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Brief report

Why computer models help to understand developmental processes



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ABSTRACT

It is argued that simulating psychological processes by means of computer models is a valuable technique to increase our understanding of adolescent developmental processes. Modelling offers possibilities to test hypotheses that cannot be reached by designing empirical studies only and it allows us to investigate adolescent development as the complex and non-linear process that it is.

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Adolescent development is characterized by rapid changes, by large inter-individual differences, by many and complex interactions with the environment, by huge intra-individual changes and fluctuations. Studying adolescent development can therefore be seen as challenging enterprise. One of the main aims in developmental research into adolescence is to test theoretical assumptions about how adolescents behave and develop, in specific conditions and depending on the presence and absence of relevant factors. In our field, theories are generally tested by formulating hypotheses on the basis of the theories, and by testing these hypotheses in empirical research. In psychology this so called empirical cycle (De Groot, 1969) is often seen as the only way to test the validity of our theories.

In this paper I will argue that computer modelling is a very valuable additional tool to get insight in developmental psychological processes. Although in psychology this technique is relatively unknown, in other domains of science it has been a major way to gain scientific knowledge for many decades. Theory based modelling as a way to represent and test theories is has been common for a long time in theoretical physics (Prigogine & Stengers, 1984), and is becoming more and more popular in fields like evolution biology, population biology, epidemiology, economy, and the last years, also more and more in sociology and psychology. Recently, handbooks were published that aim to teach the techniques of modelling in psychology to both university students and scientists, for example in biology (DiStefano, 2015), economy (Ruth & Hannon, 2012), psychology (Molenaar, Lerner, & Newell, 2014) and in the field of adolescent research (Kunnen, 2012a). In psychology this way of applying models emerged already in the last decades of the previous century (Gottman, 1995; Nowak & Vallacher, 1998; Thelen & Smith, 1994; Van Geert, 1994). However, until recently this has been a rather small corner of the field. Only in the last ten years there is an increase in the application of modelling in different topics in psychology, such as education, clinical psychology, cognitive psychology and decision making (see for example De Ruiter, 2015; Fisher, Care, & Fisher, 2015; Guevara, López, Posch, & Zúñiga, 2014; Oppenheimer & Kelso, 2015; Patterson et al., 2012). The authors mentioned here use different names for their modelling techniques, such as dynamic (systems) models or information process models, but they

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have in common that the models are quantitative representations of the theoretically assumed process, that they are iterative and assume non-linearity, and that they all concern the individual process. The latter is a necessary consequence of their assumption that development is iterative and non-linear. In this paper we will use the term “theory-based process model” to describe the members of this family of models.

What is a theory-based process model? To start with, it is important to make a distinction between theory-based and data-based models. Data-based modelling is common in psychology. It means that a model is developed that aims to describe a given data set as sparsely and simple as possible. However, the techniques and the aims of data-based modelling is completely different from theory-based modelling.

A theory-based process model is a mathematical representation of the theoretical assumptions about a process. Developmental processes are seen as the behavior of a system over time, and a system is defined as a network of interrelated variables. The model represents the variables that are considered to play a role in the process under study, and the way in which these variables affect each other over time. Two important characteristics in such models are iterativity and non-linearity. Iterativity means that development is considered to proceed by small steps in which the outcome of each step is the starting point of the next step. Non-linearity refers to the fact that in living systems relations between variables in general are non-linear. The model consists of equations that for each variable describe how its change during one iteration is affected by its own previous value, by the other variables, and by stable parameters. These stable parameters represent stable differences between systems or individuals; think for example of IQ or sensitivity. By repeatedly computing these equations a chain of iterative outcomes, thus a developmental trajectory, is generated for each variable. These generated trajectories are thus trajectories that are predicted by the theoretical assumptions underlying the model. Comparing these trajectories with empirical data allows testing the validity the theoretical assumptions. Once we have a validated model of a developmental process, many applications become possible, theoretically and also for practitioners and for practical questions.

An attractive possibility is to compare trajectories that are generated when different parameter values are entered in the model. This allows for the simulation of different groups represented by different parameter values, and generates knowledge about the developmental trajectories that are common and typical in these groups. [Van der Gaag and van den Berg \(2016\)](#) for example, simulated career choice commitment development in late adolescents who are differentially sensitive to information from the environment, and investigated whether and how this affects the quality of the career commitments that emerging adults form. In our models of commitment development ([Kunnen, 2012b](#)) we simulated individual differences in the openness to experience and the tendency to explore. Another possibility is to test the effect of a simulated disturbance in a process model. Imagine that we simulate the process of mother-child interactions. Research ([Lichtwarck-Aschoff, Hasselman, Cox, Pepler, & Granic, 2012](#)) has demonstrated that interventions in case of non-optimal interactions are more effective if the intervention destabilizes the interacting system. By means of simulated disturbances in a model one could test when, and under which conditions, it is easier to destabilize the system, and thus, when interventions are more likely to be successful. Also, a model may help to generate different types of trajectories, and to test whether these trajectories are differentially related to more or less optimal developmental outcomes.

What is the contribution of modelling to our understanding of adolescent development? As stated, the common way to test theories in developmental psychology is to formulate predictions about relations between variables, and to compare them with empirical findings. However, although well designed empirical research into valid theories is able to demonstrate relations, in general the relations that are found in research are less powerful than expected. How is it possible that in carefully designed studies, including the theoretically assumed relevant variables, the explained variance is most often below 40%?

One possible explanation for the low levels of explained variance is that it is not always possible to translate the theory in an empirical design in a valid way, because theories (and reality) are often rather complex. In designing a study, we tend to reduce a complicated theory into simpler notions in order to make them testable. Most often, this translation include assumptions about causality that are too simple ([Morrison, 2012](#)). For example, we assume that success in one's study stimulates an adolescent's development of commitment to that study. A simple common way to test this assumption is to measure students' successes on an exam and their commitment, and compute a correlation between these variables. However, we know that the actual process is more complex. For example, the relation between strength of commitment and success is probably mutual: strong commitments trigger more effort and better outcomes ([Kunnen, 2012a](#)). Moreover, the relevance and meaning of the exam counts, as does the actual level of commitment, the feedback of the teacher, the attributed reason for the exam outcome, and the effect of a success is related to the history of previous successes and failures, to the context, and many things more. Techniques as Manova and SEM allow for the inclusion of multiple variables, but the possibilities of the techniques do not meet the complexity of the theories. The development of commitments is in fact part of a complex network of mutually related variables. Commitment development takes place in the interaction between the actual commitment strength and internal and external factors such as the study outcomes, feedback, etc. and this interaction takes place not just once, but repeatedly, as a long chain of mutual interactions.

Moreover, the relation in both directions is most probably not linear. Think for example of the situation in which the commitment strength is almost at the maximal level. In that case, confirming events may still be confirming, but they do not result in an increase in the commitment strength. The fact that almost all variables have a maximum level is one of the reasons why most relations are non-linear. Often bottom and ceiling phenomena are considered in the discussion section of a study, and seen as a kind of error that affects the “real” relation. However, bottom and ceiling effects are manifestations of an important characteristic of all living systems: the process takes place in a restricted ranged of possible states of the system,

and the fact that it cannot grow endlessly affects the developmental process in a fundamental way. In addition, non-linearity is caused by phenomena such as positive and negative feedback loops. Often, systems tend to resist disturbances (Kunnen, 2012a; Van Geert, 2008). That means that changes in one variable often do not result in changes in another variable because the system tries to compensate for the disturbance. But sometimes seemingly small changes in one variable of the system may result in quite a big change. Whether or not that happens may depend on the combination of all the other relevant variables, on the history of the system, etc. For example, a highly committed student who fails at an exam will tend to see that as an exception, due to external factors. However, if she repeatedly fails, she may, after the third or sixth failure, quite suddenly start to reconsider her commitments. The trigger for that reconsideration may not even be visible in the system. It may be a remark of a friend or parents, but also something like a small illness. So, for some time failures have no effect on commitment at all and suddenly there is a large impact.

When relations are non-linear, it becomes impossible to imagine how the developmental process will proceed. In addition, it is important to realize that in such a complex network, we cannot assume that effects of other variables can be seen as random variability that can be averaged out. An essential characteristic of a dynamic complex network is that, as a consequence of the internal dynamics, the effect of a slight change in one variable may amplify and result in huge changes in the whole development.

Concluding, we plea for modelling as a valuable tool in adolescent research: it allows us to take into account the complex and non-linear character of adolescent development and can help us to understand this development.

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