How could process-oriented research approaches capture the interplay between training and competition in athlete performance preparation? The contribution of ecological dynamics

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Abstract

Analyses of training or competition environments traditionally tend to adopt a product-oriented perspective through the recording and statistical analysis of performance outcomes. Consequently, most investigations continue to ignore the *processes* underpinning functional achievement of outcomes, therefore, failing to examine contextual effects of how and why performance evolves. This critical research note highlights the need for sport psychologists, pedagogues, and other applied scientists to consider a range of alternative methodological designs for research to monitor and explain processes inherent to performance preparation and athlete development. These process-oriented designs require the continuous flow and exchange of performance data between training and competition, mediated by practitioners' experiential knowledge. We endorse a triangulation of information defined as a 'competition-coach-training' triad which needs to be better acknowledged. Redirecting the focus of practice and research away from a product-oriented (driven by broad statistical data patterns), towards a process-oriented perspective (examined through in-depth contextual analyses) may re-calibrate the theory-practice alignment.

Keywords: process-oriented approach, athlete development, contextual analysis, performance analytics, mixed-methods research, ecological dynamics

Highlights

- Performance analysts could adopt a process-oriented approach to athlete development
- Advances in mix-methodological designs could contribute to research innovations
- Athlete-environment interactions during performance must be better acknowledged
- Coaches’ experiential knowledge can mediate practice designs using competitive data

Introduction

In seeking a better understanding of how to develop and prepare athletes and teams for competitive sport, applied scientists typically acknowledge the importance of integrating information between performance in training and competition. For example, a key issue concerns the implementation of the longstanding principle of practice specificity (Henry, 1968) related to the importance of designing practice tasks aligned with competition demands. Specifically, the training specificity hypothesis proposes that, as the constraints of learning designs approximate those of competition, there are greater opportunities for a positive transfer of learning (Tremblay, 2010). Without neglecting the contribution of other psychological approaches, which have sought to enhance knowledge in sport performance research, the concepts of ecological psychology, by considering the mutuality of the of individual-environment relationship, have enhanced understanding of practice and training processes underlying performance outcomes. For example, associated with practice specificity, the ecological concept of *representative design* (Brunswik, 1956) has gained prominence in protocols for competitive sport performance preparation. Representative learning design suggests the inclusion, in task designs, of similar informational constraints characteristic of competitive environments (Pinder et al., 2011). Here, *constraints* refer to information that shapes the emergence of athletes' performance behaviours , providing them with opportunities for action (i.e., affordances (Gibson, 1979). Information from rules, equipment, surfaces, objects, events and other athletes are examples of constraints that may induce different action opportunities.

The building of representative designs challenge practitioners to sample the most relevant information sources from competition considering the age, maturation, sex, and skill levels of athletes (Woods et al., 2019). Through their experiential knowledge, based on learning over years of practical experience and reflection (Nash & Collins, 2006), practitioners may record, retrieve and interpret competitive performance data, distilling it to guide athlete(s)-environment interactions in representative designs. An ecological dynamics framework proposes that practitioners can achieve this aim by helping athletes to perceive and utilise relevant affordances in the environment (Greenwood et al., 2013). From this rationale, a major task for applied scientists is to develop evidence-based methodological designs which enhance understanding of the *training processes* underlying the achievement of *outcomes* in competition. Here, we advocate and conceptualise a *process-oriented approach* forperformance preparation interventions to design representative practice programmes adjusted to individual athlete needs. In these process-oriented practice designs, individualised opportunities for action may be embedded in preparatory performer-environment interactions prior to competition. From an ecological conceptualisation, processes refer to *why* and *how* a set of task constraints may be manipulated during practice by sport practitioners, supporting the emergence of intended technical, tactical, physical and/or emotional outcomes.

Elsewhere, we have argued that a process-oriented approach to designing athlete interactions is fundamentally based on *knowledge of* the performance environment (Ramos et al., 2020), which Gibson (1966) distinguished from *knowledge about* the environment. He clarified that *"…a distinction* [can] *be made between perceptual cognition, or knowledge of the environment, and symbolic cognition, or knowledge about the environment. The former is a direct response to things based on stimulus information; the latter is an indirect response to things based on stimulus sources produced by another human individual. The information in the latter case is coded; in the former case it cannot properly be called that."* (Gibson, 1966, p. 91).

In sport, *knowledge of* the performance environment helps support athletes' learning and performance by facilitating the construction of individualised relationships between knowledge, perception, and action to facilitate their ongoing interactions in competition (Araújo et al., 2019). In turn, *knowledge about* the environment may be provided by an external agent to describe the environment. This type of knowledge helps support verbalised responses in problem-solving and decision-making through mediation of language, abstract symbols, and instructions (Gibson, 1966). Specifically, Ramos et al. (2020) highlighted how *knowledge of* the performance environment is continuously needed in preparation, used by athletes to regulate their interactions with its problems, events, tasks and challenges during competition. In contrast, *knowledge about* the environment is more abstract, descriptive, and can be more easily symbolically coded, underpinning the capacity to describe or verbally respond to questions about tactics and strategies. This type of information is over-relied upon by sport commentators, traditional instructors, coaches and data analysts. The clear implication of Gibson's (1966) distinction for sport science is that performance analytics data should be interpreted and used to develop players' *knowledge of* the environment in a process-oriented way. Doing so, practitioners could enrich their monitoring and evaluation of continuous athlete-environment interactions in performance preparation.

For instance, in a volleyball training application, if notational data from performance patterns in competition reveal low values of blocking success percentages for a team, subsequent training sessions could address this issue in diverse and gradual ways, providing affordances for: (i) players to individually coordinate their block actions as a function of different attacking tempos (constraint of time); (ii) players' blocking actions to emerge as function of the opposition setter's tactical decisions, integrating the block action into tactical game scenarios (constraints of time and space); and (iii) designing full team practices in which successful block actions are double-scored (narrowing applications of time-space blocking actions into game contexts representative of competition). Here, the richness in analysing the performance preparation and development *process* requires an in-depth examination of *how* sport practitioners use statistical competitive performance data to support their practice designs.

Thereby, research needs to explore why coaches design specific types of performance preparation tasks, and how their interventions could be adapted as the needs of athletes and demands of competition change. Notwithstanding its relevance, there are several barriers inhibiting the progress of this *process-oriented approach* to applied sport science research.

First, despite the need for a clear association between training and competition data, applied scientists have tended to investigate these contexts independently (Ribeiro et al., 2020). This de-compartmentalisation of research on practice and competition contradicts the assumptions behind the aim to enhance competitive performance. Furthermore, it also refutes spractitioners' use of data from competitive performance to improve training designs, to satisfy athletes' needs, and to potentiate further performance outcomes. Also, such a separation provides a lack of clarity on how performance and practice contexts mutually shape each other, raising important questions, like: Is the way a team trains closely aligned with how it competes? During training sessions, are competitive constraints faithfully represented in practice tasks? A broader question is posed over whether performance during practice may, or not, be a valid indicator of athlete learning. Indeed, Whiting (1975) proposed a long time ago that *learning* is difficult to directly observe, evaluate and confirm, whereas *performance* is much easier to observe, although the latter may or may not be indicative of the former. Moreover, he highlighted that, at the heart of the confusion between performance and learning, lies the need to distinguish between performance *outcomes* and *processes* when investigating whether learning has emerged as a result of practice and experience (Whiting, 1975). These words of caution signify the need to carefully interpret data from both, competitive performance and observations during practice, when seeking to understand the effectiveness of learning designs on athlete preparation and development.

Second, constraints on competitive performance have increasingly been investigated using notational methods (Lord et al., 2020). This method documents action frequencies in a ‘what-where-when-who’ sequence of analysis, for instance indicating that one football player has successfully completed fifteen out of twenty passes attempted during offensive transition-phases in a match. Despite its relevance, this *data-driven*, statistically-oriented approach runs the risk of falling into a reductionist and linear cause-effect vision of competitive performance (Araújo et al., 2021). Over-relying on statistical outcomes, the emergent nature of continuous performer-environment interactions with competitive surroundings is often disregarded. An implication of these ideas is that a powerful theoretical framework is needed to support the utilisation and interpretation of performance data for the design of pedagogical practice (Araújo et al., 2021). Because team sports may be viewed as complex dynamical systems (those formed of multiple elements (athletes), whose interactive relations evolve over different timescales), performers’ interactions in competition are emergent, leading to adaptive transitions in system states. The dynamical property of *emergence* helps teams to rapidly co-adapt to dynamics of the competitive environment, facilitating achievement of intended performance goals (Travassos et al., 2013). Although these team properties are challenging to measure using traditional analytic methods, they can be captured and analysed through nonlinear measures. Particularly, nonlinear metrics quantify the relationship, or dependency, of data in a time series, describing their patterns or structures (Harbourne & Stergiou, 2009). In this respect, the ecological dynamics framework has conceptualised and empirically explored how nonlinear performer-environment interactions continuously evolve to shape sport performance (Araújo et al., 2021; Davids et al., 2015).

Third, an ecological paradigm has been adopted using cross-sectional designs framed upon positivist research premises, in which interventionist protocols are implemented over the first or last 20 mins of training sessions (e.g., Oppici et al., 2018). Interestingly, research has demonstrated that changes in short-term performance are frequently unrelated to long-term learning, creating a powerful illusion of competence (Björklund, 2013; Soderstrom & Bjork, 2015). Indeed, modelling and investigations from an ecological perspective have shown how performance during learning over short timescales can look messy, noisy and highly variable, although looking smoother over longer timescales (Newell et al., 2001). Empirical data reported by Newell and colleagues (e.g., 2001) have important implications for how academics and coaches could view the relational timescales for interpreting *performance outcomes* and *learning*. However, in understanding sport performance and practice, further work is needed to explain and interpret effects of ecological assumptions on athletic performance. To support this advance in research, it is vital to consider the *training process as a whole*, taking into account the global training context and structure, and re-designed learning tasks throughout extended timescales.

Fourth, many empirical investigations, despite innovative, explicitly require in their research designs that coaches do not provide any feedback to athletes (e.g., Travassos et al., 2018). This requirement is not representative of pedagogical practice since the coach's role is reduced to a mere prescriber of training tasks. This reductionist pedagogical position has been broadly criticised because coaches are not allowed to be actively engaged in athlete performance development (Robertson et al., 2019). Indeed, sport practitioners have a significant role in helping athletes to understand what to do in order to improve their interactions with a performance environment. For instance, using interrogative feedback, the coach could scaffold an individual's actions without compromising their autonomy in building their own knowledge of the environment. Recently, Ribeiro et al. (2020) showed how pedagogical principles of ecological dynamics asserts that a subtle balance is continuously needed to provide *local* athlete interactions, supported by *global* coach guidance, so that functional and adaptable coordination tendencies could emerge in performance.

Overall, these critical issues illustrate how some competition-training informational linkages in pedagogical practice may be currently dysfunctional, giving rise to the following overarching questions: (i) Has sport science research focused enough on the relevance of *how* practitioners use competitive data to interpret practice and its effects on performance over longer timescales? This mutual interaction between *product-process* oriented data could favour an interpretative analysis about *how* performance can be developed over-time, rather than focusing on *what* performance outcomes can be immediately achieved; (ii) Have prevalent sport science research designs been appropriately aligned with the need to understand how athletes prepare to compete? (iii) What role may coaches' experiential knowledge (CEK) play in driving competitive performance preparation and athlete development? and (iv), Can CEK emphasise the links between theory and practice within an applied sport science context?

To consider these issues, research needs to focus on understanding the relations between performance achievements as end products of a dynamical learning process. Applied sport science research needs to focus on examining how competitive performance preparation is planned, implemented, and adapted to help individual athletes develop and prepare to face demands of competing. Specifically, it is worth examining why, and how, sport practitioners design training sessions within programmes, as well as the implications of these design processes for preparing athletes to perform in competition. In this critical research note, we highlight the importance of considering the nuanced interplay of information between competitive and performance preparation data, within an ecological dynamic framework. We seek to examine the methodological implications of evaluating, elaborating and refining the performance-preparation relationship in future research. Accordingly, we start by scrutinising how competitive performance data can guide coaching processes during athlete preparation for performance development and competitive performance. Next, we propose alternative methodological research designs so that future applied scientific studies can monitor, explore, and examine in-depth the processes underpinning performance development. Finally, we discuss the role of CEK and sport practitioners in bridging practice and theory for the purposes of enhancing sport performance and athlete development.

Using data analytics in performance preparation: Opportunities and barriers to athlete performance enhancement

Generally, performance analytics can inform practice designs by: (i) providing feedback about previous competitive performances, (ii) advising on critical events, features and/or performance tendencies that may arise during future competitions, and (iii) offering feedback for designing representative training sessions (Araújo et al., 2021; Eccles et al., 2009; Woods et al., 2019). Framed upon competitive performance data, practice programmes broadly have two overarching interventionist purposes: coaching for athlete development and coaching for competitive performance.

The focus of *coaching for athlete development* is on the enrichment of athlete skills and expertise over time. In contrast, *coaching for competitive performance* aims to achieve successful performance outcomes, such as winning a competition. Overlapping at times, from novice to expert stages, the relationship between performance and development can be observed at different levels of accomplishment and varied scales of analysis (see Otte et al., 2021; Sullivan et al., 2021; Wormhoudt et al., 2018). Acknowledging the importance of competitive performance, from a macro-scale of analysis during athlete development pathways, the main focus should be on supporting athlete development. Indeed, such a standpoint avoids the (mis)treatment of children and youth as 'mini-adults'. At expert performance levels this relationship is never eliminated, but re-prioritised to place greater emphasis on competitive performance. From a meso-perspective, when coaches are structuring their weekly practice micro-cycles, the beginning of the week is commonly dedicated to athlete and/or team development. Later, competitive performance demands become more prominent closer to a competitive event. At a micro-perspective, training designs starts involving athlete development, ending in preparing individuals for competitive performance in collective tasks. To exemplify, training sessions often start by addressing a tactical problem for each team sub-unit and ends with all the sub-units being integrated in a full-game practice, intentionally constrained by specific conditions to readdress the initially identified problems.

To support performance preparation, sport practitioners have used notational analysis for decades to structure training content (Lord et al., 2020). However, by correlating action frequency with final performance outcomes, like score or error, the processes underpinning continuous and dynamic athlete-environment interactions are often disregarded (Duarte et al., 2012). To deal with this issue, the ecological dynamics framework, aided by non-linear metrics, such as sample entropy or relative phase, have been used to explain how such dynamical interactions constrain the emergence of different game patterns (Marcelino et al., 2020).

By cross-sectionally analysing the impact of isolated experiments, investigations have provided detailed and relevant information about how constraints manipulations affect sport performance (e.g., Travassos et al., 2018). However, a challenge for such studies has been how to consider the representative design inherent to effective competition-training interactions. Furthermore, despite seeking to focus on athletes' needs, these empirical studies have rarely considered or reported *why* specific task constraints were manipulated, neither its relevance for athlete development and performance preparation. The result is often ineffective and inefficient practice designs for athletes and decontextualized data for coaches. In this regard, Fullagar et al. (2019) argued exactly that practitioners have lamented that research questions remain misaligned with coaches' needs for implementing scientific evidence into practice. Indeed, the representative design of practice in coaching needs to be carefully considered since learning and performance development is athlete-dependent. Both processes emerge over different timescales based on athlete needs, intentions, and interactions with the environment and not necessarily when coach desires. Thereby, the focus of teaching-learning processes should be athlete-centred (Ennis, 2014). Here, the athlete is placed at the core of the learning process, playing an active role in building their knowledge of, and skills for, competitive performance. Thereby, sport practitioners can assume the role of learning facilitator, for instance by setting challenges, problems or goals, simplifying or complicating learning tasks, and providing opportunities for learners to seek performance solutions within a representative practice design (Dyson et al., 2004).

Because of these methodological issues, the processes inherent to holistic performance development have been somewhat overshadowed by the intrinsic competitive nature of sport. Nevertheless, this product-oriented approach, captured frequently in the form of generalised recipes or quick fix programmes, may not lead athletes towards long-term personal development and learning (Soderstrom & Bjork, 2015). Countering this trend requires the retrieval of accessible information from competitive performance that considers the interactive nature and complex character of the environment so that training designs can be more representative of competition (Araújo et al., 2021). There is also a need to examine training as an *individualised holistic process* to fully understand how practice may be designed to support each athlete's needs in competition. The (re)establishment of competition-training retroactive feedback requires in this vein a re-orientation from a *product* to a *process* perspective. Specifically, it entails moving from an outcome-oriented to an emergent-behaviour rationale underpinning practice design. The reverse of this trend can be supported by adopting an ecological perspective, an interpretative paradigm, and inductive reasoning, as we next address.

What can we do in future research investigations into the performance-practice relation? – Redefining methodological routes

Sport is a largely social phenomenon, and therefore, the paradigm adopted for its analysis must be aligned with its human (i.e., social and cultural) context (Giulianotti, 2016).

The well-established interpretative paradigm (Carr et al., 1994), more popular in the social sciences and humanities, should play an important role in this respect. An interpretivist approach advocates an inductive reasoning that seeks to make broad generalisations from specific observations. Specifically, many events are observed in detail, patterns are discerned, and explanations are inferred by individuals seeking to maintain objectivity, while recognising the inherent subjectivity of human experience (Klauer, 1992). The main advantage of the interpretative paradigm is that it tries to understand a phenomenon in-depth, such as the meaning of athletes' behaviours within a particular performance context (Smith & Sparkes, 2018). Here, we advocate *inductive reasoning* to comprehend the training process, instead of a deductive reasoning that seeks to explain performance outcomes as products. However, to achieve this change it is essential to reformulate traditional research designs. Next, we propose several somewhat innovative ideas that could *(and perhaps should)* be included in the research designs of future investigations.

First, regarding data analysis in competitive performance, there is a need for more longitudinal investigations with ongoing tracking of '*dynamic performance-analysis'*. Specifically, the selection and recording of performance variables is most relevant, with the key performance indicators being used to underpin designs of training contexts. As athletes train to compete, the information retrieved from analytics of competitive performance must be aligned with what was intended to be achieved. For that purpose, we endorse the integration of nonlinear metrics, like the cluster-phase method (Richardson et al., 2012), with robust and linear statistical methods. Adopting a nonlinear methodological approach would ensure that information collected is representative of the competition environment. Such approach considers the complexity of athlete(s)-environment interactions, without fragmenting them into a discrete set of cumulative statistical procedures that disregards the ecology of performance. Later, follow up comparisons and/or inferences from data may be analysed with linear procedures. Finally, applicable and relevant information can be shared by practitioners. To exemplify, Ribeiro et al. (2020) used a multilevel hypernetworks approach to collect data on player-simplice synchronies in two distinct performance conditions. First, they assessed the ecological dynamics of play, adopting nonlinear procedures, namely using cluster-phase method and sample entropy. Then they followed up these observations by testing effects on synchronies of both conditions using a conventional statistical analysis such as univariate analysis of variance.

Second, we recommend a greater focus on implementing Action-Research (AR) designs (Lewin, 1946). The AR is characteristic of a process-oriented interpretative paradigm, which have rarely been applied to sports training contexts (e.g., Ramos et al., 2020). Studies focused on understanding sport performance enhancement could benefit from this design given its cyclical, interventive and reflexive nature (Ollis & Sproule, 2007). In fact, AR affords the capacity to monitor, assess and intentionally adapt coaching interventions designed to develop performance over extended time-periods. Also, aligned with interpretative approaches, the adoption of qualitative research designs could unearth unique information, like the 'hows and whys', for sport practitioners. For instance, through qualitative analysis, McCosker et al. (2019) extended our understanding of how elite long jump athletes adapt their actions during performance in structured competition. Thus, the authors offered to sport practitioners some insights on how elite athletes regulate their performance behaviours while interacting with different competitive contexts, highlighting the perform, respond, and manage contexts of performance.

Third, and perhaps the most innovative idea, we suggest the integration of nonlinear metrics and linear statistics within an interpretative approach to extend the comprehension of observations. For instance, Ramos et al. (2021) analysed the development of competitive sport performance over three AR-cycles implemented throughout a sport season. They used nonlinear metrics to collect information about how performers ongoingly synchronized tendencies in competition, and traditional statistics to compare such interactions at different periods over the season. Adopting a collaborative and interventive approach, within a qualitative interpretation monitored over time, they described and explained the main events that dictated changes in collective performance. Doing so, they emphasized the essence of a *process-oriented approach*.

Despite the methodological designs exemplified, these studies currently represent exceptions, and not a trend, within the field of sport performance research. Redirecting research focus towards *process* analysis to guide interpretation, understanding and explanations of performance *outcomes* remains thereby urgent.

Coach's experiential knowledge (CEK): The secret ingredient disregarded by current research designs

Implicitly embedded in athlete development, coaches are undeniably orchestrators of performance preparation (Jones & Wallace, 2006). Being responsible for the process of preparing athletes to accomplish superior outcomes, coaches frequently analyse competitive data, interpreting it based on their experiential knowledge acquired over years of practice and reflection (Woods et al., 2020). As such, the CEK can be considered a crucial ingredient within the methodological designs proposed for study of athletes' performance. Specifically, coaches can be viewed as bridges that mediate the information exchange process between training and competitive data. By conceptualising and designing representative and meaningfully practice tasks for athletes, based on relevant competition data, practitioner also act like *facilitators* of learning, being a "guide on the side" (Goodyear & Dudley, 2015). Hence, grounded on CEK, the triangulation of performance information could be conceptualised in a 'competition-coach-training' triad, which needs to be better acknowledged in the design of future research investigations. Attempting to call out this issue, Greenwood et al. (2013) demonstrated how experiential knowledge could be a vital information source.

****please, insert Figure 1 around here****

Although gaining greater traction, the inclusion of CEK, or even the implicit participation of coaches, in the analysis of different pedagogical interventions remains somewhat scarce in the sport performance psychology literature. Accordingly, future investigations may adopt AR-designs, with coaches acting as an insider or external participants, but surely including and analysing their intentional influence on athletes' performance development. By doing so, understanding of how learning contexts and coaching practices may affect performance development could be made broader and richer. This research perspective has already been applied in Physical Education contexts. For instance, Farias et al. (2018) examined the scaffolding process used by teachers during classes over a yearlong-AR investigation,. They highlighted the importance of using simplified questioning, prompting active discovery game problem-solving, and adapting the instruction to the particularities of the context. However, these approaches to research are still infrequent in analyses of training contexts (for exceptions to this trend, see Ramos et al. (2020) and (2021)).

Contemporary pedagogical models which include CEK as a component integrated with empirical knowledge to mediate training-competition information exchanges, could be empirically investigated using a mix-methods design within an AR. Particularly, in Figure 1 the area shared between the bodies of experiential and empirical knowledge used by practitioners needs to be carefully researched (Rudd et al., 2021). By combining qualitative and quantitative data, mixed methods could be used to gain high quality evidence in this interactive area. This innovative research approach will allow applied sport scientists to analyse competitive performance and athlete development through exploring the perceptions of sport practitioners and athletes. Concomitantly, AR may enhance contextual understanding of the effectiveness of purposive practical modifications in athlete preparation and development over time. This integrative approach to knowledge transfer and exchange can be facilitated by an ongoing interchange using inductive and deductive reasoning to develop evidence on effectiveness and efficiency of coaching practice.

Conclusion

In this critical research note, we have re-visited the importance of practically and theoretically refreshing our understanding on how informational constraints support athlete interactions in training and their preparation for performance in competitive environments. Framed upon an ecological perspective on athlete-environment relationships and an interpretative paradigm, we have highlighted some innovative research designs for developing our in-depth understanding of athlete preparation and development. We have highlighted the value of integrating detailed, accurate and relevant performance data which needs to be mediated by the experiential knowledge of sport practitioners. A key suggestion is that the development and implementation of an *competition-coach-training* triad should be investigated more extensively in future research. By adopting mixed-methods research designs, aligned with experiential knowledge from practitioners and athletes, sport scientists could better bridge the gap between theory and practice.

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