Enactive and ecological dynamics approaches: complementarity and differences for interventions in physical education lessons

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Enactive and ecological dynamics approaches: Complementarity and differences for interventions in physical education lessons

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Abstract

We discuss outcomes from two studies of pedagogical interventions, using enactive and ecological dynamics approaches in PE, to examine potential complementarity and differences. One study investigated dynamics of student interactions in orienteering, the other examined dynamics of learning in climbing. Findings suggested caution in using principles of both approaches together, due to key epistemological and ontological differences, which may impact data outcomes and preferred methodologies. The approaches differed in conceptualising the nature of individual-environment coupling but may be complementary in investigating the complexity of this coupling. There is a need for further such mixed methods research and interventions in PE.

Key words: Learning dynamics; learning designs; enactivism; ecological dynamics; complementarity.

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1. Introduction

This paper argues that data production methods from two related perspectives - the enactive approach and ecological dynamics - while not perfectly aligned, show complementarities that can inform research and pedagogical applications. The two perspectives have developed somewhat independently over the past several decades, but are increasingly recognised as having important resonances (e.g. Chemero, 2009). Indeed, Baggs and Chemero (2018) suggested that they offer complementary accounts of skilled behaviour and the person-environment relationship.

The ecological account (in the present paper represented by the ecological dynamics approach to skill learning) addresses general or 'species-typical' aspects of the activity in question. The approach makes apparent stable, reliable structures of constraint and opportunity inherent in a given task domain; for instance, in performance of skilled actions in competition. Ecological dynamics addresses the question of how actions emerge from an individual, that may and may not help achieve intended task goals. From this perspective, the challenge for learners is to: (i) attune to available action possibilities, (ii) adapt the dynamics of their relationship to the world to achieve intended behaviours, (iii) enhance their coordination of with a performance environments (Button et al., 2020).

Conversely, Baggs and Chemero (2018) characterised enactive researchers as focusing on the individual within the activity, with key focus on their experience of it. The individual learner has no overarching perception or understanding of the task dynamics. Instead, if we take for a moment the point of view of this engaged individual we can realise that, from their perspective, the relationship between the dynamics of their own behaviour, and those of the

task, cannot be directly perceived as a whole, but only over time through perceptions of greater or lesser success or coordination. The challenge for the learner as described from this perspective, is to find their way in this landscape of dynamics on the basis of proximal hints and possibilities that their agent's particular history and capability make them sensitive to.

Baggs and Chemero (2018) suggested that these two somewhat complementary standpoints can be brought into a *productive synthesis* with each other. In what follows we seek to show how this can be the case, both in researching the learning of skilled physical activity, and in engaging in pedagogy for such activity. The enactive approach highlights the important, though complex, inter-dependence between experience and behaviour. A radical embodied approach, such as that proposed by Baggs and Chemero (2018), necessitates new methods and new approaches in which these two aspects of activity are observed, recorded, and analysed in a manner sensitive to their relationship.

The studies we describe here use two forms of data collection, methods and tools – 'enactive anthropology' exemplified in the 'course of action' scientific and technological research program (Theureau, 2003, 2004, 2015) and the 'ecological dynamics' approach (Araújo, Davids, & Hristovski, 2006; Button, Seifert, Chow, Araujo, & Davids, 2020; Davids, Handford, & Williams, 1994)

Some contemporary research on learning and teaching situations in PE follows an enactive approach (Jourand, Adé, Sève, Komar, & Thouvarecq, 2017) with a specific orientation: enactive anthropology (Theureau, 2015), and in particular the 'course of action' method. The anthropological dimension relates to human self-determination and the need for a comprehensive analysis of human activity, which makes sense for those who 'live it'. The enactive dimension specifies the anthropological orientation: interest in the meanings for the agent that emerge from his or her interactions with the environment in which he or she acts. This research program seeks to produce information, based on lived experiences, on the

meanings that emerge from the agent - environment coupling for epistemic and transformative purposes. The person is recorded in the course of action, and those recordings used to support subsequent self-confrontation interviews about their experiences (Saury et al., 2013; Theureau, 2003, 2015).

In the ecological dynamics approach, the agent – environment coupling is considered as the most relevant unit of analysis for understanding human behaviours such as learning (Araujo & Davids, 2018). The term 'ecological dynamics' signifies an approach using concepts and tools of dynamical systems to understand phenomena that occur at an ecological scale—the scale where the relationship between individuals and their environments is defined. Interactive relationships define the agent – environment couplings that emerge from a complex dynamic system, signifying the need to study agent and environment functionality in symmetric relationships (i.e. involving mutuality and reciprocity). Person-environment interactions emerge synergistically, rather than independently (Araújo et al., 2006; Button et al., 2020; Davids & Araújo, 2010). The implication of this idea is that human behaviours such as learning and performance can only be understood, not simply with reference to the characteristics of each learner, but synergistically during continuous interactions with a performance environment. In PE and sport, agent – environment couplings refer to learners enhancing the quality of their interactions with a performance environment.

While both of these approaches centre the ways in which the person and environment are coupled during continuous interactions, the conceptualisation of that coupling is somewhat different in each case. The ecological dynamics approach studies human behaviours in terms of information-movement relations and opportunities for action (affordances) that emerge from task and environmental constraints that shape for each individual's interactions (Button et al., 2020; Rudd et al., 2020). The enactive approach starts with the agent and is concerned by how it constitutes its own unique *umwelt* (von Uexküll, 1992) or lifeworld, which corresponds to the

meaningful, lived surroundings of each individual. Baggs and Chemero (2018) recently advocated for a 'productive synthesis' to understand the potential relations between competing, but complementary, ecological and enactive approaches.

In our analysis, we explore how a productive synthesis of enactive anthropology and ecological dynamics could provide fruitful contributions to design learning - teaching contexts in PE. Indeed, it is argued that, how individuals experience learning situations (i.e. how these situations make sense to each person) should be considered in designing and refining the design of those learning tasks. We also argue that practitioners in PE and sport should focus on representative learning designs to enhance specificity of learning, when needed (after Brunswik, 1956; see Davids, Araújo, Hristovski, Passos, & Chow, 2012; Pinder, Davids, Renshaw, & Araújo, 2011). Representative learning contexts need to be founded on a rich landscape of affordances (Rietveld & Kiverstein, 2014), to favour the emergence of stable perception – action couplings, but also to allow adaptive behaviours to emerge.

Our rationale for a productive synthesis between those two approaches is that they could allow PE teachers and learners in sport and PE to co-design learning – teaching situations (Adé, Gal-Petitfaux, Rochat, Seifert, & Vors, 2020; Woods, Rothwell, Rudd, Robertson, & Davids, 2020). This potential for intertwining key concepts and methods of enactive anthropology and ecological dynamics has begun to be investigated in experimental studies in sport and PE. These studies have provided some fruitful insights regarding: (1) action modes that were not accessible to pre-reflective consciousness (e.g. some biomechanical aspects of swimming behaviours; Gal-Petitfaux, Adé, Poizat, & Seifert, 2013), (2) meanings about behaviour accessible to pre-reflective consciousness (for an example during climbing, Rochat et al., 2020), and (3), dynamics of behaviours and lived experiences (for an example in orienteering, Jourand et al., 2017; Seifert, Adé, Saury, Bourbousson, & Thouvarecq, 2016; for an example in rowing, Seifert et al., 2017).

However, instead of a simple combination or juxtaposition of these two forms of data, here we suggest an 'intertwining', in order to make clear the dialectical character of the process. This is not a simple integration at a given moment of time, but a tacking back-and-forth between them in cycles of analysis (Thompson, 2004), using insights from one helping us become sensitive to, and ask directed questions of, texture and detail in the other to which we might otherwise have been oblivious. The two perspectives can offer us a form of parallax, the relationships between the records giving us a better sense of the depth of the phenomena. Useful to us as researchers in getting to grips with this rich and complex domain of study, such a combined set of approaches also offers the possibility of pedagogical interventions that not only address the questions of movement and coordination, but also the experience of learning - exploration, frustration, striving, and success - in a satisfying, systematic, and disciplined way. Our goal in this article is to build on two published studies to explore *how* to possibly intertwine the course of action and the ecological dynamics approaches in PE lessons. Using the insights provided by these innovations in the domain of research for understanding skill learning, we examine opportunities and limitations for a new pedagogical orientation.

2. Design and Results

We summarise here two previously published studies, which address skill learning through the intertwining of phenomenological and behavioural data. The first investigated the interactions between students engaged in orienteering during PE lessons (Jourand, Adé, Sève, Komar, & Thouvarecq, 2018), the second focusing on the learning of climbing skills during an individual lesson (Rochat et al., 2020).

2.1. Intertwining analysing tools from enactive and ecological dynamics approaches to assess the dynamics of dyadic interactions in orienteering lessons

Synthesis of the study

Several studies have focused on interactions between students in PE to investigate the various patterns of interactions and the social and motor learning expected by the teachers (Dyson, Griffin, & Hastie, 2004; Lehraus & Buchs, 2008; Ward, & Lee, 2005). However, few studies have examined the dynamics of those interactions (Bourbousson, R'Kiouak, & Eccles, 2015; Vors & Gal-Petitfaux, 2011). The novelty of Jourand et al.'s (2018) study was to identify the emerging patterns of dyadic interactions (i.e., co-construction, confrontation and delegation) from phenomenological data and to model the dynamics of patterns to assess the stability and switching of those dyadic interactions over. The investigation of dyadic interactions is very meaningful in orienteering during PE lessons because it invites students to collaborate to search for checkpoints. Indeed, the specific context of orienteering as an activity prevents teachers from continually supervising and regulating student behaviours during the lessons, which allows the emergence of various patterns of interactions between students over time. Therefore, using tools from ecological dynamics could help to model the dynamics of dyadic interactions and could reveal innovative insights on self-regulation within and between students.

Synthesis of the study design

This study involved 16 volunteer students (about 12 years old) who were participating for the first time in an orienteering lesson, which took place in a program of seven lessons. Student behaviours during lessons 5, 6 and 7 were analysed. During these lessons the students worked in an affinity-based dyad (8 dyads) on orienteering courses of similar levels of difficulty and time, but in three different learning contexts, a 'planning room', a 'two map', and 'trick checkpoint' condition in lessons 5, 6, and 7 respectively. The planning room was a small space set aside for the dyads to meet and plan a strategy that would respect the time limit. Each dyad had one map showing the four checkpoints to find within the time limit of 40 minutes: they had 1 minute in the planning room to look at the map and plan an itinerary. In the 'two-map' context,

each dyad member had a map and each map showed two checkpoints not on the other map. In the 'trick-checkpoint' context, trick checkpoints were placed close to the real checkpoints.

Two categories of data were collected: (1) data from audio-visual recordings as the participants searched for the checkpoints obtained unobtrusively using glasses-mounted cameras and microphones, and (2), verbalization data during the post-action interviews with the students. The verbalization data were collected immediately after each lesson using interviews inspired by the self-confrontation methodology (Theureau, 2003). Working through the recordings of their activity, each participant was interviewed regarding their actions, intentions, and perceptions in the three learning contexts. These courses of action records were then synchronised for each dyad, to allow analysis of the interactions. Three patterns of dyadic interaction were identified: co-construction, confrontation, and delegation. These categories could then be applied to the individual courses of action to examine the distribution of different these forms of interaction over the duration of the activity.

Using tools from ecological dynamics (in particular assessing behavioural variability; Davids, Bennett, & Newell, 2006), a three-minute window was defined and moved every minute until the end of the task to detect the emerging interaction into the activity of the dyads. These parameters were determined by analysing the course of collective action, which, from the first step of qualitative data processing, indicated that three minutes was a significant time window to detect changes in the dyadic interactions. This one-minute overlap guaranteed a fine-grained search for the possible transformations in the interactions without omitting any. Using this moving window, two indicators were calculated to reflect the dynamics of dyadic interactions: (1) The *ratio of change*, which was the percentage of real changes over the potential changes within the time window; (2) A *distribution index* of the patterns of interaction was calculated to determine the nature of the changes. Finally, coding the experience data, quantifying these data in terms of ratio of change and distribution index of the patterns of

interactions, made it easier to highlight the nature of the changes in between the patterns of interaction, the relative presence of the different patterns of interaction, and the changes in the interactions in each dyad.

Synthesis of the results and discussion

Although similar patterns of interactions were observed in three learning contexts, the dynamic of these patterns of interactions was specific to each dyad. When the participants could enter the planning room, the ratio of change in the interactions progressively declined; when each of the participants had their own map or were on a path with trick checkpoints, the ratio of change continuously fluctuated (Figure 1).

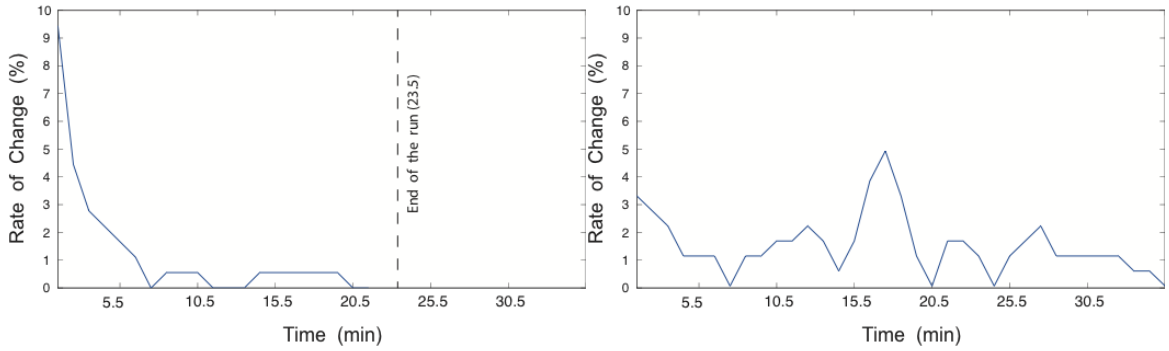

Figure 1: Ratio of change of dyad 1 with the planning-room context / Ratio of change in dyad 6 with the two-map context (from Jourand et al., 2018; reused with permission)

When the participants had access to the planning room or had their own maps, the distribution of the patterns of interaction showed a tendency to fluctuate between co-construction and delegation (Figure 2).

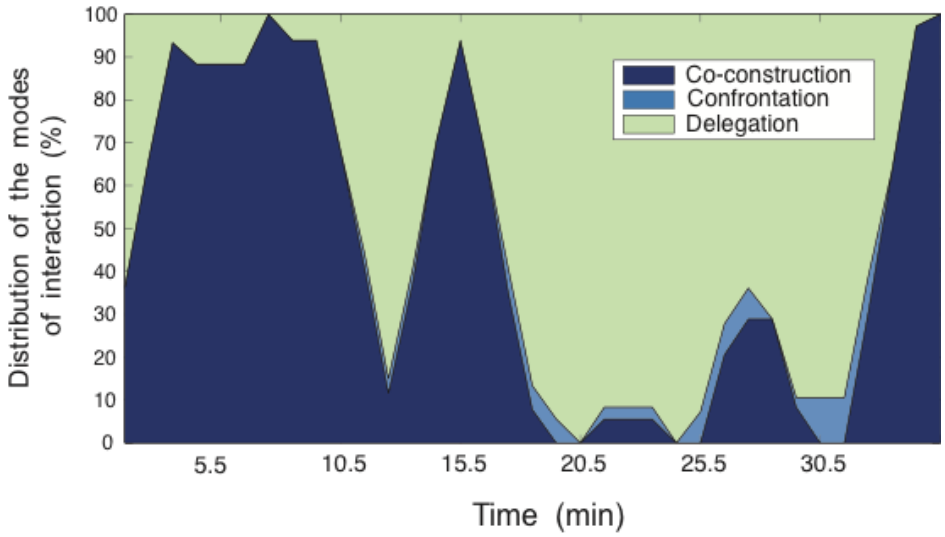

Figure 2: Distribution of the patterns of interaction in dyad 6 with the two-map context (from Jourand et al., 2018; reused with permission).

When the participants approached a trick checkpoint, the distributions of interactions indicated co-construction (Figure 3)

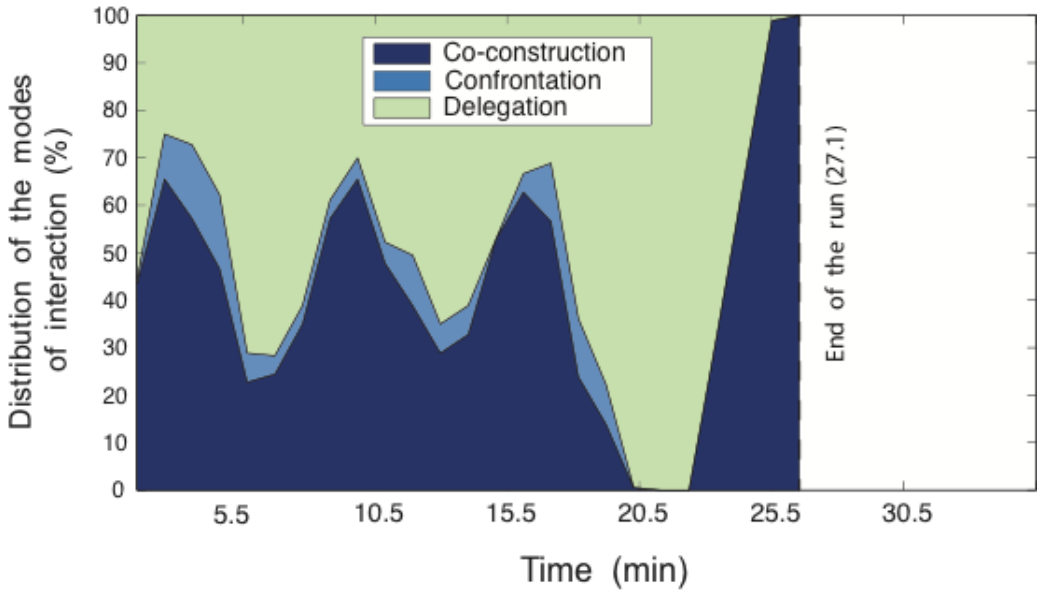

Figure 3: Distribution of the patterns of interaction in dyad 8 with the trick-checkpoint context (from Jourand et al., 2018; reused with permission).

These results emerged from the intertwining of methods from the course of action approach to proceed with phenomenological data and, from the ecological dynamics approach, to model the dynamics of the dyadic interactions by assessing the ratio of change and the distribution index of the patterns of interaction. This intertwining of methods offered new insight into the dynamics of interactions, with one main finding: The dynamics of interactions in learning are context-related (i.e., planning room, trick checkpoints, one map per participant shared by two), as demonstrated by the ratio of change and the distribution index of the patterns of interaction. These results also provide practical principles for pedagogical interventions. For example, to promote stability in one pattern of interaction, the PE teacher can take advantage of a participant's sensitivity to context cues, and tailor environments to task when stable interactions are desired. A planning room tends to stimulate exchanges between participants as they try to agree on an itinerary. In this case, building and validating an itinerary together, before leaving the planning room, encourages a shared project that the participants will carry out together. In essence, the participants co-designed the activity for the lesson. Conversely, to encourage variability, the PE teacher can distribute a different part of the map to each participant in the dyad, such that it cannot be used without associating the two parts. This proposal, to make participants work together with additional information, should foster a dynamic characterized by frequent changes in patterns of interaction.

In conclusion, this study exemplifies a 'productive synthesis' of intertwining tools and methods from enactive and ecological dynamics approaches to investigate learner - environment couplings. However, this productive synthesis requires some caution in interpreting the dynamics of dyadic interactions, especially in choosing the temporal window size and the overlap size to move the window. As mentioned previously, the phenomenological data from our study supported these methodological decisions in order to detect the different patterns of dyadic interactions and their changes over time.

2.2. Intertwining analysing tools from enactive and ecological dynamics approaches to assess the dynamic of learning in climbing

Synthesis of the study

Within the ecological dynamics approach, learning reflects the destabilisation and the reorganisation the existing perceptual-motor repertoire of each individual as a function of the task and environmental constraints (Button et al., 2020; Zanone & Kelso, 1992). Learning is characterized by a non-linear dynamics of the transition from one stable pattern to another (more functional one) (Newell, Liu, & Mayer-Kress, 2001; Schöner, Zanone, & Kelso, 1992). Viewed in this way, learning can include an intermittent regime during which the learner exploits behavioural patterns existing in their current repertoire and can search and explore new behavioural patterns to achieve the intended task goal (Chow, Davids, Button, & Rein, 2008; Chow, Davids, Hristovski, Araújo, & Passos, 2011; Komar, Potdevin, Chollet, & Seifert, 2019; Pacheco, Lafe, & Newell, 2019). This intermittent regime is accompanied by an alternation of regressions and progressions of performance (Nourrit, Delignières, Caillou, Deschamps, & Lauriot, 2003; Teulier & Delignières, 2007). However, this intermittent regime could also reflect how learners experience the task and environmental constraints, as they decide to exploit existing behaviours or explore new movement solutions. The enactive approach considers learning as meaningful lived experiences as the learner enacts a meaningful situation from their couplings with the environment (Newen et al., 2018; Stewart, Gapenne, Paolo, & Di Paolo, 2010; Theureau, 2015). The case study of Rochat et al. (2020) investigated how an individual learner enacted climbing fluency in a learning protocol in climbing. Both behavioural and phenomenological data were produced, and analysed together.

Synthesis of the study design

The learning protocol was composed of 10 climbing sessions (i.e., two sessions per

week) on an indoor, artificial wall and involved a single participant (Rochat et al., 2020). During each session, the participant performed three ascents on a control route, which never changed, three other ascents on a second route, which was a first variant of the control route, and three final ascents on a third route, which was a second variant of the control route. Emphasis in the lessons was placed on climbing fluency – that is avoiding pauses and saccades.

Phenomenological data were collected immediately after each lesson with self-confrontation interviews based on the video recordings of each climb (Theureau, 2003). The participant was invited to chronologically relive his meaningful experience throughout the climbing ascents. Then, according to methods advocated by Braun and Clarke (2006), a thematic analysis was conducted to inductively find similarities in the climber's intentions, actions, and perceptions in order to characterize the general dimensions that made up his course of experience and his definition of his enacted fluency. Finally the climber's course of experience (combining the general dimensions of the intentions, actions, and perceptions) was reconstructed for each ascent.

Behavioural data related to three fluency indicators, collected from a light and an inertial measurement unit, unobtrusively located on the back of harness worn by the participant: (1) the immobility ratio, which indicates the time spent stationary (Orth, Davids, Chow, Brymer, & Seifert, 2018), (2) the geometric index of entropy which refers to the complexity of the hip trajectory in space and time (Cordier, Mendès-France, Pailhous, & Bolon, 1994), and (3), the jerk of hip orientation, which is a spatiotemporal measure indicating the smoothness of the hip trajectory (Seifert et al., 2014).

Phenomenological and behavioural data were intertwined to determine the congruence/divergence between the climber's experience and his objectively measured climbing fluency. Then, we focused on when the climber perceived a meaningful perturbation in his climbing fluency, and we qualitatively characterized each episode on the basis of his

verbalizations during the interviews. We took into account the fluency scores in these episodes to investigate whether they were congruent or divergent with his perceived fluency.

Synthesis of the results and discussion

The results of the thematic analysis of the climber's intentions revealed three general dimensions: (1) Seeking and maintaining balance while climbing (23.4%), (2) Ensuring the correct execution of movement chaining (42.4%), and (3), Improving the timing of the climb (34.4%). The results of the thematic analysis of the climber's actions revealed four general dimensions: (1) Carrying out the planned chaining (57.6%), (2) Making errors while climbing (12.6%), (3) Deliberately modifying the planned movements while climbing (8.2%), and (4), Adjusting the foot chaining while climbing (21.6%). Results of the thematic analysis of the climber's perceptions revealed four general dimensions: (1) Sensation of being balanced (16.8%), (2) Sensation of being unbalanced (6.9%), (3) Sensation of efficient climbing timing (51.5%), and (4), Sensation of perturbed climbing timing (24.8%). Taking intentions, perception and actions together, the identification of these general dimensions indicated that the learner's definition of fluency was mainly linked to 'timing'. Indeed, his intentions mainly referred to improvements in timing, while his perceptions, mainly referred to the sensation of efficient or disturbed timing, which were mainly actualized through the execution of a planned chaining. For him, efficient timing related to no saccades, no stops, and being in constant movement.

The intertwining of the phenomenological data with the measured fluency scores revealed both convergence and divergence, which allowed us to identify four crucial episodes in the dynamics of the climber's experience (Figure 4). These episodes were identified as crucial because they were characterized by disruptions in the climbing timing. The first episode occurred at the fourth ascent and related to an unplanned hand-crossing that disrupted the timing, an observation supported by poor fluency scores that appeared in the third tercile

(Figure 4). The second episode concerned the ascents 10 to 12, during which the participant's feet positioning slowed down the ascent. This negative perception of fluency was confimed by the fluency scores in the third tercile. The third episode related to ascents 22 to 24, which was experienced as the sensation of inefficient slowness. Although he perceived his fluency as poor in this episode, these negative perceptions were contrasted by the fluency scores, which moved to terciles 2 and 1, especially for the 24th ascent. Last, the fourth episode concerned ascents 27 and 28 during which saccades and compensation were experienced, although this episode was characterized by good fluency scores in tercile 1.

In conclusion, this study also exemplifies a 'productive synthesis' of enactive and ecological dynamics approaches to investigate the individual - environment couplings, in particular to understand how the dynamics of a learner's experiences could explain the variability (captured as progression – regression tendencies) of performance observed during the learning process. Indeed, by intertwining phenomenological and behavioural data, we could identify crucial episodes in the dynamics of learning where the learner explored and experienced new solutions (revealed by the complementarity of thematic analysis of intentions, perceptions and actions).

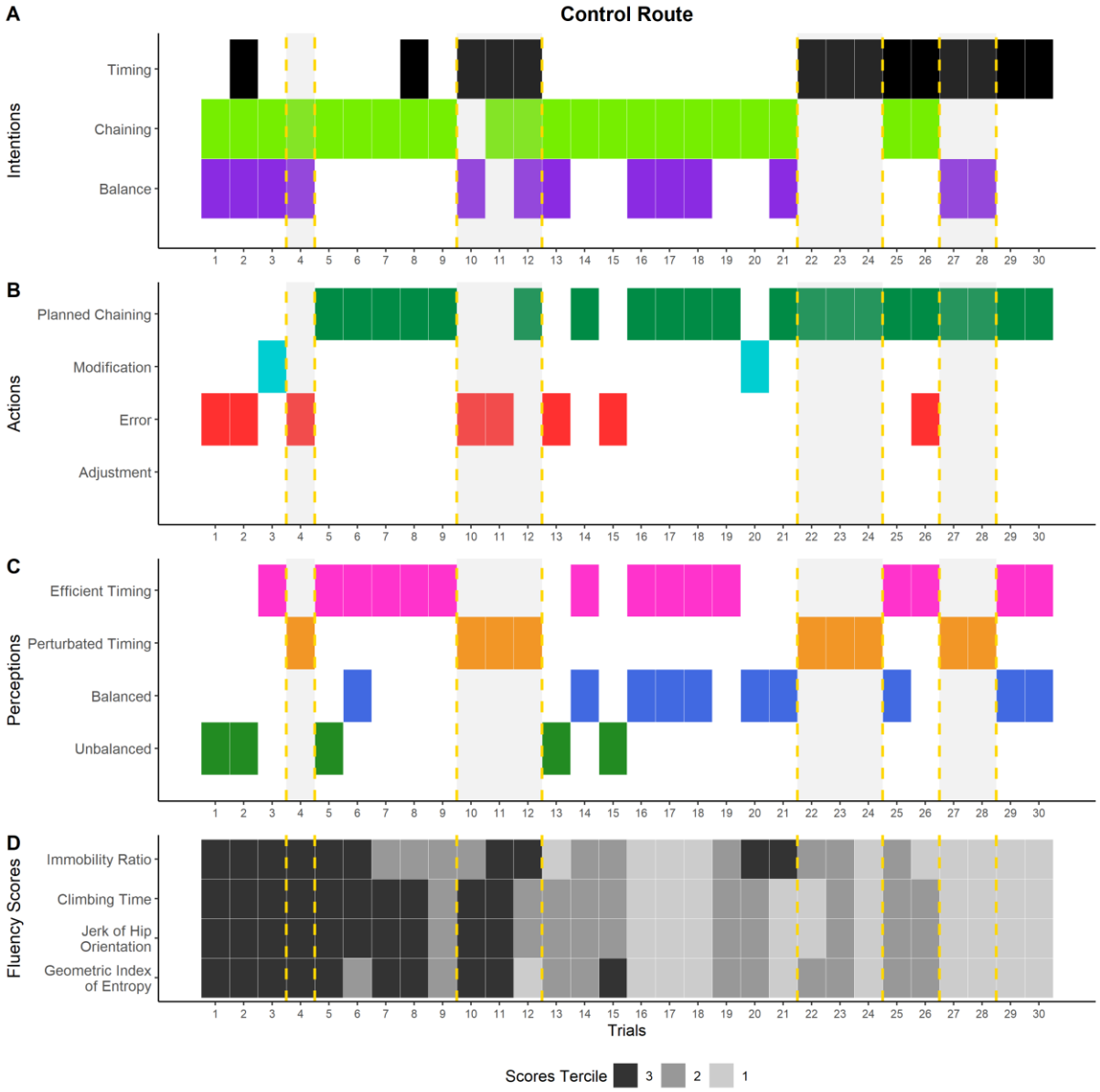

Figure 4. Dynamics of the climber's experience and fluency (from Rochat et al., 2020). Panels A–C show the temporal organization of the general dimensions of the different components of experience detected during the interviews. Panel A shows the general dimensions of the climber's intentions: Improving the timing of the climb (black), ensuring the correct execution of movement chaining (light green), and seeking and maintaining balance while climbing (purple). The climber's actions are shown in panel B: carrying out the planned chaining (dark green), deliberately modifying the planned movements while climbing (light blue), making errors while climbing (red), and adjusting the foot chaining while climbing (gold). Panel C shows the general dimensions of the climber's perceptions: sensation of efficient timing (pink), sensation of perturbed timing (orange), sensation of being balanced (dark blue), and sensation of being unbalanced (green). Panel D shows the score terciles for each fluency indicator. The climbing performance is expressed in the terciles: tercile 3 (in black) refers to his poorest

performances, tercile 2 (in dark gray) refers to his intermediate performances, and tercile 1 (in light gray) refers to his best performances. The vertical dashed lines delimit the crucial episodes in the climber's experience.

3. Discussion

Our analysis evaluated two studies to explore the potential of intertwining the enactive approach (in particular the course of action research program) and the ecological dynamics approach. There have been some suggestions advocating the potential theoretical value of this intertwining of methods and data from the different research programs, as well as the opportunity to understand the complexity of the process of sensorimotor learning in a new post-cognitivist paradigm (Gallagher, 2017; Segundo-Ortin, 2020). However, further work is needed to turn these theoretical insights into practical guidance for improved teaching and learning in PE. Here, we discuss the richness and limits of intertwining the course of action and the ecological dynamics approaches from the point of view of PE research. On this basis, we propose practical implications from the potential productive synthesis of those two approaches.

Complementarity and difference from the point of view of PE research

When it comes to conducting research on intervention situations in PE by intertwining the course of action and the ecological dynamic approaches, our research identifies two sources of complementarity and one of differentiation. Concerning complementarity, intertwining those two approaches offers the opportunity to establish connections and interrelations between first and third person data, *corroborating, unveiling,* or *initiating* relationships to examine (Adé et al., 2020; Greene, Caracelli, & Graham, 1989).

The *corroborating* relationship refers to the intertwining of different types of data, supporting convergent results and increasing the validity of findings produced by a single data source. For example, this was the case in the climbing study when, for some ascents by the participant, the good fluency scores were confirmed by the learner's perceptions.

The *unveiling* relationship corresponds to the uncovering of results, which without this intertwining of methods, tools and data, would remain unknown or in the shadow of the complementary research work. For instance, in the orienteering study, without discretising packets of the experience data into quantitative data (i.e. patterns of dyadic interactions), we would not have been able to map and analyse the dynamics of interactions in orienteering (i.e. by quantifying the ratio of change of patterns and by computing the distribution index of those patterns) in relation to the learning context (i.e. planning room, trick checkpoints, one map per participant shared by two). This observation is well aligned with the insights of Henri Poincaré (1902) the founding father of dynamical systems theory, who argued that the main objects of science are not variables, but rather the *relationships* between variables.

Finally, the *initiation* relationship, characterized the emergence of new research perspectives through the intertwining of heterogeneous data. For instance, in the climbing study, the divergence between good fluency scores and the perception of dissatisfaction and discomfort of the climber opens up research perspectives which question the 'sense of measure' (Gal-Petitfaux et al., 2013; Volkoff, 2005) or the data status when they are heterogeneous, i.e. the primacy to be afforded, sometimes, to experiential data, sometimes to empirical observations of behaviour (Adé et al., 2020).

Another complementarity emerges when data may be interpreted differently by intertwining tools and methods from one approach, that are not used in another approach. This was the case in the orienteering study, which used common tools and methods of ecological dynamics to map and to analyse the dynamics of interactions. Defending the idea that the method is linked to the theoretical pillars underpinning a scientific approach, this methodological *borrowing* seems admissible to the extent that the course of action and the ecological dynamics approaches share common epistemological features: the focus on the coupling of person and environment in continuous interaction.

However, the conditions for collecting third-person data from an ecological dynamics approach are not always compatible with the actual contexts of PE lessons. Researchers are then faced with a dilemma: (i) preserving the actual learning situation by depriving themselves of the contributions of some third-person data, accessible via research methods and tools requiring experimental conditions; or (ii), accepting these constraints and freeing oneself from the *in situ* dimension by finding compromises in the design of more 'controlled' (i.e. focused) investigative environments. This was the case in the climbing study, where the tools used to compute the fluency scores and comply with the conditions of practice did not allow data collection within an actual PE lesson. Within this intertwining of enactive and ecological dynamics approaches, this dilemma raises questions on the contextual constraints that must be respected in order to preserve the representative design of the studied PE situation and for collecting heterogeneous and significant behavioural data, in order to provide meaningful findings of practical relevance for PE teachers. Logically, these conditions seem acceptable to us if the learner activity takes place either in; (i) an actual behavioural context (such as in the orienteering study), or (ii), in a representative learning design overseen by the researcher (see Araújo, Davids, & Passos, 2007; Brunswik, 1956; Davids et al., 2012; Pinder et al., 2011), but encouraging the participant to behave naturally as they would in the learning protocol (as in the climbing study).

Implications for PE teachers resulting from this productive synthesis

Due to their epistemological convergence concerning the emergent coupling between an individual and the environment, the course of action and the ecological dynamics approaches do seem to share common orientations concerning the learning of skill. For example, they share the idea that the learning process is the product of practice and experience, as well as continuous, creative, adaptive interactions between the learner and the environment. They also

both consider that the learning process is inseparable from acting, which leads to *knowledge of* the environment gained actively by the learner (see examples in PE and high-level sport by Rudd, Pesce, Strafford, & Davids, 2020; Woods, Rudd, Robertson, & Davids, 2020). On this basis, each approach works to draw the outlines of a PE pedagogy precisely reflecting its conceptualisation of the learner - environment coupling.

The course of action focuses on a learner's entry into the coupling and favours a conceptualisation of learning the construction of meanings emerging from the interactions between the learner and their learning environment. In this conceptualisation, a so-called 'active' or 'inside' pedagogy is developed (Saury et al., 2013; Sève & Terré, 2016). This pedagogy aims to: (1) encourage students to have typical experiences (i.e. experiences that promote the development of 'dispositions to act' in familiar environments); (2) help to build collective learning stories (i.e. encourage mutual help between students to make emerge community of practice in the classroom); and (3), investigate the experience of the students (i.e. help the students to verbalise their salient experience, to re-live their salient actions).

The ecological dynamics approach focuses on the learner-environment system as acomplex, coupled relationship, conceptualising learning as a continuous re-organisation and adaptation of the entire extended system constituted by the individual learner, their environment, and especially, the relational structure connecting the two. Due to this interactive, process-oriented focus, group and individualised analyses are both important in terms of empirical observations. This re-organisation reflects the emerging coupling between the learner and a set of interacting constraints (i.e. organismic, environment, and task; Newell, 1991) to achieve an intended task-goal (Button et al., 2020; Davids et al., 2012). This coupling is continuous, complex, dynamic, non-linear and adaptive for each individual, which led to the well-known 'non-linear' pedagogy (Chow, 2013; Chow et al., 2007, 2011, 2016). Thus, non-linear pedagogy advocates the manipulations of key constraints on learners during practice and

the analysis of how each individual continually adapts to these surrounding constraints.

Based on the contributions of research on interventions in PE, conducted from an approach intertwining the course of action and the ecological dynamics, and with regard to the pedagogies developed respectively by each approach separately, our ambition is to propose the outline of a pedagogy likely to gather these two approaches and to express their productive synthesis: 3E pedagogy: *Exploration*, *Experiential* and *Empathetic*.

First, this pedagogy promotes the importance of placing the student in a situation of *exploration* in the learning process, that is to say 'exploring to learn and learning to explore' (Hacques, Komar, Dicks, & Seifert, 2020). It should be noted that there are similar advances in PE pedagogies, such as embodied exploration in learning (e.g., Barker, Nyberg, & Larsson, 2020). These contemporary educational approaches seek to help learners become more responsive to emergent opportunities for action available in the environment. As highlighted elsewhere (e.g., Rudd, Woods, Correia, Seifert, & Davids, 2021), adopting and recognising the Latin root of the word 'education' as *ex-ducere*, the long-term aim for PE becomes one of 'leading out' and encouraging children to engage in physical activity beyond the school setting. Students' exploratory activity should be encouraged by continuous manipulations of the components (e.g. task constraints) of the PE lesson, by the teacher as a 'learning designer' (Chow et al., 2011). By designing and selecting the material, temporal, spatial and social characteristics of the lesson, the PE teacher could open up possibilities for the student to explore the task and environment, while discouraging some behaviours that might be ineffective or risky for the student (for an example in climbing; Seifert, Boulanger, Orth, & Davids, 2015). In this sense, the teacher becomes a 'designer' and an 'architect' (Adé, 2016; Button et al., 2020), who sets a learning environment that invites exploration of specific fields in a rich landscape of affordances (Rietveld & Kiverstein, 2014). The design of rich landscape of affordances seeks to educate intentions and the attention of learners (i.e. through the process of attunement)

(Jacobs & Michaels, 2007). This richness should allow 'safe' exploration, as the learner can explore innovative and adaptive behaviours and task solutions and at the same time they have a back-up or a fall-back to exploit their existing repertoire of skills (Seifert et al., 2015).

Second, this rich landscape of affordances should allow each student to *experience* and to enact his or her own world (i.e. '*umwelt*'; von Uexküll, 1992) through their self-regulating sensorimotor activity (Di Paolo, Buhrmann, & Barandiaran, 2017; Thompson & Stapleton, 2009). The learner experiences situations that they recognize as effective, comparing various sensorimotor experiences. To achieve this aim, the teacher can, for example, organize climbing debates between the climber and the belayer to offer them opportunities to help each other, to share their experiences and to learn about similar problems, essentially and opportunity to reflect and interrogate their experience in an informal implementation of the course of action approach. The teacher can also design task situations familiar to the students in order to remind them of a learning situation already experienced and associated with effective actions. The sense made by the learner in their interactions with various environments would constitute 'traces of experiences' (Theureau, 2015). Indeed, learning is about adapting to environments by experiencing similarities between different environments, which may facilitate transfer of *knowledge of* the environment and skills (Chow et al., 2020). To promote this experience, designing learning tasks consists of providing students with salient, crucial movement activities and experiences. This process involves amplifying some experiences in order to focus the student's attention on particular engagement and relations with the environment. As an example, amplifying an experience may involve temporarily decreasing one source of information (e.g. vision) to reveal others (e.g. haptic) by inviting students to climb a route with their eyes closed. It may also involve changing the conditions of achievement by adding unusual objects in the performance context. For example, in orienteering, the teacher can group several checkpoints in a narrow space, which may create some confusion at the immediate location of

the useful checkpoint. This modification could amplify the value of *knowledge of* the environment to the learner (Rudd et al., in press; Rudd et al., 2020), emphasising the importance of being attuned to relevant information for action and checking them before making any final decisions. It could encourage perception, cognition, actions, deeply intertwined in processes of problem-solving and decision-making.

Finally, accessing the experiences of the students, seems to be favoured by an *empathetic* attitude of the teacher to 'access the student's world'. Adopting an *empathetic* attitude reflects the ability to put themselves in the student's shoes in order to understand what they think, perceive, feel during the learning activity. Our theoretical proximity to phenomenology leads us to consider empathy as a form of inter-subjectivity. Thus, by taking students' subjectivity into account in their field of personal experience, the teacher's field of experience is no longer subjective but becomes inter-subjective. This is because it is made up of both their own subjectivity and that of the students. For a PE teacher, this empathetic posture can take various forms such as accessing the student's workspace to change their own point of view, like 'co-designing' the task with the student. For instance, the PE teacher can set the starting hold and the end hold, and then provide eight climbing holds to the student who must choose four of them to link the starting and end holds. This empathetic posture can also relate to share motor activity with the students, in order to co-experience the learning situations and consequently the effects of the action. It could also help the students to verbalize their experiences, to relive their actions during learning activities. This narrative should stand out from the verbalization of action as defined in the cognitivist and representational paradigm, which favours a normative discourse targeting analysis, judgment and conceptualization and is closer to what has been termed *knowledge about* the environment (Gibson, 1966; Rudd et al., 2020). Rather, it is important that the teacher implements favourable conditions to allow students to interact with *knowledge of* the environment (Gibson, 1966; Rudd et al., 2020),

seeking to develop an 'active, responsive learner'. This process may be enhanced through questioning aimed at keeping the student in touch with the experienced situation and to place them in a position to seek to understand and *enact*, and not just describe, their intentions, perceptions and actions.

4. Conclusion

The relationships between the enactive and ecological approaches have begun to arouse major interest and debates in the cognitive science community (McGann, Di Paolo, Heras-Escribano, & Chemero, 2020). Some researchers involved in the rapprochement between these two approaches have even suggested the idea of an 'ecological enactivism' or 'ecological enactive' approach (Baggs & Chemero, 2018; Heras-Escribano, 2019; Kiverstein & Rietveld, 2018). In this article, we sought to assert the scientific potential of intertwining the course of action and the ecological dynamics approaches and the need to consider this productive synthesis to propose practical implications for PE teachers. On this last point, we drew the outline of a 3E pedagogy (exploration, experiential and empathetic), which needs to be further evaluated, outlined and shared with PE teachers, in further research to study its outcomes.

Disclosure statement

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