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Resilience in Sports from a Dynamical Perspective

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Abstract

On the road to excellence, it is essential to develop resilience, that is, to be able to positively adapt within the context of significant adversity. Researchers tend to agree that resilience is a complex process with a multitude of underlying variables. To stimulate research on the process of resilience, we propose the dynamical system approach that provides a theoretical perspective on mapping out and understanding how resilience unfolds over time. Furthermore, we will demonstrate how the findings of previous research on resilience in sports fit with several dynamical properties, including complexity, iterativity, and the formation of attractor states. New findings on the dynamic properties of resilience will result in in-depth knowledge about, and understanding of, the process of how individuals adapt to adverse events. Practitioners might benefit from this approach by being able to detect early warning signals of critical transitions (e.g., critical slowing down) and take preventive actions before breakdowns in performance occur.

Keywords: Adversity, Complexity, Critical Slowing Down, Dynamical Systems, Psychological Momentum

Resilience in Sports from a Dynamical Perspective

On the road to excellent performance, athletes unavoidably encounter stressful events, which they have to overcome to become successful. These events can be either sports-related or non-sports-related and range from short time scales (e.g., losing a point in a match) to long time scales (e.g., a serious injury or parental divorce, Fletcher & Hanton, 2003; Gould, Jackson, & Finch, 1993; Rees et al., 2016; Sarkar & Fletcher, 2014). In the sports literature, the process of positive adaptation within the context of significant adversity is defined as *resilience* (see Fletcher & Sarkar, 2012, 2013; Galli & Gonzalez, 2015). A definition of resilience that is commonly used in sports emphasizes "the role of mental processes and behavior in promoting personal assets and protecting an individual from the potential effect of negative stressors" (Fletcher & Sarkar, 2012, p. 675, 2013, p. 16). This definition acknowledges both the underlying trait-like protective factors and (mental) processes, which define how one adapts to adversity (Fletcher & Sarkar, 2012, 2013). In addition, the speed of the resilience process can vary across different setbacks and people over time (Carver, 1998; see also Egeland, Carlson, & Sroufe, 1993; Fletcher & Sarkar, 2012). Although resilience in sports and in other contexts, such as the organizational and personal domain, is generally considered as a process (Fletcher & Sarkar, 2012), there are few studies in sports on the characteristics of the resilience process. Sports researchers have primarily focused on identifying protective factors, such as personality traits and psychosocial variables, in order to explain individual differences in resilience (see Sarkar & Fletcher, 2014).

In line with the view that resilience is a complex process (Fletcher & Sarkar, 2012; Galli & Vealey, 2008), we draw upon the dynamical systems approach (e.g., Kelso, 1995; Nowak & Vallacher, 1998; Van Geert, 2009), which provides tools that allow researchers to capture the properties of the resilience process. A dynamical system can be defined as a set of elements, which are in constant dynamic interactions and undergo change over time (e.g., Kelso, 1995; Nowak & Vallacher, 1998; Vallacher & Nowak, 1997; Van Geert, 1994). In the next section, we will demonstrate how the findings of previous research on resilience in sports provide a logical fit with several dynamical properties, including complexity, iterativity, and the formation of attractor states.

The Complexity of Resilience

The property of complexity entails that the explanation of a system state cannot be reduced to its constituent elements. In other words, the system is *interaction dominant*, meaning that the state of the system emerges through dynamic interactions between multiple components (e.g., Van Orden, Holden, & Turvey, 2003; Den Hartigh, Cox, & Van Geert, 2017). In terms of resilience, this would entail that a state of resilience develops through an interaction between various factors (cf. Fletcher & Sarkar, 2012; Galli & Vealey, 2008), and cannot be reduced to specific contributions of isolated explanatory components. Indications for the complexity of resilience can be derived from studies focusing on protective factors, that is, the resources protecting an individual from setbacks or helping in responding positively to adverse events. In these studies, a large number of variables have been identified that protect athletes or help them to be resilient, such as perceived social support, positive personality, motivation, confidence, and focus (see Fletcher & Sarkar, 2012; Sarkar & Fletcher, 2014). For example, a sport-specific study of psychosocial determinants found that swimmers who recovered from a negative performance differed from swimmers who failed to recover from a setback in perceived level of endurance, coping styles, self-concept, and social support (Mummery, Schofield, & Perry, 2004).

However, so far no single factor or set of factors has been identified to give rise to resilience across contexts, settings, or individuals (Galli & Gonzalez, 2015; Rutter, 1981). For some variables even opposite effects have been found. For example, whereas Fletcher and Sarkar (2012) found that high levels of perceived social support were positively related to resilience, Mummery and colleagues (2004) observed that resilient athletes demonstrated lower levels of perceived social support than their non-resilient counterparts.

Another indication for the complexity of the resilience process comes from the presumption that resilience is determined by the person-environment interaction (Egeland et al., 1993). Different situational demands may require different processes and facilitative responses from athletes in order to adapt well to a given situation (Fletcher & Sarkar, 2012). For example, responses that promote positive adaptation to personal stressor (i.e., stressors related to the non-sporting, personal life domain) might not be applicable to competitive stressors (i.e., stressors directly related to the competitive performance context), and vice versa (Sarkar & Fletcher, 2014). Therefore, scholars concluded that resilience is strongly coupled to the situational demands of the adverse event (Fletcher & Sarkar, 2013; Rutter, 1981). In other words, resilience is a function of person- and environment-related explanatory variables, among which complex interactions likely exist (Egeland et al., 1993; Fletcher & Sarkar, 2012, 2013, 2016; Galli & Vealey, 2008; Luthar, Cucchetti, & Becker, 2000). Indeed, sports researchers tend to agree that resilience is a complex process with a multitude of underlying variables rather than a component-driven ability. It seems to be a process that emerges from the constant interactions of the various components within the person and the environment over time (cf. Fletcher & Sarkar, 2013; Sarkar, Fletcher, & Brown, 2015).

The Iterativity of Resilience

The property of iterativity implies that a given state of the system develops out of the system’s previous state, and hence that any future state depends on the system’s history of preceding states (e.g., Den Hartigh, Van Dijk, Steenbeek, & Van Geert, 2016; Gernigon, Vallacher, Conroy, & Nowak, 2015; Nowak & Vallacher, 1998; Vallacher, Van Geert, & Nowak, 2015; Van Geert, 1991). Therefore, a given variable can act as an effect in the one moment and as a cause in the next (Vallacher & Nowak, 1997). Translated to resilience, the complex interactions among the protective factors and the environmental demands over time form an ongoing process, which determines an athlete's state of resilience through iterative steps (cf. Egeland et al., 1993; Fletcher & Sarkar, 2012, 2013, 2016; Fletcher & Scott, 2010; Seery, 2011; Seery, Holman, & Silver, 2010). To the best of our knowledge, there are currently two sport-specific studies providing clues for such an iterative process, which are based on interviews with athletes who successfully overcame adversity during their careers (Fletcher & Sarkar, 2012; Galli & Vealey, 2008). For example, the findings of Fletcher and Sarkar (2012) indicate that the protective factors influence challenge appraisals and meta-cognitions, which in turn yield facilitative responses. More specifically, all protective factors aid the facilitative interpretation of emotions, effective decision-making, reflecting, and task engagement. This, in turn, leads to increases in effort and commitment (Fletcher & Sarkar, 2012). Therefore, no factor can be singled out as the main determinant for the process of adapting well to adversity and no protective factor can be neglected. Rather, the complex interactions among all elements form the process, from which successively resilience emerges (Fletcher & Sarkar, 2012, 2013; Galli & Vealey, 2008).

The complex, iterative process of resilience is also likely to occur on the time scale of single matches. For example, in a tennis match, the person (the player), the environment (the opponent), and the task (i.e., playing/scoring points, the situational demands) are in constant interaction. The behaviors of players and their opponents constantly influence each other as they adapt to the changing circumstances. This means that the player and the opponent build a match history together that includes (among many other things) successes and setbacks (i.e., adverse events in the performance context). Thereby the situational demands and the protective factors constantly alter each other and adapt to the changing circumstances. Therefore, the displayable level of resilience changes in accordance with the history of these setbacks and successes. For instance, it might be easier for an athlete to demonstrate resilience when a first adverse event is encountered than if several adverse events have preceded this particular event. In accordance with this idea, the role of the history of performance patterns has been demonstrated repeatedly in studies on *psychological momentum* (PM, see also the next sub-section). Positive PM describes an individual's perception of moving towards a desired goal, whereas negative PM describes an individual's perception of moving away from a desired goal (Adler, 1981, Briki et al., 2013, Den Hartigh et al., 2014; Den Hartigh, Van Geert, et al., 2016; Vallerand, Colavecchio, & Pelletier, 1988). These studies showed that the impact of an adverse event, such as losing points or seconds on the opponent, is embedded in the process, that is, the athlete's performance history (Briki, Den Hartigh, Markman, Micallef, & Gernigon, 2013; Den Hartigh, Gernigon, Van Yperen, Marin, & Van Geert, 2014; Den Hartigh, Van Geert, Van Yperen, Cox, & Gernigon, 2016; Gernigon, Briki & Eykens, 2010).

Resilience as Defining Attractor States

Attractors emerge from the iterative process of the system's underlying components, as the components adjust to each other in a self-organizing process (Nowak & Vallacher, 1998; Vallacher & Nowak, 1997; Vallacher et al., 2015). A fixed-point attractor is a relatively stable state of the system, towards which it develops over time and returns to after being perturbed (Gernigon et al., 2015; Vallacher et al., 2015). This state is characterized by a recurring pattern of affect, behavior, and cognition. A metaphoric conceptualization of different attractor states usually depicts a hilly landscape over which a ball is rolling (see Figure 1). Under the forces of gravity the ball will roll into a valley (i.e., attractor state) and remains there, unless an external force sets the ball into motion (i.e., a perturbation). The depth of the valley indicates the strength of the attractor. The deeper the valley, the stronger the perturbation (i.e., incidents that shake the stability of a system) needs to be in order to push the ball out of the valley. However, the attractor landscape may not remain stable over time (see Figure 1). Repeated perturbations may cause the strength of an attractor state to decrease while simultaneously increasing the strength of another attractor state, thereby changing the landscape of the attractor states (for an example in sport psychology, see Den Hartigh, Van Geert et al., 2016).

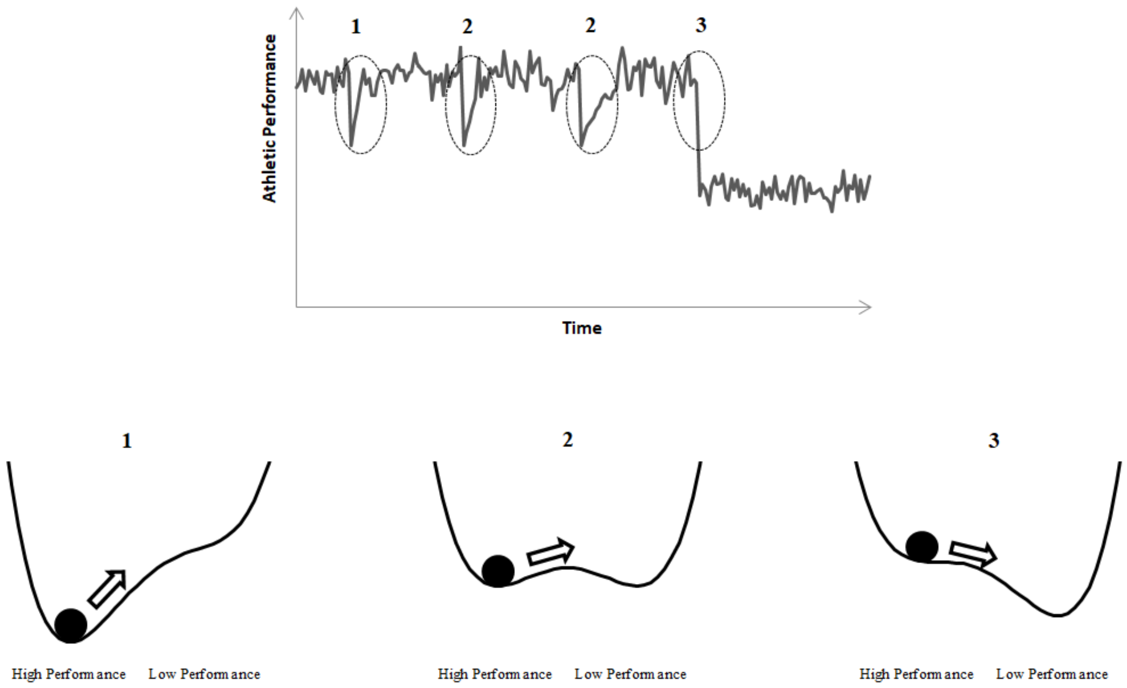

Figure 1. Hypothetical time-series of an athlete's performance trajectory. The dotted circles mark the occurrence of an adverse event. Critical slowing down occurs as the athlete requires increasingly more time to recover from an adverse event, which signals a change in the attractor landscape (1, 2, and 3). The current state is represented by the ball rolling over the landscape and the arrows indicate the direction of the perturbation. With repeated adverse events the attractor for the high performance level becomes weaker while the attractor for the low performance level becomes stronger (2), ultimately leading to a qualitative shift in performance (3).

Although never explicitly studied, indications for the existence of attractor states in resilience research comes from studies that have operationalized resilience as adapting well after experience a worse-than-expected performance (for examples, see Mummery et al, 2004; Seligman, Nolen-Hoeksema, Thornton & Thornton, 1990). Resilient individuals were able to return to their previous level of performance after encountering the perturbation, whereas non-resilient athletes' negative performance was followed by another negative performance. In terms of attractor states, some individuals were able to return to their (prior) attractor state, whereas for others a critical transition occurred to a lower performance level (cf. Dai, Vorselen, Korolev, & Gore, 2012; Kelso, 1995; Scheffer et al., 2012; Schöner & Kelso, 1988; Van de Leemput et al., 2014). Following such a transition, it is typically difficult for the athlete to recover his or her previous performance level (Bonanno, 2004; Den Hartigh, Van Geert et al., 2016; Gernigon et al., 2010; Gernigon et al., 2015). Furthermore, the commonly applied definition of resilience in sports also points to the protection of potential negative consequences of stressors (Fletcher & Sarkar, 2012, 2013). According to Sarkar and Fletcher (2014), this definition implies that resilience is defined by an equilibrium in the level of functioning when facing an adversity (cf. Bonanno, 2004; Mancini & Bonanno, 2009; Holling 1973).

Research on PM in sports provides additional support for the link between resilience and attractor formation (e.g., Briki et al., 2013; Den Hartigh et al., 2014; Den Hartigh, Van Geert et al., 2016; Gernigon et al., 2010). For example, Briki et al. (2013), Den Hartigh et al. (2014), and Gernigon, Briki, and Eykens (2010) found that negative PM is a relatively strong attractor state, meaning that it is relatively easily entered and difficult to escape from. Den Hartigh, Van Geert, et al. (2016) recently provided deeper insights into PM attractor dynamics. In a study in which participants took part in an ergometer rowing tournament spanning four weeks, the athletes who had lost the first three races (i.e., successive adverse events) entered negative PM more rapidly in the fourth race (i.e., decline in effort and self-efficacy), when they started losing seconds to their opponent, than the athletes who had won the previous races (Den Hartigh, Van Geert, et al., 2016). This line of research suggests that (a) adapting well to adversity (i.e., resilience) is embedded in the performance history both on a short timescale (within a single performance) as well as over the course of several weeks, and (b) the attractor landscape may change.

In summary, various findings across different domains of sports research point to the dynamic properties of resilience. The dynamical systems approach seems to be an appropriate framework for understanding resilience. However, this approach is not limited to descriptive support; it also yields practical implications for future research, which will be discussed later.

Measuring Resilience in the Context of Athletic Performance

A key question with regard to measuring the process of resilience in sports is: What should we measure (Sarkar & Fletcher, 2013)? Concrete recommendations in this regard can be derived from research on resilience outside the field of sport psychology. A recent article on resilience on the domain of clinical psychology has described the history-dependence and the change in the attractor landscape that arises from an iterative process, based on time-serial data (Van De Leemput et al., 2014). These authors demonstrated the effect of encountering several subsequent stressors on the development of a depressive episode. More specifically, the exposure to several adverse events after another can lead to a period in which a system takes increasingly more time to demonstrate resilience, called “critical slowing down” (see also Dai et al., 2012; Scheffer et al., 2012). This means that the system requires increasing amounts of time to positively adapt to perturbations. A series of setbacks within a short time can reduce the displayable level of resilience so much that a single stressor (even if it has a low magnitude) can cause a person to develop a depressive episode (Van de Leemput et al., 2014). Therefore, a critical transition of the stability of a system is anteceded by a period of reduced resilience (i.e., critical slowing down, Dai et al., 2012; Kelso, 1995; Scheffer et al., 2012; Schöner & Kelso, 1988; Van de Leemput et al., 2014). As this line of research provides insight into the dynamic properties of resilience, we suggest transferring it to the domain of sports.

Since the proposed complex interplay of underlying components (i.e., protective factors and environmental demands) manifests itself in the actual behavior that an athlete displays in a performance context (cf. Luthar & Cicchetti, 2000), the state of the system can be defined as the athlete's current performance level. Whereas adjustment to parental divorce may take several months or years and is meaningful in the time scale of an athlete's career, adapting well to a lost point in a tennis match occupies merely a few seconds and is meaningful in the time scale of a single match. Therefore, the type of adversity and the positive must occur in a meaningful timeframe (Den Hartigh, Van Geert et al., 2016).

Following the dynamical systems approach, to map out how the resilience process unfolds, individual time-series (dense repeated measurements) need to be established (e.g., Araujo et al., 2015; Den Hartigh et al., 2017). Assessing multiple measurement points allows insight to be gained into how the trajectory of resilience is formed for any given adverse event or series of adverse events (cf. Fletcher & Sarkar, 2013; Sarkar & Fletcher, 2013). When the aim is to investigate the resilience process on a short time scale, during actual performance, a future research agenda should address the following issues and considerations. First, relevant measures of athletic performance should be defined, which can be measured repeatedly (preferably as continuously as possible) in order to compile a time-series (Araujo et al., 2015). For example, for cyclists, their pace can be continuously tracked and measured. Second, the behavior of participants should stay close to their behavior in the usual sports setting, thereby optimally capturing the dynamics underlying athletic performance (see Araujo et al., 2015;

Davids & Araujo, 2010; Davids, Araujo, Vilar, Renshaw, & Pinder, 2013; Davids Glazier, Araújo, & Bartlett, 2003; Pinder, Davids, Renshaw, & Araujo, 2011).

When conducting experimental studies on resilience, researchers could use, for instance, stationary bikes or rowing ergometers which can continuously collect measures of power output and allow for controlled manipulations of adverse events (e.g., Den Hartigh et al., 2014; Den Hartigh, Van Geert et al., 2016). This could be accomplished by using software in which adverse events during performance can be manipulated. As an illustration, in studies on cycling (Briki et al., 2013) and rowing (Den Hartigh et al., 2014; Den Hartigh, Van Geert et al., 2016), athletes were performing on ergometers. In one of the conditions they took a comfortable lead, but then, at repeated intervals (e.g., 1 minute), the athletes lost their advantage. In this way, adverse events (here, losing the lead) were systematically manipulated in a controlled experimental setting. For data collection in naturalistic settings, new technological advancements, such as local position measurement systems, can be used to gather continuous performance data of naturalistic behavior (e.g., Frencken, Lemmink, & Delleman, 2010). Third, and most importantly, in order to measure resilience, the duration and shape of the trajectory following an adverse event with a decline in performance must be assessed (Bonanno, 2004; Carver, 1998; Van de Leemput et al., 2014). Increases in the duration of time required for the resilience process after experiencing a series of adverse events (i.e., critical slowing down) can signal a critical shift in performance toward another attractor state (see Figure 1). Such patterns can be detected in time-series data by using techniques, such as auto-correlation or running correlations (Araújo et al., 2015). Therefore, based on intra-individual performance processes over time following several adversities, future breakdowns in resilience can be predicted (cf. Van de Leemput et al., 2014).

To investigate resilience on a long time scale, longitudinal studies based on an integration of physical sensor data from wearables (such as a smartwatch) and self-report data may be employed. For instance, Blaauw et al. (2016) coupled self-reported mental health variables (diary data over a period of 30 days) with physical measures (such as heart rate) collected via wearable sensors in smartwatches over the same period of time. Together, the accumulated data offered insight into the intra-individual variability of the assessed variables over time, as well as the dynamic relationships between them. Translated to an example of athletic resilience, cyclists could report a certain practice route they take every day with stable environmental conditions, which refrain inferences that can influence the performance (Araujo et al., 2015). During this activity, sensors in wearables can collect and report various physical measures, positional measures, and completion times. This would yield objective measures of athletic performance over a longer period of time. In addition to the physical measures, self-report questionnaires on cognitions, behaviors, emotions, as well as the type of adversity and protective factors (Sarkar & Fletcher, 2013) over the same period of time, could be integrated in order to provide insight into the dynamical interactions of behavioral and psychological processes. Again, researchers can then specifically focus on periods of critical slowing down that may precede a breakdown in resilience (cf. Van de Leemput et al., 2014).

Conclusion

Research on resilience in sports has increasingly focused on investigating the process that defines resilience (Fletcher & Sarkar, 2012, 2013; Galli & Vealey, 2008). To improve our understanding of this crucial concept for athletic performance, we call for using dynamical systems approach to understand resilience as an iterative process that is driven by ongoing interactions among a multitude of variables. New research designs should be tailored to measure adequate performance behavior and capture how the resilience process unfolds over time (Galli & Gonzalez, 2015). Specifically, researchers need to demonstrate the dynamic properties of resilience in individual time-series in realistic performance contexts and throughout athletes' careers. We expect this research agenda to result in in-depth knowledge about, and understanding of, the process of how individuals adapt to adverse events. Furthermore, practitioners might benefit from the dynamical systems approach by being able to detect early warning signals of critical transitions (e.g., critical slowing down, Scheffer et al., 2012) and take preventive actions before breakdowns in performance occur.

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