

Cognitive vs ecological dynamic approach: a synthetical framework to guide effective educational choices

ELISA PUGLIESE¹; PASQUALINA FORTE²; CRISTIANA D'ANNA³

^{1,2,3}Department of Human Sciences, Pegaso University, Naples, ITALY

^{1,2} School of Advanced Studies, University of Camerino, Macerata, ITALY

Published online: September 30, 2023

(Accepted for publication September 15, 2023)

DOI:10.7752/jpes.2023.09285

Abstract:

In recent decades, educational neuroscientific studies have been tracing important trajectories to design effective learning environments that support the acquisition, development, and improvement of motor skills. The logic of non-linearity that characterizes the neuroscientific approach allows us to understand, through the study of motor behavior and targeted actions, realities such as cognition and behavior, affectivity, and relationship. The aim of the study is to provide a synthetic framework of the two main teaching approaches used for learning motor skills and sport-specific movement skills, highlighting strengths and weaknesses. This is in order to emphasize the principles that guide educators' choices in respect of the constraints of the individual, the task, and the environment. Through studying the key points of the different theoretical approaches for the acquisition of motor skills and analyzing the scientific evidence, a summary framework will be developed, highlighting strengths and critical points and focusing on the specific phase of the acquisition of motor skills. The two main approaches in the theoretical framework are the cognitive approach, in which the concept of prescriptive style prevails, and the ecological-dynamic approach, in which the concept of the heuristic approach prevails. The criterion for the methodological-educational choice is based on scientific theories and the studies examined have shown that there is no preferred teaching methodology; a good practitioner must be able to evaluate which teaching methodology to use without excluding an integration or an alternation of both. The systemic perspective leads to new research possibilities to verify how much the implementation of learning environments based on the ecologic-dynamic approach allows the most appropriate basic motor development.

Key Words: heuristic approach, motor skills, motor learning, non-linear pedagogy, prescriptive approach, teaching and learning

Introduction

In recent decades, educational neuroscientific studies have been tracing important trajectories to design effective learning environments which support the acquisition, development, and improvement of motor skills. Neuroscience may help create learning environments which support the acquisition, development and improvement of motor skills. The logic of non-Linearity that characterizes the neuroscientific approach allows us to understand, through the study of motor behaviour and targeted actions, realities such as cognition and behaviour, affectivity and relationship (D'Anna et al. 2023).

Several studies have shown how physical activity, sport and generally the practice of motor skills contribute to the development of higher-order cognitive functions (Davis et al. 2011; Moon, 2022; Liu et al.2020). Particularly, when the effects of physical activity on the brain, especially the front hippocampus, was observed it was found that areas related to cognitive functions such as: the prefrontal lobe, had more developed synaptic structures and that neurogenesis, angiogenesis and brain blood flow accelerated (Dolu et al. 2016).

The numerous scientific evidences regarding the positive effects induced by physical exercise on cognitive functions support a three-level model to explain the interaction between brain and movement: 1. increased cerebral vascularization which in turn increases brain activity; 2. development of complex neural circuits related to movement and their interconnection with executive functions; 3. release of neurotransmitters that promote neurogenesis, memory, attention, concentration (Doherty et al. 2019; Canli et al. 2022). The latter are of particular importance during the developmental age as key elements of the learning process.

Currently there are two main theoretical approaches that are used to explain control and motor learning: the cognitive approach and the ecological-dynamic approach. Both are based on different theoretical disciplines, explain partially different aspects of control and motor learning and lead to different methodological-educational conclusions. The cognitive approach consists of a predominantly prescriptive teaching/learning, while the ecological approach is classified as a heuristic approach. Since the ecological-dynamic approach is more recent than the modern cognitive approach, it has not yet created an amount of educational relapses similar to that of the cognitive approach; moreover, because according to the ecological-dynamic motor learning is predominantly heuristic, it would be a contradiction if detailed teaching indications were provided, of a prescriptive type,

comparable to those of the cognitive approach (D'Anna et al., 2023). It is necessary to examine the characteristics of the two approaches, in order to understand which to use, propose, also based on the characteristics of the students, the motor task and the context in which the learning takes place, without excluding an integration of both. (Pesce, 2002). In particular reference to the different characteristics of the learning processes of the learners, we must take into account that the learning process differs based on the way they elaborate, perceive and use information (Patel & Kaufman 1996). Substantial differences between novice and expert students are also expressed during motor performance (Ianovici & Weissblueth, 2016). A high level of control in both motor and cognitive perspectives is needed in order to succeed at a given motor task (Wrisberg 2001).

Ecological psychology and nonlinear dynamics comprise a scientific framework known as ecological dynamics, which examines human behaviours at the level of performer-environment interactions. Ecological dynamic approach is learner- and learner-centred; learners must be helped to acquire skill sets that allow them to improve in dynamic performance environment (such as sport), which are uncertain and complex. Learners must be exposed to different kind of performance contexts and must be able to multitask and continuously adapt their actions (Ozmun et al. 2016; Chow, 2021).

Key ideas in ecological dynamics have many important implications for how practitioners plan practices, deliver instructions, structure tasks and provide informational constraints to learners. Motor and sports sciences play a crucial role in the development of young people and the learning of all those transversal skills useful for everyday life skills, the demands of the world of work and social integration. The practice of physical activity and sports could be an indispensable tool to offer a quality experience that can have a positive effect on these skills, facilitating the learning process (Alexandr et al., 2016; Drenowatz, 2021). Motricity in children contributes to learning through instinctive and innate representations that they tend to have with the world and their surroundings. These representations are incorporated by their senses and the concepts change depending on the constantly variable environmental motion-based elements (Forte et al., 2023).

The relationship between physical education (PE) and social aspects is closely interconnected although not always immediate. In fact, PE offers a unique environment/context in which students interact, are induced to collaborate and develop important 'relationship skills' because to self-include in the "magic circle" of play and challenge, unavoidable two-way interactions and dynamics are triggered (Lovecchio, 2023). In this regard, PE if properly mediated by a teacher-educator can play an important role in the development of life skills. Skills that beyond the maturation of physical abilities trigger an osmotic maturation of personal qualities that are fundamental and useful for the interaction between peers (and not) in all the life contexts that a person in society is called to live and manage.

Considering what emerged and to recall the educational aspect, it is essential that the educator is able to create learning environments favorable to the acquisition of motor skills.

The aim of the study is to provide a synthetic theoretical framework of the two main teaching approaches used for learning motor skills and sport-specific movement skills, highlighting, strengths and weaknesses. This is in order to highlight the principles that guide the choices of educators in respect of the constraints of the individual, the task, and the environment (Newell, 1984).

The purpose of this analysis is to guide the practitioners on the use of the two approaches, integrating them, and to provide a complete and clearer picture of the characteristics of both approaches, as well as some insights into the application aspects of motor and sports activity.

Material & methods

Through the study of the key points of the different theoretical approaches for the acquisition of motor skills and the analysis of the scientific evidence, a summary framework will be developed, highlighting strengths and critical points, focusing on the specific phase of the acquisition of motor skills.

It is necessary to pay attention even before the teaching methodology, on the way athletes learn. Motor learning is defined as a set of processes, which associated with practice and experience, determine a relatively permanent change in performance or behaviour potential (Schmidt & Lee, 2014). Learning is usually measured through tests performed at a distance of time, transfer tests, or tests carried out on similar skills. For an athlete, the best test of technical learning is represented by the ability to effectively apply the technique even in stressful competition situations.

When an athlete has learned a skill well, it is possible to observe some signs such as:

1. the gradual improvement of the execution, which becomes more correct and precise compared to the initial phase, getting closer to the requested gesture;
2. the athlete becomes more consistent in the execution of the skill, so that the performances are similar to each other as the exercises proceed;
3. an important feature of learning is also the persistence of improved performance capacity, which is maintained for increasingly prolonged periods and becomes almost permanent;
4. Finally, another indication of learning a skill is adaptability, which is the ability to successfully perform the skill even in different or modified situations.

Results

The two broad theoretical approaches used to explain motor control and motor learning are distinguished by the way they consider perception and address the relationship between perception and action (Edwards, 2011).

The first one, which is the best known and most widespread, is a cognitivist approach that involves the use of centralized mechanisms of information processing. This approach develops within a cognitivist perspective that enhances the role of the central nervous system, considering the brain as a computer that receives information, processes it and generates a response. The approach involves a closed loop or open loop control system, in which everything is explained within the system itself.

The second approach, on the other hand, is dynamic and considers perception as a direct mechanism through which the individual, with no need to rely to memory, immediately seeks or identifies in the environment the information already present and functional to the action. This approach is also defined ecological, because it considers the complex interaction between individual, task and environment.

Both theories identify three successive stages in the transition from an initial performance to an expert performance, and both recognize the three stages of learning as the same behavioral characteristics.

1) Verbal-cognitive stage or development of raw coordination.

2) Motor stage or development of fine coordination.

3) Autonomous stage or development of variable availability.

Table I summarizes the characteristics of each of the 3 stages.

Table I. The different aspects of movement within the 3 stages of learning

	<i>Stage Of Development of Raw Coordination</i>	<i>Stage Of Development of Fine Coordination</i>	<i>Stage Of Development of Variable Availability</i>
<i>Task</i>	Broadly understood and conducted only under favorable conditions	Understood more thoroughly	Carried out safely and with minimal energy expenditure
<i>Action</i>	Stiff movement, uneconomical, slow response time	Perfected and more precise, smooth and fluid; decreases error rate	Accurate and controlled
<i>Execution</i>	Same even with environmental variations	Corresponding to the required model	rapid; coordinate; effective; even in unpredictable situations
<i>Mechanics Of The Gesture</i>	Inaccurate	Faster movements	Appropriate, with few errors and a high correction
<i>Perception</i>	Confused	More precise	Very accurate
<i>Timing</i>	Simple skill = takes little time	Moving to the next step requires: strong motivation; good teaching; Individual sports-specific characteristics	High-level performance stage, slow improvements, not all athletes get to this stage

Cognitive approach vs ecological-dynamic approach

The cognitive approach argues that there are motor programs that guide action and that the memory plays a fundamental role in attributing meaning to certain stimuli. According to this approach, stimuli are perceived, recorded and treated like computer data, and learning is a kind of data processing in which movement is shaped according to information coming from the previous movement. The theory of generalized motor programs (Schmidt & Wrisberg 2010), for example, it assumes that programs containing motor commands that define the deep structure common to an entire class of movements are stored.

The ecological-dynamic approach is more recent, it has started developing since the 80s, even if the roots date back to many years before. Learning is seen not as a consequence of centralized control, but as derived directly from the interaction of different body systems with the surrounding environment. The most significant aspect is the relationship between perception and action, which does not involve central cognitive processes of processing and memory usage. The perception-action interaction is specific to each situation, and the adapted motor ability is the result of the constraints linked to the interaction between the motor task, the individual and the environment. Therefore, the technique used in a sport or activity is not as important as the repertoire of skills and executive variants used (Colella & D'Arando, 2021).

The learner, to effectively grasp the stimuli coming from the surrounding environment, acts to seek the greatest amount of significant sensory stimuli; when an individual begins to act, perception and action control his movements. The practitioner assumes a decisive role by proposing and creating a highly stimulating environment for the learner. The indications from the practitioner are less frequent and refer to the fundamental patterns of the movement or technical gesture. The teacher uses a descriptive approach and the indications try to transfer skills starting from the meanings. The learner is introduced into the situation and puts into practice techniques and movements that he considers most functional according to a process of self-regulation (theory of dynamical

systems, Gibson 1979; Handford 2002). In the processes of self-regulation, learners almost naturally tend to constantly organize and reorganize his motor behavior to be efficient with respect to the requests.

In this theory, the sensorimotor system would possess properties of self-organization that do not require the use of a motor program or a precise space-time parameter by the brain (control center). This approach is based on the idea that the central nervous system (CNS) is not regulated by specific laws but develops starting from the environmental influences on neuronal groups that specialize on specific tasks (Edelman, 1987). To provide a clear and comprehensive overview, Table II was developed comparing the key points and characteristics of each approach.

Table II. Cognitive approach vs ecological dynamic approach

	<i>Cognitive Approach</i>	<i>Ecological Dynamic Approach</i>
	Theory of generalized motor programs	Theory of dynamics system
<i>Skills are the result of the development of:</i>	Movement patterns Motor programs with invariant characteristics and approximate characteristics	Stimuli deriving from environmental characteristics: space-time constraints, structural constraints (playing surfaces, equipment, etc.), weather conditions, etc.
<i>Educators strategy</i>	Using prescriptive approaches (Presetting gesture executions and solving tasks) Conducting training	Self-organization (adaptations and technical behaviors in response to educational problem) Encourage stimuli generated by problem solving
<i>Learning is based on:</i>	Stimuli that involve the repetition of the gesture and technical (and tactical) solutions	Stimuli provide for the repetition of the task, therefore, leaving greater technical and tactical behavioral freedom
<i>Principle of variability</i>	It acts both on the variation of motor sense parameters (superficial components of motor behaviour): speed, amplitude, strength, and direction of movement, both on the variation of the motor program (more cognitive) Educator's action: act on motor behavior (tendency to modify executive techniques)	It acts both on the variation of sensory-motor parameters (Superficial components of motor behaviour): speed, amplitude, strength and direction of movement; and on the variation of the motor program (more cognitive) Educator's action: aimed at modifying the characteristics of the operating situation, orienting response and technical behavior
<i>Feedback</i>	External feedback on performance and feedback on the result are more frequent and more oriented to highlight the error (lower tolerance). Internal, non-practitioner-mediated feedback is more accurate; Prescriptive feedback	Performance feedback and result feedback are less frequent and more oriented to favor technical expertise by delaying correction interventions (greater fault tolerance). Internal feedback (not mediated by the practitioner) is more global; Descriptive feedback

Discussion

Each of the two theories considered has strengths and weaknesses, but together they provide perspectives which neither can provide on its own.

Weaknesses of the cognitive approach

- *Context-conditioned variability.* The cognitivist approach considers the central control mechanism as the only responsible for the execution of a movement: Each action depends on the specific commands contained in the motor program. In this way, however, the possible variability of the context deriving from external factors is not taken into account. This problem occurs in all those sports situations based on actions that must be changed very quickly, not enough for sensory feedback to send the information necessary to readjust the program to the level of the central nervous system.
- *Degrees of freedom.* Given the complexity of human movement, to perform a skill it is necessary the effective control and coordination of all the structures involved. Degrees of freedom refer to the anatomical structures that must be controlled to perform an action. It must also be borne in mind that the same action can be carried out in different ways depending on the situation, and each small variation changes the organization of the structures involved.

Strengths cognitive approach

- The learner receives clear and precise indications through a demonstration and verbal phase of the technical task to be learned (Schmidt 1980; Schmidt & Wrisberg, 2000).
- The practitioner has the task of suggesting control parameters, procedures for correcting techniques, emphasizing the patterns of the movement to be performed.

Weaknesses of ecological dynamic approach

- The theory does not consider the role of memory. But it is clear that if the execution of a task were due only to forms of self-organization, an individual could correctly perform a complex gesture even the first time it is experienced.

- The other critical aspect concerns the insufficient explanation of the processes underlying decision-making. The theory suggests that people, through experience, better recognize the significant stimuli present in the environment, but it does not explain how they decide which stimuli are most useful.

Strengths of the dynamic ecological approach

- Through guided discovery, the ecological dynamic approach, encourages freedom of exploration and since this approach is characterized by a prevalent autonomy and motor freedom, the learner is urged to find personal answers to the problem, to experiment with new solutions, and to direct technical growth towards the achievement of a creative sports personality. This procedure produces transfer effects in the medium to long term greater than the block practice, which involves constant repetitions and with few variations. This could be useful especially for children who are subject to a precarious attention often generated by boring and repetitive exercises, in fact, a teaching based on a relationship with high contextual interference would result in a good adaptation reaction (Wulf, 2013).
- The theory of dynamical systems proposes an educational approach that favors learning through experimentation and errors. Learners start from simple systems of action and, involving a limited number of movement structures, explore and learn to use their movement possibilities in an increasingly broad and coordinated way. In addition, through this process, they also improve the ability to understand the environmental situation and to automatically associate stimuli configurations with effective responses even in changing situations. In summary, the educational proposal based on the theory of dynamical systems, enhances the heuristic approach and experimentation as fundamental tools for learning (Bortoli & Robazza, 2016).

The two main approach in the theoretical framework are cognitive approach, in which prevails the concept of prescriptive strategy and ecological- dynamic approach, in which prevails the concept of heuristic. The criterion for the methodological-educational choice is based on scientific theories and the studies examined have shown a change of direction from the theory of generalized motor programs to the dynamical systems theory. The key issue is to engage in dedicated programmes at the right time in an individual's development.

From the learners' perspective, the experience also can be prescriptive since they receive constant feedback for reproducing forms of movements or patterns of play (Davids et al., 2012). But the program one-size-fits-all fails to support physical literacy (Rudd et al., 2021). The other problem that has often been detected is that practice environments are the same week-in week-out, and emphasise, the number of repetitions or even the time spent in certain intensity thresholds. Programs that depend upon these parameters have high dropout rates (Côté et al., 2009; Coutinho et al., 2016). However, there are contemporary pedagogical frameworks that suggest how these problems can be prevented, with the support of physical literacy. Everything analyzed, leads to these considerations:

A good practitioner must be able to evaluate which teaching methodology to use without excluding an integration or an alternation of both. The methodology to be adopted is chosen according to the characteristics of the individual, according to the task and according to the environment (Newell, 1984). We must consider in particular the learning phase in which the learner is located in addition to the feedback we receive from the athlete.

Conclusion

The theory of generalized motor programs and the theory of dynamical systems are different, explain different phenomena and therefore have different applicative implications.

Through an in-depth analysis of motor control and motor learning in a neuroscientific perspective, it is possible to choose the most appropriate teaching strategies. Fundamental is the ability of the practitioner to use the best strategies according to the opportunities proposing, even in the same training session, an alternation of approaches. The choice of teaching approach must take into account a series of characteristics: age, years of activity, technical level and attitude, periodization, ability to adapt, more or less favorable moments (e.g., problems related to peak growth of individual stature etc.) time of year, environmental conditions, climatic conditions etc. The two approaches together offer the potential for a future unifying theory, which may also derive from rapid advances in research technologies (Pesce, 2002). In conclusion, neither the cognitivist approach nor that of dynamical systems can fully explain expert performance. The cognitivist approach is probably better at explaining decision-making, while the ecological approach seems to be better suited to explaining movement control. The consideration and evaluation of all these factors accentuate and underline the Non-linear character of the educational choices that are closely interconnected to the three constraints: task, feedback, environment. What emerged highlights the complexity of motor learning that requires a systemic and non-linear perspective that can guide the choices of the educator to implement meaningful learning.

References

- Alexandr, A., Sergij, T., & Olena, O. (2016). Role of physical education on the formation of a healthy lifestyle outside of school hours. *Journal of Physical Education and Sport (JPES)*, 16(2), 335.
- Bortoli, L., & Robazza, C. (2016). L'apprendimento delle abilità motorie. *Due approcci tra confronto e integrazione. SDS-Rivista di cultura sportiva*, 109(1), 23-34.

- Canli, U., & Samar, E. (2022). Exploring the effect of physical activity level on balance, aerobic performance and cognitive function in young sedentary individuals. *Journal of Physical Education and Sport (JPES)*, 22(10), 2504-2512.
- Chow, J. Y., Davids, K., Button, C., & Renshaw, I. (2021). *Nonlinear pedagogy in skill acquisition: An introduction*. Routledge.
- Colella, D., & D'Arando, C. (2021). Teaching styles and outdoor education to promote non-linear learning. *Journal of Physical Education and Sport (JPES)*, 21, 507-513.
- Côté, J. E. A. N., Lidor, R., & Hackfort, D. (2009). ISSP position stand: To sample or to specialize? Seven postulates about youth sport activities that lead to continued participation and elite performance. *International journal of sport and exercise psychology*, 7(1), 7-17.
- Coutinho, P., Mesquita, I., Davids, K., Fonseca, A. M., & Côté, J. (2016). How structured and unstructured sport activities aid the development of expertise in volleyball players. *Psychology of Sport and Exercise*, 25, 51
- D'Anna, C., Forte, P., Vivona, A., Pugliese, E., & Gomez Paloma, F. (2023). Physical Fitness and Potential Intelligence in Primary School: Acorrelational Study. *Research Journal of Sports and Health Psychology*, 5, 1-6.
- D'Anna, C., Pugliese, E., Forte, P., & Ambretti, A. (2023). Video feedback in learning sport specific skills. Cognitive approach vs ecological approach. *Italian journal of health education, sport and inclusive didactics*, 7(2).
- Davids, K., Araújo, D., Hristovski, R., Passos, P., & Chow, J. Y. (2012). Ecological dynamics and motor learning design in sport. *Skill acquisition in sport: Research, theory and practice*, 112-130.
- Davis, C. L., Tomporowski, P. D., McDowell, J. E., Austin, B. P., Miller, P. H., Yanasak, N. E., Allison, J. D., & Naglieri, J. A. (2011). Exercise improves executive function and achievement and alters brain activation in overweight children: a randomized, controlled trial. *Health psychology: official journal of the Division of Health Psychology, American Psychological Association*, 30(1), 91-98. <https://doi.org/10.1037/a0021766>
- Doherty A and Forés Miravalles A (2019) *Physical Activity and Cognition: Inseparable in the Classroom*. Front. Educ. 4:105. doi: 10.3389/feduc.2019.00105
- Dolu, N., Bahur, S., Demirer, F., Kulak, E., & Çam, A. (2016). The effect of physical activity on cognitive functions. *Izmir University Medical Journal, D (5)*.
- Drenowatz, C. (2021). Association of motor competence and physical activity in children-does the environment matter?. *Journal of Physical Education & Sport*, 21.
- Edelman, G. M. (1987). *Neural Darwinism: The theory of neuronal group selection*. Basic books.
- Edwards, W. H. (2011). Motor Learning and Control. *From Theory to Practice*. Belmont: Wadsworth.
- Forte, P., Pugliese, E., Ambretti, A., & D'Anna, C. (2023). Physical Education and Embodied Learning: A Review. *Sport Mont*, 21(3), Ahead of Print. doi: 10.26773/smj.231020
- Gibson, J. J. (1979). The ecological approach to visual perception. *生態学的視覚論*.
- Handford, C. (2002). 17 Strategy and practice for acquiring timing in discrete, self-paced interceptive skills. *Interceptive actions in sport: Information and movement*, 288.
- Ianovici, E., & Weissbluth, E. (2016). Effects of learning strategies, styles and skill level on closed and semi-open motor skills acquisition. *Journal of Physical Education and Sport (JPES)* , 16(4), 1169.
- Liu, S., Yu, Q., Li, Z., Cunha, P. M., Zhang, Y., Kong, Z., Lin, W., Chen, S., & Cai, Y. (2020). Effects of Acute and Chronic Exercises on Executive Function in Children and Adolescents: A Systemic Review and Meta-Analysis. *Frontiers in psychology*, 11, 554915. <https://doi.org/10.3389/fpsyg.2020.554915>
- Lovecchio N., 2023. *Il gioco dell'allenamento*. Marcianum.
- Moon, J. (2022). Connecting sport coaching, physical education, and motor learning to enhance pedagogical practices. *Journal of Physical Education and Sport (JPES)*, 22(1), 3-12.
- Newell, K. M. (1984). Physical constraints to development of motor skills. *Motor development during childhood and adolescence/edited by Jerry R. Thomas*.
- Ozman, J. C., & Gallahue, D. L. (2016). Motor development. *Adapted Physical Education and Sport E*, 6, 375.
- Patel, V. L., Kaufman, D. R., & Magder, S. A. (2014). The acquisition of medical expertise in complex dynamic environments. In *The road to excellence* (pp. 127-165). Psychology Press.
- Pesce, C. (2002). Insegnamento prescrittivo o apprendimento euristico? *SDS*, 21(55), 10-18.
- Rudd, J., Renshaw, I., Savelsbergh, G., Chow, J. Y., Roberts, W. M., Newcombe, D., & Davids, K. (2021). *Nonlinear pedagogy and the athletics skills model*. London: Routledge.
- Schmidt, R. A., & Lee, T. D. (2014). Motor learning and performance: From principles to application (5th éd.). *Champaign, IL: Human Kinetics*, 203-5.
- Schmidt, R. A., & Wrisberg, C. A. (2000). *Apprendimento motorio e prestazione*. Società stampa sportiva.
- Schmidt, R. A. (1980). Past and future issues in motor programming. *Research quarterly for exercise and sport*, 51(1), 122-140.
- Wrisberg, C. 2001. "Levels of Performance Skill." In *Handbook of Sport Psychology*, edited by R. N. Singer, H. Wulf, G. (2013). Attentional focus and motor learning: a review of 15 years. *International Review of sport and Exercise psychology*, 6(1), 77-104.