

Education and transfer of water competencies: An ecological dynamics approach

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Title

Education and transfer of water competencies: An ecological dynamics approach.

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Abstract

To cope in various aquatic environments (i.e. swimming pools, lakes, rivers, oceans), learners require a wide repertoire of self-regulatory behaviours such as awareness of obstacles and water properties, floating and moving from point to point with different strokes, decision making, emotional control, and breathing efficiently. By experiencing different learning situations in stable indoor pool environments, it is assumed that children strengthen aquatic competencies that should be transferable to functioning in open water environments, where prevalence of drowning is high. However, this fundamental assumption may be misleading. Here, we propose the application of a clear, related methodology and theoretical framework that could be useful to help physical education curriculum specialists (re)shape and (re)design appropriate aquatic learning situations to facilitate better transfer of learning. We discuss the need for more representativeness in a learning environment, proposing how the many different task and environmental constraints on aquatic actions may bound the emergence of functional, self-regulatory behaviours in learners. Ideas in ecological dynamics suggest that physical educators should design learning environments that offer a rich landscape of opportunities for action for learners. As illustration, three practice interventions are described for developing functional and transferrable skills in indoor aquatic environments. It is important that aquatic educators focus not just upon ‘learning to swim’, but particularly on relevant transferable skills and self-regulatory behaviours deemed necessary for functioning in dynamic, outdoor aquatic environments.

Keywords: Drowning prevention, Foundational movements, Physical education, Representative learning design, Swimming, Water safety.

Word count: 7725

Introduction

Learners are typically taught to swim in comfortable, clear and calm aquatic environments (Kjendlie et al., 2013; Quan et al. 2015), mainly for safety and logistical reasons. However, such physical education (PE) approaches do little to simulate the varied environmental constraints, such as currents, tides, cold temperatures, weather or waves (i.e. major determinants of aquatic environments), that are characteristic of open water environments. This is potentially problematic since research has shown that many people are incapable of demonstrating ‘far’ transfer from practice environments to natural, dynamic environments (Seifert et al., 2019) in which adaptive survival behaviours maybe required to prevent drowning (Langendorfer, 2015). This has sometimes been recognised as a lack of ‘vertical’ transfer in which more elaborated skills are not acquired (Issurin, 2013). Indeed, the generally-held assumption that learning to swim in stable, calm environments, such as swimming pools, can prevent drowning in open water may be somewhat misleading (Quan et al. 2015).

This position paper proposes a re-conceptualisation of aquatic competencies as foundational movement patterns (Hulteen et al., 2018), which can enhance an individual’s functionality in water, and support drowning prevention. Our approach is predicated upon calls for a radically different approach to aquatic education that is based upon the key contributing factors to drowning (Stallman et al., 2017). Here, we propose that new models of aquatic education need to be predicated on a clear theoretical framework to support a new pedagogical approach, as indicated by Stallman and Kjendlie (2008). In this position paper, we develop a salient conceptualisation from the theory of *ecological dynamics* and predicated on principles of *nonlinear pedagogy*. Particular emphasis is given to *constraints on actions* (see

Langendorfer, 2015), and the relevance of *representative learning design* (Pinder et al., 2011) in aquatic learning programmes. This conceptualisation advocates for the design of learning environments where adaptive behaviours may be developed, acquired and then **transferred to more complex** aquatic contexts. Finally, we propose some examples of foundational aquatic skill activities for PE teachers, based on the core messages of this article.

Skill acquisition through ecological dynamics to underpin drowning prevention education

Ecological dynamics is a theoretical framework that regroups ideas and tools of dynamical systems theory (Kelso, 1995; Newell, 1986) with concepts of ecological psychology (Gibson, 1979) and the complexity sciences in neurobiology (Edelman and Gally, 2001). Ecological dynamics is built on three main pillars (Seifert et al., 2017), providing an integrated explanation for human behaviour in physical activities and sports. The first pillar considers learners as *complex adaptive systems* in the sense that their emergent behaviours might vary, so that **main** outcomes can be achieved in different ways (e.g. diving through or turning back to avoid a wave in the ocean). This non-proportional relation between a given **natural** context and behavioural dynamics stipulate that a major change in coordination patterns is not systematically associated with a dramatic improvement or decrement of **movement accuracy** (Seifert et al., 2017). Rather, the movement system's sensitivity to initial conditions is fundamental, explaining why a small change in behaviour (e.g. confidence to put the head underwater) may greatly impact **the main movement outcomes** (e.g. possibility to escape a sinking vehicle).

The second pillar of ecological dynamics relies on the work of James Gibson (1979), who considered that humans' perceptions of the environment in which they have evolved guides their actions, which in turn, guides future perceptions supporting a cyclical, dynamic and tight coupling. Within this conceptualisation, internal representations of the world are not emphasized (Araújo and Davids, 2011), instead it is conceived that functional behaviours emerge from **both the properties of the environment and the individual him/herself** (Fajen et al., 2008; Seifert et al., 2017), termed as *action capabilities* (Araújo and Davids, 2011). This emergence is predicated on the presence of *affordances* in the surrounding environment of the learner (Gibson, 1979), viewed as opportunities or invitations (rather than obligations) to act in accordance with the task goal. Therefore, individuals are continuously challenged by the nature, quality and quantity of information in the **natural dynamic** environment that support a *landscape of affordances* (Rietveld and Kiverstein, 2014).

The third pillar of ecological dynamics considers the performer–environment relationship as the smallest unit under scrutiny to appropriately characterise the coordination and control in human behaviour (Guignard et al., 2017b). An individual's emergent behaviours cannot be dissociated from his/her environment since intentions and perceptions guide his/her actions in the environment, which, in turn, shape further intentions and perceptions (Gibson, 1979). The implication of these reciprocal, functional performer–environment relationships are coherent when characterizing movement organisation and skill acquisition in aquatic environments (Guignard et al., 2017b). This environment offers both support to maintain the body afloat and resistances (i.e. viscosity and density properties) that can perturb movement

efficiency. Therefore, goal-directed behaviours cannot be dissociated from the aquatic environment in which they are undertaken, and vice-versa.

These theoretical considerations shape processes of skill acquisition, which emerge as a consequence of multiple and indeterminate interactions between learners and their surrounding environments (Davids et al., 2012). The term ‘environment’ proposed here captures the environment in which individuals are moving, other individuals or key objects, surfaces, places or events that may occur during performance (Gibson, 1979). In ecological dynamics, skill acquisition is facilitated since ‘each individual learns to perceive the surrounding layout of the environment in the scale of his or her body and action capabilities’ (Davids et al., 2012: 113). Successively reshaped from the initial insights of Newell (1985), the clear boundaries of a three-stage model of motor learning recently emerged to explain how skills are acquired by individuals performing in dynamic environments (Renshaw et al., 2015). In the first stage, individuals **are guided by teachers to search and explore** the surrounding environment to identify informational variables on which to rely on (Davids et al., 2012; Renshaw et al., 2015). Exploring various learning situations during formal PE classes will help children to *educate their attention* (Jacobs and Michaels, 2007): with time and experience, an individual learns that specific behaviours are more functional than others in **different environments. At this stage, the educator’s role remains essential to avoid a learner being stuck in a rut (Chow, 2013) by incorporating perturbations (e.g. verbal instructions, equipment) that will guide the exploration and adoption of appropriate behaviours, without prescribing them.**

In the second stage of learning, task solutions are discovered and stabilized by selecting the most salient resource among the numerous informational variables that continuously surround the learner (Davids et al., 2012; Renshaw et al., 2015). In psychology, these processes refer to *self-regulation*, which has been defined as all ‘self-generated thoughts, feelings and actions that are planned and cyclically adapted to the attainment of personal goals’ (Zimmerman, 2000: 14). From an ecological dynamics rationale, self-regulation can be conceptualised in a broader behavioural framework, rather than referring to cognitive and emotional processes only. Individuals learn to self-regulate by becoming attuned to a wider range of specific informational variables in their **natural** and practice environments (i.e. education to attention; Jacobs and Michaels, 2007). **This process is facilitated by feedback and guidance of practitioners, using a structured pedagogical approach adapted to the learner’s level (i.e. specifying which particular informational variables need to be perceived and used to regulate actions).** It implies that more experienced individuals learn to engage in more self-regulated learning behaviours, becoming more autonomous, leading to positive impacts on **their performance behaviours**, when faced by unexpected perturbations. **For instance, based on: (i) the expertise of PE teachers that design and shape adapted training situations, and (ii), the capabilities of novices at that stage of learning, it could be beneficial to set unexpected problems to solve, choices to resolve and decisions to make (e.g. sudden perturbations of artificial waves in a pool) to help learners acquire transferable survival skills. This pedagogical approach will help children to develop autonomy, competence, persistence, relatedness and problem solving (Chow, 2013).**

Finally, the last stage of the model corresponds to the exploitation of the most relevant affordances to support actions. In other words, individuals are able to scale their movements to the key information sources and to perceive the environment in intrinsic system units (Araújo and Davids, 2011), a process called *calibration* (Jacobs and Michaels, 2007). The information on which action relies may partly explain differences in **behavioural outcomes** between learners and experts in specific uncertain contexts: experts display behavioural flexibility to exploit surrounding information for affordances to appropriately and efficiently achieve task goals (Fajen et al., 2008). Applied to drowning prevention, these behavioural processes encourage learners to progressively identify and respond to key informational variables that will help them to self-regulate in risky situations. Although presented for clarity here in a sequential manner, this is important to conceive of these stages as nested altogether, since the appearance of a new behaviour strongly challenges subsequent exploration and exploitation of resources present in the surrounding environment (Renshaw et al., 2015).

Skill transfer: bridging the gap between theory and practice for drowning prevention

In ecological dynamics, the emergence of self-regulatory behaviours is predicated on the design of dynamic and challenging aquatic environments, rather than on the mere repetitive rehearsal of specific movement patterns in stable pool environments. Therefore, skill acquisition in a safe water environment is only the first step of an ongoing process, with the objective of developing aquatic competencies that are *transferable* to an outdoor environment. This is a vital design principle because drowning primarily occurs outdoors in open water environments (e.g. harbours,

oceans, rivers and lakes), while most contemporary swimming programs are pool-based (Quan et al., 2015). In Norway, over 93% of drowning accidents occur in open water (Kjendlie et al., 2013), the corresponding value being 63% in France (Santé Publique France, 2019). In France, the prevalence of drowning has considerably increased (from 398 vs. 492 drowning cases between the summers of 2015 and 2018) and these reports may even underestimate the true statistics (Vignac et al., 2015). The key issue in alleviating these problems for swimmers, which we address in this paper, concerns the transferability of skills between aquatic environments (Quan et al., 2015).

Training (far) transfer is defined as the capacity of motor behaviours learned in a training simulation (e.g. the standardized pool) to influence the emergence of behaviours in another task or untrained situation (e.g. less predictable outdoor environments) (Issurin, 2013; Rosalie and Müller, 2012; Seifert et al., 2019). Transfer is a complex process (Barnett and Ceci, 2002), sensitive to surrounding conditions at the time of transfer and may emerge in similar or dissimilar contexts than training (Rosalie and Müller, 2012). This first level of consideration is predicated on the degree of *similarity* between the training tasks and the natural dynamic environment: high similarity corresponds to *near* transfer (e.g. jumping into water and pool diving), whereas larger disparities between environments relate to *far* transfer (Issurin, 2013; Rosalie and Müller, 2012; Seifert et al., 2019). Far transfer is instrumental in learners being able to develop more difficult and complex skills in the natural dynamic environment, leading to the achievement of a higher level of competence (Barnett and Ceci, 2002). The second level relates to the gap in difficulty that may exist between tasks: for similar complexity/difficulty, *lateral* (or *horizontal*) transfer may occur.

While these two first levels relate exclusively to the task itself, PE teachers should also consider transfer as relational between an individual and his/her environment. In this model, past experience, width of an individual's existing motor repertoire, but also task and environmental demands are considered together. More precisely, this *specificity vs. generality* continuum of skill transference is characterized by the level of cooperation operating between the existing intrinsic dynamics of the learner and the task demands in which he/she is involved (Seifert et al., 2016b). Therefore, specific (general) transfer might be observed when the level of cooperation is high (low) between intrinsic dynamics of the learner and the dynamics of a new task to be learned (Seifert et al., 2016b). General transfer leads mainly to deep and structural developments among sub-systems of the learners (Barnett and Ceci, 2002).

This 'specific/general' transfer continuum is particularly relevant for understanding how to characterize movement behaviours performed in aquatic environments. From the well-known principle of specificity, transfer of skills should classically be expected due to structural similarities between water-based environments: maintaining buoyancy and resisting drag is intended both in- and outdoors. However, Issurin (2013) rightly emphasised that the possibilities of behaviour transfer in multiple aquatic environments may appear strongly challenging, mainly related to the inherent properties of the water. For instance, it is conceivable that the presence of strong currents in a river or in the ocean make these environments potentially risky in comparison to closed lake or swimming pool, in which the body of water remains quasi-static. It has been recently highlighted that swimming against a current (materialised indoors by the use of a flume) in comparison to moving in a classic swimming pool leads to behavioural adaptations (e.g. decrease of glide; increase of time spent in propulsive phases) among a sample of skilled swimmers

(Guignard et al., 2017a). **In the flume, information for action was better specified due to** artificial currents that mimic the dynamics of an outdoor aquatic environment. **Here, transfer** relies on environmental properties, which should be exploited as external forces available as support to achieve a task goal (e.g. take advantage from the power of a wave to surf it). Therefore, previous considerations must guide the actions of PE teachers to educate the attention of learners by accurately scaling their actions to the particularities of the **performance environment**.

From an ecological dynamics perspective, transfer should be operationally facilitated and potentiated by the notion of *representative design* proposed by the ecological psychologist Brunswik (1956). This concept concerns the designed properties of a controlled or laboratory task that should seek to *represent* the properties of a **natural** context, to which the outcomes tend to be generalised. Pinder et al. (2011) extended this notion to skill acquisition and the design of learning tasks as *representative learning design*. For instance, perceiving the actions of a ‘live’ bowler when cricket batting is more representative than when batters faced a bowling machine (Pinder et al., 2009). Broadly, they emphasised the importance of the *representativeness* of a learning task to support transfer of behaviours, which underpin functionality in an environment. Davids et al. (2012) suggested the need for appropriate *sampling* of the information available from the **natural context to training situations**. **Representative learning design is a clear expression of ecological dynamics principles since the learner is viewed as a complex adaptive system highly coupled to the information sources of his/her performance context to utilise affordances. Practice task designs need to faithfully simulate these information sources in order to facilitate skills transfer to a performance environment.** The criteria that may enhance representative learning design need to be: (i) complex (see for instance Tomporowski

and Pesce 2019), (ii) dynamic, (iii) novel and related to achievable goals (e.g. different degrees of success are conceivable when retrieving rings from **one** to 10 m depth), (iv) supportive of active perception, and (v), providing sufficient access to key sources of information in the surrounding performance environment (Davids et al., 2012). Taken together, manipulating these levers increases the chances of successful skill acquisition and transfer, characterized by the emergence of behaviours that are adaptable for (re)organisation of action in **various and dynamic outdoor aquatic environments** (Araújo and Davids, 2011; Seifert et al., 2016a).

There is a strong need to understand the relevance of this conceptualisation of skill adaptation to drowning prevention since, although knowing how to swim is a protective mechanism against drowning, it is also over-simplistic since statistics reveal that many drowning victims were actually competent swimmers (Potdevin et al., 2017). Therefore, competencies in swimming remain undoubtedly essential, but should no longer be viewed as a challenge of merely being able to cover a given distance **in a minimum amount of time** in the aquatic environment. Instead, a more functional interpretation is that swimming competency should be considered as a *supplement* to the acquisition of to a range of aquatic skills that may prevent drowning. This conceptualisation highlights the complex interaction of factors implicated in drowning events, revealing instead a dynamic, multifactorial explanation (Potdevin et al., 2017). **A major consideration here is the clear distinction between acquiring aquatic competencies and being able to manage a swimming stroke: the best swimmer of a group of learners is not systematically the most ‘water competent’.** To illustrate, Potdevin and colleagues (2017) investigated the influence of spontaneous swim stroke selection on beginners (10 years old) in water safety tests

(wearing either clothes or swimsuits). Results showed that breaststrokes treaded water in a vertical position for longer than other groups, while backstrokes were able to float in a horizontal backwards position for longer (both essential competencies for drowning prevention). In contrast, using front crawl (although considered the fastest stroke to travel from A to B) was less effective for these specific purposes, mainly due to the need for aerial arm recovery phases and breathing. Hence, the term 'performance' in terms of drowning prevention is the ability to appropriately behave, using a range of competencies, when confronted with a potentially dangerous aquatic situation, while the swimming community may emphasise a less inclusive term (i.e. mastering a swimming stroke). From this logic, pedagogical practice, learning and training are needed to be updated to help individuals acquire 'physical, cognitive, and affective competencies which together make a person water competent and thus less susceptible to the risk of drowning' (Stallman et al., 2017: 2).

In fact, Stallman et al. (2017) proposed fifteen water competencies (see Figure 1) considered as essential to reduce risks of drowning. To enhance skill transfer, they proposed that some of the most common causes of drowning should shape the way we teach children to cope with aquatic environments (Stallman et al., 2008).

[insert Figure 1.]

Obviously, aquatic competencies should encompass swimming, but in addition many different functional actions, in varied locations, including at the water surface and underwater (Stallman et al., 2008). Such a holistic approach should enhance individual functionality, better reflecting the *perturbations and uncertainties* of the aquatic environment, offering a wide range of decision-making and motor learning opportunities (affordances), especially when facing risky situations that are

not included in traditional ‘learn-to-swim’ programs. Kjendlie et al. (2013) **practically supported this re-conceptualisation by soliciting** 66 children aged 11 years (with previous swimming knowledge) to perform identical tests in a calm swimming pool vs. a simulated ‘wavy’ environment (30–40 cm amplitude waves). Skill tests consisted of 200 m swimming time trials, a **three** min floating test, a diving entry test, and a rolling entry test (i.e. some essential aquatic competencies; see Figure 1). Their findings revealed that only 59% of the sample was able to function in the ‘wavy’ water course (compared to 80% in calm conditions). Test performance perturbed by waves clearly showed a decrement (14% longer time to complete the swimming test and 21%, 16% and 24% lower scores for rolling entry, diving and floating tests, respectively). Such findings highlight that children –even with previous swimming knowledge– ‘should not be expected to reproduce swimming skills they have performed in calm water with the same proficiency in unsteady conditions during an emergency’ (Kjendlie et al., 2013: 303).

Clearly motor learning theorists and practitioners need to better consider subtle differences in the individual–environment system with respect to co-designing tasks in aquatic education programmes. In this sense, the concept of water competencies can be integrated with the notion of *foundational movement patterns*, which underpin complex and specialised actions to develop and acquire during lifespan. Indeed, the development of aquatic skills to prevent drowning is as relevant as locomotory, object control and stability skills during childhood (Gallahue, 2012). Yet despite their presumed importance for lifespan development, aquatic skills have been insufficiently considered in the literature on movement development (Button, 2015). Foundational movement skills are viewed as ‘goal-directed movement patterns that directly and indirectly impact an individual’s capability to be physically active

and can be developed to enhance physical activity participation and promote health across the lifespan' (Hulteen et al., 2018: 1536). With this conceptualisation, foundational movement patterns in aquatic environments include freestyle swimming strokes and treading water skills in a non-exhaustive list of essential skills that one should develop, acquire and maintain during **the lifespan**.

Including aquatic competencies in foundational movement patterns is a first step to structure the key behaviours individuals should acquire through learning, experience, practice and training (i.e. ontogenetic activities) to prevent drowning. Moreover, an absence of opportunity to develop self-regulatory skills, when an individual is perturbed in representative learning contexts, may explain why so many people underestimate risk, whilst **also having an erroneous perception of their own physical abilities** (McCool et al., 2008; **Button et al., 2016**). Indeed, an important design principle here is to be able to gradually simulate the levels of anxiety and emotional engagement commonly experienced in open water environments in beginners to more advanced swimmers (Croft et al., 2013).

Learning behaviours need to be tightly coupled with particular aquatic environments, and the exploitation of environmental resources to support an individual's functionality can be directly linked to the design of the learning programmes that simulate some of the uncertainties and perturbations commonly encountered in outdoor contexts. In this programme design learners may be challenged to use cognitions (Tomporowski and Pesce, 2019), perceptions, emotional control and actions in a deeply intertwined way to continuously regulate their functional interactions with surrounding task and environmental constraints of the environment (Guignard et al., 2017a), such as objects, water properties, weather features, and other people. Immersion in uncertain and risky environments may be

facilitated and guided by using physiological, biomechanical, or psychophysiological biofeedback to assist learners to perform movements more efficiently (Issurin, 2013). Also, using varied levels of cognitive control and effort in more challenging learning environments (emphasising attention, perception, problem solving, and anticipation) may favour transfer of behaviours to a complex **natural** environment (Tompsonowski and Pesce, 2019).

A concrete illustration occurs when individuals are confronted with sudden immersion in cold water. This unexpected situation is associated with reflex physiological responses such as hyperventilation and sympathetically-mediated increases in cardiac output or blood pressure (Croft et al., 2013) that may 'freeze' the emergence of functional behaviours. Croft et al. (2013) promoted the use of several cognitive skills (e.g. goal-setting, arousal regulation, imagery, positive self-talk) to help learners cope with the noxious stimuli associated with cold-water immersion. Therefore, although challenging to simulate in training conditions, such physiological constraints are key determinants to consider following immersion since they may perturb the self-regulatory behaviours of actions including adaptations to breathing, emotional control (Langendorfer, 2015) and decision making of each individual. Linked to representative learning design principles to enhance positive transfer, the manipulation of task and personal constraints may be facilitative in guiding learners to develop functional behaviours that may be helpful in life-threatening situations.

Developing foundational aquatic skills for negotiating unpredictable environments: a nonlinear pedagogy approach with practice interventions

What does this conceptualisation infer for physical education (PE) curricula, worldwide? The practical consequence is that aquatic learning environments need to

include events that perturb an individual's cognitions, perceptions and actions during swimming activities. This is how these practice environments can be made more challenging and representative of conditions at beaches, lakes and rivers. From this perspective, PE specialists should seek to identify and manipulate key constraints to enhance the acquisition of foundational aquatic skills, while de-emphasizing those which are not immediately essential for interactions with by a learner (Davids et al., 2008). **This is not a straightforward task: beforehand, practitioners need to scale the impacts of different constraints to determine which may enhance a learner's exploration possibilities (Davids and Glazier, 2009).** The manipulation of key constraints encourages the learner to pick up and utilise informational variables to improve his/her skills and functionally regulate his/her actions **according to their maximum capabilities.** Such a *constraints-led approach* (Davids et al., 2008) is based on the initial contribution of Newell, (1986) who identified three categories of constraints which can influence the dynamics of skill acquisition. *Individual* (organismic) constraints are relative to the intrinsic characteristics of a performer, *task* constraints are directly related to the specific goals of an activity, while *environmental* constraints appear more difficult to control since they represent all external physical and social constraints surrounding a performer. These intertwined constraints are evolving and dynamic and may alter or facilitate every time an action emerged (Araújo and Davids, 2011), reinforcing the behavioural adaptability of **learners.**

The constraints-led approach provides a framework for designing motor learning programs using principles of a nonlinear pedagogy (NLP). In NLP, PE teachers have a **comprehensive knowledge of the activity that allows them to identify the nature of the interacting constraints acting** 'on each individual learner and how to manipulate key task constraints to facilitate the emergence of functional movement

repertoires' (Chow et al., 2007: 259). This pedagogical framework is termed 'nonlinear', since it highlights the dynamical properties of learning contexts, characterised by sudden transitions between coordination modes (Chow, 2013). In this respect, NLP combines representative learning design and the manipulation of key constraints to understand and develop emergent learning behaviours (cognitions, perception, actions, and emotions) in embedded contexts (Chow, 2013). Therefore, a major challenge for PE curriculum specialists is to identify the most salient constraints of a **dynamic performance** environment to present them to children in safe learning programmes. In such approaches, constraints on action are considered as boundaries, which guide –without prescribing– the emergence of goal-directed behaviours (Chow et al., 2014), that are generally individual-dependent (Chow et al., 2007). These constraints may occasionally take the form of verbal instructions (revealing the importance of chosen appropriated words, sentences and emphases), rules, **scaled spatial areas** or even equipment (Chow et al., 2014). **However, instructional constraints should not be used to prescribe learners how** to process information, make decisions and experience action consequences (Tomporowski and Pesce, 2019). **Rather, behaviours should emerge from learners' exploratory interactions with a performance environment.**

NLP contrasts with traditional instructional approaches, emphasising the reproduction and rehearsal of actions, presented in simplified technical demonstrations of components of skill or movement to acquire, by the teacher (Lee et al., 2014). Rather, NLP is a *learner-environment* centered approach (**third pillar of ecological dynamics**), not a learner-centered approach (Renshaw et al., 2015) that conceptualizes practice as a form of 'repetition without repetition' (Bernstein, 1967, p134). When not considered as 'random variability', with unknown consequences on

learning (Davids et al., 2012), variability added to practice task constraints may exploit nonlinearity in human learning behaviours to support skill adaptation (Chow, 2013; Araújo & Davids, 2010). The addition of ‘constrained variability’ in learning designs can support and amplify the learner’s exploration of the environment, leading to the emergence of individual and functional behaviours adapted to the task goal (Chow, 2013).

To illustrate, Lee et al. (2014) compared the effectiveness of linear and nonlinear pedagogies on motor skill acquisition of a tennis forehand groundstroke over two groups of right-handed girls (9 to 10 years old). Following a 4-week intervention, both groups improved accuracy in the task, highlighting that the **replication** of a putative model of coordination is not the only way to ensure the task goal. Children from the NLP group adapted to the surrounding constraints by adjusting their ball hitting patterns when contexts demanded it (they were allowed to make a choice). It was observed that skill transfer was enhanced when participants faced situations where perceptual-motor exploration was facilitated by manipulation of the surrounding constraints (Lee et al., 2014). Such research findings suggest that less repetition of specific movement patterns, and more varied activities and problem solving opportunities should enhance cognition and long-term changes in the way that individuals perceive information (Tompsonski and Pesce, 2019). Associated with principles of ecological dynamics, and notably representative learning design, such a nonlinear approach seems encouraging to apply during PE classes in aquatic environments.

A non-trivial point regarding multiple aquatic environments is that they are often structurally different. Open-water environments offer complex affordance

landscapes (rich in behavioural opportunities) with currents that can move a swimmer away from or towards the shore, waves differing in height that can be avoided by diving or rising above, multiple ambient temperatures, light or dark water, swirling wind patterns, variable depths, obstacles and hazards. In contrast, swimming pools typically offer a stable landscape of affordances (with few opportunities for interaction), offering learners a clear volume of water with a regulated temperature and a calm, predictable surface. The implication is that pools are sanitized, highly-structured environments in which a learner can utilise affordances in restricted ways, which are only relevant very early in learning. Throughout learning, the ways each individual learner perceives and copes with his/her aquatic environment remain closely linked to the nature of the constraints faced. Later in learning, the level of anxiety or fear associated with sudden immersion needs to be manipulated as individual constraints, through exposure to more varied surface waves and dynamic currents as environmental constraints and wearing clothes/shoes as task constraints. This type of manipulation can provide learners with opportunities to self-regulate with respect to interacting constraints, during training and practice, exemplifying some basic educational interventions for developing meaningful aquatic competencies for learners of all ages (Figure 1).

At this stage, some exemplar practice designs may be helpful to illustrate the previous conceptualisation (Table 1). Situated interventions are straightforward to conduct within the context of a PE class (low expense resources needed within a standard swimming pool), and they can be used to develop essential skills that can be transferred to more risky and unpredictable outdoor aquatic environments. They are built upon various methods such as goal setting, various practice situations, reinforcement and verbal persuasion (Tomporowski and Pesce, 2019) of the PE

teachers to be fully implemented with a group of learners. Of particular interest, these interventions may help learners to: (i) better estimate their own action boundaries; (ii) appropriately cope with perturbations and solve encountered problems; and (iii), provide opportunities for self-regulation and autonomy. These are three of the most relevant competencies that swimmers need to acquire to interact with varied dynamic aquatic environments.

[insert Table 1.]

Table 1. A proposition of three foundational aquatic skill activities performed in safe indoor environments (i.e. swimming pool) that recall the natural and dynamic context of open water environments, in which drowning mainly occurs.

	Intervention one	Intervention two	Intervention three
Participants	Min: one; max: group	Min: three; max: group	Min: one; max: group
Main protocol / General instructions	1) Stand on the side of the pool; 2) voluntarily jump into deep water	1) Two lines of learners facing each other about two meters apart; 2) simulate a wavy environment with hands (creating splashes in the same direction to develop an artificial current); 3) other individuals, fully clothed (with shoes on) navigate through this tunnel	1) Select and retrieve bright colour rings from the pool floor; 2) multiple rings on the pool floor: to estimate the maximum number of rings participants can bring up to the surface within a single dive
Variations	Learners forewarned to be gently nudged into deep water from the side, but they do not know when	Experience the water current both ways (i.e. restricting vs. facilitating the movements) to highly reproduce natural outdoor currents	Solicit haptic and proprioceptive information in negotiating objects under water when vision is degraded
Aim of intervention: Why? How? and Drill example	<p><u>1) PFD competence:</u> W: experience the effects of wearing a PFD/lifejacket on flotation and buoyancy (change action capabilities); H: submersion with the PFD/lifejacket; D: try to go underwater with the PFD/lifejacket from a safe and controlled manner. <u>2) Stationary surface competence:</u> W: apprehension of personal density (ratio between body mass and volume), knowledge of few non-floater learners (<5/100, Stallman et al., 2017); H: acquire flotation and water-treading aquatic skills; D: maintain a star-shape at the surface. <u>3) Consolidate self-regulation skills and enhance emotional constraints following sudden immersion:</u> W: being calm to select appropriate affordances for action; H: relaxation and breathing exercises; D: ask learner to count from 30 to 0 with a stabilized body position at the surface. <u>4) Breath control competence:</u> W: voluntary breath control to prevent a possible cold shock response; H: breathing efficiently to make appropriate decisions; D: return to the side of the pool calmly and safely exit it</p>	<p><u>1) Clothed aquatic competence:</u> W: experience air being trapped in clothes and shoes for flotation (change action capabilities); H: jump into deep water fully clothed; D: released progressively air to experience impacts on body buoyancy. <u>2) Stroke choice:</u> W: selecting strokes that limit high resistances; H: breaststroke rather than front crawl (Potdevin et al., 2017); D: spontaneous selection of a stroke to pass through the wavy environment. <u>3) Stationary surface competence:</u> W & H: see Intervention one; D: maintain a stationary position (30 sec, both ventrally and dorsally) against and along the dynamic current. <u>4) Open water competence:</u> W: develop individuals' ability to adapt to unpredictable, constraining and dynamic fluid forces to achieve task goals efficiently, effectively and in a timely way (individual–environment coupling); H: representative learning design to select appropriate affordances provided by the water currents; D: perform a zig-zag path in the current (both ways). <u>5) Collective behaviour:</u> W: exploit the functional solutions of behaviours that only emerged from social interactions (social affordances; Araújo & Davids, 2011); H: perform exercise collectively; D: assist a person to safely going</p>	<p><u>1) Knowledge of local hazards competence:</u> W: representation of visual perceptual constraints in dark swimming environments in rough water (rocks and hazards); H: reduce visual field with special goggles (with filters or petroleum-based jelly); D: use an aquatic motion over 25m. <u>2) Landscape of affordances:</u> W: becoming better attuned to affordances for action in natural environments; H: retrieve an immersed object and return to the surface; D: select and retrieve bright colour rings at different depths. <u>3) Underwater competence and breath control competence:</u> W: emphasise underwater propulsion and breath control; H: progressively asking participants to overpass their limit; D: increasing the number and decreasing the proximity of the rings. <u>4) Assess personal competence:</u> W: estimations of action boundaries are generally wrong (Button et al., 2016); H: assess participants effectivities or capabilities; D: ask participants how many rings they can bring up to the surface within a single dive and compare to the real result of their actions</p>

through the 'tunnel'

Note: Min: minimum; Max: maximum; W: why?; H: how?; D: drill example

Future directions/limitations

Currently, some constraints of outdoor aquatic environments may be too challenging to simulate in typical training programmes, without direct exposure to them, such as immersion in freezing cold, choppy, dark and undulating waters. However, learning designs could seek to simulate key aspects of their properties (e.g. immersing swimmers in cooler water and using wave machines in practice contexts, perhaps harnessing augmented reality technology in the future) to help participants perceive, act and self-regulate in the surrounding constraints of more risky contexts. The aim here is not to replace swimming lessons in PE programmes since the link between the learner and his/her aquatic environment is essential to be maintained, but rather to complement activity with the practical training interventions described above, underpinned with theoretical insights. Indeed, carefully-designed simulations would enhance the way that participants self-regulate emotions, perception, action and cognitions under task constraints which simulate hazardous outdoor aquatic environments.

For example, dangerous rip currents are not always obvious to see in oceans and harbours. These rip currents are responsible for the greatest cause of lifeguard rescues worldwide (Woodward et al., 2015) since they are often incorrectly identified (wrongly assimilated to invisible currents, undercurrents, or movement of waters that will drag the swimmer's body underneath the water surface). As an example, in **the United Kingdom (UK)**, 65% of beach users interviewed (Woodward et al., 2015), reported poor knowledge of rip currents, which generally afford the opportunity to swim inside them since the water appears calm (Figure 2). The use of emerging technologies such as augmented reality and drone footage of these currents may help individuals to develop relevant perceptual skills by learning that: (i) before entering

the water, they need to visually search the area; (ii) if the water is darker, calm, and does not appear foamy, these areas need to be avoided; (iii) if they become trapped in a rip current, they couple actions to explore a perpendicular escape route from the rip current or calmly float along the current flow until the onshore flows bring them back to the beach. Such interventions are intended to support learners' self-regulating tendencies by using relevant perception-action couplings to function more effectively in a variety of challenging aquatic environments.

[insert Figure 2.]

Conclusions

There are different approaches to enhancing functional aquatic competencies in the outdoors and the most direct would be to expose individuals to open water environments. Unsurprisingly, learning designs for appropriate aquatic skills in such environments are sometimes highly constrained by risk assessments, safety considerations and logistical challenges. Therefore, learning designs – rooted in a strong theoretical framework – should be considered as a complementary step towards improving training for drowning prevention among participants in safe aquatic environments that are re-designed to successfully simulate unpredictability of open water areas. Ecological dynamics, through principles of nonlinear pedagogy, promotes the design of representative tasks in which learners can acquire foundational aquatic skills that they need to transfer to varied outdoor environments, which typically contain a richer range of affordances than indoor swimming pools. **In this sense, teaching learners how to become competent swimmers should not be considered as the sole primary focus for drowning prevention, but rather as complementary to situations designed to help learners to feel comfortable in varied**

aquatic environments. Encouragingly, this approach has begun to be implemented in certain countries where swimming outside is meaningful or culturally anchored. For instance, swimming and water safety are explicitly mentioned in the United Kingdom curriculum as relevant key stage competencies, just like other meaningful physical activities (e.g. running, throwing, jumping, catching). Among other considerations, the curriculum recommends that pupils should be able to exploit relevant aquatic **behaviours** competently, confidently and proficiently over a distance of at least 25 m, with the capacities to undertake a safe ‘self-rescue, if needed, in different water-based situations. In New Zealand (NZ), after the ‘Aquatic Education in Schools’ survey report, the country aimed to develop children’s understanding of being safe in, on and around water (PE is taught to develop students’ knowledge and understanding of health outcomes of physical activity). People in island nations, like the UK or NZ, are surrounded by water and they need to be helped to become better attuned to the information, appropriate behaviours and affordances of such exhilarating outdoor aquatic environments (early in the lifespan), allowing them to be safely experienced.

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Contributors

CB conceived the study, participated in its design, coordination and writing and drafted the manuscript, BG helped in the design of the study and helped to draft the manuscript; KD and LS reviewed and improve the general shape of the manuscript several times.

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Figures and table captions

Table 1. A proposition of three foundational aquatic skill activities performed in safe indoor environments that recall the **natural** context of open water environments, in which drowning mainly occurs

Figure 1. A depiction of **15** aquatic competencies (numbered in gray at the upper left corner), based on the water competencies identified by Stallman et al. (2017) to prevent drowning

Figure 2. Rip current flow circulation that may be used as visual depiction to inform learners regarding the way to avoid and/or escape such dangerous situation