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BRIEF REPORT

Nonergodicity in Protective Factors of Resilience in Athletes

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Resilience is a key construct to understand when athletes continue to perform optimally, or when they break down. Although there is consensus that resilience can be conceptualized as a dynamic process, it remains an open question whether studying such a process on a group level adequately represents the individuals within a given sample. As a first step to answer this question, we designed a diary study to test whether the statistics for repeated assessments of protective factors and resilience can be generalized from group-level trajectories to the individuals. By tracking resilience and the protective factors over 21 days in athletes, we found divergent patterns of group-level and individual-level statistics for the repeated assessments. This so-called "ergodicity problem" implies that the individual, rather than the group, should be placed at the level of analysis to avoid wrong conclusions and ineffective interventions on their resilience.

Keywords: complexity, dynamical systems, generalizability, time series

When doing sports at a competitive level, setbacks such as injuries or losing matches occur frequently for athletes. To continue the engagement in sports and reach high levels of performance, it is essential that athletes have the ability to bounce back or recover from these stressful events. The positive adaptation to such events is called *resilience* (Galli & Gonzalez, 2015; Hill, Den Hartigh, Meijer, De Jonge, & Van Yperen, 2018a; Sarkar & Fletcher, 2014). Because researchers have been interested in studying resilience, a large range of different conceptualizations have emerged over the years. However, currently, there seems to be consensus that resilience is a dynamic process that emerges from ongoing interactions between the person and the environment (Carver, 1998; Hill et al., 2018a; Pincus, Kiefer, & Beyer, 2018; Pincus & Metten, 2010). Despite this consensus, scholars still debate on how this process should be measured and analyzed in athletes. Specifically, although the dominant approach in psychology focuses on analyses of group-level data, many studies point out that measuring processes over time on the basis of group-level data may lack generalizability to the individuals within the group. Put simply, statistics such as means or standard deviations calculated on group-level data may differ from the same statistics calculated on the individual level before being summarized for the group. Thus, group-level statistics may not represent the actual tendencies displayed by the individuals within a given sample, which is called the *ergodicity problem* (Den Hartigh, Hill, & Van Geert, 2018; Fisher, Medaglia, & Jeronimus, 2018; Liu, Mayer-Kress, & Newell, 2006; Molenaar & Campbell, 2009).

According to the dynamic process conceptualization of resilience, the psychological characteristics that may help an individual to demonstrate resilience (i.e., protective factors)

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change over time and across situations, as different stressors require different adaptations (Hill et al., 2018a). Typical protective factors found in the psychological literature are confidence (Gucciardi, Jackson, Coulter, & Mallett, 2011), motivation (Fletcher & Sarkar, 2012), perceived social support (Freeman, Coffee, & Rees, 2011), or adaptive perfectionism (Stoeber & Otto, 2006). Owing to these ongoing changes in the person–environment interaction, resilience in athletes changes accordingly. Such a process can be considered as ergodic if the underlying changes follow a common pattern across individuals and can therefore be generalized to the individuals in the sample (Molenaar & Campbell, 2009). In the field of psychology, however, group-level trajectories often *cannot* be generalized to the individual level, which means that the studied processes are nonergodic (Fisher et al., 2018; Molenaar & Campbell, 2009). Indeed, nonergodicity has been observed, among others, in the domain of (motor) development (Liu et al., 2006), the Big Five model of personality (Hamaker, Dolan, & Molenaar, 2005), language development (Van Geert, 2008), and neural networks (Medaglia, Ramanathan, Venkatesan, & Hillary, 2011).

Research has shown that nonergodicity can be detected in statistics that capture the central tendency and spread of a process, such as means, medians, and standard deviations (cf. Fisher et al., 2018). When ignoring the possibility of nonergodicity, scientific outcomes could lead to wrong conclusions and interventions for individual athletes. Hence, it is essential to test whether statistics based on group data represent the statistics that would be obtained when analyzing each individual's process.

The Current Study

The aim of the present research is to test the ergodicity assumption on a popular topic in sport psychology: resilience. The primary focus is on the protective factors of resilience. Specifically, for 3 weeks, participants filled out questionnaires assessing resilience and four protective factors that have been proposed in previous sport psychological research: confidence, motivation, perceived social support, and adaptive perfectionism (Sarkar & Fletcher, 2014). Confidence as a protective factor describes the extent to which athletes are confident that they possess necessary capacities to excel in their sport and maintain this belief in the face of adversity (Beattie, Hardy, Savage, Woodman, & Callow, 2011). Motivation in athletes can be self-determined, meaning that they engage in their sport because individuals find the task interesting and enjoyable in its own right (intrinsic motivation), which is assumed to help an athlete continue their engagement despite adverse events (Standage, 2012). However, research has shown that successful athletes are also more likely to engage in their sport compared to less successful athletes because the activity is subjectively associated with external rewards (extrinsic motivation, Mallett & Hanrahan, 2004). Therefore, both intrinsic and extrinsic motivation are assessed as protective factors in this study. Perceived social support refers to the degree to which an individual believes that others in their social environment would provide assistance if requested (Freeman et al., 2011). Finally, perfectionism denotes individuals' tendency to set high personal standards for themselves and the perceived discrepancy between their current and desired performance (Rice, Richardson, & Tueller, 2014).

To test the ergodicity assumption, we checked whether medians and standard deviations computed at the group level differ from (i.e., are not equal to) the same statistics computed on the individual level. Furthermore, we applied linear mixed models to every protective factor and resilience to assess whether there are systematic differences between individuals that need to be accounted for. Finding a lack of generalizability from group-level statistics to individual-level statistics (i.e., nonergodicity) would suggest that we need to take the individual athlete seriously as a level of analysis.

Method

Participants

A total of 111 university students who engage in competitive sports on a regular basis (i.e., at least once per week) signed up to participate in the current study in exchange for course credits. Forty-nine (44.14%) participants did not adhere to the study protocol either by not completing the full 21 days or by not filling in the daily questionnaire regularly (e.g., several questionnaires in 1 day or intervals larger than 2 days between assessments) and were removed from the sample. The final sample consisted of 62 participants (21 male, 41 female), with 91.94% being 22 years of age or younger. On average, the participants practiced their specific sport 2.81 (*SD* = 1.94) times per week. An a priori power calculation with G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) for a one-sample *t* test design with medium effect size (*d* = .5), an alpha of .05, and a power of .80 yielded that a sample size of 34 participants was required.

Materials

For the current study, we used an online platform, where participants were able to complete the daily assessments of the different questionnaires at any time of the day using either a computer or their smartphones. Each daily assessment contained the exact same items for the different protective factors (Table 1): confidence (Beattie et al., 2011), motivation (Mallett, Kawabata, Newcombe, Otero-Forero, & Jackson, 2007), perceived social support (Freeman et al., 2011), and perfectionism (Rice et al., 2014). Table 1 also shows that resilience was measured with the Brief Resilience Scale (Smith et al., 2008). Each item of the included scales was with a visual analogue scale of 100 points ranging from 0 (*strong disagreement*) to 100 (*strong agreement*).

Procedure

After receiving the approval of the Ethical Committee Psychology, University of Groningen (research code: 18267-SO), the study was activated in the University's online research platform. Before the participants were able to start the study, they were informed that

Table 1
Overview of the Scales for Each Protective Factor and the Subscales Included in This Study

Protective factor and questionnaire	Included subscales	Example item	Correlation
Confidence Trait Robustness of Sports-Confidence Inventory-8 (Beattie, Hardy, Savage, Woodman, & Callow, 2011)	Full scale (eight items)	If I make a mistake, it has quite a large detrimental effect on my self-confidence.	.88 [.81, .93]
Motivation	Extrinsic Motivation (four items)	I play sports for the prestige of being an athlete.	.76 [.63, .85]
Sport Motivation Scale-6 (Mallett, Kawabata, Newcombe, Otero-Forero, & Jackson, 2007)	Intrinsic Motivation (four items)	I play sports for the excitement I feel when I am really involved in the activity	.71 [.56, .82]
Perceived social support	Emotional support (four items)	If needed, to what extent would someone show concern for you?	.76 [.62, .85]
Perceived Available Support in Sports Questionnaire (Freeman, Coffee, & Rees, 2011)	Esteem support (four items)	If needed, to what extent would someone enhance your self-esteem?	.81 [.70, .88]
	Informational support (four items)	If needed, to what extent would someone give you tactical advice?	.69 [.53, .80]
	Tangible support (four items)	If needed, to what extent would someone help with travel to training and matches?	.80 [.69, .87]
Perfectionism	Personal standards (four items)	I have high expectations of myself.	.86 [.78, .91]
Short Almost Perfect Scale (Rice, Richardson, & Tueller, 2014)	Discrepancy (four items)	I hardly ever feel that what I've done is good enough.	.74 [.60, .84]
Resilience Brief Resilience Scale (Smith et al., 2008)	Full scale (six items)	I tend to bounce back quickly after hard times.	.84 [.75, .90]

Note. The correlation represents the lowest group-level correlation from one assessment day to the next (e.g., Day 1 with Day 2, Day 2 with Day 3, etc.) over the 21 measurement points with the according 95% confidence intervals.

they would be asked to fill out questionnaires on a daily basis assessing confidence, motivation, perceived social support, perfectionism, and resilience for a period of 21 days. Each assessment was estimated to take about 5 to 7 minutes. To proceed with the first questionnaire, the participants had to indicate their informed consent, demographics, and their e-mail address to automatically receive the URL for the following questionnaire. The first and all subsequent questionnaires assessed the protective factors and resilience. After completing the daily survey, the participants received the link to the survey of the upcoming day until they completed 21 assessments.

Data Analysis

To test the ergodicity assumption in the protective factors and resilience, we first computed an average trajectory across the 21 measurement days for each protective factor and resilience by computing the daily group mean, thus forming a time-series of the 21 daily mean scores for each protective factor and resilience. For each averaged trajectory, we computed the mean, median, and standard deviation. Next, we computed the individual-level statistics by computing the mean, median, and standard deviation based on the 21 measurement points for each individual before summarizing these statistics across the sample. Mathematically, this results in the same mean values for group-level and individual-level statistics, but may yield different values for the other statistics. Because ergodic processes are marked by homogeneity of group-level and individual-level statistics, the ergodicity assumption is not supported when the group- and individual-level statistics differ from each other (Fisher et al., 2018; Molenaar & Campbell, 2009). We therefore checked whether the group-level and individual-level statistics are equal to each other, and if not, we conducted one-sample *t* tests to assess whether the group-level statistic could represent the mean score of the distribution of the same individual-level statistics.

In addition, we ran linear mixed models for the time series of each protective factor and resilience. Under the assumption that the underlying change of the variables is linear over time, linear mixed models can test whether there is significant interindividual variability (i.e., random effects) in the *y*-axis intercepts and the slopes of the time series, which need to be accounted for. When the confidence intervals of the estimates of the random effects of the intercept and the slope do not include 0, accounting for individual differences improves the model estimation of how the participants change over time. This would provide converging evidence for the problem of generalizing of group-level findings to the individuals (i.e., nonergodicity).

Results

As shown in Table 2, we observed divergent patterns of group-level and individual-level medians and standard deviations. For example, the standard deviations of the daily mean scores (i.e., standard deviation of the averaged trajectory) is not equal to the mean standard deviation for the individual trajectories. This means that there is a difference between computing statistics by first averaging the data before the calculations versus first calculating the statistics for each individual before averaging these results. Moreover, the *t* tests revealed that only for the centrality measures (i.e., mean and median) the averaged statistic may represent the mean value of the individual-level distributions ($ps < .001$). These results are further supported by the linear mixed models. None of the confidence intervals for the estimates of random effects for the intercepts and the slopes of the protective factors and resilience included 0 (Table 2). This means that the model fit improves significantly when accounting for individual differences in both the *y*-axis intercepts and slopes when mapping protective factors and resilience over time.

Discussion

The aim of the current study was to empirically test whether group-level statistics of protective factors and resilience generalize to the individuals within the sample. Contrary to the ergodicity assumption, we observed divergent patterns of group-level and individual level statistics for the spread measure. Applying linear mixed models further indicated that the interindividual variation when measuring protective factors and resilience over time needs to be taken into account. Therefore, the protective factors and resilience do not follow a uniform pattern over time and may be better analyzed for

Table 2
Overview of the Statistical Results

Variable	Mean	Median		SD		Y-intercept	Slope
	Ind./Group	Ind. (*SD*)	Group	Ind. (*SD*)	Group	Estimate [95% CI]	Estimate [95% CI]
Confidence	50.33	50.74 (22.67)	50.93	7.43* (3.08)	1.81	19.81 [16.55, 23.71]	.67 [.55, .82]
Motivation							
Extrinsic motivation	35.48	34.95 (25.48)	35.53	8.55* (4.70)	.96	21.93 [18.30, 26.28]	.76 [.62, .93]
Intrinsic motivation	75.36	76.21 (16.45)	76.09	7.59* (3.93)	2.73	17.01 [14.18, 20.40]	.62 [.51, .76]
Perceived social support							
Emotional support	81.24	81.99 (18.65)	81.66	6.29* (4.05)	1.57	17.94 [14.98, 21.48]	.54 [.44, .67]
Esteem support	72.60	73.27 (20.53)	73.33	7.75* (3.79)	2.29	19.07 [15.92, 22.85]	.67 [.54, .82]
Informational support	62.40	62.99 (22.12)	62.91	8.27* (3.93)	2.31	19.11 [15.94, 22.91]	.59 [.48, .74]
Tangible support	55.55	55.85 (27.29)	56.73	8.59* (4.10)	2.42	23.99 [20.05, 28.72]	.75 [.61, .92]
Perfectionism							
Personal standards	68.92	69.25 (21.74)	69.14	6.93* (3.20)	.97	20.90 [17.47, 25.01]	.55 [.44, .67]
Discrepancy	51.87	52.05 (26.45)	51.85	8.55* (3.37)	.89	23.43 [19.58, 28.05]	.72 [.58, 88]
Resilience	54.76	55.17 (22.82)	54.58	7.04* (2.89)	1.18	20.23 [16.90, 24.21]	.57 [.47, .71]

Note. First, the group-level and individual-level (i.e., ind.) statistics (with standard deviation) for protective factors and resilience and second, the estimate (with confidence intervals) of the y-intercepts and slopes of the linear mixed models are reported.
[*] $p < .001$. $|d| > 0.8$.

each individual before collapsing the results for the sample.

Interestingly, the idiosyncratic patterns we found occurred despite using scales based on trait-like conceptualizations of the different constructs, which are assumed to remain stable within individuals over time. Thus, these patterns may become even more profound when assessing state-like variables with high intraindividual variability and fluctuations, such as emotions and cognitions, which are related to an individual's resilience (Hill, Den Hartigh, Cox, De Jonge, & Van Yperen, 2020; Van de Leemput et al., 2014). Because of the ergodicity problem demonstrated in our study, group-level findings of protective factors need to be interpreted with caution, as they may not adequately reflect how these factors operate on an individual level. Thus, to develop efficient interventions, the applicability of a certain set of factors to the individual needs to be assessed.

Limitations and Future Directions

The design of the current study has two limitations. First, our findings are based on 21 assessment points of relatively few participants. Although the drop-out rate for this assessment range already approached 50%, increasing the number of data points allows for more rigorous assessment of time variation in respondents' behavior, even for relatively small samples to test for ergodicity problems in repeated assessments (Den Hartigh, Cox, Gernigon, Van Yperen, & Van Geert, 2015). Second, the current study centers around the use of self-report measures of protective factors and resilience only. However, it should be noted that the aim was to capture the pattern of how these factors change over time rather than how an athlete adapts to the occurrence of a stressor. This means that contrary to contemporary approaches (Hill, Den Hartigh, Meijer, De Jonge, & Van Yperen, 2018b; Sarkar & Fletcher, 2013), resilience was not measured following induced or systematically manipulated stressors. In general, this is difficult to implement in ecological momentary assessment research, but it remains an important challenge for the future (cf. Dejonckheere, Mestdagh, Kuppens, & Tuerlinckx, 2020). Furthermore, although there is often not a better method to measure psychological variables, the quality of self-report data is not always evident (Berg & Rapaport, 1954). Nevertheless, the diary study was a deliberate choice for testing the hypothesis, as this design allows for continuous assessment of psychological variables over an extended period. Future studies may include data from different sources, including psychological, behavioral, and physiological parameters (Blaauw et al., 2016), while including the occurrence of stressors and mapping out the responses.

As a final note, mixed models are not be mistaken for a reliable statistical test of nonergodicity in a time series. These models can inform about interindividual variability in slopes and intercepts of variables measured over time and are appropriate for the data generated in this study. However, they may not detect nonergodicity when the underlying model is based on nonlinear change, which likely underlies the resilience process (Hill et al., 2018a, 2020; Van de Leemput et al., 2014).

Conclusion

In conclusion, the current study provides empirical support for the notion that resilience may best be conceptualized as a dynamical, nonergodic process (Hill et al., 2018a). We therefore propose that the individual, rather than the group, should be placed at the level of analysis for resilience. This is necessary to draw the right conclusions about individual athletes' resilience processes, and to design individually tailored interventions to improve resilience.

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