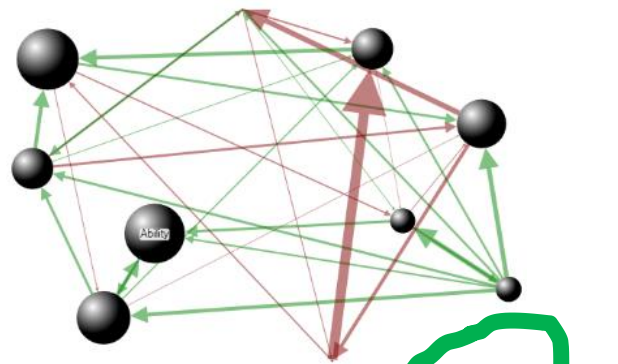




The development of excellent performance in sport: A dynamic network approach



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- > Talent selection and development
- > Psychological momentum
- > Resilience





Outline

- › What is excellent performance?
- › Prevailing approaches to understand its development
- › Properties of excellent performance and its development
- › Understanding excellent performance development
 - A dynamic network model
 - The use of computer simulation
- › Future directions



Talent and Excellence^{1,2}

- › Talent: Potential or capacity to excel in a particular domain that requires special skills and training
- › Talent *development*: Process through which potential turns into manifest (excellent) abilities
- › Excellent performance: Repeated demonstrations of superior performance, observed in achievements

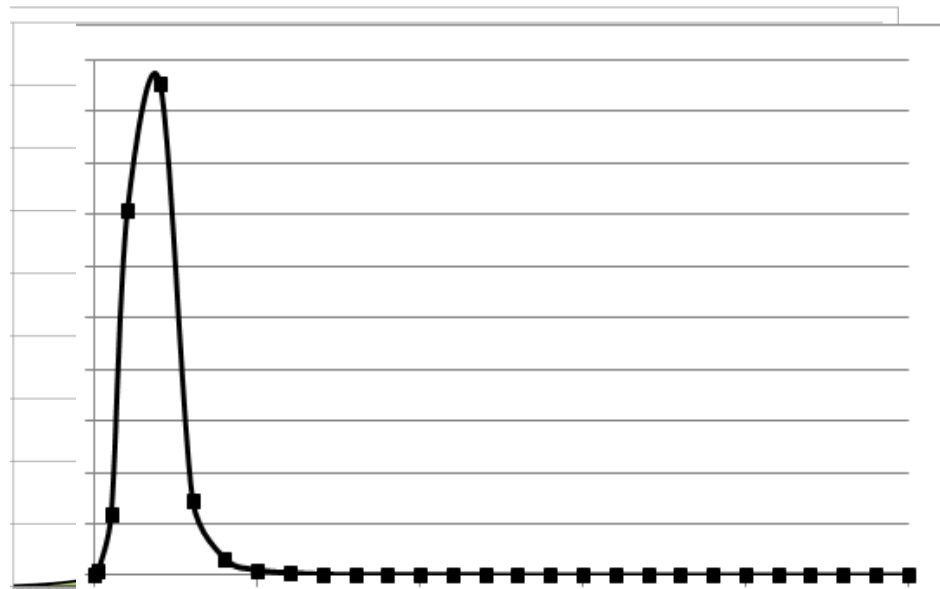
¹ Den Hartigh, Hill, & Van Geert (*Complexity*, 2018)

² Simonton (*Psychol. Rev.*, 1999)



Talent and Expertise

› Reaching true expertise is rare¹



ROGER FEDERER

WEEKS NUMBER 1: **310**

OLDEST NUMBER 1: **36 y 320d**

DAVIS CUP CHAMPION: **2014**

CAREER SINGLES TITLES: **103**

GRAND SLAM
SINGLES CHAMPION
RG: 1, W: 8, USO: 5

TOUR FINALS
WON

MASTERS 1000
CHAMPION

OLYMPIC MEDALIST
G: DOUBLES 2008
R: SINGLES 2012

SPORTSMAN
YEAR

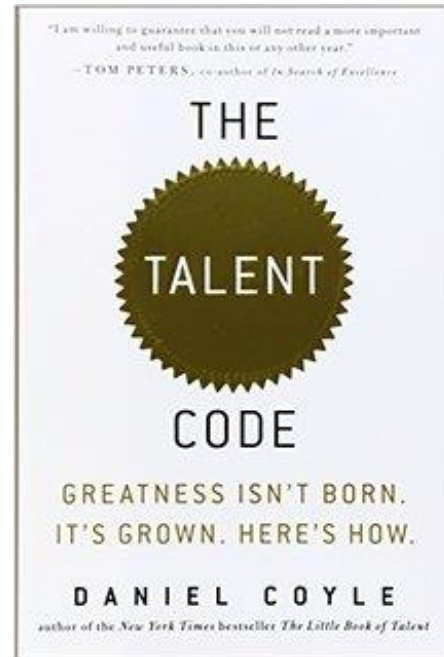
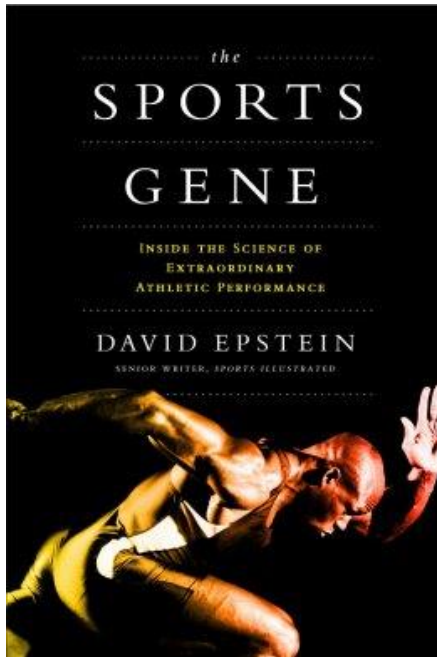
Images of other athletes: Serena Williams, Usain Bolt, and Venus Williams.

¹ Den Hartigh, Van Dijk, Steenbeek, & Van Geert (*Front. Psychol.*, 2016)



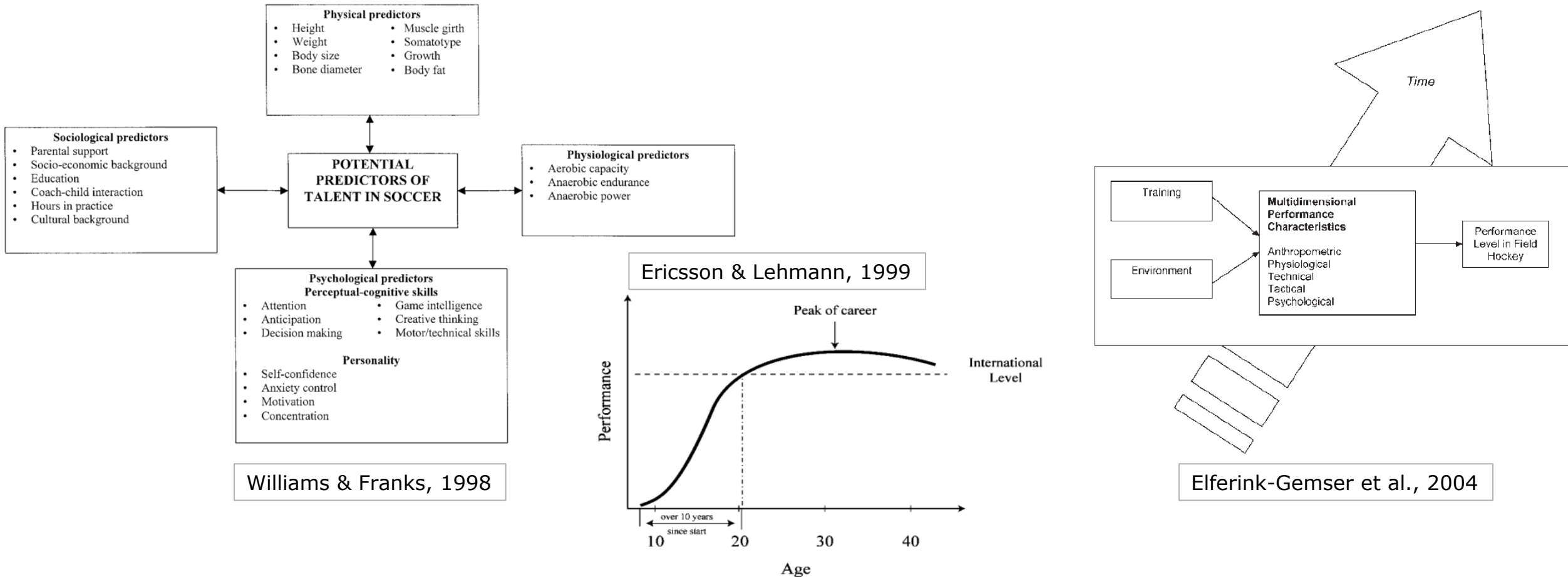
Explanations for excellent performance

- › Some popular thoughts
 - Talent is in the genes
 - You need to practice 10,000 hours / ten year rule





Explanations for excellent performance



But how does excellence develop?

- › What research and reality show...¹⁻⁴
 - Excellence develops in different ways



- 1 Den Hartigh, Van Dijk, Steenbeek, & Van Geert (*Front. Psychol.*, 2016)
- 2 Phillips, Davids, Renshaw, & Portus (*Sports Med.*, 2010)
- 3 Abbott, Button, Pepping, & Collins (*Nonlinear Dyn. Psychol. Life Sci.*, 2005)
- 4 Gulbin, Weissensteiner, Oldenziel, & Gagné (*Eur. J. Sport Sci.*, 2013)

But how does excellence develop?

- > What research and reality show...¹⁻⁴
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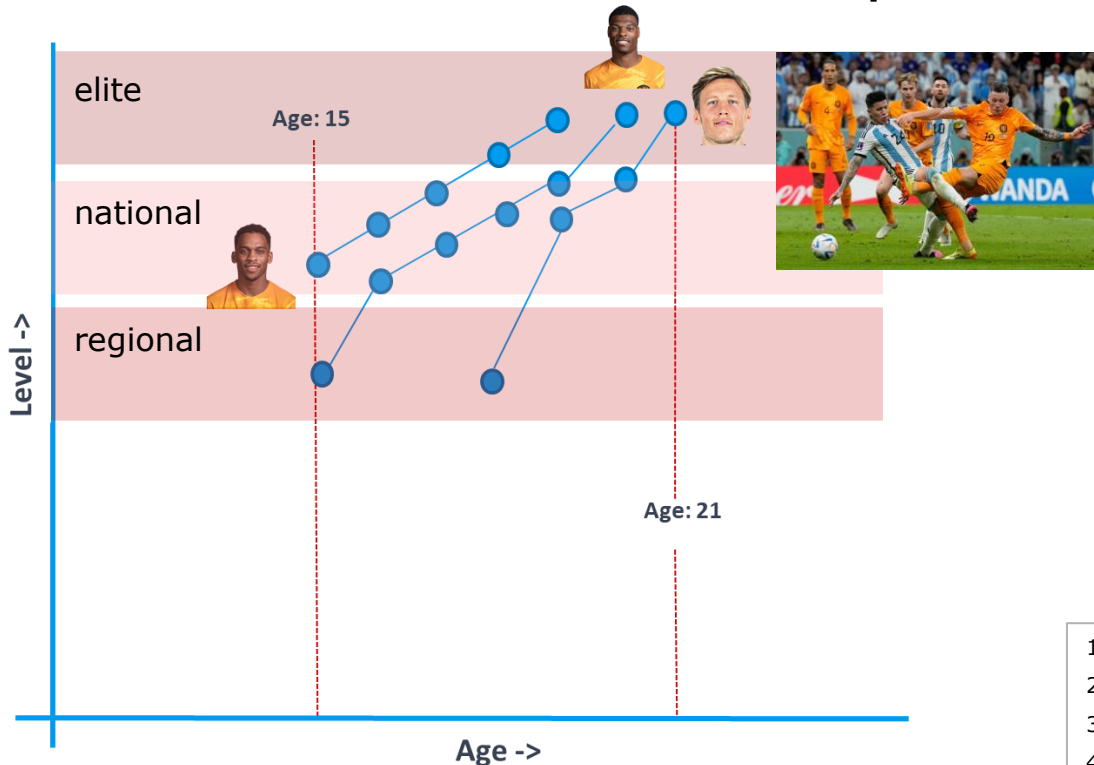


Table II. Type and frequency of linear and non-linear competition pathway trajectories through the Athlete Development Triangle (ADT) ($n = 256$).

	Developmental pathway trajectory							
	Linear		Non-linear					
	A. Pure ascent		B. Mixed ascent			C. Mixed descent		
Overall ($n = 256$)	16.4		26.2			57.4		
Partitioned ($n = 256$)	P1. Junior 7.0	P2. Senior 9.4	P3. Single crossover 10.2	P4. Concurrent 12.9	P5. Multiple crossover 3.1	P6. Single crossover 23.8	P7. Concurrent 22.7	P8. Multiple crossover 10.9
Trajectory								
Sport classification								
Cgs ($n = 118$; 10 sports)	27.1		30.5			42.4		
Non-cgs ($n = 138$; 17 sports)	7.2		22.5			70.3		
p value	<0.001		n.s.			<0.001		

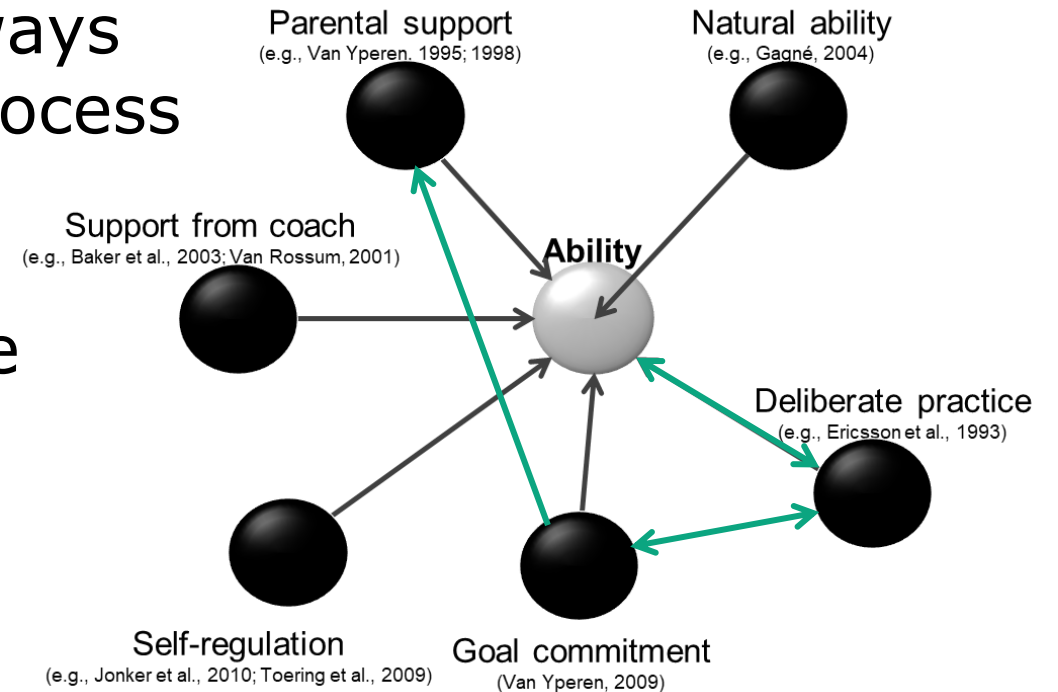
Note: A *crossover* denotes moving between junior and senior competition, or vice versa. Concurrent competition indicates the simultaneous participation in both junior and senior competition.

- 1 Den Hartigh, Van Dijk, Steenbeek, & Van Geert (*Front. Psychol.*, 2016)
- 2 Phillips, Davids, Renshaw, & Portus (*Sports Med.*, 2010)
- 3 Abbott, Button, Pepping, & Collins (*Nonlinear Dyn. Psychol. Life Sci.*, 2005)
- 4 Gulbin, Weissensteiner, Oldenziel, & Gagné (*Eur. J. Sport Sci.*, 2013)

But how does excellence develop?

- › What research and reality show...¹⁻⁴
 - Excellence develops in different ways
 - Dynamic and multidimensional process

- Early indicators of later excellence are unreliable



¹ Den Hartigh, Van Dijk, Steenbeek, & Van Geert (*Front. Psychol.*, 2016)
² Phillips, Davids, Renshaw, & Portus (*Sports Med.*, 2010)
³ Abbott, Button, Pepping, & Collins (*Nonlinear Dyn. Psychol. Life Sci.*, 2005)
⁴ Gulbin, Weissensteiner, Oldenziel, & Gagné (*Eur. J. Sport Sci.*, 2013)



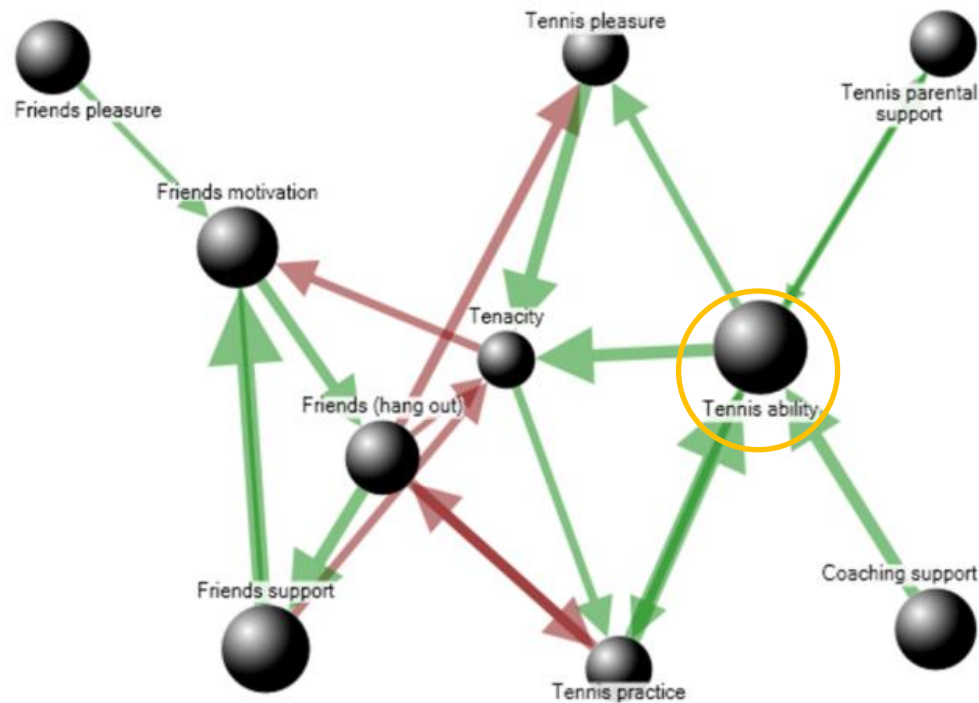
A theoretical model of excellence

> Account for:

- Dynamics and multidimensionality
- Various developmental trajectories
- Lack of early indicators
- Highly right skewed distribution of excellent performance

Dynamic network model

> Coupled logistic growth equations^{1,2}



Ability change	Fixed resources	Variable resources
----------------	-----------------	--------------------

$$\left. \begin{aligned}
 \frac{\Delta L_A}{\Delta t} &= \left(r_{L_A} L_A \left(1 - \frac{L_A}{K_{L_A}} \right) + \sum_{v=1}^{v=i} s_v L_A V_v \right) \left(1 - \frac{L_A}{C_A} \right) \\
 \frac{\Delta L_B}{\Delta t} &= \left(r_{L_B} L_B \left(1 - \frac{L_B}{K_{L_B}} \right) + \sum_{v=1}^{v=j} s_v L_B V_v \right) \left(1 - \frac{L_B}{C_B} \right) \\
 &\dots \\
 &\dots \\
 &\dots
 \end{aligned} \right\}$$

¹ Den Hartigh, Van Dijk, Steenbeek, H. W., & Van Geert (*Front. Psychol* ,2016).

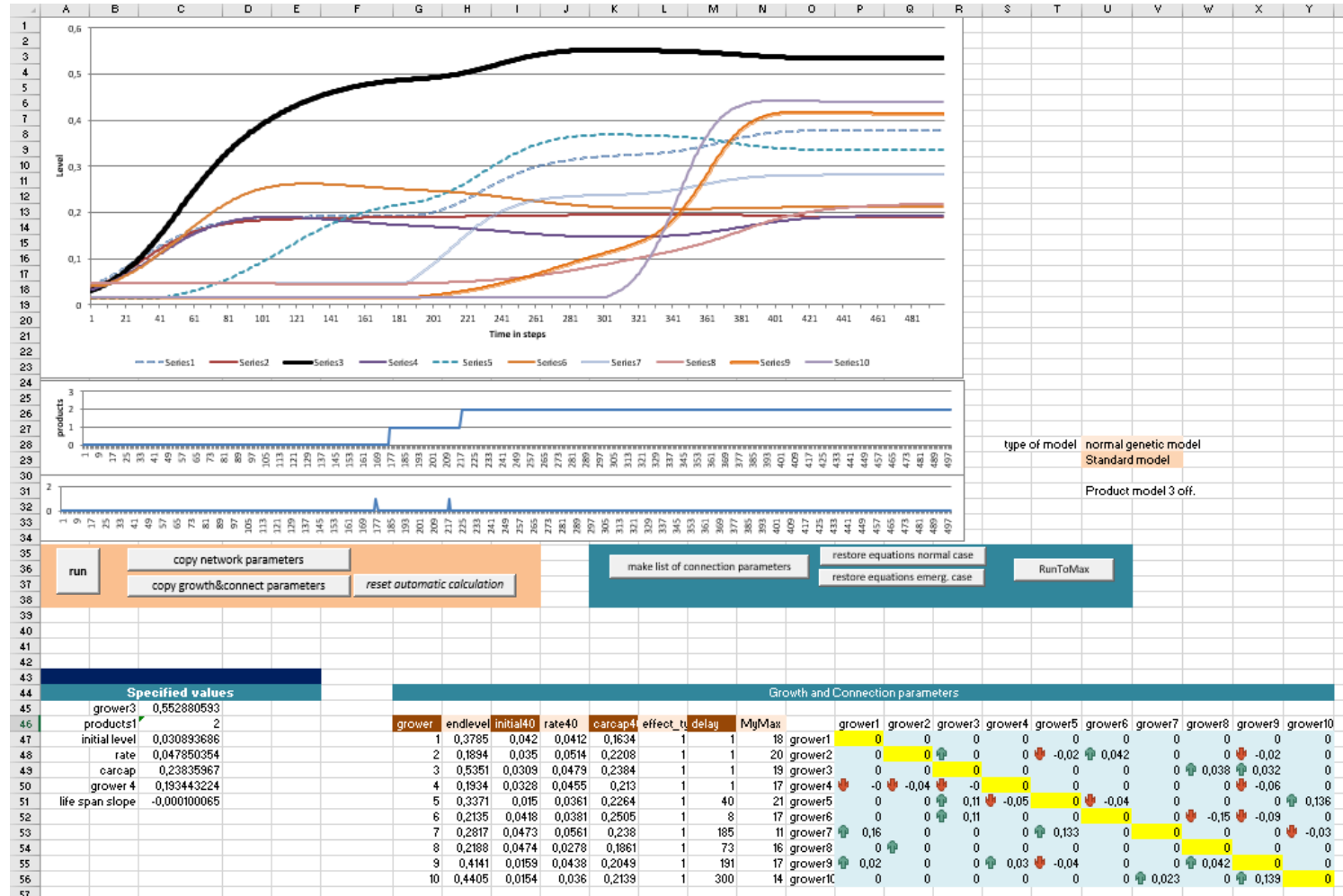
² Van Geert (*Psychol. Rev.*, 1991)



Dynamic network model simulations

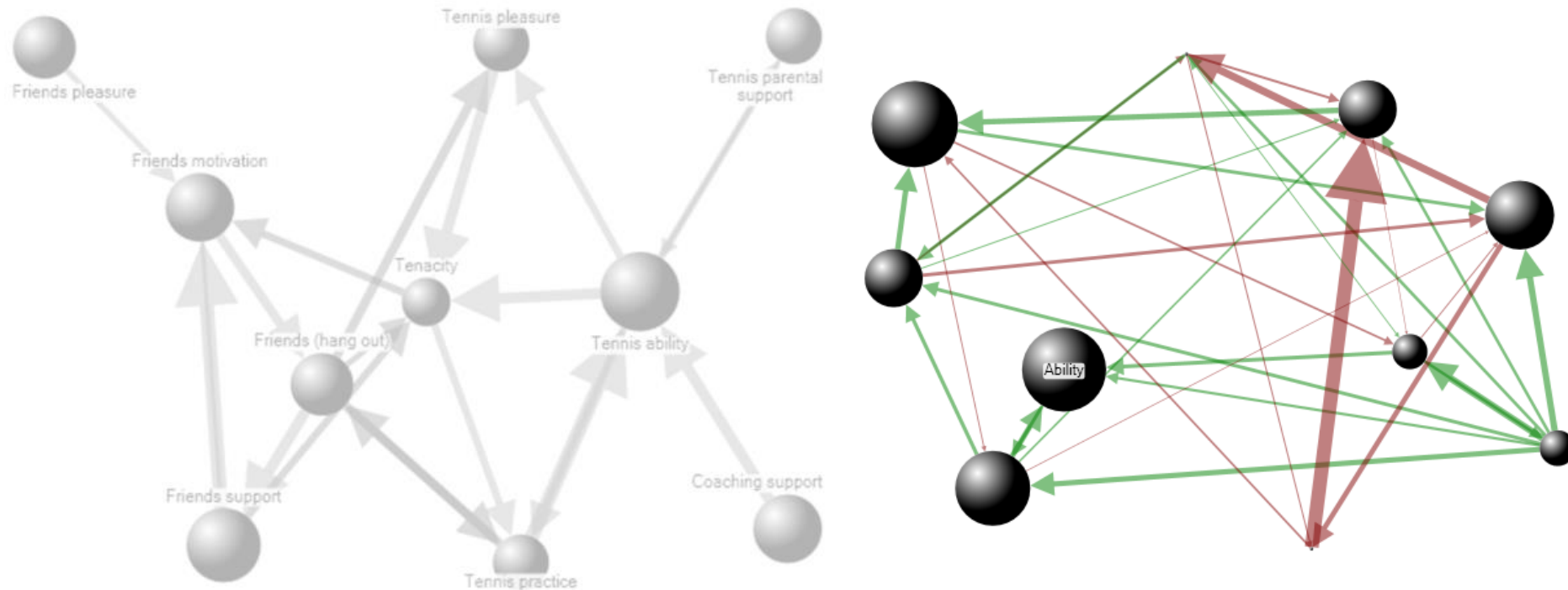
Parameter sheet

NETWORK PARAMETERS			
	min/average	max/stdev	
initial level	0	0,05	
resource consumption rate r	0,05	0,01	
connection strength	0	0,1	
genetic factor normal case	0,2	0,03	
genetic factor emergenic case	0,5	0,25	
delay of onset	1	350	
maximum range	10	25	
connection probability	0,25		



Dynamic network model simulations

➤ A dynamic network model of talent development¹⁻³



¹ Den Hartigh, Hill, & Van Geert (*Complexity*, 2018).

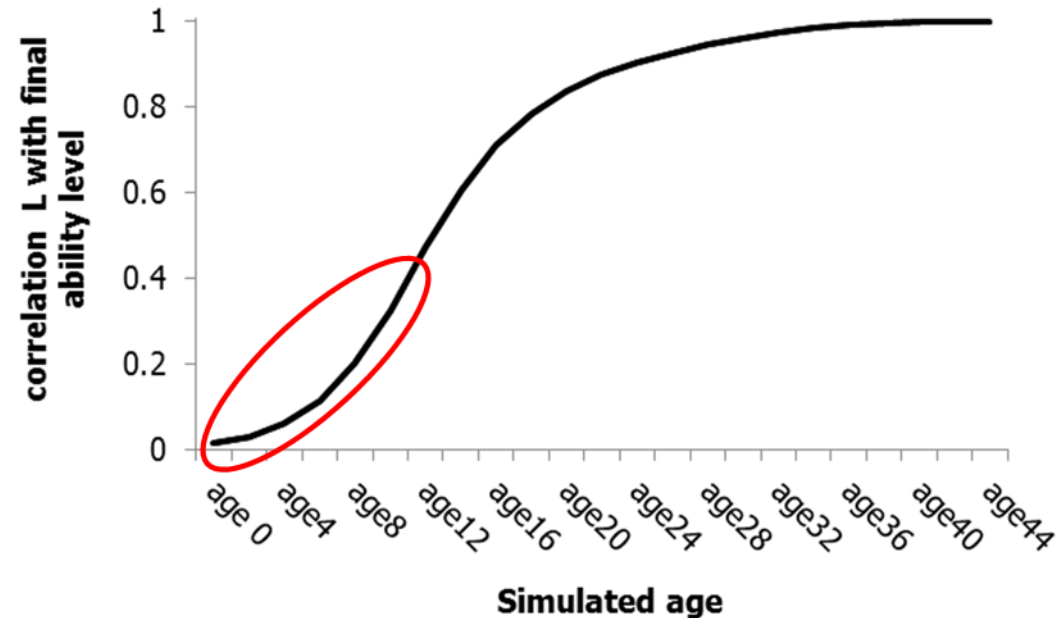
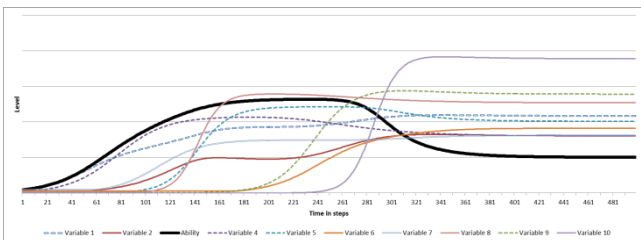
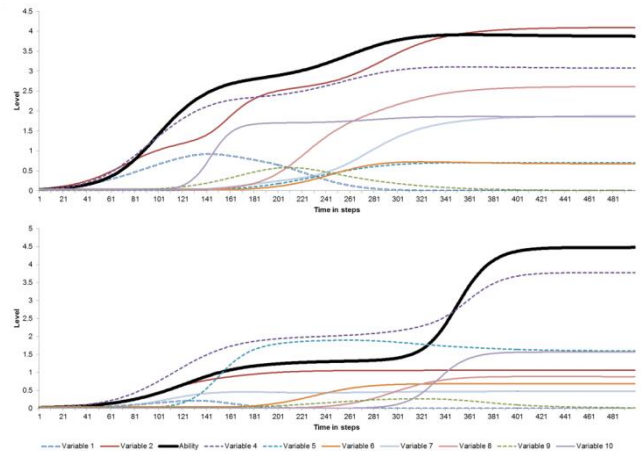
² Den Hartigh, Van Dijk, Steenbeek, H. W., & Van Geert (*Front. Psychol* ,2016).

³ Zwerwer & Den Hartigh (*Nonlinear Dyn. Psychol. Life Sci.*, 2022).



Individual trajectories

- › Different forms
- › Changing underlying factors
- › Early indicators of later excellence are often absent (n = 1,000)



Excellent performance achievements

> Distributions of excellent performance^{1,2}

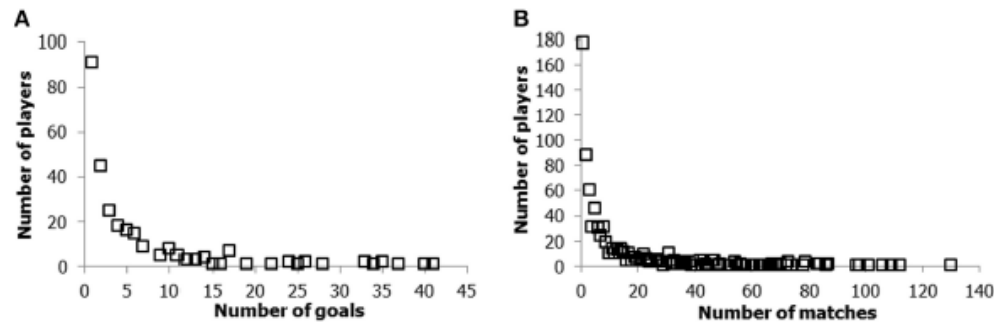
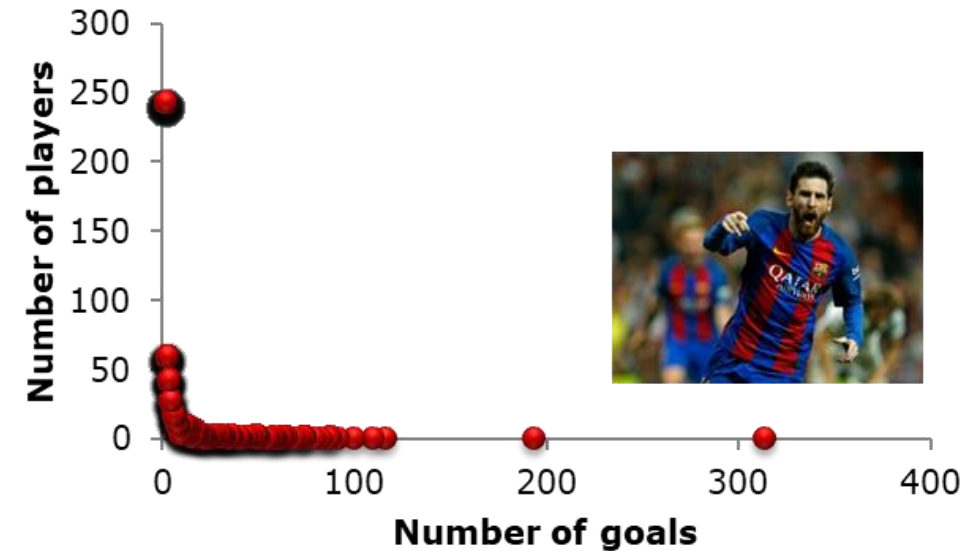


FIGURE 1 | Distributions of the number of goals made during international matches of the Dutch soccer team against the number of players scoring the corresponding number of goals (A), and the number of international matches a soccer player played in the Dutch national team (B).

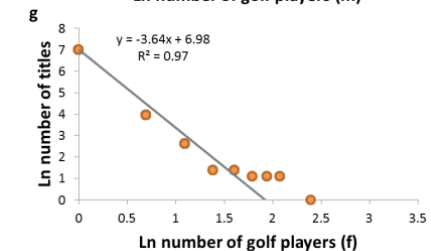
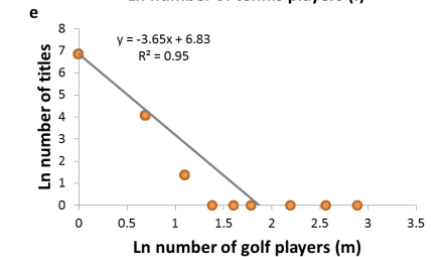
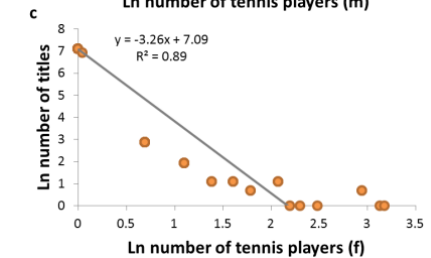
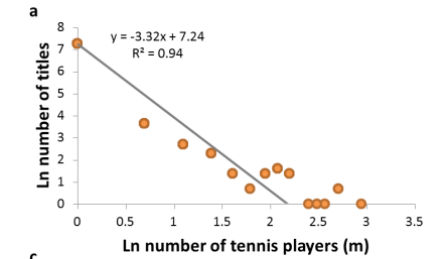
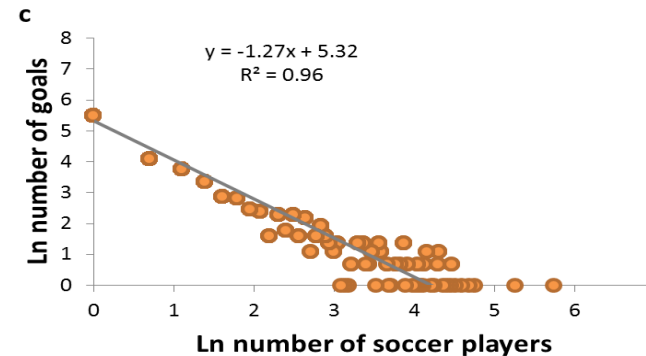
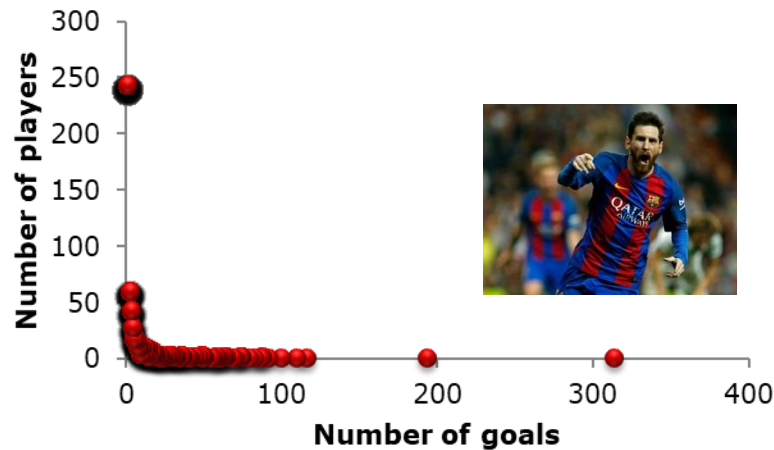


¹ Den Hartigh, Van Dijk, Steenbeek, & Van Geert (Front. Psychol., 2016)

² Den Hartigh, Hill, & Van Geert (*Complexity*, 2018)

Excellent performance achievements

› Distributions of excellent performance¹



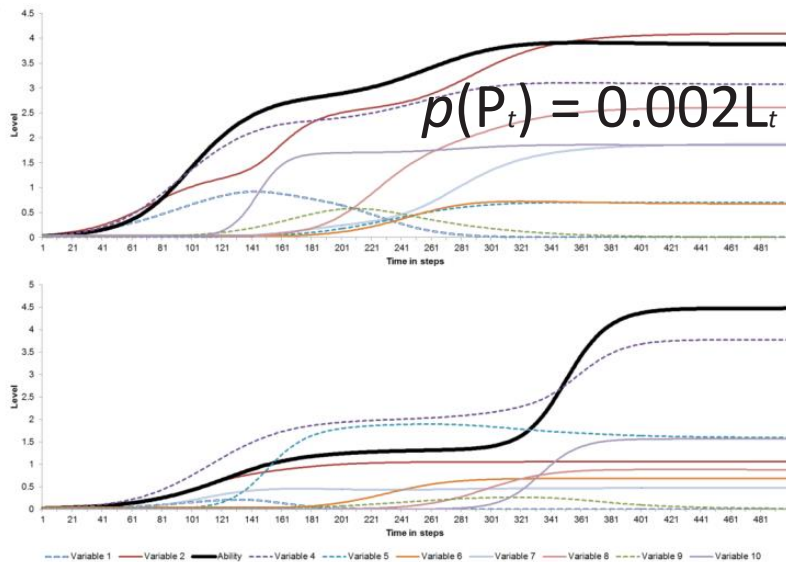
¹ Den Hartigh, Hill, & Van Geert (*Complexity*, 2018)



Excellent performance achievements

› Distributions of excellent performance¹⁻³

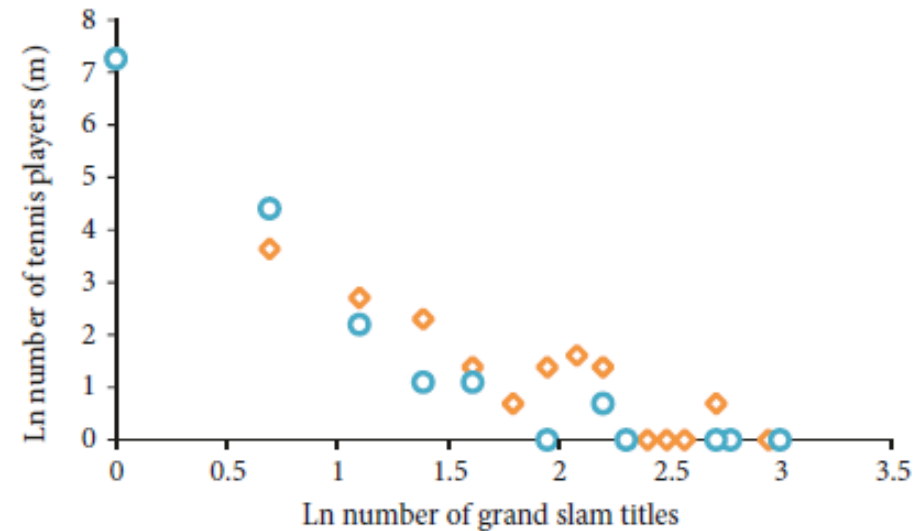
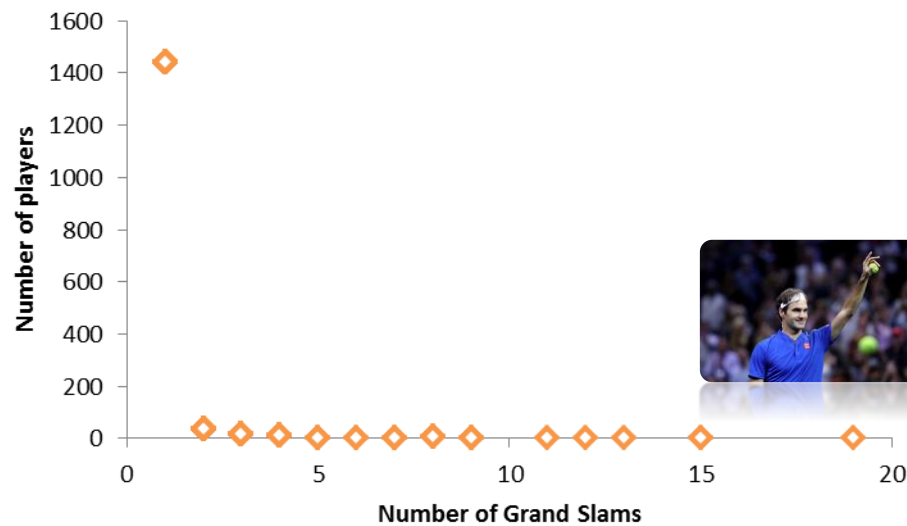
$$p(P_t) = \varphi L_t.$$



1 Den Hartigh, Hill, & Van Geert (*Complexity*, 2018).
2 Den Hartigh, Van Dijk, Steenbeek, H. W., & Van Geert (*Front. Psychol*, 2016).
3 Zwerwer & Den Hartigh (*Nonlinear Dyn. Psychol. Life Sci.*, 2022).

Excellent performance achievements

› Distributions of excellent performance (until 16-02-2017)¹

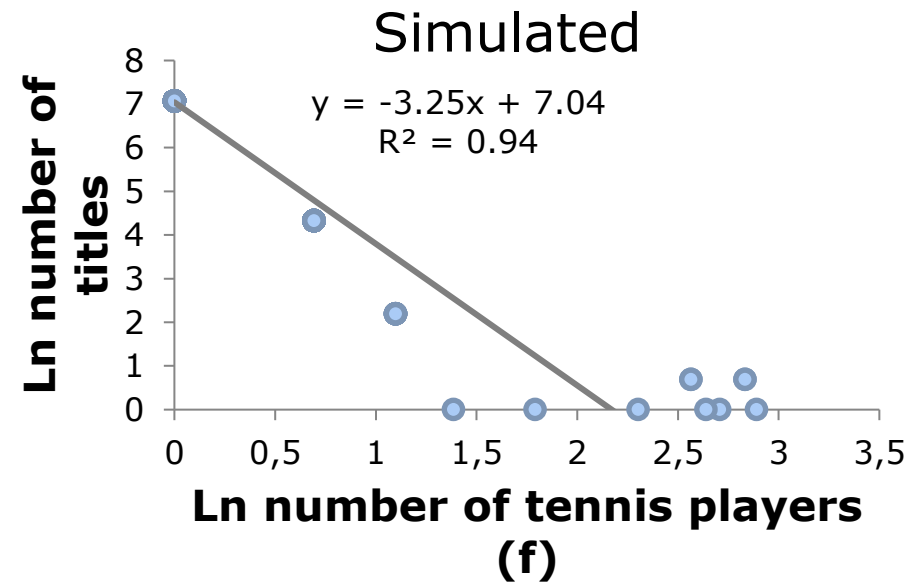
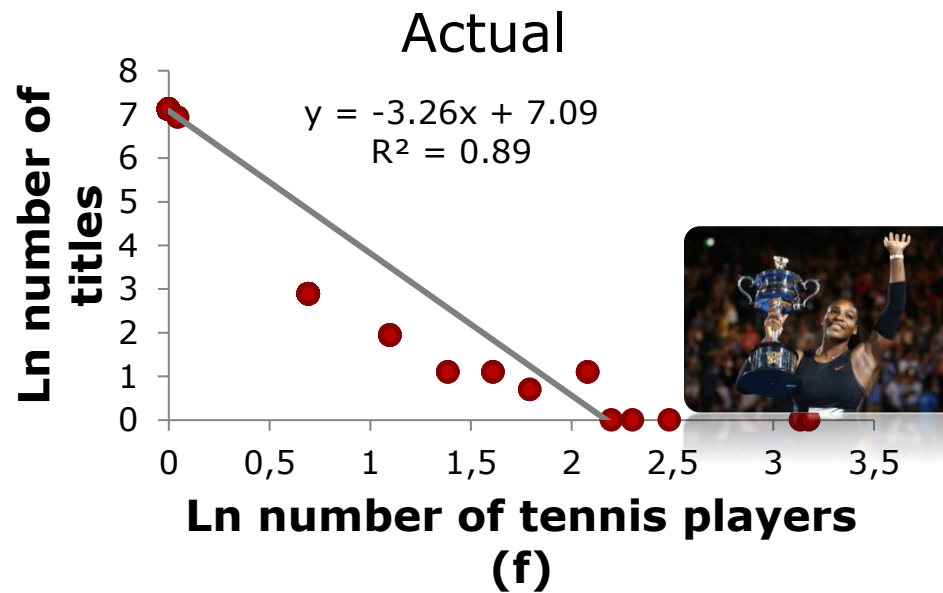


◆ Actual distribution
● Simulated distribution

¹ Den Hartigh, Hill, & Van Geert (*Complexity*, 2018)

Model Predictions

> Distribution of female Grand Slam victories¹

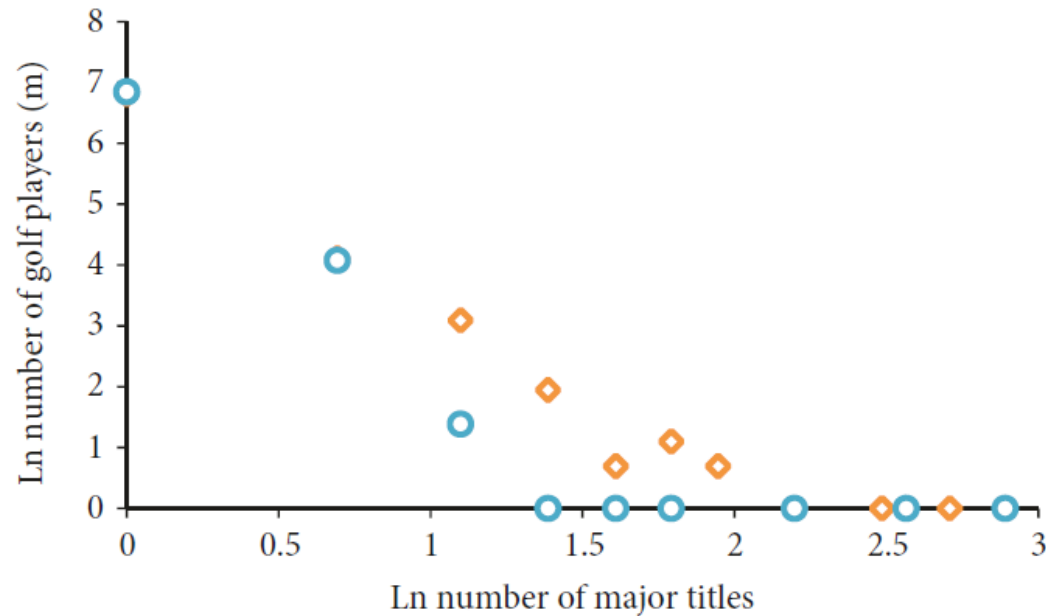


¹ Den Hartigh, Hill, & Van Geert (*Complexity*, 2018)

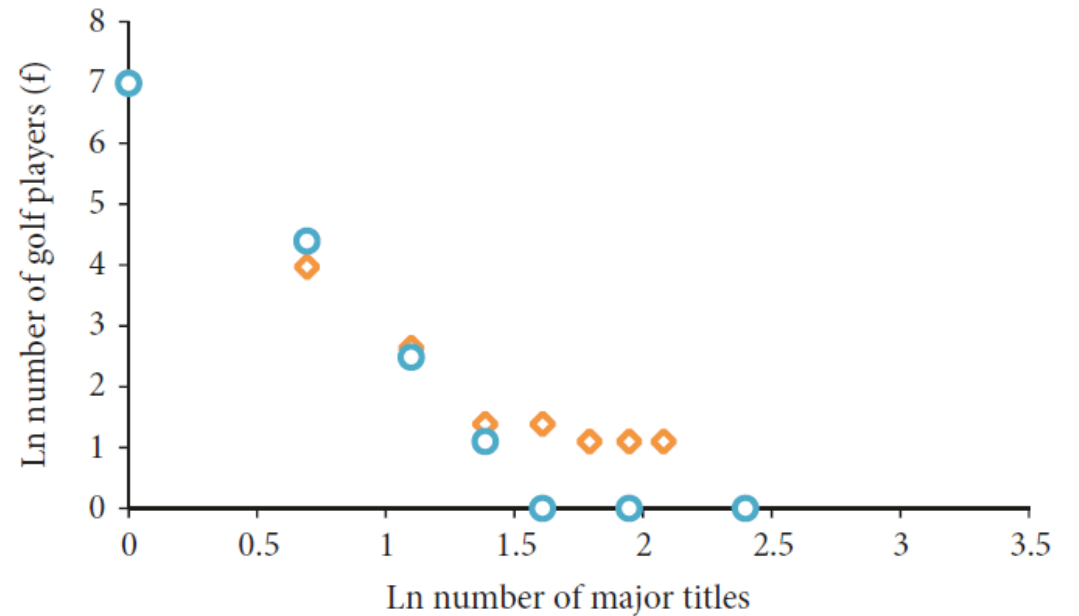


Model Predictions of Sport Performance

> Distribution of major titles in golf



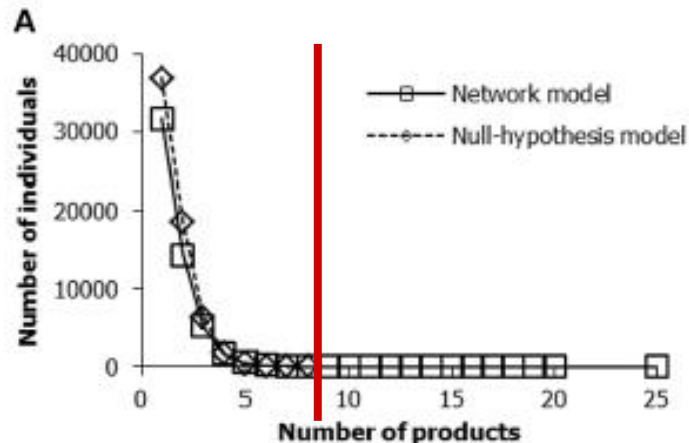
◆ Actual distribution
● Simulated distribution



◆ Actual distribution
● Simulated distribution

Limitations?

- › “I know of no formal model that is this comprehensive and precise.” (Simonton, reviewer 2)
- › “with four parameters I can fit an elephant, and with five I can make him wiggle his trunk”
 - No additive model fitted with the data
 - Dynamic network model universally applies across sports



¹ Den Hartigh, Van Dijk, Steenbeek, & Van Geert (*Front. Psychol.*, 2016)



Conclusion

- › Dynamic network model of excellence in sports:
 - Accounts for complex dynamic nature
 - And explains typical properties
 - Individual developmental patterns
 - Changing underlying constituents
 - Various forms (e.g., linear, stepwise...)
 - A lack of early indicators
 - Distributions of Performance output

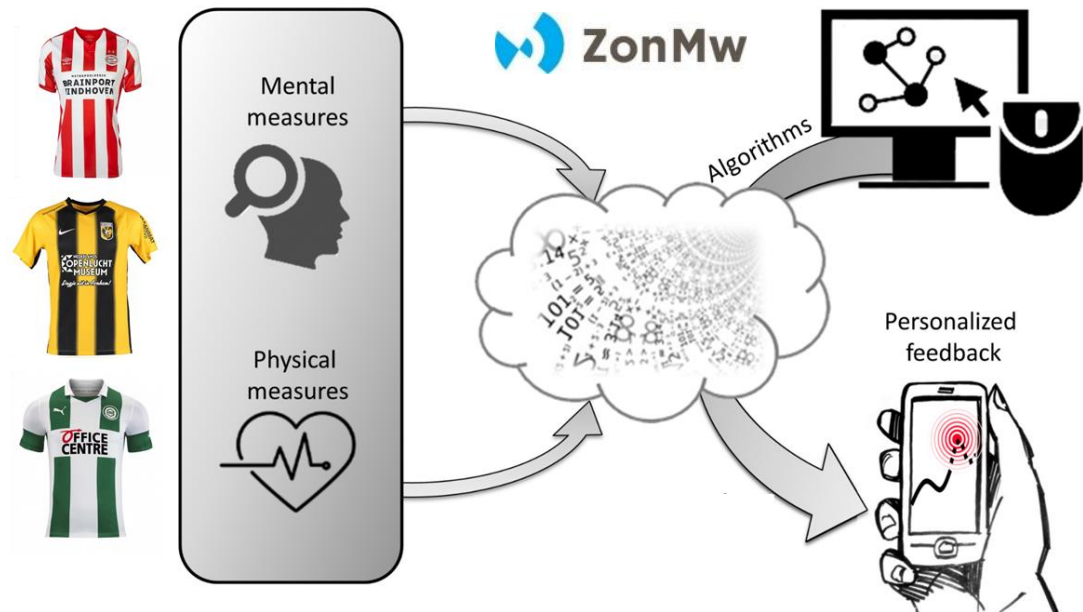
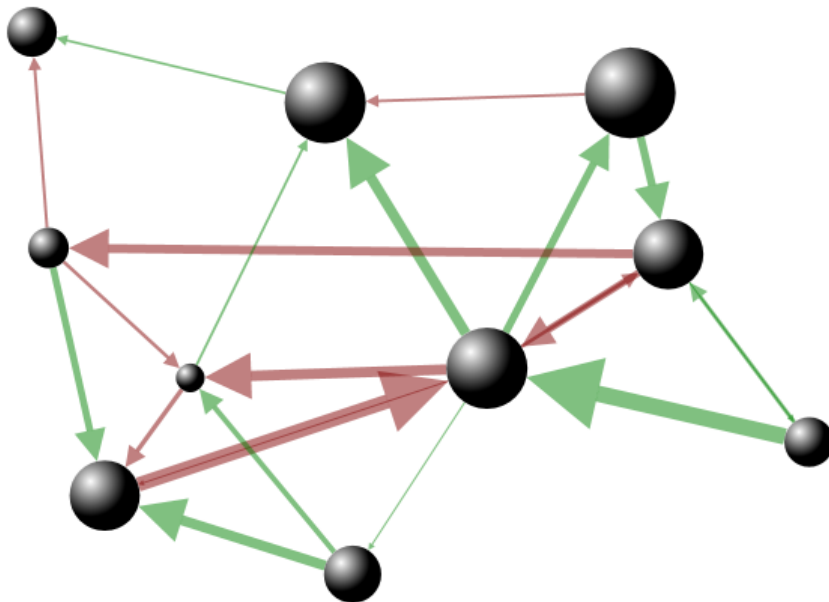
¹ Den Hartigh, Hill, & Van Geert (*Complexity*, 2018).

² Den Hartigh, Van Dijk, Steenbeek, H. W., & Van Geert (*Front. Psychol* ,2016).

³ Zwerwer & Den Hartigh (*Nonlinear Dyn. Psychol. Life Sci.*, 2022).

Conclusion

- › How to proceed in the field?
 - Try to get a grip on the complex dynamics (which is difficult)

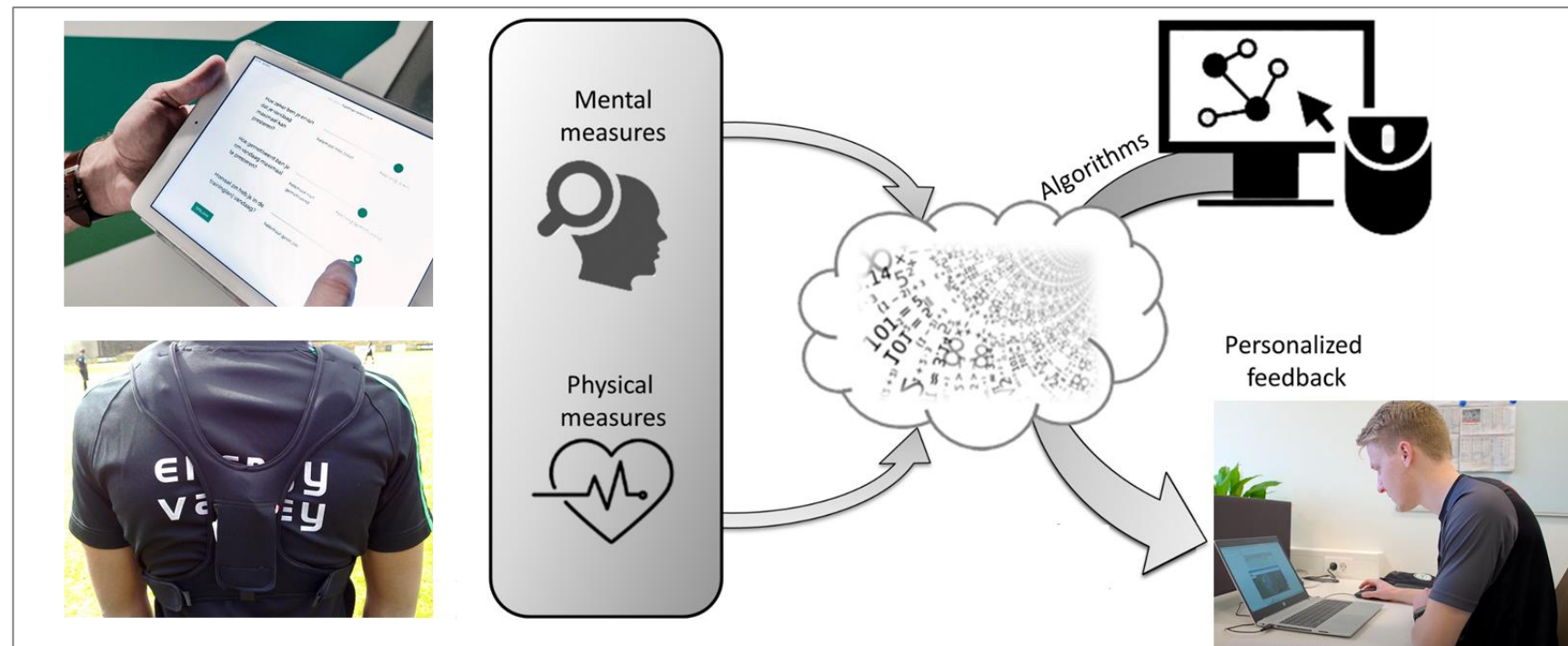


Conclusion

> How to proceed in the field?

- Self-efficacy
- Motivation
- Mood
- Recovery

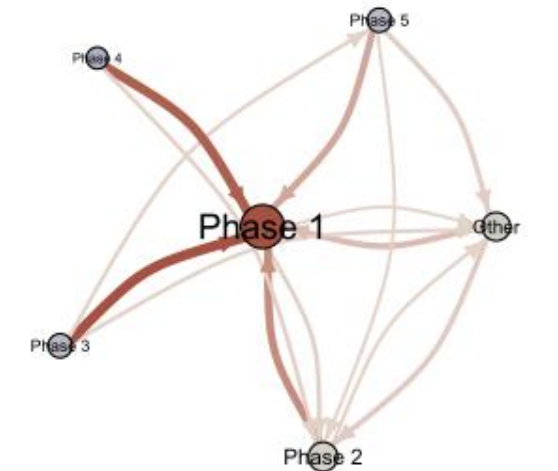
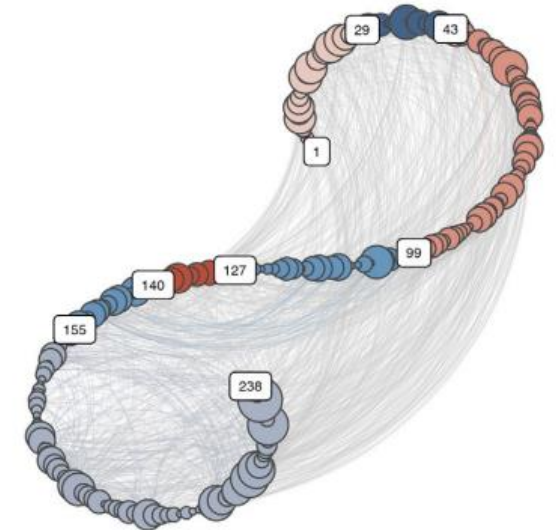
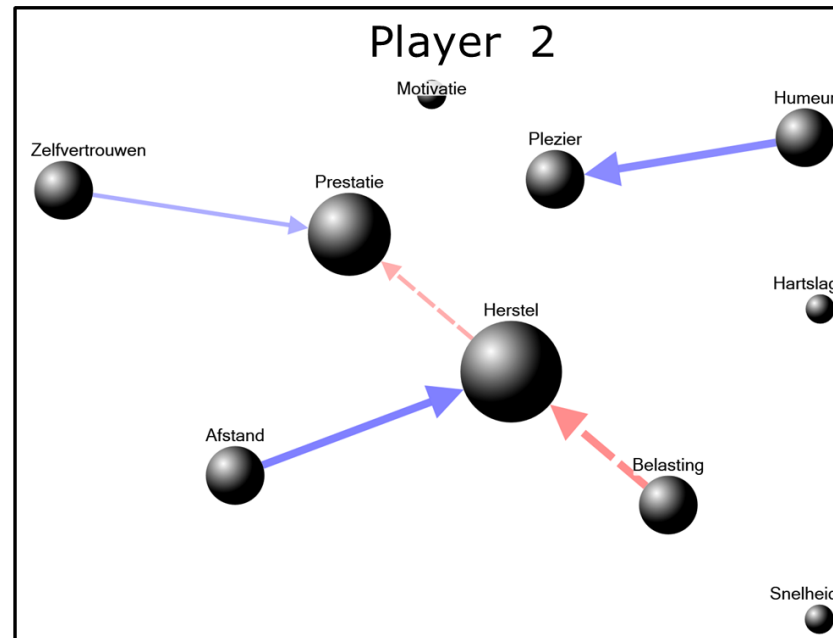
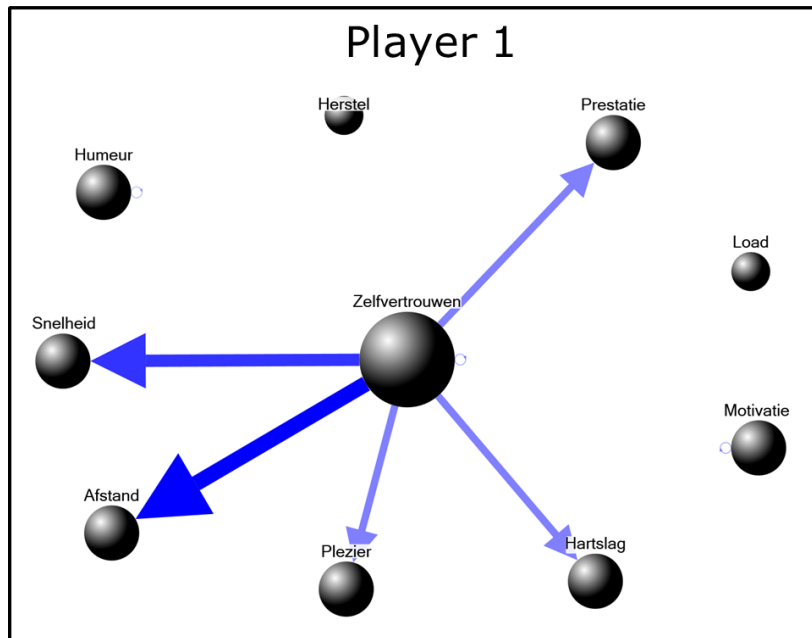
- Load
- Enjoyment
- Performance





How to proceed

- › Current analyses
 - Time-varying VAR models (linear)
 - Multiplex recurrence networks





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