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## Interdisciplinary Research: A Promising Approach to Investigate Elite Performance in Sports

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### ABSTRACT

While the call for interdisciplinary studies has been loud and clear over the last decade or so, the number of interdisciplinary publications in sport sciences is rather limited. One of the reasons for this scarcity is the complexity of the research process itself. Still, the combination and integration of information from different scientific disciplines seems to be important to better explain how elite performance comes about. In this article, we focus on this issue and discuss the advantages of interdisciplinary research for understanding how elite athletes are able to achieve such high-proficiency levels. The first section provides an overview of the studies that investigated elite performance in sports. In the second section, we focus on the issue of interdisciplinarity and illustrate how the ecological–dynamical approach and the concept of dimensional reduction can be used to explain how elite performers cope with the complex nature of sport skills. In the last section, we present a research outline and some practical considerations that can be helpful for researchers who aim to study sport skills from an interdisciplinary perspective.

### KEYWORDS

Dynamical systems; ecological approach; elite performance; interdisciplinary research; sport

## Introduction

Elite performance,<sup>1</sup> whether it is in sports, music, or dance is as appealing and attractive for the observers as it is challenging and demanding for the individuals that bring these skills to fruition. For example, playing the piano poses great pressure on the human motor system, as the artist needs to fluently coordinate the subsequent movements at impressive speed and accuracy (Baumann et al., 2007). Sport skills wander in the same zone of extreme complexity, yet elite athletes demonstrate over and over again their ability to smoothly control the multiple aspects that shape and affect these complicated movements. As a result, observing an elite athlete perform sport skills might engender an illusion of easiness. However, even the simplest actions rely on complex interactions. Whether they represent the error prone ball catching by toddlers or the swirling ball handling of the experts, these skills are all the result of the intimate and continuous interplay of many components, both from the body itself and from the surrounding environment. It should not be surprising that this interplay

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is far from efficient in novices, while elite players demonstrate an overwhelming level of mastery. To understand this mastery, research paradigms are needed that capture the complex multidimensional nature of these skills and provide insight in how these dimensions continuously interact.<sup>2</sup>

Given the strong flavor of complexity attached to the execution of sport skills, in particular at the highest proficiency level, many researchers have attempted to understand how subjects organize and control such complex movements. This query led to the formulation of different theories and frameworks (e.g., Bernstein, 1967; Gibson 1979; Newell, 1991; Schmidt, 1975)—all trying to find and define some general rules and concepts (e.g., self-organization, perceptual invariants, or schema-like representation) that underpin the control of this type of behavior. Later in this manuscript, two concepts will be discussed—the dynamical approach and the ecological approach—that strongly build upon the idea of dimensional reduction as the answer for coping with the complexity a player or athlete is confronted with when executing complex sport skills.

It is important to mention here that the terms complex and complexity are used throughout this article in the sense proposed by Auyang (1999), “to describe self-organized systems that have many components and many characteristic aspects, exhibit many structures in various scales, undergo many processes in various rates, and have the capabilities to change abruptly and adapt to external environments” (p. 13). Embedding reasoning within the boundaries of this definition already indicates that an interdisciplinary perspective is opted for, as the various scales referred to in this definition call for the integration of more than one scientific discipline. Note, however, that this position does not imply the refusal of mono-disciplinary research; it remains extremely important to advance disciplinary knowledge, primarily because of its own merits, but also to further nourish interdisciplinary projects.

The goal of this article is to provide some schema to study complex sports skills in an interdisciplinary research context. So, the scope of this article is not to consider interdisciplinarity in the broad context of kinesiology, which includes not only sports and athletics, but also exercise and other forms of physical activity. In contrast, the issue of interdisciplinarity will be focused on in the context of elite performance related to sports. It is accentuated that this issue will be looked at from the perspective of the control of movement, and more specific, in an alignment with the perception–action approach. In the next section, the playing field will be prepared, as a number of experiments will briefly be discussed that investigated elite performance; a topic that attracted a lot of attention from sport scientists (e.g., Elferink-Gemser, Visscher, Lemmink, & Mulder, 2004; Ericsson, Krampe, & Tesch-Römer, 1993; Farrow & Abernethy, 2003). In the second section of this article, we will not only discuss the interdisciplinary issue, but also link it to the theoretical frameworks that capture the complex nature of sport skills. More explicitly we will elaborate on the dynamical systems approach and the ecological approach, two frameworks that have been largely exploited in the field of motor learning and control. Both frameworks, recently combined in the ecological–dynamical approach, thrive on the idea of dimensional reduction to cope with the complexity issue. In the third and final section we will follow a more practical trail and focus on how an interdisciplinary research project can be conceived and implemented.

## Capturing elite performance: A complicated task

Elite athletes and players have to put a considerable amount of time, energy, and also tenacity into their sport disciplines. Apparently many factors, among which practice is very common, affect the final proficiency level attained by the elite performer (Abernethy, Farrow, & Berry, 2003). This observation—in line with the common belief among coaches (e.g., Buekers, 2001)—found a strong echo in the work of B. N. Macnamara, Hambrick, and Oswald (2014), as their meta-analytical study revealed that practice is a relevant, yet not the sole contributor, to elite performance. Note that these findings favor a multidimensional basis for explaining the proficiency level attained by elite athletes, making it, as stated above, a perfect case for interdisciplinary research.

Be that as it may, the interest in multidimensional explanations surfaced in a large number of articles, mainly in the sphere of talent detection—the search for the designated future experts—but also in studies examining the factors that shape elite performance. These studies cover sport disciplines as diverse as volleyball (Rikberg & Raudsepp, 2011; Smith, Roberts, & Watson, 1992), handball (Massuça, Fragoso, & Teles, 2013; Matthys et al., 2013), soccer (Huijgen, Elferink-Gemser, Lemmink, & Visscher, 2012; Ziv & Lidor, 2011), and cricket (Sarpeshkar & Mann, 2011; Weissensteiner, Abernethy, Farrow, & Gross, 2012), to mention the most important ones. For example, Massuça et al. (2013) examined a number of variables stretching from morphological characteristics over psychological abilities to handball-specific skills, to investigate their predictive value for identifying future elite handball players.

A focus on multidimensional reasoning was also apparent within the different scientific disciplines. For example, in psychology a number of factors (e.g., high levels of commitment, self-confidence, determination, and motivation) were shown to determine elite performance (A. MacNamara, Button, & Collins, 2010), even in developing athletes (Holland, Woodcock, Cumming, & Duda, 2010). Also, studies related to, among others, stress (A. P. Allen, Kennedy, Cryan, Dinan, & Clarke, 2014) and coping (Anshel, Sutarso, & Jubenville, 2009) were inclined to the benefits of the multidimensional approach. A similar orientation was present in the physiological domain (Boone & Bourgois, 2013; McMillan et al., 2005) and in the field of neuroscience (Balsler et al., 2014; Tomasino, Maieron, Guatto, Fabbro, & Rumiati, 2013).

There is nothing extraordinary about the fact that all these studies validated the multidimensional nature of elite performance, even though it appears the factors that underpin this performance are sport-specific, as they imitate the physical, psychological, biomechanical, and informational requirements of the given discipline, or even the specific position in the game (Boone & Bourgois, 2013; Delextrat & Kraiem, 2013; Milanese, Piscitelli, Lampis, & Zancanaro, 2011; Pojskic, Separovic, Muratovic, & Uzicanin, 2014). For example, Boone and Bourgois (2013) showed high endurance, agility, and speed in basketball guard players, whereas higher muscle strength was found for centers and power forwards. On the other hand, Milanese and colleagues (2011) revealed a different physical and body composition profile between wing players and the other playing positions in handball.

However, even though these studies provided information that proved to be valuable for scientists and coaches, and in spite of the broad scope of the multidimensional designs used in these studies, they still failed to cope with one of the key elements of performance

in general, and elite performance in particular, namely the interaction between the different dimensions that shape skilled behavior. So, the main concern still remains in place. In spite of the multiple dimensions under scrutiny, the interactions between these dimensions are left out of the equation.

In the next section, interdisciplinary research will be focused on; an approach at the forefront of integrating different scientific disciplines, interactions included. In addition, the ecological–dynamical theoretical framework will be discussed as it nicely illustrates how the complexity of elite performance can be made manageable through dimensional reduction.

### **Interdisciplinary research in sports: More than a methodology**

As the title of this section suggests, interdisciplinary research brings more considerations to the forefront than just methodological issues. To truly capture the complexity of sport skills, the various dimensions and components that define and shape movements need to be taken into account. Schary and Cardinal (2015) expressed this integrative and holistic nature very well, as they stated that interdisciplinary research is a synthesis (or derivative) of concepts, models, and/or theoretical frameworks from two or more distinct academic disciplines. To unravel how complex systems function, research formats are required that unite the knowledge, the protocols, the theoretical viewpoints, and the methodologies of different disciplines. It is not difficult to understand that such an approach is extremely demanding, both from a theoretical and practical perspective, and requires an outspoken preparation and a continuous monitoring of the research project by the stakeholders from the different disciplines.

In any case, it is impressive to notice the longstanding plea for interdisciplinary research in sports. Whether the research question is nested in the field of elite performance, talent detection, coaching, expertise, or learning, the mantra is the same. To better understand human motor behavior, the integration of knowledge from the different disciplines concerned with human movement is of great importance. At least this is the refrain that emerges in articles that can be traced back as far as the mid-90s (e.g., Burwitz, More, & Wilkinson, 1994; Davids, Handford, & Williams, 1994). Researchers pleading in favor of interdisciplinary research in sports all referred to the multiple advantages associated with this research perspective (e.g., Fiore, Hoffman, & Salas, 2008; Kalenscher & Tobler, 2008; ; Phillips, Davids, Renshaw, & Portus, 2010; Weiss, 2008). According to Townsend, Pisapia, and Razzaq (2015), these advantages stretch from benefits for the individual researcher over benefits for the individual discipline, to benefits for the society as a whole. However, even though the call for interdisciplinary studies (e.g., J. B. Allen & Shaw, 2013; Spaaij, 2014) or interdisciplinary projects (Black & Copsey, 2014) never faded, and despite the fact that many researchers are involved in interdisciplinary research, there are still many barriers in place that impede the implementation of interdisciplinary projects. The reasons for this struggle to engage in interdisciplinary research are manifold. For example, funding strategies and validation issues may have a strong negative impact on the commitment of researchers to be involved in interdisciplinary research. It is beyond the scope of this article to go into debate on these latter obstacles. In contrast, a cause of concern that relates to the scientific content and lies in the complexity of the process itself will be focused on.

We first want to mention that the cooperation of different disciplines requires an extremely solid preparation and a very thorough discussion of the research goals,

protocols, procedures, and designs. Even though this rigor is a normal prerequisite for all research, regardless of its nature, the differential approaches delineating and defining each of the disciplines certainly do not facilitate the integration process. Yet, the positive impact of studies in fields as different as public health (Kessel et al., 2009), music (Kruse-Weber & Pamcutt, 2014), law-making (Schrunk, 2012), environmental sustainability (Uiterkamp & Vlek, 2007), or geography (Ioris, 2013), illustrates the possible benefits of interdisciplinary research. One can readily assume that the field of movement and sport would also have a lot to win when different scientific disciplines join forces.

One of the first problems encountered in conducting interdisciplinary research in elite sport performance is the multitude of dimensions that delineate how a particular player will execute a specific skill. Clearly, these dimensions represent a vast amount of scientific disciplines ranging from history, sociology, psychology, over biology and biomechanics, to physiology and neurosciences, just to name a few. There is no intrinsic priority list attached to these different disciplines, as they all add specific explanatory power to the understanding of elite performance. However, even though integrating as many disciplines as possible could add to a more profound comprehension, the difficulty to accomplish such an enterprise would be extremely high, and for the time being, presumably impossible. For this reason it seems appropriate to limit the number of scientific disciplines and integrate those that are instrumental to the specific research question. There is no absolute rule that governs the choice for specific scientific disciplines. Sometimes this choice is an emerging process inspired by the availability and strength of specific research units in a particular institution. In other cases, the choice can be influenced by the granting policy or by the preferences of a single principal investigator. Be that as it may, even though many combinations are possible, it is not uncommon to find the disciplines of biomechanics, neurosciences, exercise physiology, and psychology to be high on the priority list of researchers who examine elite performance.

An interesting solution to the problem and a way to integrate the different dimensions within an overarching theoretical umbrella, the ecological–dynamical approach was presented by Davids, Hanford, and Williams (1994). In their expose, the authors depict the expert athlete as a dynamical biological system that enables the unfolding of complex motor skills through a continuous interaction and cooperation of different components. Note that this interaction is not limited to the elements of the body itself, but also reaches out to the continuously changing environment that also shapes the movements of the elite athletes. The importance of both elements (body and environment) is nicely expressed in a quote from Auyang (1999): “We gain a better understanding of an individual if we also grasp the relation between its behavior and the behavior of its constituents or the behavior of the system in which it participates” (p. 46).

Actually the authors draw on insights from both the dynamical approach (Bernstein, 1967) and the ecological approach (Gibson, 1979). One of the common core elements of these approaches is the intent to unravel how complexity can be simplified by dimensional reduction. Said differently, a limited number of crucial dimensions would suffice to (1) organize the movement itself; and (2) integrate and blend these movements into their environmental context. In the following paragraphs, we will give a concise explanation of both approaches and illustrate how the dimensional reduction operates, both for the organization of the movement itself, and for the interaction with the environment. We will do so by using two examples from the field of sports.

The blueprint for the dynamical approach to the control of action was inspired by Bernstein's (1967) ideas about the nature of biological movements. In his reasoning, Bernstein tackled—amongst other things—the degrees of freedom problem, referring to the observation that movements in general, and sport skills in particular, can be produced by a range of different combinations of joint angles. For example, the final position of the hand in a basketball free throw can be obtained using a high or low throwing style. This means that the trajectory of the hand may be different, but the final release angle and release velocity of the ball can still be identical. According to Bernstein, the regulation of such complex movements is not centrally controlled, but distributed over the different interacting elements that shape the movement. The advantage of such a distributed control system, with its redundant degrees of freedom, is significant, as it adds robustness and flexibility to the motor system, enabling it to cope with the complex nature of elite performance. Or, as stated by Ibáñez-Gijón et al. (2016): “It is not difficult to imagine that such a system offers the expert player all the tools needed to successfully evolve in the extremely demanding settings of high-level games” (p. 3).

An additional assumption of Bernstein's theory is that one or more essential variables represent the relation between the various components that shape the final coordination pattern, reducing the complexity to controlling a reduced number of dimensions. Temprado, Della-Gastra, Farrell and Laurent (1997) conducted an elegant experiment to test this assumption. Overhand volleyball serves from novice and expert players were examined in their study. The goal was to test the assumption that one or more essential variables represent the relation between the various components that shape the final coordination pattern. The results of their study were in agreement with this assumption, as they revealed that the wrist–shoulder coupling was the essential variable for the coordination in the overhand serve. In the dynamic systems literature, the term synergies has been used to label these coordination patterns.

The ecological approach concentrates on the interaction of the moving body within its environment (Gibson, 1979) and rests on the principle of a circular relationship between perception and action; that is to say, perception is not just a prime mover, functioning as an initial trigger that provokes actions. In contrast, perception and action join forces to cope with the demands of the task. In this sense, perception is direct and has an action specific meaning to it (Turvey, 1977). According to this approach, the perceptual control of a given task (e.g., running to catch a ball in baseball) could rest on the use of a single high order perceptual variable informing the agent about the appropriateness of the current behavior. One of these high order variables is the optical acceleration of the ball (Chapman, 1968; Michaels & Oudejans, 1992), resulting from the combined displacements of both the player and the ball. Cancelling the optical acceleration of the ball (i.e., maintaining its displacement velocity constant) through displacement velocity adjustments of the player (if necessary) during the unfolding of the action, allows the player to get to the right place at the right time. In this example there is no need to anticipate the arrival time or location of the ball, or to integrate several sources of information to disambiguate the visual scene. The player only needs to detect—through smart perceptual devices (Runeson, 1977)—the optical velocity changes, and to change the displacement velocity accordingly. In this sense, optical acceleration is prototypical of what is meant by the reduction of perceptual dimensionality.



Even though these examples convey the same message, namely that a player or athlete can handle complexity through dimensional reduction, both the dynamical systems approach and the ecological approach were long considered and studied within the boundaries of their own rights.

Actually, Davids et al. (1994) were among the first to combine the two approaches in the context of expertise and elite performance into an ecological–dynamical framework, in which both the intrinsic dynamics of the body and its reciprocal interaction with the environment, were integrated. This implied that both the synergies of the body and the perceptual invariants had to be taken into account and needed to be linked together. Ibáñez-Gijón et al. (2016) tried to add some extra substance to this framework by elaborating a scale-based approach, in which the concepts within the ecological and dynamical approaches were recapitulated to define an integrated theoretical and methodological framework for interdisciplinary research in sports sciences. The two essential aspects of this approach are (1) the distinction between the task level (the ecological scale) and the execution level (the organic scale) and (2) the methodological integration of both scales.

From our perspective, the distinction between these two levels of analysis provides a strong and promising foundation to study elite performance. The primary level of description is situated at the level of the task, which encompasses the complex relationship between the subject and the environment (i.e., the ecological scale). By considering the task as the pivotal element of exploration, the importance of integrating all elements that define the final movement outcome within its environmental context is emphasized. The second level is situated at the execution level and refers to the elements that bring about the movement patterns (i.e., the organic scale, referring to the biomechanical/physiological dimension). Crucial in this approach is that the complex interactions—both within and between these two levels of analysis—are taken into account and are also captured in the analysis of the movements of the player.

An elegant application of this line of thinking was provided in the work of De Rugy, Taga, Montagne, Buekers, and Laurent (2002), as they were able to show how the internal organization of the neuromuscular system was linked to a specific perceptual invariant in a simple locomotor pointing task. As the model proposed by these authors connects the intrinsic dynamics to the environmental constraints, it also offers the tools to apply different additional constraints (e.g., psychological stress, fatigue, instructions) on a player, hereby enlarging the research scope as it enables the expansion of the dimensions that shape performance. The advantage of this model and the integrated ecological–dynamical approach is its inclination toward interdisciplinarity, favoring the involvement of different scientific disciplines to unravel the mysteries of elite performance.

To combine all the relevant dimensions into an equation that simultaneously takes into account the relation with the environment, specific methodological tools, such as the uncontrolled manifold (UCM) and principal component analysis (PCA), are required.<sup>3</sup> Although it is beyond the scope of this article to discuss these methodological issues in more detail, it is stressed that the choice of specific methodologies is intimately linked to the research perspective chosen, as well as to the level of analysis the researchers are pursuing. This latter issue will be discussed more extensively in the next section.

In this section, the ecological–dynamical framework has been put forward as a valuable approach to sort out how complex sport skills performed by elite players are organized



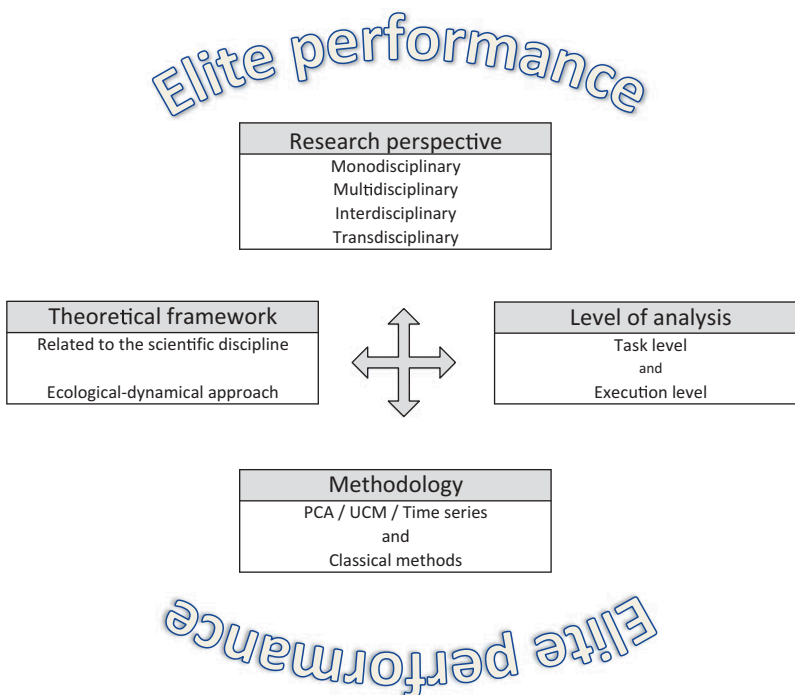
and executed. The concept of dimensional reduction was used to show how complexity could be brought back into manageable proportions, both at the level of the task and at the execution level. In the next section, we want to change track and look at the interdisciplinary issue from a more practical angle.

## From theoretical considerations to practical application

In the previous sections, this article reflected on the usefulness of interdisciplinary research for studying elite performance in sport. The goal of this final section is more practical as it is aimed, first to present an ordered overview of how the interdisciplinary perspective fits into a more general framework of studying elite performance. The second aim is to provide some reflections about possible problems that may arise when conducting this type of interdisciplinary research and, where possible, indicate how these issues can be solved. It is emphasized that these reflections are to be situated within the movement control perspective, even though the overall philosophy can be considered as a general attribute to interdisciplinary research.

### The research outline

The outline presented in [Figure 1](#) reiterates the most important elements that nourished the theoretical reasoning. However, before entering into the details of this outline, we want to clarify a possible caveat related to the research model that is proposed. This problem is associated with the basic premise, namely that the study of elite sport skills



**Figure 1.** Overview of the different components of the research outline.

requires interdisciplinary research based on the ecological–dynamical approach. As was already touched upon in the introduction, this premise could unintentionally produce the presumption that mono-disciplinary research has no role to play in the study of elite performance. Obviously, such an assumption is erroneous, as there is no a priori limit to the richness or usefulness of the information made available by individual disciplines. For example, biomechanics can study the chain of forces that lead to the final position of the hand in a basketball free throw (the organic level) and/or the forces resulting from the interaction between the player and its environment (the task level). In this respect, the information derived from such experiments may have a great validity, as it encompasses the so important link with the task that needs to be executed on the court. So the only claim made here is that interdisciplinary research has the potential to broaden the explanatory power of the project, as adding extra scientific disciplines to the experimental table can give a more complete account of the issues that are studied.

### *The research perspective*

The above-mentioned consideration already reveals an important issue related to the first element of this research outline (see [Figure 1](#)), namely the choice of a suitable research perspective. As was stated previously, different options are available to study sport skills and, regardless of the nature of the skill, it is important to position the study on the scale of disciplinarity.<sup>4</sup> Actually, this scale is a continuum ranging from mono-disciplinary to transdisciplinary research, enveloping the multidisciplinary and interdisciplinary perspectives. This positioning process is a deliberate choice to be made by the researcher and depends not only on scientific preferences, but also on contextual factors as, for example, funding options or organizational complexity. The preference shown for an interdisciplinary approach is no indication of a higher esteem for this type of research, as all types bring their own value to the table. However, by multiplying the resources of information stemming from different disciplines, the explanatory value of the data can increase, not only because they provide complementary information but, even more importantly, because they highlight how the distinct variables interact to outline the movement skills as they are produced on the field.

In the second section we identify the choice of the disciplines as one of the inherent problems of multidisciplinary approach. At first glance it seems reasonable to try and assimilate as many disciplines as possible in the project, as each of these fields can bring in specific knowledge that is of interest for creating a model that reflects the actual behavior as close as possible. Even though this may be true, there is a caveat hidden in this assumption, as every additional discipline, whether it originates from the human sciences, the exact sciences, or the biomedical sciences, will also bring supplementary complexity to the table. Most probably, the best way to proceed is not by gathering as many participating disciplines as possible, but by first defining the most important influencing variables for the phenomenon to be studied. Even though it seems that biomechanics, psychology, physiology and neurosciences are crucial in most studies of motor skills, other combinations are very well possible. It is up to the researchers to decide on this matter.

So, even though all the experiments conceived within the disciplinary line of thinking will be finally brought back to the actual sport skill and thus be integrated into the ecological scale of analysis, each of the disciplines mentioned above can add some explanatory value to the nature and mechanisms that define elite performance. Given

this observation, one could also suggest to assimilate the important field of social psychology as a significant discipline, because the interactions between individuals and the behavior of individuals within groups clearly have the potential to affect performance. However, for now, it is believed that the mode of operation proposed represents a valuable step in understanding skilled performance of elite athletes.

### ***The theoretical framework***

The choice for a specific theoretical framework is not just the result of an isolated decision to tackle specific research questions. In contrast, this choice is influenced by many different elements, of which the research perspective and the scientific discipline(s) in which one is involved are certainly not the least important ones. So, the preference is to turn to the ecological–dynamical framework as the theoretical underpinning of these research schemes is closely connected to the interdisciplinary orientation of these projects. In addition, both the ecological and the dynamical approach earned some strong credits in the field of motor control and sport sciences, while the overarching ecological–dynamical framework offers the required theoretical umbrella to integrate the information derived from different scientific disciplines. This illustrates how strongly entwined the research perspective and the theoretical framework can be, an observation that also holds for the other elements of the outline, as shown in the next paragraphs.

### ***The level of analysis***

The third element of the research outline concerns the level of analysis selected by the researchers. Here, the two extreme options would be to (1) study, for example, a basketball free throw or a forehand drive in tennis measuring all the dimensions that influence the actual performance of the elite player or (2) study only a specific aspect of this skill, for example the release angle of the throwing hand in the same free throw, or the peak velocity of the arm during the forehand drive. Even though the first option is difficult to imagine, confronting the player with situations that mirror the actual skill as closely as possible has the potential advantage to increase the validity of the results.

As argued previously, putting forward the level of the task as the designated entry point was inspired by the need to unravel the complexity of elite performance and understand how high level skills are produced and controlled. Again, the considerable value of studies that focus on the execution level is not questioned; it is just claimed that ecologically valid inferences are possible only at the level of the task description. Consider the example of the basketball free throw. Analyzing the trajectory of the center of pressure or the forces exerted on a force platform will certainly be instructive. However, in their isolation, they will fall short of explaining the complex chain of interactions that lead to the actual performance of this skill. Only when this movement is studied from the perspective of this chain of interactions, i.e., within the task level of description, will it enable us to grasp the complexity of expert behavior.

### ***The methodology***

The final element of this research outline concerns the methodology used to grasp the underlying complexity of the different dimensions. Even though this issue was not elaborated on in the present article, using the proper methodological tools to analyze the sometimes massive number of data that originate from the experiments is crucial,

more so as different scientific disciplines are inclined to their proper analyzing techniques, making it difficult to find the appropriate tools. Moreover, the selection of these tools is also a consequence of the level of the analysis that is used, stressing again that the different elements of this research outline are intimately interwoven. The preference for using time series or more complex methods, like the UCM and the PCA, is not just a fancy choice, but is delineated by the other elements of the outline.

## Conclusion

The argument in this article is that the study of elite behavior should be rooted in the perspective of the ecological–dynamical approach, as this perspective considers the movement system in its closest connection to the actual sport skill in its natural setting. When the ultimate goal of the experiments is to make strong claims about sport expertise in its natural settings, i.e., the skills performed on the court, the task level of description is crucial. So, an effective way to proceed is to examine the behavior of elite athletes within the ecological–dynamical framework, taking into account all the associated methodological issues. This is not to say that local levels of description are less important, as they provide very relevant information about the mechanisms that underpin the movements at the execution level. Take, for example, the recent study of Kaya, Callaghan, Donmez, and Doral (2012), in which the authors examined the relation between the shoulder-joint position strength and the free-throw percentage in professional basketball players. It is clear that their research question emerged from the discipline of biomechanics, resulting in some interesting findings for coaches and athletes. However, as far as only the execution level of analysis was at stake here, no inferences could be made with respect to the global scale, that is to say how the many variables that also affect performance would interact with these parameters to produce expert performance on the court.

Most likely the information that is provided in this review will engender thoughts about the challenging nature of interdisciplinary research. Different disciplines need to be integrated and complex methodologies need to be mastered; not to mention an additional element that should not be overlooked, namely the managerial elements that can influence the process. The cooperation of many colleagues may mirror the complexity of the process. So, as nicely documented by Black and Copsey (2014), implementing well thought procedures to prevent possible problems is certainly not a luxury.

Be that as it may, when these complications are compared to a hurdles race in which every obstacle taken correctly adds to the final goal of crossing the end line, this challenging nature becomes an extra motivation; more so because of the huge pay off, namely results that provide a more thorough understanding of the amazing performance level demonstrated by elite athletes. While the call for interdisciplinary research is growing, and while the technology and analytical methods needed to set up and conduct experiments are available, there is no reason not to be involved in this interdisciplinary approach. Doing so will enable us to better understand elite sport performance and from that, provide the coaches and athletes with valid information to conceive and implement better training programs. This article takes the firm viewpoint that the ecological–dynamical approach, with its specific methodological strengths, is the key element in this endeavor.

## Notes

1. The term elite performance, and not expertise, is chosen as the lead term in this article as the latter term incorporates the process of becoming an elite athlete, while the former centers on the actual outcome or result of this process. The present research project aims at examining elite performance as such.
2. The term dimension is used throughout this article in an abstract manner and refers to all the components (e.g., body segments, environmental elements) that may play a role in the generation of movements. Consequently, the term multidimensional is used to describe phenomena with different dimensions.
3. A comprehensive discussion of these tools and their application within the context of a basketball free throw has been given by Ibáñez-Gijón et al. (2016). Moreover, for the interested reader, further details of these methods can be found in articles by Schöner and Scholz (2007); Scholz and Schöner (1999); and Daffertshofer, Lamoth, Meijer, and Beek (2004).
4. For an interesting discussion on a conceptual framework of interdisciplinarity and the different levels of disciplinarity, see Schary and Cardinal (2015).

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