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Visualizing individual dynamics: The case of a talented adolescent¹

Joske K. Van der Sluis, Steffie van der Steen, Gert Stulp, & Ruud J. R. Den Hartigh

Research on talent and performance development has primarily focused on inter-individual differences. However, research suggests that performance and the underlying determinants change over time, in an individual-specific dynamic way. This chapter illustrates a method to measure, understand, and visualize the performance- and psychosocial dynamics of a talented adolescent athlete. During one season, a talented tennis player filled out an online diary questionnaire twice a week. We visualized the results using R-scripts that we made openly available. This facilitated the interpretation of the athlete's performance- and psychosocial dynamics, which are influenced by particular events in the athlete's life. Altogether, the current study provides insight into how the adolescent and the context interact and mutually affect each other in successive iterations.

When transitioning from childhood to adolescence, an individual discovers *what one wants to do or be* (Bee, 1992). This process of identity formation, where individuals search for a sense of self and personal identity through an intense exploration of personal values, beliefs, and goals (Erikson, 1950; 1963), is a core developmental task that becomes crucial in adolescence (Crocetti, 2017). After exploring the possibilities, an individual can make identity choices and commit to a certain occupation or ideology (Marcia, 1966). Some individuals may decide to devote most of their time to one, for them very important, aspect of their life, and strive for excellence in this domain. This can be in music, sports, or any other domain to which the adolescent strongly commits him- or herself. However, not every highly committed adolescent becomes an excellent performer. The underlying physical and psychosocial components of performance, and their interplay, play an important role in determining whether or not an adolescent achieves excellence. Understanding how the roles of these components are embedded in the individual's developmental process may contribute to (a) a theoretical understanding of domain-specific performance development, and (b) clues for intervention to (re-)direct the individual's development.

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So far, researchers have primarily attempted to search for *inter*-individual differences in performance determinants to understand why an adolescent ultimately reaches excellence in a particular domain (see next section). However, research increasingly suggests that both performance and the underlying determinants change over time, and that these changes are individual-specific and dynamic. That is, they shape performance in many different ways (e.g., Abbott et al., 2005; Den Hartigh et al., 2017; Phillips et al., 2010; Sarmento et al., 2018). Therefore, methods and tools focused on understanding *intra*-individual patterns would greatly add to our understanding of the development of excellence. In this empirical chapter we describe the performance- and psychosocial dynamics of a talented adolescent athlete who devotes much time to tennis. Our aim is to illustrate a method to measure, understand, and visualize the performance- and psychosocial dynamics. We therefore conducted a study in which we focused on understanding how these dynamics may be influenced by particular events related to tennis and the participant's social life. More generally, the method we present is a tool to visualize the development of a dynamic system. It focuses explicitly on individual change, and on how the adolescent and the context interact and mutually affect each other in successive iterations. This opens the door to novel and more extensive analyses for the study of intra-individual performance patterns in talented adolescents. In practice, our method can be used as a talent tracking system to provide insights into the progress a talented individual makes in his/her career. In turn, this will provide clues on how to intervene and help the adolescent to reach excellence.

Inter-individual differences in sports performance

Research on inter-individual performance patterns has shown that there is a broad variety of physical and psychosocial factors that can determine excellent sports performance (e.g., Elferink-Gemser et al., 2011; Gould, 2002; Johnston et al., 2017; Pankhurst et al., 2013; Vaeyens et al., 2008; Williams & Reilly, 2000). For example, psychological factors as confidence, mental toughness, competitiveness, a hard-work ethic, coachability, and optimism could explain excellent performance of Olympic athletes (Gould 2002). In a recent study, Hardy et al. (2017) analyzed super-elite and elite athletes on different psychosocial factors. Super-elite athletes are those who had won multiple medals at major international championships (e.g., the Olympic Games), and elite athletes are those who had won medals in international competitions, but not at major championships. The authors found that commitment to practice was a commonality across super-elite and elite athletes. Additionally, in terms of motivation, attaching a greater importance to sports than to other aspects of

everyday life was a defining characteristic of super-elite athletes. In a study among Dutch soccer players, Van Yperen (2009) assessed different psychosocial factors among adolescents of a soccer youth academy. He found that players who had a successful career 15 years later (i.e., who had played for years at a European Premier League club) had a higher commitment to reaching their goal of becoming a professional soccer player during their adolescent years. In addition, these players engaged more in problem-focused coping, and perceived to have more social support at the time they were assessed in the youth academy.

In line with the finding that perceived social support appears important to reach excellence, researchers have examined the role of the social environment in talent development (e.g. Gould, 2002; Côté, 1999). For instance, several authors discussed the significance of parental involvement and the role of the coach to develop excellent sports performance (Côté, 1999; Lauer et al., 2010; Pankhurst et al., 2013, Scanlan & Lewthwaite, 1988; Vaeyens et al., 2008; Van Yperen, 1998). With regard to parental involvement, Lauer et al. (2010) revealed that parents of junior tennis players are directly involved in their developmental pathway to excellent performance. Moreover, the support provided by parents as well as teammates may help (or hinder) athletes' positive responses to stressors such as injuries or losing matches (Fletcher & Sakar, 2012; Freeman & Rees, 2009, 2010; Rees & Hardy, 2000). In addition to the parents and teammates the coach also plays an important role. Cushion and colleagues (2002) summarized several studies on coaching behavior, stating that the actions of coaches have a significant impact on the athletes' behaviors, cognitions and affective responses. This, in turn, has an influence on the performance levels the athletes can achieve (Amorose, 2007; Mageau & Vallerand, 2003; Smoll & Smith, 2002), and on their social, emotional, and physical well-being (Horn, 2002; Miller, 1992; De Marco et al., 1996; Jones et al., 1997).

The psychosocial components described above are only a selection of factors that influence young athletes' performance. Numerous additional relevant variables have been unravelled by other studies, such as practice hours (Ericsson et al., 1993), physical characteristics (e.g., Abbott et al., 2005; Abbott & Collins, 2004; Elferink-Gemser et al., 2012), and sheer luck (e.g., Elferink-Gemser et al., 2011; Gladwell, 2008; Mlodinow, 2008). Altogether, a variety of factors may play a role in determining whether or not adolescents reach excellence in sports.

Intra-individual dynamics

Recent research in the domain of talent development increasingly suggests that predicting excellence on the basis of separate (or simple interactions between) psychosocial and physical factors is difficult, because performance as well as the underlying factors are dynamic and can fluctuate in different ways (e.g., Abbott et al., 2005; Den Hartigh et al., 2016; Gulbin et al., 2013; Phillips et al., 2010; Sarmento et al., 2018). For instance, Gulbin et al. (2013) analyzed 256 elite athletes, and discovered that a linear trajectory from junior to senior excellent performance occurred in only 7% of the athletes. Furthermore, in their recent meta-analysis on talent identification and -development in soccer, Sarmento et al. (2018) found that “*the most successful players present technical, tactical, anthropometric, physiological and psychological advantages that change non-linearly with age*” (p.907). As a consequence, inter-individual differences in underlying factors at a particular moment in time often do not have a strong predictive value with regard to the development of excellent performance. Indeed, in his work on talent development Simonton (2001) describes that (a) early inter-individual indicators of ultimate exceptional abilities are rare to nonexistent and unreliable, (b) different individuals may exhibit a similar ability level at different ages, (c) the underlying constituents of a particular ability can change over time, and (d) talent can be changed or lost during a person’s life span. Thus, although the great majority of previous research focused on inter-individual differences, we need to shift our theoretical and empirical focus to intra-individual dynamics of performance development.

Recently, researchers proposed theoretical models that explain how performance, underlying determinants, and their interactions change over time, as well as why this process differs between individuals (e.g., Den Hartigh et al., 2016; Philips et al., 2010). These researchers proposed the dynamic systems perspective as a theoretical approach to understand how multiple interacting factors shape the performance of individual athletes. In their dynamic network model, Den Hartigh et al. (2016) showed that the development of excellent performance is not driven by the additive effects of underlying factors, but emerges out of dynamic, individual-specific factors that are interconnected. More specifically, an individual’s ability is dynamically embedded in a network of interacting variables, such as motivation, parental support, practice, etc. Whether or not an individual is able to demonstrate excellent performance at a particular moment (e.g., win a major international tournament such as a Grand Slam in tennis) is a function of the current ability level and a chance factor. Altogether, this model fits with previous literature stating that the development of excellence is

multidimensional, multiplicative, and includes the role of chance (e.g., Elferink-Gemser et al., 2011; Gladwell, 2008; Phillips et al., 2010; Simonton, 2001). Using computer simulations, Den Hartigh et al. (2016) compared the model with a null-hypothesis (additive) model and showed that the dynamic network model provided much better predictions of actual performance data across different fields, including arts, music, science, and sports. In a recent extension of the dynamic network model, Den Hartigh et al. (2018) introduced events in the form of “perturbations” to the model. One of the authors’ findings was that some individuals could overcome such events and attain excellent performance, whereas others were not capable of doing so, or even broke down.

Taken together, dynamic systems principles likely underlie the development of excellent performance, and can account for recent empirical findings. A challenging question is: How can we translate a theoretical dynamic model to empirical and practical methods focused on the development of talented adolescents? In order to answer that question, we need to (a) collect data on individual cases, (b) follow individuals across time to detect intra-individual patterns of performance, physical, and psychosocial factors, as well as events that may have an impact, and (c) analyze and/or visualize the patterns in a way that they can be interpreted by researchers and practitioners.

The Current Study

The aim of the current chapter is to provide a first step in the empirical study of intra-individual dynamics of performance and psychosocial factors, and how these may be influenced by particular events in the life of a talented adolescent. The method we employed can be used with different individuals across different domains (sports, but also education, work, and music, for instance). In our study we conducted repeated measurements on (self-reported) physical and psychosocial factors, as well as on performance of an adolescent top-level tennis player. The data were collected by using online diary questionnaires, which allowed us to track the athlete for nine weeks during an important period of the tennis season. We visualized the results to make them understandable for both researchers and practitioners, facilitating the interpretation of patterns within the data. Based on the collected data, we specifically focused on understanding 1) the intra-individual variation of performance and psychosocial factors, and 2) how these factors respond to positive and negative events that occurred during the period of data collection.

Method

Participants

In our original study, the sample consisted of five tennis players ($M_{\text{age}}=14$, $SD= 1.00$). They were two male and three female players, who were ranked in the top of their age category in the Dutch national tennis rankings. To provide an in-depth illustration of intra-individual dynamics, this chapter focuses on one case. For reasons of privacy, no further details on this case are provided, and the results section only provides a general description of the positive and negative events the participant experienced. Because the majority of participants were female, we will refer to the case illustrated here as “she”.

Measures

Performance and psychosocial factors. In order to gain insight into the performance and psychosocial dynamics of the participant, an online accessible diary questionnaire was developed. Based on the existing literature, the online diary served to capture repeated measures of the following factors: Match performance, training, importance of coach/trainer, parents, team-/training mates, (non-tennis) friends, the athlete’s confidence, commitment, and physical fitness. An example of a question about confidence is ‘At this moment, how confident are you that you will become a top tennis player?’, and an example question for fitness is ‘How fit are you at this moment?’. For the psychosocial factors parents/family, coach/trainer, (non-tennis) friends, and team/training mates, the athletes had to answer the same question for each factor, namely: ‘How important are, at this moment, your parents/coach/etc. for you?’. Athletes had to indicate a score by positioning a slider between 0 (not at all) and 10 (very much).

The impact of events. To explore the influence of particular events on the participant’s performance and other (psychosocial) factors, she was asked to take in mind the most important event—either positive or negative—that happened since she last filled out the questionnaire. The participant was then asked to share more details about the event by responding to the following items: What factor was the event related to?; How important was the event to you?; How pleasant/unpleasant was the event to you (on a scale from 0 to 10)?; On which other factors did the event have an influence?; and How big was that influence (on a scale from 0 to 10)?

Procedure

The diary questionnaire was constructed using Qualtrics (www.qualtrics.com), which is an online survey creator. The questionnaire was pilot-tested by two training mates of the participant, where the main goal was to correct for mistakes, fluency, and to make an estimation of the time needed to fill it out. Following the pilot test, an informative briefing session was scheduled with the targeted participants, during which tennis players and their parents were informed about the purpose of the study and the procedure of the research. Players were informed about the importance of filling out the questionnaire alone and about responding as accurately and clearly as possible. In addition, we explained that the responses of the players would be kept anonymous. After the players and parents signed the informed consent, the players had to complete a general baseline questionnaire for the different components investigated, and additional questions about their daily training routine and current ranking in the Dutch tennis system.

The players who agreed to participate were monitored during an entire competition season. They were asked to fill in the diary every Monday- and Friday evening (i.e., eight weeks, 16 questionnaires). Using the Monday questionnaire, the participants could reflect on matches during competition and/or tournaments that are typically held in the weekend. Using the questionnaire on Friday, participants could reflect on the last week, including school, training and tournaments. Participants received an email and a mobile phone message when the questionnaire was ready to be completed. It took the participants about 15 minutes to complete a questionnaire.

Visualization

The main aim of our study was to understand the intra-individual processes of performance and psychosocial factors, and how these may be influenced by particular events related to tennis and the participant's social life. Collecting repeated measurements over time is key to get an understanding of the nature of these processes, yet these repeated measurements also bring challenges in terms of analysis and interpretation. An important step in interpreting patterns in data is visualization (Tukey, 1977; Cleveland, 1993). In this paper, we demonstrated the data in two ways: 1) by showing the intra-individual variation of performance and psychosocial factors over the course of the measured period, and 2) by showing the (raw) trends of the measured factors over time, and how they could be linked to

the events. Together, these figures present a rich picture of the varying nature of the measurements and how they are associated with performance. All visualisations were done in R (R core team, 2017). We made use of the tidyverse-packages (Wickham, 2017), in particular the ggplot2-package (Wickham, 2016). The specific scripts that we used, along with the data, are available at hdl.handle.net/10411/FIRICT.

Results

Variability of performance and psychosocial factors

Figures 1 and 2 show the intra-individual variation of performance and psychosocial factors across the entire study period for the selected athlete. It is evident that even within this rather short period (16 measurements across 8 weeks), there is variation in the time series of all factors, with considerable differences between the factors. This becomes particularly evident when we visualize the temporal variation within each factor as measured by the mean-squared successive differences (MSSD, Von Neumann et al., 1941). The least variation was seen in the commitment of the athlete, which was always very high. Low levels of variation were also seen in the perception of how successful the match was played (swinging around the mid-value of 5). The confidence the athlete had to reach the top was typically low, with low variation. Large variation was seen in the impact an event had on the matches played, with events perceived to have a very minor effect (a score of 1) or sometimes very strong effects (a score of 9). The perceived importance of friends also varied quite extensively (see Figure 1).

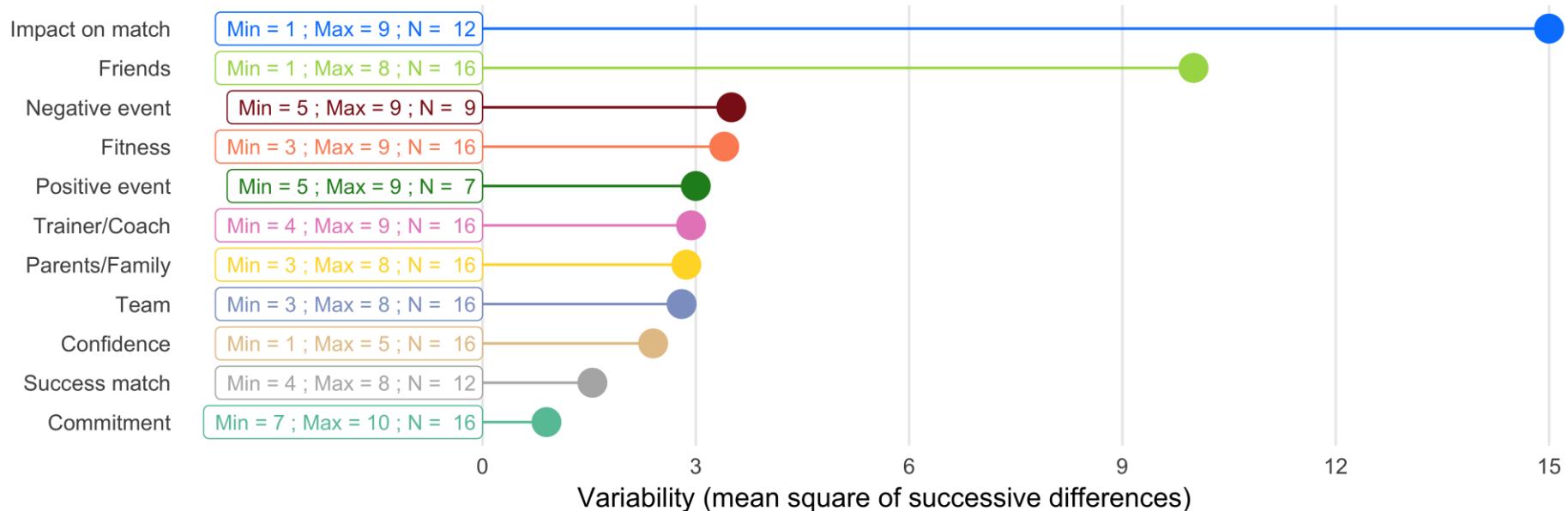


Figure 1. The intra-individual variability (as measured by the MSSD) across all the measures in this study. “Min” and “Max” refer to the minimum and maximum score on that measure (on a scale ranging from 1 to 10), while “N” refers to the number of scores the MSSD is based on.

Dynamics of performance and psychosocial factors

Subsequently, we wanted to gain insight into how the psychological factors and performance changed across time, and how they responded to positive and negative events that occurred during the period of data collection. The four events that were most important for the athlete were selected in order to provide a qualitative description of the various factors and how they seem to relate. This description is based on Figure 2, which is a visual presentation that enhances the interpretation of a complex dataset consisting of time series of different factors.

At the second measurement the participant reported having played a bad match. In the diary, the participant described that there were technical problems with the swing, which is an event of major importance (8 on a 10-point scale). The participant and the coach/trainer decided to make technical adjustments to the swing, and it took until the fourth measurement before the participant was satisfied with the swing again. When the technical issues first appeared, there was a striking drop in importance of friends from 6 points to 1 point. Throughout this phase of technical problems, the athlete trained every day with the trainer/coach, who was considered very important at that moment (9 points). At the same time, parents became less important (they dropped from 8 to 5 points). The match that was played between the third and fourth measurement was rated as the least positive (4) in the sequence of matches. During this phase the commitment decreased from 9 to 7 points, which was rather rare (see also Figure 1). The fitness was also rated 1 point lower during these measurements. When the participant eventually reported at the fifth measurement that the swing was gradually improving, there was an increase in commitment from 7 points to 9 and the importance of parents increased again from 5 to 6, whereas the importance of the coach dropped from 9 to 7 points. In addition, school friends became more important again (from 2 to 5 points).

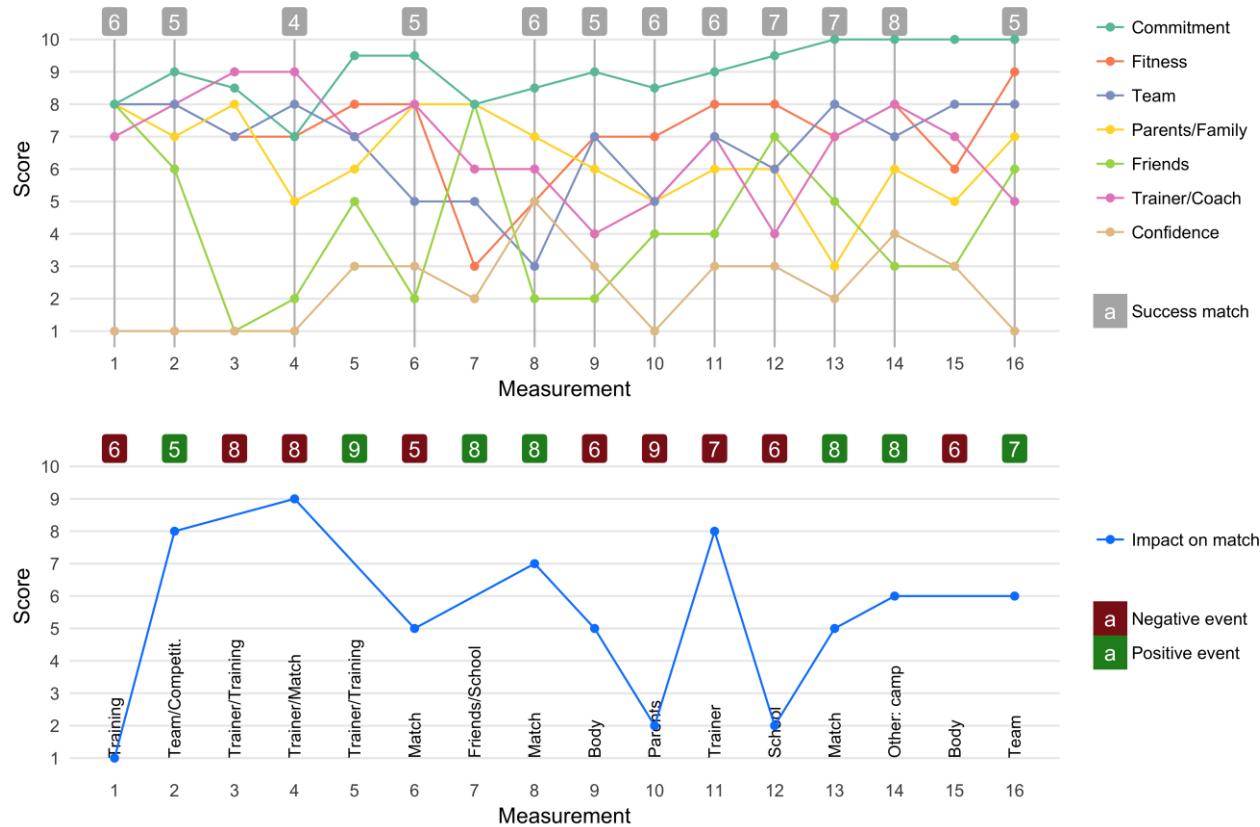


Figure 2. The measures across time. In the top panel, individual factors are visualized. The vertical lines refer to the matches played since the previous measurement, where the numbers in grey reflect how well these matches went. The participant had to rate the perceived impact of the event on the match on a scale from 1 to 10, which is depicted in the lower panel. Note that some ratings are missing, in these instances the participant did not play a match. The text in the graph represents the factors that the event pertained to, which are connected to a brief narrative. The numbers at the top reflect on a scale of one to ten how pleasant or unpleasant the event was for the participant. Events in red were negative events and those in green were positive events.

Between the sixth and the seventh measurement, the participant went on a school trip during the week. Shortly after return, a strong increase in the importance of friends (from 2 to 8 points) was reported. Fitness showed the reverse pattern, a strong decrease from 8 to 3 points. Commitment to tennis and the importance of the trainer also dropped during the school trip. In the weekend that immediately followed this trip, the participant played an important match during a tournament, which she won. The importance of school friends immediately dropped again to its level before the school trip (2 points). Fitness increased from 3 to 5 points, and commitment also started to rise again, albeit only with .5 points. The importance of team members was at its lowest point, which may be due to the fact that this was an individual tournament. In the diary, the participant commented on winning the match, and mentioned the opponent was particularly highly ranked. Interestingly, the confidence of the participant to become a professional tennis player peaked at the same time, and there was also a decrease in the importance of friends.

After this successful tournament, the participant was feeling sick and had a cold at measurement nine. In the weekend that followed, the participant played a bad match, which was witnessed by one of the parents. That evening, one of the parents had a conversation with the participant and mentioned to be upset with her weak mental performance and attitude. If this behavior would be shown again, the parent argues, it would be better for the participant to quit playing tennis. Subsequently, a large decrease in confidence was observed in measurement 10 (from 5 to 0), and the importance of parents decreased from 7 to 5 points. Friends, however, gained importance from 2 to 4 points.

Finally, between the thirteenth and fourteenth measurement, the athlete travelled with team members and the trainer/coach to participate in a tournament. The thirteenth entry in the diary is right after the athlete played qualification matches for the tournament. At this moment, there was an increase in the importance of team members and trainer/coach, who witnessed the matches. The importance of the coach increased from 4 to 7 points. At the same time, the importance of school friends, and particularly the importance of the athletes' parents (who were not present) decreased. In the diary the athlete commented on having a good time with team members and the coach. Right after the tournament (fourteenth measurement), the participant indicated that she shared these experience with her parents, who expressed their enthusiasm. Subsequently, the parents' importance rose again with 3 points. Although the

importance of the coach continued to increase after the trip (+1 point), the athletes' team members became less important again (-1 point).

Discussion

The aim of this study was to capture the intra-individual dynamics of performance and psychosocial factors in a talented adolescent tennis player, and to visualize how these factors respond to positive and negative events that occurred during the period of data collection. Recently, several authors suggested that we should apply a dynamic systems approach to understand athletes' performance development (e.g., Den Hartigh et al., 2016; Phillips et al., 2010). This suggestion is in line with increasing evidence that underlying physical and psychosocial components of performance are dynamic and shape performance in different ways (e.g., Abbott et al., 2005; Den Hartigh et al., 2017; Phillips et al., 2010; Sarmento, et al., 2018). However, empirical research looking at the dynamics of performance and psychosocial factors is scarce. In the current study, we collected time series of such factors to increase our understanding of intra-individual performance- and psychosocial dynamics.

First, we looked at the intra-individual variability across all measures. We showed how performance and the related psychosocial factors do not remain stable and demonstrate substantial variation over time. For instance, the participant's commitment was always high with relatively little variation, whereas the perceived impact an event had on the matches played, and the perceived importance of the coach and friends varied considerably. This is in line with previous empirical evidence that performance, and performance-related factors often change non-linearly across time (e.g., Abbott et al., 2005; Gulbin et al., 2013; Sarmento et al., in press).

The second aim was to connect the participant's performance and psychosocial dynamics to the most important events experienced, in order to get an understanding of how these dynamics are shaped. We therefore constructed two graphs that included (a) the fluctuations of match performance and the psychosocial variables, and (b) the impact of the events. This facilitated the interpretation of the time series, revealing some general patterns for this participant, including the existence of seemingly competing factors (*cf.* the notion of carrying capacity in developmental processes, Van Geert, 1991, 1994). First, there was a trade-off between the coach and the parents. The coach became more important when the participant encountered difficulties related to tennis, whereas parents became less important during these

phases. When there were technical difficulties, the participant relied on the coach for improvement. Indeed, coaching strategies and instructions have been shown to enhance the self-efficacy of athletes (Weinberg & Jackson, 1990), which is seen in the increasing commitment and confidence of our participant. When these issues were resolved, parents gained in importance and the importance of the coach decreased. Parents are essential in the process of talent development, mainly via various forms of support (Gould et al., 2008), which is seen in the high rates of parental importance for this athlete. Second, the confidence of the athlete fluctuated in relation to performance during important matches. Interestingly, the participant mentioned receiving negative comments from the parents after a weak mental performance during a match, including statements that the athlete would have to quit playing tennis, because it costs a lot of time and money. Parents who over-emphasize outcome goals, and/or focus on a return of their investment often create stress, uncertainty, and a lack of motivation (Gould et al., 2008), which may explain the drop in confidence, commitment and the importance of parents for this participant.

Finally, there was a trade-off between school friends and tennis-related activities. School friends became more important when there were no major tennis-related activities, whereas they decreased in importance during main tennis events. Such trade-offs between seemingly remotely related factors are interesting from a dynamic systems perspective, according to which relationships between factors can be nonlinear and influences of one factor on another can be indirect. As an example from our participant, the technical adjustments she had to make had an (indirect) influence on the importance of her friends. Overall, such patterns provide support for the idea that the psychosocial factors and performance are all embedded in a network of dynamic factors that can be related in direct and indirect ways (Den Hartigh et al., 2016, 2017).

In dynamic systems terms, the negative events that are reported by the participant could be regarded as ‘perturbations’ on the road to excellence (Den Hartigh et al., 2018). Some athletes are not able to overcome negative events, or even break down. An interesting future avenue is to investigate whether patterns of change and variability in performance and psychosocial factors can provide clues for if, and when, an athlete is likely to breakdown. Hill, Den Hartigh, Meijer, De Jonge, and Van Yperen (2018), for instance, proposed that an athlete needs increasing amounts of time to recover when encountering a series of negative events (i.e., critical slowing down). As a consequence, when an athlete is in a vulnerable state after

some setbacks, even a small next negative event within a relatively short time frame could cause a breakdown in the athlete's performance (and psychological state).

Conclusion

This research provided first insights into the intra-individual variation of performance and psychosocial factors, and how these factors respond to positive and negative events. We focused on the case of a talented tennis player, but our approach can be extended to cases of adolescents who are talented in another domain (e.g., music or education). The visualizations of the factor dynamics and the participant's descriptions in the diary allowed us to better understand and interpret the patterns in the data. Note that the aim of this study was not to create a generalizable model that applies to some population-average. This is at odds with a 'one size fits all' approach, where one model is generated that applies to every individual, in which researchers focus on particular (presumed) key components. The data and specific scripts we used to analyze these individual dynamics are made available at hdl.handle.net/10411/FIRICT, which may aid researchers to visualize and interpret data on psychological and behavioral dynamics.

Our individualized approach can be further strengthened by collecting data across a longer period of time and/or by collecting more dense time series. When more measurements of individual cases are taken, there are more possibilities to analytically detect patterns in the data (e.g., dynamic patterns such as critical slowing down). In addition to the visual explorations that we presented here, machine learning algorithms may help to detect patterns (e.g., Blaauw, 2018). Using such techniques researchers could detect (changing) relationships between variables in the network of individual athletes. For instance, the importance of the parents and coach may change over time, and such changes may differ between athletes. Getting a grip on such patterns may help tailoring the stimulation of individual talent development. Furthermore, when applying machine learning algorithms across larger samples of athletes, it could be possible to detect mechanisms underlying changes in performance that are shared across (clusters of) individuals.

To conclude, the performance and psychosocial factors of an athlete develop according to dynamic systems principles (e.g., Den Hartigh et al., 2016; Phillips et al., 2010). When collecting empirical data from athletes, fine-grained visual analyses provides deeper insight into the intra-individual dynamics, and has additional implications for practice. For example,

the visualisations could provide an overview of the progress a talented individual makes in his/her career and these dynamics could be used as talent tracking systems, where data is organized in a clear and structured way. This might in turn generate ideas for the environment (e.g., parents, coaches, sport psychologists) on how to intervene to avoid a negative spiral for the athlete, but also to facilitate a positive spiral.

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