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Experimenting with a nonlinear dynamic model of juvenile criminal behavior

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A simple dynamic model describing the age development of juvenile criminal behavior is extracted from such criminological theories as career theory, learning theory, and rational choice theory. The resulting nonlinear model appears to be as good as, or in some aspect better than, a static correlational model in explaining data from the longitudinal Utrecht Study of Adolescent Development. The model provides the basis for a more systematic study of nonlinear dynamic models for the description of the development of learning of criminal juveniles.

KEYWORDS: *computer simulation; criminal behavior juveniles; learning environment; nonlinear model; rational choice.*

Although all criminological theories share the common aim of explaining criminal behavior, they use different variables in different manners to achieve this goal. Many criminological researchers use independent variables that are assumed to be unchanging and to have a long-lasting effect on deviant behavior, for example, sociodemographic variables (Cox, 1996) or psychological characteristics like self-control (Heimer, 1996; Hirschi & Gottfredson, 1994; Longshore, Turner, & Stein, 1996) and early childhood socialization (Fagan & Wexler, 1987). Many theories dealing with social influences on criminal behavior employ independent but not necessarily unchanging variables, such as social control (Nagin & Paternoster, 1994), the association with other deviant individuals (Akers, 1996; McCarthy, 1996), unemployment (D'Alessio & Stolzenberg, 1995), and poverty (Hsieh & Pugh, 1993; Ohlemacher, 1995). Both kinds of independent variables can be used as predictors in a straightforward correlational model.

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There are, however, also variables used in criminological models that are dependent on the criminal behavior itself, such as behavioral outcome, and variables that are dependent on individual growth and development, or learning. Instances include the growth of insight and matured evaluation of consequences. We call these variables *dynamic* because they and their effects change over time. The criminological theories that most clearly use this kind of variable are criminal career theory, which uses developmental variables, and rational choice theory, which makes use of behavioral results and the evaluation of behavioral results. Neither simple correlations and correlational models nor the description of differences that exist at any particular moment in time can adequately describe the more complex relations between these dynamic variables and delinquency.

For the study of the adolescent development of delinquency, part of the longitudinal Utrecht Study of Adolescent Development (USAD), we began to question whether correlational models are adequate to describe adolescent development and which alternatives might be better suited. Expressing similar doubts, Dieter and Kerner (1988) differentiate between static and dynamic models. In static models, the career is dependent on individual deficiencies and correlational models are used, whereas in dynamic models the criminal act influences individual characteristics and vice versa. Their empirical study—drawing data from records of 500 juvenile offenders from two correctional institutes and covering 20 years—supported the dynamic view. In a recent study by Johnson, Hoffmann, Susan, and Gerstein (1996), the idea was introduced that the rate of change of the deviance of an individual depends on the level of deviance already attained. We place that idea in the context of criminal career theory and assume that there are learning effects: an individual's criminal act will influence his or her environment, which will promote or not promote his or her criminal career, and learning this will in turn influence the criminal act of the individual. To test this dynamic theory, one has to look at differences in the characteristics of individuals (cases) in different periods of their lives, and preferably to work with dynamic models.

The Construction of a Dynamic Model

According to the career theory there is an interaction between the criminal act and the environment of the criminal. Following this theory and learning theory, we assume that the criminal can observe this interaction and learn from it to promote his or her career as a criminal. For the question of how this process of learning occurs we will use the ideas of rational choice theory (Schneider & Ervin, 1990): The criminal promotes his or her career by maximizing the profits and minimizing the costs of the crime. Within this frame of reference we can summarize the rationale of our model. The dynamic variables in this model are criminal behavior (resulting from profits and damage) and the attitude of youth (resulting from the evaluation of profits and damage), combined with a growing sense of responsibility for the damage done to others. The static variables are age and social control.

With these variables it is possible to formulate a (simple) dynamic theory of criminal behavior, in which subsequent criminal behavior is dependent on previous criminal behavior together with a changing evaluation of the behavioral effects. Criminal behavior is dependent on a decision which in turn depends on an attitude toward criminal behavior. In our view, early adolescents evaluate the consequences of criminal behavior by overestimating expected profits and underestimating the damages to others. This attitude changes as the result of learning, accumulating in a more mature and more realistic reasoning about expected profit and expected damage.

With the help of such reasoning, a limited number of cause-effect propositions can be selected as starting points for a dynamic model of criminal behavior.

1. The criminal behavior of an individual results from a decision that depends on: (a) an opportunity and (b) an attitude of permissiveness of the individual toward criminal behavior.
2. The attitude of permissiveness to criminal behavior of the individual as a result of learning depends on (a) the expected profits for the criminal and damage for the victims, (b) the social control exerted on the individual, and (c) the real profits and damage (indirectly via the expected profits and damages).
3. The adolescent period is characterized by decreasing parental control and a search for the adolescent's own values and moral standards. This gives rise to an attitude in early adolescence of permissiveness toward criminal behavior, in which there is an underestimation of the damage done to others and an overestimation of the profits for oneself.
4. As the adolescent criminal grows older, he or she experiences the real effects of criminal behavior more often and will correct the expected profits and damage in a more realistic way.
5. The social control exerted on girls is different from the social control exerted on boys.

From these propositions, a causal diagram can be constructed that expresses graphically how causes are related to effects and vice versa. The result of this mapping is shown in Figure 1. In this diagram, feedback loops are included in the chain of causes and effects and as a result variables refer to themselves in the long run. The value of the variable CriminalBehavior (at time t), for example, depends on the value of the same variable CriminalBehavior exhibited earlier (at time $t - dt$).

Differential Equations

In dynamic models, variables refer (after a time delay) to themselves and for this reason such models can be represented by differential equations (Dieter & Kerner, 1988; Forrester, 1968; Hanneman, 1988; Johnson et al., 1996).

In our model, the state of being criminal (CriminalBehavior) results over time in (real) profits for the individual (Effectself) and after a longer period of time (TimeDelay) in (real) damage to others (EffectOthers). At regular moments (each dt), the criminal can decide (GoNotGo) to transform an opportunity into a criminal act that will add to its CriminalBehavior(t) of that moment. Criminal behavior expressed in the time-dependent state variable CriminalBehavior(t) is influenced by the former state of the variable itself (CriminalBehavior($t - dt$)).

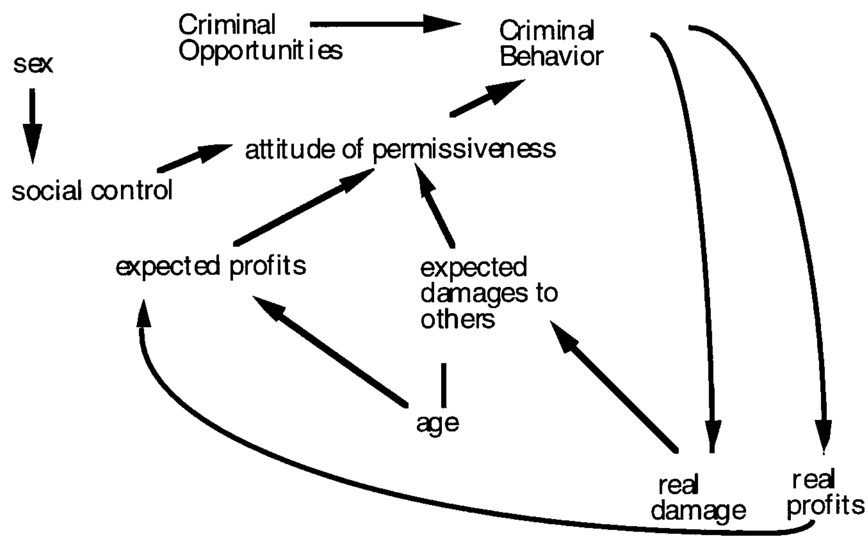

FIGURE 1: A Causal Map of a Dynamic Model

These statements can be mathematically represented by two simple linear equations and a differential equation:

$$\text{EffectSelf} = \text{CriminalBehavior}/\text{TimeDelay1}, \tag{1}$$

$$\text{EffectOthers} = \text{CriminalBehavior}/\text{TimeDelay2, and} \tag{2}$$

$$\text{CriminalBehavior}(t) = \text{CriminalBehavior}(t - dt) + (\text{GoNotGo} - \text{EffectSelf} - \text{EffectOthers}) \times dt. \tag{3}$$

Following the causal diagram, one can in this way make mathematically explicit how variables are related to each other when one steps from the past ($t - dt$) to the present (t). The reference of CriminalBehavior to itself (influenced by the variable GoNotGo) and an estimation of the effects of the CriminalBehavior is such that it results in a nonlinear differential equation. In this equation independent variables such as gender and social control, which could have different values, can give rise to different patterns for different individuals. Using the causal diagram leads to an extended set of (differential) equations that can be used to calculate the effect of the changing of past values of variables for the changing of values in the present. In other words, one can do a computer simulation study with these equations.

To facilitate these calculations (i.e., this computer simulation study) we used the software STELLA™ to build and make explicit the set of equations. To conduct experiments with those equations rapidly and efficiently we used the software MADONNA™.

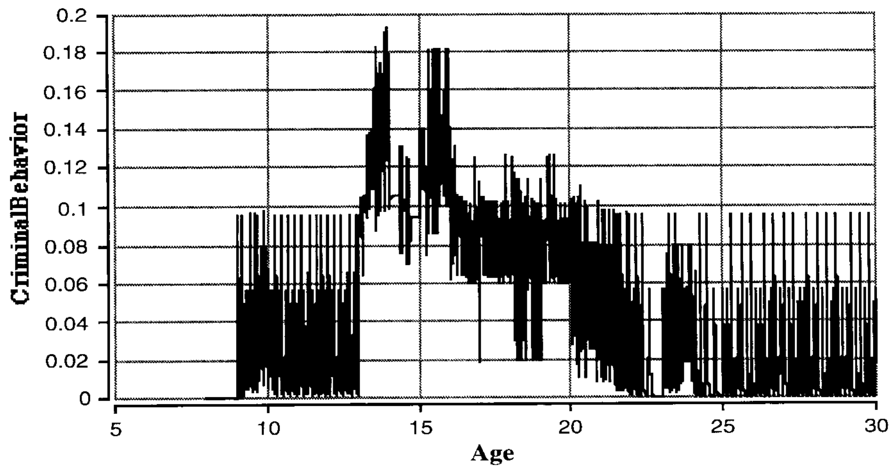

FIGURE 2: Individual Criminal Behavior

Simulation Results

The simulation model produces time series on criminal behavior for an individual. Because of differentiation between gender in our data we compare the model and data for boys and girls separately. The data from the model are produced by simulating average boys and girls; in the correlational model, one also works with averages. To start with, we gave a variable we introduced as social control, the (more or less arbitrary) value 1.25 representing in our model the average social control of boys (see Figure 2).

The behavior seems random and represents the nonlinearity of the model. In the real world this could be interpreted as follows: Sometimes an opportunity is used, sometimes not. The frequency with which an opportunity is converted into a criminal act gives the intensity of criminal behavior. To express this intensity one smears out the frequency of criminal behavior in an average. A smooth function can be used to perform this averaging (Richardson & Pugh, 1981). This produces the graph in Figure 3.

Criminal behavior begins (then > 0) at the age of 8, increases to a maximum at the age of 16, and decreases with some fluctuations until the age of 30.

Comparing the Models With Empirical Data

From our survey we obtained data on (a) attitudes toward criminal activity (AtCrAct) and (b) the frequency of criminal activity (FreqCrAct). The correlational model is a simple statistical model in which the frequency of criminal activity is

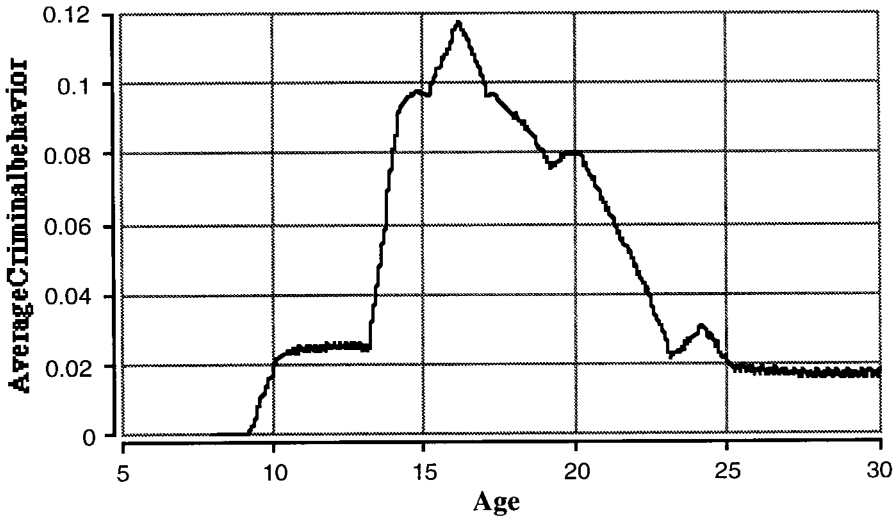

FIGURE 3: Averaging the Criminal Behavior of the Individual

estimated with the help of the correlation between the variables mentioned above. The model is estimated separately for boys and girls.

In our dynamic model the outcome of the simulation model of average criminal behavior (AvCrBeh) is used as an estimate for the frequency of criminal behavior. The data from the survey are an aggregation of individuals of different age classes and stratified for gender. The simulation produced aging individuals, boys separate from girls, because it was assumed that social control would be greater for girls (4) than for boys (1.25). We assume in a cross-validation design that the development of an individual is a constant pattern in the 12-year period of adolescence included in our research. This means that the individuals' age group of $x + 1$ can be seen as a valid representation of the development of the x-age individuals after 1 year.

To enable a comparison between the models and the data and place the values of the variables on the same range, we standardized the relevant variables.[1]

Comparison for Girls

A graphic plot of the standardized variables can be used to compare the model with the data for girls. In Figure 4, the three different variables are plotted[2] as a basis for inferring conclusions by visual inspection.

According to our hypothesis, the resulting variable of the model AvCrBeh should be a better estimate of the measured frequency of criminal activity FreqCrAct than the measured attitude AtCrAct. In other words, the dynamic model should give more information than is given by the correlational model. According to System Dynamics, the latter is aimed at a different level of validation of the model and has to be

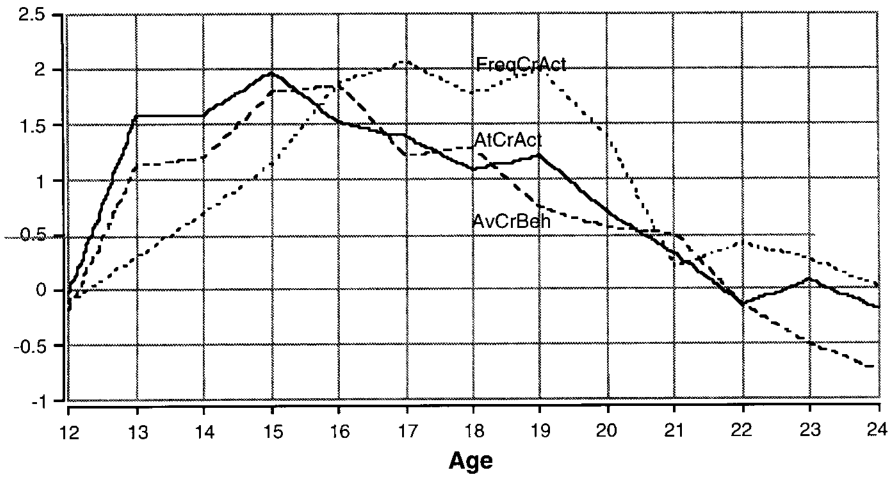

FIGURE 4: Outcome for Girls of the Dynamic Model (AvCrBeh) and the Correlational Model (AtCrAct), Compared With Data (FreqCrAct)

interpreted as the use of the model in explaining the data. Anyway, our dynamic model seems to be an advance over the correlational model, although both models underestimate the criminal activity of girls before year 16 and systematically underestimate it after the age of 16. However, the idea that the dynamic model is closer to the data appears plausible (is not falsified) on visual inspection, but cannot be verified in this way. To test that hypothesis we calculated the sum of the squares of the differences between each variable: (a) the distance between the model variable (AvCrBeh) and the measured criminal activity (FreqCrAct) as DifModCrAct, summed to SumDifMod CrAct; and (b) the distance between the measured attitude (AtCrAct) and the measured criminal activity (FreqCrAct) as DifAtCrAct, summed to SumDifAtCrAct. A plot of these variables is given in Figure 5.

It is clear from this figure that our hypothesis is not refuted. The variable of the dynamic model gives a better representation of the empirically measured frequency of criminal activity than the measured attitude from the correlational model. We therefore conclude that, for our data, the dynamic model for girls is as good as or better than the correlational model.

Comparison for Boys

One of the main differences in our model for boys is that the value for social control is lower for boys than for girls. This produces a different pattern in AvCrBeh for boys, which also can be compared with empirical facts about boys as expressed in the variables FreqCrAct and AtCrAct. But we also expect here that the variable of the model AvCrAct is a better estimate for the FreqCrAct than AtCrAct. That could be inferred

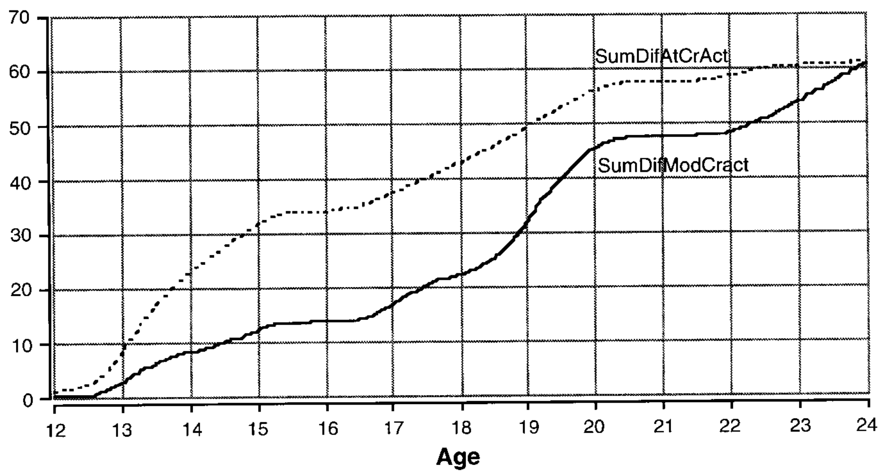

FIGURE 5: Sum of the Squares for Girls as a Measure for Comparison Between the Dynamic Model (SumDifModCrAct) and the Correlational Model (SumDifAtCrAct)

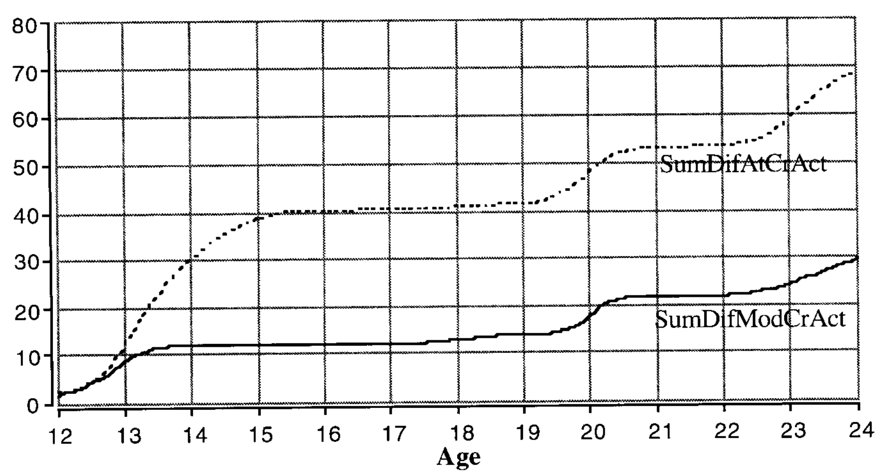

FIGURE 6: Sum of the Squares of the Standardized Variables for Boys as a Measure for Comparison Between the Dynamic Model (SumDifModCrAct) and the Correlational Model (SumDifAtCrAct)

from a visual inspection of Figure 6. Compared with girls, the prediction by the dynamic model of the period in which criminal activity is at maximum is much better.

But also, to be exact, we calculated the sum of the squares of the differences between each variable, a plot of which is given in Figure 7.

This plot also suggests that the dynamic model is better than the correlational model. Moreover, the dynamic model for boys seems even more close to the data than the dynamic model of the girls.

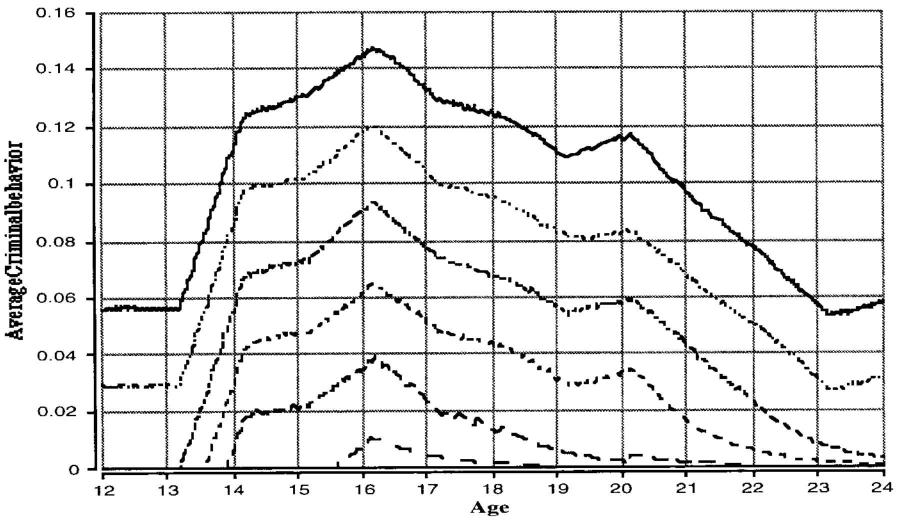

FIGURE 7: The Variety of the Average Criminal Behavior of Individuals Dependent on Different Levels of Social Control

Other Explorations of the Model

As has been shown, empirical data can be adequately represented by the model. We therefore turn to experiments using the model. One can, for example, vary the value of social control and see how it influences the frequency of criminal activity (see Figure 8).

The difference between girls and boys can be reproduced in this way, but more interesting, of course, is the question of how social control works, why it is different for boys and girls, and what kind of learning submodel might be introduced to explain and to experiment with that difference.

Another experiment can be done with the time delay in Equation 2. This delay can be interpreted as the time it takes before the damage done to others results in penalties for the criminal.

It is clear that the influence of sanctions shapes criminals differently from social control. This can also be built into a learning submodel with which one can experiment.

Discussion and Conclusion

With this study of a simple dynamic model, we gathered evidence to show that a dynamic model is useful for the analysis of longitudinal data. The main argument is that with a dynamic model the logic of a theory can be made more transparent. Moreover, because our model assumes that crime can be explained by a rational choice between profits and costs (Devine, Sheley, Smith, & Dwayne, 1988; Wiese, 1994) and youth can learn from the difference between expected profits and costs of crime on one

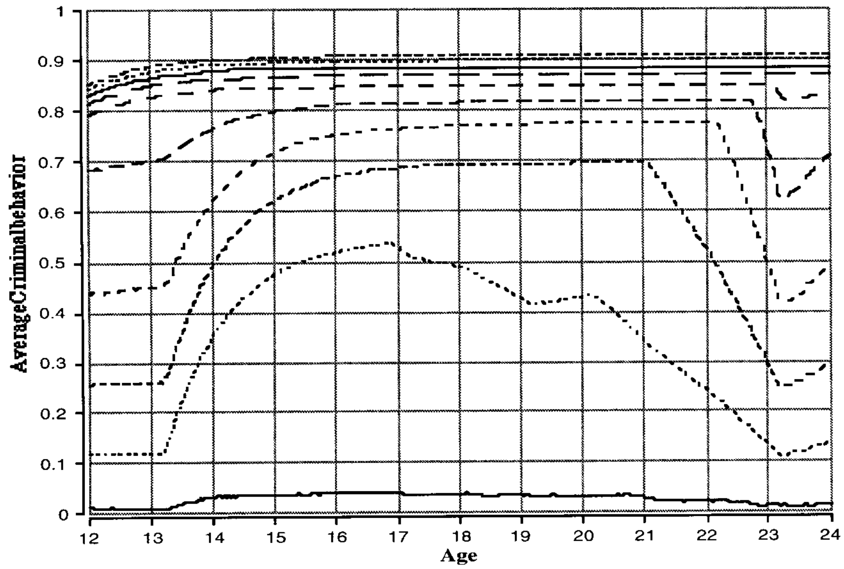

FIGURE 8: The Variety of the Average Criminal Behavior of Individuals Dependent on Different Levels of Time Delay of Sanctions

hand and observed profits and costs on the other hand, it can be a base for ideas of intervention in which learning plays an important role. With those ideas policy makers can perhaps shape learning environments in which early and smart prevention of crime is possible.

Our learning model is nonlinear and makes explicit the way in which criminal behavior changes with age. In developmental psychology, the nonlinear processes of growth, particularly those concerning cognition, are explored with the aid of nonlinear differential equations. In criminology, such models have been partially explored by Johnson et al. (1996). Both models are still experimental with regard to mathematical and theoretical aspects. In our model, the typical outcome of a nonlinear process could be managed and compared with empirical data, but an analytical expression of the relation between age and expected profits and damages could also be introduced (DeHoede, 1997). In addition, an exact analysis of the differential equations is required. The model can also be expanded, as mentioned earlier, by using other relevant variables. In this study we aimed at the development of a suitable model for a restricted data set, but it is evident that we would have to validate an expanded model with the aid of an elaborated data set at a subsequent stage.

The variable social control can also be better explored. We assumed that this variable would be constant, though different for boys and girls. That went well with boys, but perhaps because of this simplification the criminal activity of girls before year 16 is systematically overestimated and after the age of 16 underestimated.

To be more accurate in this aspect, we have to introduce a distribution of the variable social control in which the average for boys and girls differs in a statistically significant way and the social control for girls is less constant than for boys. Then the question is why social control is different for boys and girls. This question might perhaps be clarified by a survey of the literature, but in this case too a dynamic model is useful (David, 1993). The differentiation between the sexes incorporated in our model could be followed up by an expansion into submodels, in which gender differences might be explained by psychological and cultural factors. In Johnson et al.'s study (1997), a number of clusters of social and psychological variables are mentioned that influence juvenile criminal behavior: parental psychiatric problems, lack of parental support, living arrangements with no or a single parent in residence, low family income, and male gender. It would be interesting to experiment with these variables to see how the interaction between them and gender takes place.

To conclude, the variable time delays in Equations 1 and 2 could also subsequently be interpreted as variations in the speed of (different types of) learning of individuals. That could be incorporated in a more extended logic of learning for which differences in gender are also interesting to analyze.

The models that are the result of such simulation experiments can be used as building blocks for interactive learning environments to prevent juveniles from crime.

Notes

1. That implied subtraction of the mean and division by the standard deviation.

2. Because the standardization values below zero are shown, which of course cannot be interpreted in an absolute way as existing values.

References

Akers, R. L. (1996). Is differential association/social learning cultural deviance theory? *Criminology*, *34*(2), 229-247.

Benda, B., & Whiteside, L. (1995). Testing an integrated model of delinquency using LISREL. *Journal of Social Service Research*, *21*(2), 1-32.

Cappell, L., & Sykes, G. (1991). Prison commitments, crime, and unemployment: A theoretical and empirical specification for the United States, 1933-1985. *Journal of Quantitative Criminology*, *7*(2), 155-199.

Cox, R. P. (1996). An exploration of the demographic and social correlates of criminal behavior among adolescent males. *Journal of Adolescent Health*, *19*(1), 17-24.

D'Alessio, S. J., & Stolzenberg, L. (1995). Unemployment and the incarceration of pretrial defendants. *American Sociological Review*, *60*(3), 350-359.

Devine, J. A., Sheley, J. F., Smith, F., & Dwayne M. (1988). Macroeconomic and social control policy influences on crime rate changes. *American Sociological Review*, *53*(3), 407-420.

Dieter, H., & Kerner, H. J. (1988). Die eigendynamik der ruckfallkriminalitat. *Kölner Zeitschrift für Soziologie und Sozialpsychologie*, *40*(3), 485-504.

Fagan, J., & Wexler, S. (1987). Crime at home and in the streets: The relationship between family and stranger violence. *Violence and Victims*, *2*(1), 5-23.

Forrester, J. (1968). *Principles of system*. Cambridge, MA: Wright-Allen Press.

Hanneman, R. A. (1988). *Computer-assisted theory building: Modeling dynamic social systems*. Newbury Park, CA: Sage.

Heimer, K. (1996). Gender, interaction, and delinquency: Testing a theory of differential social control. *Social Psychology Quarterly*, *59*(1), 39-61.

Hirschi, T., & Gottfredson, M. R. (1994). *The generality of deviance*. Somerset, NJ: Transaction.

Hsieh, C. C., & Pugh, M. D. (1993). Poverty, income inequality, and violent crime: A meta-analysis of recent aggregate data studies. *Criminal Justice Review*, *18*(2), 182-202.

Johnson, R. A., Hoffmann, J. P., Susan, S., & Gerstein, D. R. (1996). Growth curves of deviant behavior in early adolescence: A multi-level analysis. In *Controling crime and achieving justice: 1996 abstracts*. Columbus, OH: The American Society of Criminology.

Levine, R. L., & Fitzgerald, H. E. (Eds.). (1992). *Analysis of dynamic psychological systems*. New York: Plenum.

Longshore, D., Turner, S., & Stein, J. A. (1996). Self-control in a criminal sample: An examination of construct validity. *Criminology*, *34*(2), 209-228.

MADONNA. Zahnley, T. (1996). University of California at Berkeley. Available: http://www.berkeley madonna.com

McCarthy, B. (1996). The attitudes and actions of others: Tutelage and Sutherland's theory of differential association. *British Journal of Criminology*, *36*(1), 135-147.

Nagin, D. S., & Paternoster, R. (1994). Personal capital and social control: The deterrence implications of a theory of individual differences in criminal offending. *Criminology*, *32*(4), 581-606.

Ohlemacher, T. (1995). Eine okologische regressionsanalyse von kriminalitatsziffern und armutsraten: Fehlschluss par excellence? [An ecological regression analysis of crime and poverty: An old tale told once again?]. *Kölner Zeitschrift fur Soziologie und Sozialpsychologie*, *47*(4), 706-726.

Richardson, G. P., & Pugh, A. P. (Eds.). (1981). *Introduction to system dynamics modeling*. Cambridge, MA: Productivity Press.

Schneider, A. L., & Ervin, L. (1990). Specific deterrence, rational choice, and decision heuristics: Applications in juvenile justice. *Social Science Quarterly*, *71*(3), 585-601.

STELLA. Richmond, B. (1993). Hanover: High Performance Systems. Available: http://www.hps-inc.com

Wiese, H. (1994). Okonomie des lügen und betrügen. *Kölner Zeitschrift für Soziologie und Sozialpsychologie*, *46*(1), 65-79.

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