 School Information Sheet

Study Title: Enhancing participation and performance in physical activity through primary level physical education- The role of physical literacy

Researchers: Prof. Dave Collins DJCollin@uclan.ac.uk

Prof. Jim Richards JRichards@uclan.ac.uk

Research Student: Susan Giblin SGiblin@uclan.ac.uk

The following information is designed to provide you with answers to questions that you may have about the school participating in this study. Please take your time to read the following information carefully. If you have any questions please do not hesitate in asking any one of the research team. This study is being conducted as part of a doctoral project.

Background of the Study

Physical Literacy (PL) has become a major focus of physical education, physical activity and sports promotion throughout the world. PL comprises of the physical, psychological and behavioural skills required to reach potentials and engage in physical experiences throughout the life span. Despite the widely acknowledged benefits of PL for health, academia, sports performance and physical activity participation. There is currently no 'gold-standard' protocol for providing PL education. One reason for this is due to inadequate tools to monitor PL in education settings. Exer-gaming technology, as used in this study, could provide an appropriate and accessible method for evaluating and educating PL skills in school settings.

What is the purpose of the study?

The purpose of this study is to promote participation and performance in physical activity through primary level physical education.

Why have I been chosen?

Your school has been invited to participate in this research study because your institution provides primary level education to students that include a curriculum of physical education.

What will I have to do?

Taking part in the study will involve a selection of students (aged 4-8 approx. 2 class groups of students) engaging in physical education using exergaming technology. Parent information will be provided for potential participants to ensure full informed consent is obtained for students to participate. The equipment will be provided by the researcher. Time and scheduling for participating will be arranged at the convenience of the staff. Full consideration and cooperation with school regulations, time constraints and curricular demands will be ensured during participation.

Questionnaire

Parents will be asked to complete a questionnaire for health and safety purposes before taking part in the study. This questionnaire is to ensure the safety of the children and highlight any risk factors to taking part in physical activity. The health and safety of your students is priority in our study and as such, any individual identified as 'at risk' will be not included.

Physical activity

The study will use 'exer-gaming' technology to engage children in movement skills (e.g. jumping, balancing) involving whole-body coordination. The exer-game will be used in the class room and under the instruction of myself (the researcher) and the teacher. Children will perform a whole-body dynamic warm up (jumping-jacks, squat stretch, arm rotations) prior to activity and complete stretching under instruction after the activity. Children will be instructed to move to match the shape presented on screen. The speed and accuracy of movement will be monitored. If any child is unwell or unwilling to participate in activity at any point throughout the study they will not be forced to do so, the teacher and researcher will monitor your child's well-being through-out the study.

What will be recorded?

During the testing session the students movements will be recorded using commercially available digital motion capture devices (Microsoft Xbox Kinect), (the data captured appears as animation on a computer screen and the data will be recorded in movement coordinates). Speed and accuracy of the child's movement to match the shapes appearing on screen will be recorded.

What should students wear?

To ensure the comfort and safety of students, footwear and clothing usually worn during physical activity in the classroom is recommended.

Who will be involved?

The study will be conducted in the school with the children, class teacher and researcher.

The analysis of the study will involve a team of researchers made up of experts in the field of human movement sciences, physical education and psychology.

Post-study Debriefing

Teachers' feedback will be sought on completion of the study. Research findings will be summarised in a written report and provided to the school.

Are there any risks in taking part?

The study will not involve any movements that exceed the range of movement or loading that would normally occur during physical activity, therefore the risk of injury is minimal.

No external equipment (sports or gaming) will be involved, reducing the risk of injury further.

The level of physical activity will be individually determined and each student will engage in and proceed at their own level depending on movement abilities.

A full risk assessment has been conducted to ensure the area, actions of the exercise and the equipment is safe for participation.

Do I have to take part?

No, the study is entirely voluntary. Parents will be free to withdraw their children from the study at any time with no explanation required. This is highlighted to parents in the information sheet and informed consent.

Use of information

The information gathered in this study will be used in a doctoral thesis, research presentations and publications relating to the PhD research project. All data used in any such publications will be anonymised and participants will not be identifiable.

Confidentiality

All data and information recorded will be safeguarded with anonymity, stored on researchers password protected computer for a period of 5 year post-study and then destroyed. Data has no identifiable factors and is represented by simple data points bearing no resemblance or identifiable aspects to any individual. Consent form will be kept within a locked cupboard, within a locked room which has limited access at UCLan.

Conflict of Interest

The study forms part of a doctoral project funded by the University of Central Lancashire. The study does not include any funding from technology or software companies.

Ethical Review

Ethical clearance for the study has been obtained from the BuSH (Built, Sport, and Health) subcommitteeof the University of Central Lancashire (UCLan). The researcher has received clearance in the UK and Ireland to work with children in education settings. The researcher has extensive experience teaching and coaching children. The researcher is also fully certified in first aid and advanced CPR and manual handling.

Further Information

If you would like further information or any clarification then please contact:

Susan Giblin (researcher)

Doctoral Student - University of Central Lancashire

SGiblin@uclan.ac.uk

0868195864

Complaints Procedure

If you are unhappy with how you have been dealt with or have any other issues and would like to discuss matters then please contact:

John Minten

Head of School

School of Sports, Tourism and the Outdoors

Greenbank Building (GR 159)

University of Central Lancashire

jhminten@uclan.ac.uk

Appendix 4 Informed consent

Informed Consent

Enhancing participation and performance in physical activity through primary level physical education - The role of physical literacy

The purpose of this study is to promote participation and performance in physical activity through primary level physical education.

Researchers: Prof. Dave Collins DJCollin@uclan.ac.uk

Research Student: Susan Giblin SGiblin@uclan.ac.uk Please initial box

I have been informed that the general purpose of this study is to examine physical education using exer-gaming technology.

I have been informed that participation in this study will involve my child performing of a variety of movement skills similar to those used to engage in physical activity, exercise and sport.

I have been informed that any information or data gathered about my child will be kept confidential and that identity will be kept anonymous in any presentation of data.

I have been informed that there are no known expected discomfort or risks involved with my child's participation in this study.

I have been informed that the researchers will gladly answer any questions regarding the procedures in this study at any stage.

I have been informed that I am free to withdraw from any part of the study at any time.

I understand that if I have any concerns about this project I can contact Susan Giblin at SGiblin@uclan.ac.uk or any member of the research team listed above.

I acknowledge I have received a copy of this form, an information sheet and physical activity readiness questionnaire and that I have read and understand the above information regarding my participation in this study.

Name of student:________________________

Signature of parent: _____________ Date: __________________

Signature of researcher:________________________________

Appendix 5 Parent Information Sheet

The following information is designed to provide you with answers to questions that you may have about your child participating in this research study.

Study Title: Enhancing participation and performance in physical activity through primary level physical education- The role of physical literacy

Researchers: Prof. Dave Collins DJCollin@uclan.ac.uk Susan Giblin SGiblin@uclan.ac.uk

Please take your time to read the following information carefully. If willing to consent to your child's participation please complete, sign and return the attached form to your child's teacher. If you have any questions please do not hesitate in asking any one of the research team. This study is being conducted as part of a doctoral project.

What is the purpose of the study?

The purpose of this study is to promote participation and performance in physical activity through primary level physical education.

What will I have to do?

Participation in the study will involve your child taking part in normal physical activity in the class room during school hours. This will be included as physical education. You will be required to complete a consent form.

Physical activity

The study will use 'exer-gaming' technology (Microsoft Kinect) to engage children in movement skills (e.g. jumping, balancing, hopping). If your child is unwell or unwilling to participate in activity at any point throughout the study they will not be forced to do so, the teacher and researcher will monitor your child's well-being through-out the study.

Use of information

The information gathered in this study will be used in a doctoral thesis, research presentations and publications relating to the PhD research project. All data used in any such publications will be anonymised and participants will not be identifiable.

Confidentiality

Data has no identifiable factors and is represented by simple data points.

Ethical Review

Ethical clearance for the study has been obtained from the University of Central Lancashire (UCLan). Vetting procedures have been completed.

Further Information

If you would like further information or any clarification then please contact:

Susan Giblin (researcher) 0868195864

Appendix 6 DVD of KPL Tool in action

Appendix 7 Statistical Output

Correlations

				HEAD	TRHEAD
HEAD	Pearson Correlation			1	-.874**
	Sig. (2-tailed)				.000
	N			40	40
	Bootstrap[b]	Bias		0	.002
		Std. Error		0	.033
		95% Confidence Interval	Lower	1	-.923
			Upper	1	-.793
TRHEAD	Pearson Correlation			-.874**	1
	Sig. (2-tailed)			.000	
	N			40	40
	Bootstrap[b]	Bias		.002	0
		Std. Error		.033	0
		95% Confidence Interval	Lower	-.923	1
			Upper	-.793	1

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

				TRBAT	BAT
TRBAT	Pearson Correlation			1	.721**
	Sig. (2-tailed)				.000
	N			40	40
	Bootstrap[c]	Bias		0	-.012
		Std. Error		0	.101
		95% Confidence Interval	Lower	1	.461
			Upper	1	.859
BAT	Pearson Correlation			.721**	1
	Sig. (2-tailed)			.000	
	N			40	40
	Bootstrap[c]	Bias		-.012	0
		Std. Error		.101	0
		95% Confidence Interval	Lower	.461	1
			Upper	.859	1

**. Correlation is significant at the 0.01 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Correlations

					HOP	TRHOP
HOP	Pearson Correlation				1	-.714**
	Sig. (2-tailed)					.000
	N				40	40
	Bootstrap[b]	Bias			0	-.008
		Std. Error			0	.054
		95% Confidence Interval	Lower		1	-.814
			Upper		1	-.600
TRHOP	Pearson Correlation				-.714**	1
	Sig. (2-tailed)				.000	
	N				40	40
	Bootstrap[b]	Bias			-.008	0
		Std. Error			.054	0
		95% Confidence Interval	Lower		-.814	1
			Upper		-.600	1

**. Correlation is significant at the 0.01 level (2-tailed).

b. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

ANOVA

Hop

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10827.764	2	5413.882	19.973	.000
Within Groups	85112.305	314	271.058		
Total	95940.069	316			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Hop

	(I) 1=5,2=8,3=10	(J) 1=5,2=8,3=10	Mean Difference (I-J)	Std. Error	Sig.	99% Confidence Interval Lower Bound	99% Confidence Interval Upper Bound
Tukey HSD	1.00	2.00	9.67428*	2.34285	.000	2.7985	16.5501
		3.00	15.80754*	2.50542	.000	8.4546	23.1605
	2.00	1.00	-9.67428*	2.34285	.000	-16.5501	-2.7985
		3.00	6.13326	2.15244	.013	-.1837	12.4502
	3.00	1.00	-15.80754*	2.50542	.000	-23.1605	-8.4546
		2.00	-6.13326	2.15244	.013	-12.4502	.1837
Bonferroni	1.00	2.00	9.67428*	2.34285	.000	2.7445	16.6040
		3.00	15.80754*	2.50542	.000	8.3969	23.2182
	2.00	1.00	-9.67428*	2.34285	.000	-16.6040	-2.7445
		3.00	6.13326	2.15244	.014	-.2333	12.4998
	3.00	1.00	-15.80754*	2.50542	.000	-23.2182	-8.3969
		2.00	-6.13326	2.15244	.014	-12.4998	.2333

*. The mean difference is significant at the 0.01 level.

ANOVA					
Head					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10.697	2	5.348	.928	.397
Within Groups	1816.430	315	5.766		
Total	1827.127	317			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Head

	(I) Group2	(J) Group2	Mean Difference (I-J)	Std. Error	Sig.	99% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1.00	2.00	-.00785	.34027	1.000	-1.0065	.9908
		3.00	.38988	.36408	.533	-.6786	1.4584
	2.00	1.00	.00785	.34027	1.000	-.9908	1.0065
		3.00	.39773	.31394	.415	-.5236	1.3191
	3.00	1.00	-.38988	.36408	.533	-1.4584	.6786
		2.00	-.39773	.31394	.415	-1.3191	.5236
Bonferroni	1.00	2.00	-.00785	.34027	1.000	-1.0143	.9986
		3.00	.38988	.36408	.855	-.6870	1.4667
	2.00	1.00	.00785	.34027	1.000	-.9986	1.0143
		3.00	.39773	.31394	.618	-.5308	1.3263
	3.00	1.00	-.38988	.36408	.855	-1.4667	.6870
		2.00	-.39773	.31394	.618	-1.3263	.5308

ANOVA					
Bat					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	133.505	2	66.752	38.708	.000
Within Groups	544.951	316	1.725		
Total	678.456	318			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Bat

	(I) Group3	(J) Group3	Mean Difference (I-J)	Std. Error	Sig.	99% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1.00	2.00	1.50531*	.18531	.000	.9615	2.0491
		3.00	1.50499*	.19838	.000	.9228	2.0872
	2.00	1.00	-1.50531*	.18531	.000	-2.0491	-.9615
		3.00	-.00033	.17169	1.000	-.5042	.5035
	3.00	1.00	-1.50499*	.19838	.000	-2.0872	-.9228
		2.00	.00033	.17169	1.000	-.5035	.5042
Bonferroni	1.00	2.00	1.50531*	.18531	.000	.9572	2.0534
		3.00	1.50499*	.19838	.000	.9182	2.0917
	2.00	1.00	-1.50531*	.18531	.000	-2.0534	-.9572
		3.00	-.00033	.17169	1.000	-.5081	.5075
	3.00	1.00	-1.50499*	.19838	.000	-2.0917	-.9182
		2.00	.00033	.17169	1.000	-.5075	.5081

*. The mean difference is significant at the 0.01 level.