Conceptualizing Physical Literacy within an Ecological Dynamics Framework

O'SULLIVAN, Mark <http://orcid.org/0000-0001-6851-6167>, DAVIDS, Keith <http://orcid.org/0000-0003-1398-6123>, WOODS, Carl T. <http://orcid.org/0000-0002-7129-8938>, ROTHWELL, Martyn <http://orcid.org/0000-0002-3545-0066> and RUDD, James <http://orcid.org/0000-0003-1546-576X>

Conceptualizing physical literacy within an ecological dynamics framework

Abstract

Currently, there are numerous definitions and interpretations of the concept of physical literacy within the literature, potentially leading to a lack of consensus as to how to employ it in practice. In this position paper, we argue that ecological dynamics is well-positioned to provide a theoretical framework that will bring clarity, as well as support the operationalisation of physical literacy in practice. We argue that this theoretical conceptualisation provides an excellent framework for understanding physical literacy because of its emphasis on the person-environment relationship. More directly, we propose the establishment of an *individual-environment fit* across varied movement contexts over a lifespan as a central tenet of the physical literacy concept. We conclude by discussing how sports practitioners, national governing bodies, public health and education sectors could re-design sport, exercise and physical activity environments, in accordance with an ecological dynamics rationale to enhance physical literacy.

Key words: Individual-environment fit; non-linear pedagogy; functional skill adaptation; self-regulation; affordance landscapes; environment design

Introduction

Recently the concept of physical literacy has gained increased attention beyond physical education, sport discourse and into the public health arena (Young, O'Connor & Alfrey, 2019; Jurbala, 2015), entering policy and practice in many countries (Spengler & Cohen, 2015). Physical literacy is not a new term, having been referenced as early as the 1900s (Corbin, 2016). However, it was Whitehead's conceptualisation emerging from the physical education literature in the United Kingdom (Whitehead, 2001) that initially stimulated interest and usage among practitioners and academics. Whitehead defined physical literacy as 'the motivation, confidence, physical competence, knowledge and understanding to value and engage in physical activity for life' (IPLA,

2017). This holistic approach to physical literacy rejected the Cartesian view of the mind and body being separate entities, instead promoting the idea of *embodiment* (Whitehead, 2007). Whitehead argued that sport and physical activity represents just one context in which embodied capacities are both challenged and celebrated throughout an individual's lifespan (Whitehead, 2001, 2007; Whitehead & Murdoch, 2006). This capacity to capitalise fully on our embodied dimension could be captured in the term 'physical literacy' (Whitehead, 2007).

The increased interest in physical literacy has mirrored that of physical activity epidemiologists from academic institutions, public health departments and the World Health Organization who have highlighted that 1.4 billion adults do not meet the WHO recommended levels of physical activity (Guthold, Stevens, Riley, & Bull, 2018). This number will continue to rise in years to come, as it has been predicted that by 2030 in the United States of America: (i) 1 in 2 adults will be obese; (ii) the prevalence of obesity will be higher than 50% in 29 states and not below 35% in any state; and (iii), nearly 1 in 4 adults is projected to have *severe* obesity by 2030. In response to the health consequences and financial economic burden, which is estimated to be over £50 billion per year, enhancing physical literacy has been seen as a key focus in policy to integrate public health, recreation, sport, and education agencies to engage youth into a life of physical activity (Dudley, Cairney, Wainwright, Kriellaars, & Mitchell, 2017).

Physical literacy and its definitional vagueness

A problem for those interested in promoting the construct has been the emergence of many different interpretations of physical literacy (see Edwards et al., 2016, Shearer et al., 2018; Young, O'Connor, & Alfrey, 2019). This has led to a lack of consensus as to how to define and employ it in practice (Foulkes, Foweather, Fairclough & Knowles,

2020; Hyndman & Pill, 2018; Jurbala, 2015), seemingly resulting in an oversimplification of the concept (Whitehead, 2010). For example, McKenzie and Lounsbery (2016) identified that many practitioners cannot discriminate between physical activity, physical fitness and physical education, and that adding another term such as physical literacy could increase confusion. Further, likening movement 'literacy' with language 'literacy' may be problematic (Jurbala, 2015). Designed to appeal to educators, managers and policy makers (Jurbala, 2015), the construct has been promoted in the media through the notion that children should be taught physical literacy in the same way that they learn numeracy or grammatical skill (Addley, 2019). Arguably, this adopted perspective positions the term as a testable or measurable phenomenon, whereby generic assessments that reflect the traditional standardised testing of reading, arithmetic and writing may suffice to understand its 'acquisition' by an individual (Tremblay & Lloyd, 2010).

Indeed, physical literacy test objectives have been questioned for their inadequate simplistic linear methodologies and designs that attempt to reduce movement into measurable components, while showing a lack of appreciation for the contexts in which movement takes place (Edwards, Bryant, Keegan, Morgan, & Jones, 2016; Ng & Button, 2018). Physical literacy, in this sense, provides a reductionist or 'textbook' application of a source of representational knowledge which needs to be applied in a practical settings in checkbox fashion (Roberts, Newcombe, & Davids, 2018). Jurbala (2015) challenged these approaches when he argued that physical literacy can instead be viewed as a journey throughout a lifespan that extends beyond formally-organised and competitive sports and physical education. Through such a lens, physical literacy is not viewed as a series of 'acquired' movement competencies and skill components, but a

continuingly evolving concept that could positively impact the mental and physical wellbeing of individuals throughout childhood, adulthood, and into old age.

Physical literacy policy across the world

Despite its definitional vagueness, popularity of the concept of physical literacy among sport and physical activity practitioners and policy makers continues to grow (Jurbala, 2015), with many publication on the construct often produced by government funded organisations and departments (Lynch, 2019). For example, in Canada it has been placed as 'the cornerstone of both participation and excellence in physical activity and sport' (Way, Balyi, Trono, Harber, & Jurbala, 2014, p. 23). A comprehensive approach has been taken in Australia, reducing physical literacy to 30 elements across four physical literacy domains (physical, psychological, social and cognitive), accompanied by a five-step, staged approach for implementation (Sport Australian, 2019). In England, physical literacy has been reduced to a set of capabilities and achievements that every child should achieve (Sport England, Strategy, 2016), while in Sweden, Lundvall and Tidén (2013) have shown how physical literacy has been integrated into physical education as a form of generic assessments. It is apparent that many government policy programmes of physical literacy are underpinned by stage-based models of movement development, with a focus on measurement, that are seemingly grounded in health-based epidemiological models of physical activity promotion. For example, fundamental movement skills have been promoted within physical literacy under the assumption that they are associated with an initiation in to competitive sport and health, while uncritically been accepted as central to physical education (Almond, 2014). Such an approach to physical literacy moves the primary focus away from the learning process, enhancing understanding of how to enrich self-regulation in movement contexts, towards evaluation of outcomes. Measurement choices are made

based upon psychometric properties of assessment feasibility, reliability and validity (construct, predictive, convergence) (Cools, Martelaer, Samaey, & Andries, 2009; Webster & Ulrich, 2017). However, relevant forms of validity are not well-understood, such as face and content validity, that would question whether the assessment is valid under scrutiny of contemporary theories of motor learning and development.

To summarise so far, the concept of physical literacy, despite its definitional vaguenes, is becoming an integral component of national health policy and a key focus of the physical education curricula across the globe. It is seemingly doing so through a health-based model of physical activity. This perspective moves away from enhancing understanding of the motor learning process, perhaps leading to a paucity of evidence to support how practitioners may integrate it in curricula and erecting barriers to its utility (Roberts, Newcombe, & Davids, 2018, Rudd et al., 2020).

Towards a theoretical framework to enhance the conceptualization of physical literacy .

We propose that these misconceived conceptualisations and the definitional vagueness, in part, may be due to a lack of a persuasive, comprehensive theoretical grounding. To assist in the conceptulization of physical literacy situated in an ecological dynamics framework, in Table 1 we outline the synergies that may exist between Whitehead's (2001) original definition of physical literacy and an ecological dynamics rationale.

See Table 1

Ecological dynamics moves us beyond describing what physical literacy is, towards guiding practitioners by supporting how they can operationalize the concept. This is because the emphasis is on the person-environment relationship, and the value of adopting that interaction as the scale of analysis. This scale contrasts with perspectives

that examine physical literacy effects on the individual or environment considered separately and so is better aligned with the philosophical and embodied nature of physical literacy put forward by Whitehead (2007).

Advancing physical literacy is therefore a journey of individual enrichment through movement experiences in a variety of movement contexts. A wide variety of rich interactions with varied environments ranging from quality organised sports to recreational physical activity experiences will lead to *self-regulation* (i.e., an individual's ability to adapt and organise functional behaviours independently, i.e. without the external input of a coach, teacher, or parent) (Chow, Davids, Shuttleworth, & Araújo, 2020; Button, Seifert, Chow, & Araújo, 2020). The shared intentionality across sporting and physical activity landscapes should be about supporting self-regulation, thus supporting the individuals' continued physical literacy across a lifespan. More directly, if we are to embrace the concept of physical literacy, then it should be viewed not as an outcome-oriented end-point, but presented as a process-oriented journey across the lifecourse, influenced by a unique set of interacting constraints encountered by each individual. As we elucidate next, negotiating the emergent, interacting constraints in a life trajectory is the challenge for each self-regulating individual seeking a more functional (i.e. fruitful, engaging and productive) relationship with varying performance environments over the lifecourse (Rudd, Pesce, Strafford &, Davids, In Press).

An ecological approach to the concept of physical literacy

Through supporting functional interactions of the dynamic elements of behaviour (i.e., activities, relationships, and settings), the long-term outcomes of positive youth development (i.e., performance, participation, and personal development) are likely to

be achieved (Allan, Turnnidge, & Côté, 2017). Through development, a child's varied movement contexts provide different opportunities for (inter)action that are fundamental to promoting motor competence (Flôres, Rodrigues, Copetti, Lopes, & Cordovil, 2019), with these contexts inviting, permitting or inhibiting interaction (Bronfenbrenner & Ceci, 1993). This process, of course, extends into adult life and is relevant throughout a lifespan, with the manifestations of the process and outcomes (each individual's performance levels and aspirations will differ) needing to be tailored to the individual's needs, capacities, desires and stage of development. So, if the concept of physical literacy is to be woven into health education, sport and recreation, in both policy and practice, then it needs to be conceived, like motor skill 'adaption', as a dynamic system that should be viewed as a lifelong, individualised process (Allan et al., 2017; Clarke, 1995).

An ecological perspective is ideally suited to frame this process, since this ontology implies that physical literacy should be understood not as an entity, and should certainly not be merely implicated with physical movement outcomes. Rather, physical literacy should be reflected in the dynamic, emergent behaviours (i.e., physical, social, emotional, social, cognitive, perceptual) of each individual-environment system, continuously subjected to the influence of changing personal and environmental constraints. The focus is on interacting dimensions of movement and physical activity behaviours (i.e., perceptions, cognitions, emotions, social interactions and physical actions) which emerge to support an adaptive functional, dynamical relationship between the individual and his/her environment (Araújo & Davids, 2011). In ecological dynamics, the term 'functional' refers to the adoption of supportive, adaptive, and relevant behaviours with respect to achieving intended task goals during performance (Davids, Araújo, Hristovsk, Passos, & Chow, 2012). This systems approach calls for a

shift in perspectives, from ‘fundamental’ to ‘functional’, from the reductionist interpretation of physical literacy discussed previously, to one which facilitates the systemic emergence of greater functional relationships between the learner and the environment over a lifespan (Renshaw & Chow, 2018). As noted earlier, self-regulation is the means by which appropriate levels of functionality are achieved in different performance contexts (from recreational to elite) requiring an individual to use perception, action and cognition to interact with a performance environment (including its social, emotional and physical dimensions) during goal-directed behaviour.

Ecological dynamics: Appropriateness for framing physical literacy

Ecological dynamics is an integrated theoretical framework (Araújo, Davids, & Hristovski, 2006) of use for studying human behaviour in performance contexts such as work, education and sport, through the lenses of constraints on dynamical systems (Newell, 1986; Kelso, 1995), ecological psychology (Gibson, 1966, 1979), the complexity sciences (Edelman & Gally, 2001) and evolutionary science (for an overview, see Button et al., 2020). Fundamentally, an ecological dynamics rationale views perceptions, cognitions and actions as interacting and self-organising phenomena that emerge from the cyclically dynamic interaction between an individual’s action capabilities and the opportunities or invitations for action (referred to as *affordances*) offered by a specific performance environment (Araújo et al., 2006; Button et al., 2020; Chow et al., 2020; Ross, Gupta, & Sanders, 2018). Within this framework, the environment is perceived in behavioural terms, where objects, places, surfaces, events and other people, provide different opportunities or invitations for (inter)actions.

Affordances can be understood as properties of an individual-environment system, scaled to each individual’s action capabilities (e.g., speed, strength), body

dimensions (Davids, Araujo, Vilar, Renshaw, & Pinder, 2013), and are perceived by the individual as they learn to establish an individual-environment fit. This idea of a *fit* between each individual and a performance environment highlights the idea that humans perceive the environment in relation to its functionality, and its meaningfulness detected in affordances, which provides insights in to what they learn and know and how they can decide to act (Araújo et al., 2006). Thus, an ecological dynamics framework enables the appreciation of how behaviours emerge at the ecological scale of analysis, the individual-environment relations (Araújo et al., 2006). This appreciation highlights the reciprocity of an individual and the environment coupled as a dynamical system (Warren, 2006), which was eloquently described in the seminal work of Gibson (1979, p. 223) when he stated "we must perceive in order to move, but we must also move in order to perceive". As we will discuss next, it is the *individual-environment fit* that should form the crux of how we understand and integrate the concept of physical literacy in education and training programmes.

Constraints on the individual-environment fit

Viewing physical literacy as establishing and enhancing an individual-environment fit across varied movement contexts over a lifespan captures the construct not as an as end point, but as a continued journey influenced by a unique set of interacting constraints imposed upon an individual. From this perspective, learning to skilfully navigate a task or performance setting can be understood as the gradual emergence of an adaptive, functional relationship between an individual and his/her environment (Renshaw & Chow, 2018), satisfying a confluence of interacting constraints over a lifespan (Davids, Araújo, Vilar, Renshaw, Pinder, 2013).

Constraints shape coordinative patterns within human movement by acting as boundaries or limits within which movement systems emerge (Clark, 1995; Kugler, 1986). Constraints were first categorised by Newell (1986) as Individual (e.g., height, weight, speed, motivation, emotions), Task (e.g., specific to the activity to be performed, goal of task) and Environmental (e.g., light, temperature, facilities, social values and societal/cultural expectations) in nature. These three classes do not operate in isolation, rather, they interact and evolve over varying timescales of performance. Movement coordination from an ecological dynamics perspective, results as an emergent property from interacting individual, task and environmental constraints (Seifert, Button & Davids, 2013). This connotation implies that constraints can be manipulated and exploited to provide opportunities (affordances) for actions to emerge.

Physical literacy as an individual-environment fit

From an ecological dynamics perspective, the concept of physical literacy may be best defined, not in terms of the person or the environment, but rather as their degree of "(mis)fit". The level of analysis is the reciprocal interactions between characteristics of each individual and an environment. This perspective avoids problems with defining physical literacy as a characteristic of an individual (referred to as an 'organismic asymmetry', see Dunwoody, 2006; Davids & Araújo, 2010), or as a characteristic of the environment.

A good example of this is how we can frame 'motivation'within a particular individual-environment relation. In order to meet the psychological needs of the individual, an ecological dynamics rationale proposes the adoption of the principle of self-organization under constraints manipulation (Renshaw, Oldham, & Bawden, 2012). This approach has been shown to be effective in helping learners to acquire skills and

maintain a high level of engagement and motivation in sport and physical education contexts (Moy, Renshaw, & Davids, 2014; Moy, Renshaw, Davids, & Brymer, 2015). Indeed, the concept of affordances moves the notion of motivation in a different direction away from the more traditional organismic view of being dependent on an internal process towards something, not necessarily intrinsic, but shared with the environment (E. J. Gibson, 1997). Gibson (1979) considered motivation more broadly as objects, surfaces, events or other people that have value and meaning (or not) for each individual and this can change with experience and a person's needs. The affordance is not changed, but the value or meaning (and hence the motivation to use an affordance or not) changes for each person-environment relationship as individual needs change. So, a well-designed activity or environment, where individuals are invited to learn about affordances through choosing the level of difficulty, will encourage individuals to develop their ability to interact with their immediate environment and modify behaviors in response to changes in body, skills, environment or task (Adolph, 2019).

So, physical literacy can be understood as the degree to which properties of each individual and environmental characteristics match in varying contexts over a lifespan. In this way, physical literacy, conceptualized as the functionality of the fit between an individual and the environment, is a work in progress; a nonlinear, dynamic relationship which can regress, stabilise or progress, depending on the experiences undertaken over the lifecourse.

Both distal and proximal influences impinge on the individual-environment fit. Distal determinants (e.g. national, institutional, political, socio-cultural and socio-economical) are more stable (Flay & Petraitis, 1994), and can play an indirect influence on proximal factors (e.g. playgrounds, sports clubs, amenities, open spaces). The

individual-environment fit, for better or for worse, will primarily be reflected in the proximal environment given its immediacy and emotional salience to human beings (Bradley & Corwyn, 2004). Throughout growth and development, the nature, type and complexity of these immediate settings change, as certain environmental affordances for movement become more inviting than others. New physical, social and cultural characteristics invite, permit or inhibit reciprocal interactions that establish the individual-environment fit (Bronfenbrenner & Ceci, 1993). Accordingly, while it can be understood that affordances vary with learning and development (E. J. Gibson & Pick, 2000), they are just as deeply sociocultural as they are related to an individual's action abilities (Rietveld & Kiverstein 2014; van Dijk & Rietveld, 2017). For example, sociocultural constraints might limit the opportunities for (inter)actions invited of individuals to access contexts where they could practice a skill. The reductionist and linear idea that if we teach the fundamental movement skills (such as the overarm throw) it will develop perceived competence in individuals, which will lead to seeking out performance opportunities in specific throwing games, which will eventually lead to playing sports involving throwing, does not address sociocultural and/or environmental barriers. Thus, an understanding of the individual-environment (mis)fit across varied movement contexts over a lifespan should, therefore, be a central tenet of the concept of physical literacy.

Physical literacy as a constant evolving state

An ecological dynamics framework involves the appreciation of the whole body (embodied) in close relationship with opportunities for action offered by the environment (embedded) (Araújo, Davids & Renshaw, 2020). Thus, the current status of the body and the environment shapes biomechanical constraints on task performance. For example, Adolph and colleagues (2018) suggested that when infants are learning to

297 walk, their behaviour is continually shaped by the immediate context (i.e., changes in
298 their bodies and in their physical and social environments they are experiencing). These
299 interacting constraints on motor behaviours extend through infancy, childhood and
300 adolescence, and in to adulthood, as individuals' action capabilities and the nature, type
301 and complexity of the affordances within their environment are continually changing.
302 This process also highlights the sociocultural constraints that influence individuals,
303 where experiences are shaped as much by the social milieu as they are by each
304 individual's physiology, anatomy or psychology (Uehara, Button, Falcous, & Davids,
305 2014). In line with these ideas, physical literacy can, therefore, be seen as an emergent
306 property from interacting individual, task and environmental constraints (Seifert,
307 Button, & Davids 2013). However, given the dynamics and non-linearity of interacting
308 constraints, it is likely that a change in one category may lead to a change in emergent
309 movement behaviours (Clarke, 1995), resulting in changes in the way an individual
310 interacts with the environment. This characterisation allows us to conceptualise physical
311 literacy as a construct that changes and evolves over a lifespan.

312 The human body can move in many different ways, while at the same time,
313 being constrained by its structural organisation, enhancing (due to growth in size) or
314 limiting (due to aging, injury, disease) movement capabilities. From a dynamic systems
315 perspective, it is acknowledged that different systems might act as rate limiters for
316 different skills over different timescales (Thelen, 1998). For example, environmental
317 features offer different affordances for individuals as they are assessed in relation to the
318 individual, not according to an objective standard (Konczak, 1990). Our perception of
319 affordances changes as our capability for action changes; in other words, affordances
320 change as individuals change, and therefore the nature of our physical literacy changes.
321 This idea implies that environmental features are framed in terms of body scaling and

action capabilities over an individual's lifespan. For instance, a child might not be able to climb a staircase structure of particular dimensions due to a mismatch between step riser heights with the dimensions of his/her arms and legs at a specific state of development (acting as a rate limiter). Until the child's growth, maturation and development processes allow him/her to reach a critical ratio of leg length to step riser height, the affordance of "*climbability*" of the structure by stepping is not perceived (Warren, 1988). The nature, type and complexity of the settings change as certain environmental affordances for action become more inviting (Withagen, Harjo, Araujo, & Pepping, 2012). than others. Perception of affordances changes as capability for action changes.

Enhancing opportunities for individuals of all ages to interact with their environments

One of the key features of learning design in physical education and sport, from an ecological dynamics perspective, is to design 'in' affordances that can enhance the opportunity for learners to develop stable functional perception-action couplings to support performance (Chow et al., 2016). An important aspect of this, however, is the need to 'match' the utility and meaning of the affordances designed into a learning environment to the current action capabilities (known as effectivities in ecological psychology) of the individual perceiving them (Woods et al., 2020). It is this design feature that is likely to assist individuals to improve their perception-action coupling as they are guided toward actualizing the most *soliciting* or inviting affordances within their performance environment (Withagen et al., 2012). Importantly, these design principles can extend beyond organised sports and physical education. In urban planning and recreation, the designing in of rich and inviting opportunities for action can support diverse and meaningful movement-based experiences for individuals at varied stages of life. For instance, playgrounds have traditionally been synonymous

with young children, albeit having a little too much symmetry and risk aversion (Gill, 2007). However, Sales and colleagues (2017) argued for the benefits of designing playgrounds for the elderly, where activity programmes, equipment and landscape are deliberately designed (scaled) for action opportunities in seniors, according to their effectivities (current intrinsic dynamics and capacities).

Recently, the UN World Population Prospects report (2019) revealed that the global population of older adults is increasing at an unprecedented rate. Evidence points to a positive association between older adults' physical activity and well-being (Nimrod 2011). Accordingly, aspects of urban designs could be re-configured (manipulation of environmental constraints) to promote physical activity within older populations to maintain their quality of life. Moreover, in a Guardian interview (2016), Stefano Recalcati, a project leader behind the report 'Shaping Ageing Cities' explained that cities must adjust if older people are to maintain quality of life, stating:

> "*it's important to be conscious of the ageing trend. It is a huge challenge for world cities – they will need to change, to make sure older people continue to play an active role in the community and don't become isolated. Isolation has a negative impact on health so tackling that is really important*."

From an ecological dynamics perspective, this issue needs to address accessibility. Exploiting the 'invitational' nature of environmental affordances through deliberate design, has the potential to offer different opportunities for action to increase (or maintain) healthy behavior over a lifespan (Withagen & Caljouw, 2016). For instance, the infamous and ubiquitous "No Ball Playing" signs in modern urban settings give a clear signal to the population (especially children), actually inviting sedentary and compliant lifestyles. Integrated policy making between politicians is needed in modern town/city planning projects. For example, Anna Lind (2019), the Swedish Minister for Sports, almost demanded an integrative policy making approach when querying town

planning policy from a child's rights perspective in the Swedish national newspaper Dagens Nyheter (Johansson, 2020). She raised a question, when new homes are built, that we all need to consider in other spheres of life: How often is the child's opportunity to interact with the immediate environment (e.g. recreation areas) considered and designed 'in' to the planning? To promote physical literacy through an ecological dynamics framework, practitioners need to constantly consider and enhance opportunities for individuals at all ages to interact with their environments. By doing so, we may allow individuals the freedom to evolve their 'own' physical literacy, by enhancing personal engagement through establishing an individual-environment fit. Physical literacy involves self-regulation tendencies which can be guided and supported by education and health-care professionals, but it is not the sole remit of these experts.

Concluding Remarks

The vagueness associated with the construct of physical literacy, as revealed in the literature, elucidates a clear need for a comprehensive theoretical rationale to underpin how to apply its concepts. We have argued, from an ecological dynamics perspective, the concept of physical literacy can be enriched and extended in, and beyond, organised sports and physical education, through the re-conceptualisation of an individual's relationship with the specific environmental settings they interact with over a lifespan. This ongoing and continuously developing relationship can be understood through the assessment of available affordances for movement opportunities (expressed through cognitions, perception and (inter)actions) in those specific settings (Flôres et al., 2019), underpinned by how these contexts invite, permit or inhibit an individual-environment fit (Bronfenbrenner, Ceci, 1993). Physical literacy can, therefore, be understood at the level of the individual-environment system, where the dynamic and reciprocal

relationships between an individual and their environment can be developed and analysed over time (Seifert, Orth, Button, Brymer, & Davids, 2017).

References

Addley, E. (2019, October 5). You could be Dina: teach children physical literacy, says Sport England. *The Guardian*. Retrieved from https://www.theguardian.com/sport/2019/oct/05/physical-literacy-children-dina-asher-smith

Adolph, K. E. (2019). An Ecological Approach to Learning in (Not and) Development. *Human Development*, 1-22.

Adolph, K. E., Hoch, J. E., & Cole, W. G. (2018). Development (of Walking): 15 Suggestions. *Trends in cognitive sciences*, 22(8), 699-711.

Adolph, K., & Kretch., K. (2015). Gibson's Theory of Perceptual Learning. International Encyclopedia of the Social & Behavioral Sciences. 10. 10.1016/B978-0-08-097086-8.23096-1.

Allan, V., Turnnidge, J., & Côté, J. (2017). Evaluating Approaches to Physical Literacy Through the Lens of Positive Youth Development. *Quest*, 69(4), 515-530.

Almond, L. (2013). Physical literacy and fundamental movement skills: An introductory critique. *Journal of Sport Science and Physical Education*, 65, 81–89.

Almond, L. (2014) Serious flaws in an FMS interpretation of physical literacy. *Science and Sports*, 29, 60.

Araujo, D., & Davids, K. (2011). What Exactly is Acquired During Skill Acquisition? *Journal of Consciousness Studies*, 18. 7-23.

Araújo, D., & Davids, K. (2009). Ecological approaches to cognition and action in sport and exercise: Ask not only what you do, but where you do it. *International Journal of Sport Psychology*, *40*(1), 5–37.

Araújo, D., Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise*, 7(6), 653-676.

Bernstein, N. (1967). *Co-ordination and regulation of movements.* Pergamon Press.

Bradley, R. H., & Corwyn, R. F. (2004). Life satisfaction among European American, African American, Chinese American, Mexican American, and Dominican American adolescents. *International Journal of Behavioral Development*, 28(5), 385–400.

Bronfenbrenner, U., & Ceci, S. J. (1993). Heredity, environment, and the question ‘‘How?’’: A first approximation. In R. Plomin & G. E. McClearn (Eds.), *Nature, nurture & psychology*, 313–324. Washington, DC: American Psychological Association.

Button, C., Seifert, L., Chow, J.-Y., Araújo, D., & Davids, K. (2020). Dynamics of Skill Acquisition: An Ecological Dynamics rationale (2nd Edition). Champaign, Ill: Human Kinetics.

Chow, J.-Y., Davids, K., Button, C., & Renshaw, I. (2016). Nonlinear pedagogy in skill acquisition: an introduction. London. New York: Routledge.

Chow, J.-Y., Davids, K., Shuttleworth, R. & Araújo, D. (2020). Ecological dynamics and transfer from practice to performance in sport. In *Skill Acquisition in Sport: Research, Theory and Practice* (3rd Ed.) (Edited by A.M. Williams & N. Hodges), 330-344. Routledge: London.

Clark, J. E. (1995). On Becoming Skillful: Patterns and Constraints. *Research Quarterly for Exercise and Sport*, 66(3), 173–183.

Cools, W., De Martelaer, K., Samaey, C., & Andries, C. (2009). Movement skill assessment of typically developing preschool children: A review of seven movement skill assessment tools. *Journal of Sports Science & Medicine*, *8*(2), 154.

448 Corbin, C. (2016). Implications of physical literacy for research and practice: A
449 commentary. *Research Quarterly for Exercise and Sport, 87,* 14–27.
450 Davids, K., & Araújo, D. (2010). The concept of 'Organismic Asymmetry' in sport
451 science. *Journal of science and medicine in sport, 13*(6), 633–640.
452 Davids, K., Araújo, D., Correia, V., & Vilar, L. (2013). How small-sided and
453 conditioned games enhance acquisition of movement and decision-making skills.
454 *Exercise and sport sciences reviews*, 41, 154-161
455 Davids, K., Araújo, D., Hristovski, R., Passos, P., & Chow, J. Y. (2012). *Ecological*
456 *dynamics and motor learning design in sport*. In N. J. Hodges & A. M. Williams (Eds.),
457 Skill Acquisition in Sport: Research, Theory and Practice (2nd ed., pp. 112-130).
458 London: Routledge
459 Davids, K., Araújo, D., Vilar, L., Renshaw, I., & Pinder, R. A. (2013). An ecological
460 dynamics approach to skill acquisition: Implications for development of talent in sport.
461 *Talent Development & Excellence*, 5, 21-34.
462 Dudley, D., Cairney, J., Wainwright, N., Kriellaars, D., & Mitchell, D. (2017). Critical
463 considerations for physical literacy policy in public health, recreation, sport, and
464 education agencies. *Quest*, *69*(4), 436-452.
465 Dunwoody, P. T. (2006). The neglect of the environment by cognitive
466 psychology. *Journal of Theoretical and Philosophical Psychology*, *26*(1-2), 139–153
467 Edelman, G. M., & Gally, J. A. (2001). Degeneracy and complexity in biological
468 systems. *Proceedings of the National Academy of Sciences of the United States of*
469 *America*, *98*(24), 13763–13768.
470 Edwards, L. C., Bryant, A. S., Keegan, R. J., Morgan, K., & Jones, A. M. (2016).
471 Definitions, Foundations and Associations of Physical Literacy: A Systematic
472 Review. *Sports Medicine*, 47(1), 113–126.

Flay, B.R., & Petraitis J. (1994). The Theory of Triadic Influence: A New Theory of Health Behavior With Implications for Preventive Interventions. *Advances in Medical Sociology*, 4. 19-44.

Flôres, F. S., Rodrigues, L. P., Copetti, F., Lopes, F., & Cordovil, R. (2019). Affordances for Motor Skill Development in Home, School, and Sport Environments: A Narrative Review. *Perceptual and Motor Skills*, 126(3), 366–388.

Foulkes, J.D.; Foweather, L.; Fairclough, S.J.; Knowles, Z. "I Wasn't Sure What It Meant to Be Honest"—Formative Research Towards a Physical Literacy Intervention for Preschoolers. *Children* 2020, *7*, 76.

Gibson, E. J. (1978). C'est Moi [Review of the book *Insights from the blind: Comparative studies of blind and sighted infants*, by S. Fraiberg & L. Fraiberg]. *Contemporary Psychology, 23*(9), 609–611

Gibson, E. J. (1988). *Exploratory behavior in the development of perceiving, acting, and the acquiring of knowledge.* In M. R. Rosenzweig & L. W. Porter (Eds.), *Annual review of psychology. Annual review of psychology, 39*, 1–41.

Gibson, E. J. (1997). *An ecological psychologist's prolegomena for perceptual development: A functional approach.* In C. Dent-Read & P. Zukow-Goldring (Eds.), *Evolving explanations of development: Ecological approaches to organism–environment systems*, 23–45.

Gibson, E. J., & Pick, A. D. (2000). An ecological approach to perceptual learning and development. New York: Oxford University Press.

Gibson, J. J. (1966). *The senses considered as perceptual systems*. Boston, MA: Houghton Mifflin.

Gibson, J. J. (1979). The ecological approach to visual perception. Boston, MA: Houghton Mifflin.

Gill, T. (2007). *No fear: Growing up in a risk averse society*. London: Calouste Gulbenkian Foundation.

Grahame, A. (2016, April 25). Improving with age? How city design is adapting to older populations.. *The Guardian*. Retrieved from https://www.theguardian.com/cities/2016/apr/25/improving-with-age-how-city-design-is-adapting-to-older-populations

Guthold, R., Stevens, G.A., Riley, L.M., & Bull, F.C. (2018). Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1.9 million participants. *The Lancet Global health*, 6 (10).

Headrick, J., Renshaw, I., Davids, K., Pinder, R.A., & Araújo, D. (2015). The dynamics of expertise acquisition in sport: The role of affective learning design. *Psychology of Sport & Exercise* 16**,** 83-90.

Hyndman, B., & Pill, S. (2018). What's in a concept? A Leximancer text mining analysis of physical literacy across the inter- national literature. *European Physical Education Review*, 24(3), 292–313.

International Physical Literacy Association (IPLA). (2017). Retrieved from https://www.physical-literacy.org.uk/

Johansson, M. (2020, January 12). Amanda Lind: Idrotten har en hemläxa att göra. *Dagens Nyheter*. Retrieved from https://www.dn.se/sport/amanda-lind-idrotten-har-en-hemlaxa-att-gora/#receipt-page

Jurbala, P. (2015). What Is Physical Literacy, Really? *Quest*, 67(4), 367–383.

Kelso, Scott. (1995). Dynamic patterns: the self-organization of brain and behavior. *Choice Reviews Online*, 33(03).

Konczak, J. (1990). Towards an Ecological Theory of Motor Development: The Relevance of the Gibsonian Approach to Vision for Motor Development Research. New York: Advances in Motor Development Research.

Kugler, P. N. (1986). A morphological perspective on the origin and evolution of movement patterns. In M. G. Wade and H. T. A. Whiting (eds.), *Motor Development in Children:Aspects ofCoordination and Control*, 459-525.

Lundvall, S., & Tidén, A. (2013). Assessing embodied knowledge in Swedish PEH: the influence of physical literacy. *International Council of Sport Science and Physical Education Bulletin*, (65), 325–335.

Lynch, T. (2019). Global Policy: Holistic Health, Wellbeing and Physical Education Evolution. *In Physical Education and Wellbeing* (pp. 43-58). Champaign: Palgrave Macmillan.

McKenzie, T., & Lounsbery M. (2016). Physical literacy and the rose: What would Shakespeare say? *Physical Activity Plan Alliance Commentaries on Physical Activity and Health, 2*. Retrieved from http://www.physicalactivityplan.org/commentaries/McKenzie.html

Moy, B., Renshaw, I., & Davids, K. (2014). Variations in acculturation and Australian physical education teacher education students' receptiveness to an alternative pedagogical approach to games teaching. *Physical Education and Sport Pedagogy* 19 (4), 349-369.

Moy, B., Renshaw, I., Davids, K., & Brymer, E. (2015). Overcoming acculturation: Physical education recruits' experiences of an alternative pedagogical approach to games teaching. *Physical Education and Sport Pedagogy*, 21, 386–406.

Newell, K.M. (1986). Constraints on the Development of Coordination. In *Motor Development in Children: Aspects of Coordination and Control*, 341–360. Amsterdam: Springer Science and Business Media.

Ng, J., & Button, C. (2018). Reconsidering the fundamental movement skills construct: Implications for assessment. *Movement and Sports Sciences*, 4, 19-29.

Nimrod, G. (2011). The Impact of Leisure Activity and Innovation on the Well Being of the Very Old. In L. Poon & J. Cohen-Mansfield (Eds), *Understanding Well-Being in the Oldest Old* (pp. 240–257). Cambridge: Cambridge University Press.

Renshaw, I., & Chow, J.-Y. (2018). A Constraint-Led Approach to Sport and Physical Education Pedagogy. *Physical Education and Sport Pedagogy*, 24(2), 103–116.

Renshaw, I., Oldham, A. R., & Bawden. M. (2012). Nonlinear pedagogy underpins intrinsic motivation in sports coaching. *The Open Sports Sciences Journal*, 5, 88-99.

Rietveld, E., & Kiverstein, J. (2014). A Rich Landscape of Affordances. *Ecological Psychology*, 26(4), 325-352.

Roberts, W. M., Newcombe, D. J., & Davids, K. (2018). Application of a Constraints-Led Approach to pedagogy in schools: embarking on a journey to nurture Physical Literacy in primary physical education. *Physical Education and Sport Pedagogy*, 24(2), 162–175.

Ross, E., Gupta, L., & Sanders, L. (2018). When research leads to learning, but not action in high performance sport. *Progress in brain research*, *240*, 201–217.

Rudd, J. R., O' Callaghan, L., and Williams, J. (2019). Physical Education Pedagogies Built upon Theories of Movement Learning: How Can Environmental Constraints Be Manipulated to Improve Children's Executive Function and Self-Regulation Skills? *International Journal of Environmental Research and Public Health* 16.

Rudd, J. R, Crotti, M., Fitton-Davies, K., O'Callaghan, L., Bardid, F., Utesch, T., … Foweather, L. (2020). Skill Acquisition Methods Fostering Physical Literacy in Early-Physical Education (SAMPLE-PE): Rationale and Study Protocol for a Cluster Randomized Controlled Trial in 5–6-Year-Old Children From Deprived Areas of North West England. *Frontiers in Psychology*, *11*, 1228.

Rudd, J. R, Pesce, C, Strafford, B, Davids, K (In Press) Physical Literacy, a journey of individual enrichment: an Ecological Dynamics rationale for enhancing performance and physical activity in all. *Frontiers in Psychology*

Sales, M., Polman, R., Hill, K. D., & Levinger, P. (2017). A Novel Exercise Initiative for Seniors to Improve Balance and Physical Function. *Journal of Aging and Health*, *29*(8), 1424–1443.

Seifert, L., Button, C., & Davids, K. (2013). Key Properties of Expert Movement Systems in Sport. Sports Medicine 43(3), 167–178.

Seifert, L., Orth, D., Button, C., Brymer, E., & Davids, K. (2017). An Ecological Dynamics Framework for the Acquisition of Perceptual–Motor Skills in Climbing. *Extreme Sports Medicine*, 365-382.

Shearer, C., Goss, H. R., Edwards, L. C., Keegan, R. J., Knowles, Z. R., Boddy, L. M., & Foweather, L. (2018). How is physical literacy defined? A contemporary update. *Journal of Teaching in Physical Education*, 37(3), 237–245.

Spengler, J. O., & Cohen, J. (2015). Physical literacy: A global environmental scan. Washington, DC: The Aspen Institute.

Sport Australia (2019). The Australian Physical Literacy Framework. Retrieved from https://www.pescholar.com/wp-content/uploads/2019/08/The-Australian-Physical-Literacy-Framework.pdf

Sport England (2016). Towards an Active Nation. Strategy 2016-2021. Retrieved from https://sportengland-production-files.s3.eu-west-2.amazonaws.com/s3fs-public/sport-england-towards-an-active-nation.pdf

Thelen, E. (1998). Bernstein's legacy for motor development: How infants learn to reach. In M. Latash (Ed.), *Progress in Motor Control* (pp. 267-288). Champaign, IL: Human Kinetics.

Tremblay, M., & Lloyd, M. (2010). Physical literacy measurement—the missing piece. *Physical and Health Education Journal*, 76(1), 26–30.

UNICEF. (2007). Child poverty in perspective: An overview of child well-being in rich countries—A comprehensive assessment of the lives and well-being of children and adolescents in the economically advanced nations. Innocenti Research Centre Report Card 7 C. Florence: The United Nations Children's Fund. Retrieved from https://unicef-irc.org/404.html?request=/publications/pdf/rc7_eng.pdf

Uehara, L., Button, C., Falcous, M., & Davids, K. (2014). Contextualised skill acquisition research: a new framework to study the development of sport expertise. *Physical Education and Sport Pedagogy*, *21*(2), 153–168.

United Nations. (2019) Department of Economic and Social Affairs (2019). Retrieved from https://population.un.org/wpp/

van Dijk, L., & Rietveld, E. (2017). Foregrounding Sociomaterial Practice in Our Understanding of Affordances: The Skilled Intentionality Framework. *Frontiers in psychology*, *7*, 1969.

Warren. W.H. (1988) Action modes and laws of control for the visual guidance of action. In O. Meijer & K. Roth (Eds.), *Movement behavior: The motor-action controversy.* Amsterdam: North Holland

Warren, W. H. (2006). The dynamics of perception and action. *Psychological Review*, 113(2), 358-389.

Way, R., Balyi, I., Trono, C., Harber, V., & Jurbala, P. (2014). Canadian Sport for Life-Long-term athlete development resource paper 2.0. Vancouver: Canadian Sport Institute-Pacific.

Webster, E. K., & Ulrich, D. A. (2017). Evaluation of the psychometric properties of the Test of Gross Motor Development—third edition. *Journal of Motor Learning and Development*, *5*(1), 45-58.

Whitehead, M. (2001). The concept of physical literacy. *European Journal of Physical Education*, *6*(2), 127–138.

Whitehead, M. (2007). Physical Literacy: Philosophical Considerations in Relation to Developing a Sense of Self, Universality and Propositional Knowledge. *Sport, Ethics and Philosophy*, 1(3), 281–298.

Whitehead, M. (2010). *Physical literacy: Throughout the life course*. London: Routledge.

Whitehead M. (2013). Definition of physical literacy and clarification of related issues. *International Council of Sport Science and Physical Education Bulletin*, 65, 28–33.

Whitehead, M. And Murdoch, E. (2006) Physical Literacy and Physical Education: Conceptual Mapping, *Physical Education Matters*, 1(1), 6-9

Withagen, R., Harjo, D. P., Araujo, D., & Pepping, G.-J. (2012). Affordances can invite behavior: Reconsidering the relationship between affordances and agency. *New Ideas in Psychology*. 30. 250-258.

Withagen, R., & Caljouw, S. R. (2016). 'The end of sitting': An empirical study on working in an office of the future. *Sports Medicine*, 46(7), 1019–1027.

640 Woods C.T., McKeown, I., Rothwell, M., Araújo, D., Robertson, S., Davids, K. (2020).
641 Sport Practitioners as Sport Ecology Designers: How Ecological Dynamics Has
642 Progressively Changed Perceptions of Skill 'Acquisition' in the Sporting Habitat.
643 *Frontiers in Psychology*, 11.
644 Young, L., O'Connor, J., & Alfrey, L. (2019). Physical Literacy: a Concept Analysis.
645 *Sport, Education and Society*, 1–14.
646
647
648 <Table 1>

Whitehead 2001 Physical Literacy Definition	*Ecological Dynamics Rationale.*
Line 1: A physically literate individual moves with poise, economy and confidence in a wide variety of physically challenging situations.	To move with *poise, economy and confidence* is predicated on an individual's functional and structural capacities, such as their prior movement experiences, their motivational and emotional states (Headrick et al., 2015) and their cognitive self-regulation skills (Rudd et al., 2019). These interact with the physics and structural features of the environment as well as the individual's specific intentions during an activity or task (Davids et al., 2013). A physically literate child playing a game in a playground or formal sport setting has 'skilled intentionality' if he/she is able to adapt to a range of *challenging situations* that emerge from the interacting performance constraints in order to functionally achieve a successful outcome during the activity (Chow et al., 2016).
Line 2: the individual is perceptive in 'reading' all aspects of the physical environment, anticipating movement needs or possibilities and responding appropriately to these, with intelligence and imagination.	A physically literate child is able to *read* an environment through exposure to a range of varied task constraints, and he/she progressively becomes attuned to the relevant affordances (invitations for action) within his/her environment. This attunement process is predicated on the perception of information to regulate actions, which helps children adapt movements to exploit key constraints to functionally achieve a task goal (Araujo & Davids, 2009). *…Responding appropriately to these emergent task constraints, with intelligence and imagination* is similar to the idea of 'dexterity' put forward by Bernstein (1967). He

	argued that dexterity is the ability to find a movement solution for any external situation, to adequately solve any emerging movement problem arising from the changing nature of environmental and tasks constraints.
Line 3: Physical literacy requires a holistic engagement that encompasses physical capacities embedded in perception, experience, memory, anticipation and decision making'	Ecological dynamics is a theoretical framework that seeks to understand human behaviours such as performance and learning at the individual-environment scale of analysis, as they interact to form the individual-environment system. From an Ecological Dynamics perspective, learners are regarded as complex adaptive systems, seeking opportunities for action (affordances) from their environment. The concept of affordances highlights the continuous and *holistic* interactions between the environmental features and e*mbedded* functional capabilities of the individual.