Although it is well known that during adolescence the delinquent involvement of females is consistently less when compared to male involvement, it remains an important question whether the development of delinquency has a similar trajectory for both sexes. The main hypothesis tested is whether sex differences in delinquency, specifically growth, peak age, and decline, are constant. An autoregression model in continuous time, implemented as a structural equation model, is used for the description of the development of delinquency in males and females. The data are collected in an overlapping cohort design, and both within-person and between-persons data are integrated into a single model. The result shows that the involvement with delinquency over time is different for males and females. The main difference increases up to the age of 16, and decreases thereafter. The model indicates that both sexes reach the maximum in delinquency at the same age. It is concluded that males and females differ both in their start level at age 12 and in the amount of change with age.

Hirschi and Gottfredson have argued that using social correlates to explain desistance is misguided, as the factors that explain crime or its absence are constant across the life course (Hirschi & Gottfredson, 1983, 1984, 1994; Gottfredson & Hirschi, 1988, 1990). They showed that a similar age-crime curve has been found in many studies in

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different times and places. In most of these studies, cross-sectional data have been used, which excludes the possibility of making appropriate inferences regarding changes over time.

Two demographic variables appear to be especially important for the explanation of juvenile delinquency: age and sex. According to Hirschi and Gottfredson (1983), "the age distribution of crime cannot be accounted for by any variable or combination of variables currently available to criminology" (p. 554). Shavit and Rattner (1988) have presented data that confirm Hirschi and Gottfredson's position, whereas Tittle and Ward (1993) have also provided support. With regard to the relation between sex and crime, Gottfredson and Hirschi (1990) asserted that sex differences appear to be invariant across time and space, with males committing more offenses than females. Hagan (1998) endorsed this conclusion, stating that sex is the best predictor of criminality, of all the available demographic variables. D'Unger, Land, and McCall (2002) used a nonparametric mixed Poisson model to study the differences between male and female trajectories. Their tentative conclusion is that patterns are similar for males and females, with lower overall offending levels for females. Self-report studies show that the more serious the offense, the greater the disproportionately (Adler, Mueller, & Laufer, 1998). Overbeek, Vollebergh, Meeus, Engels, and Luijpers (2001) found that a relatively stable pattern of offending is a relatively strong predictor of the rate of later offenses. VanderValk, Spruijt, de Goede, Maas, and Meeus (2005) applied the latent growth curve (LGC) model with a quadratic component and found that the development of delinquency does not differ by gender. However, Hoyt and Scherer (1998) concluded their extensive review concerning female juvenile delinquency with the statement that the research results are not conclusive. Females have a slight lead in development during adolescence, and the difference in timing of puberty (Palmert & Boepple, 2001) may have significant implications for the development of adolescent delinquent behavior. Adolescent females also tend to associate with males who are somewhat older (Harrington Cleveland, 2003). Males and females may therefore differ on such measures as peak ages of committing the offense. Even though this difference has not been reported in earlier studies (Van der Ende & Verhulst, 2005; D'Unger, Land, & McCall, 2002), we could expect that general developmental differences are also reflected in the development of delinquent behavior. An interesting question is whether the differences between males and females are constant over their respective developmental curves; that is, whether sex differences in delinquency are invariant across
age. Main differences can concern the proportion of offenders, the frequency of offense, and the age at which delinquency reaches a peak level. The model presented here is based on the autoregressive differential equation, which features parameter estimates that are independent of the chosen origin and measurement interval.

METHOD

Model. An autoregression model states that current delinquency is dependent on prior delinquency (Dijkum & Landsheer, 2000). For both males and females, autoregression parameters are estimated, and these parameters can be compared to describe the developmental differences. Our main question is whether different parameters are necessary to describe the development, and, if so, what parameters are needed. An autoregressive model in continuous time can be described in an elegant way by a differential equation. The basic model (Oud, 1978, 2001) is a practical, statistical extension of the work of Coleman (1968). The exact discrete model (EDM) links exactly the discrete time parameters, based on the discrete measurements, to the underlying continuous time parameters (Oud & Jansen, 2000; Oud, 2002).

The authors describe change with the following differential equation (formula 1):

\[ \frac{dx(t)}{dt} = a \cdot x(t) + (b + c \cdot t) + g \cdot dW(t)/dt \]

In this formula, \( a \) represents the drift parameter of change in \( x(t) \), \( b \) represents the constant contribution to change, \( c \) the contribution to change linearly increasing or decreasing with time, and parameter \( g \) the amount of stochastic fluctuation as can be described by the Wiener process \( W(t) \) (Oud, 2002). The \( c \) parameter contributes more (\( > 0 \)) or less (\( < 0 \)) as time progresses. Focusing on the (statistical) expected outcome, this differential model has a solution in the form of a compound exponential equation. The expected value of the state variable \( x(t) \) can be interpreted as a proportion, and the resulting curve indicates the inclination and declination of delinquency.

Design. We have used the overlapping cohort design (OCD). The OCD has been developed to tackle the problems that are inherent to longitudinal designs, especially attrition (Raudenbush & Chan, 1993). Essentially, this design uses a reduced number of longitudinal measurements, but multiple overlapping cohorts. This reduces the chance that respondents drop out as it limits the commitment period of the respondents.

Sample. The data were collected as part of an extensive research project, the "Utrecht Study of Adolescent Development (USAD)
This is a longitudinal study with three waves and three-year intervals.

Each wave can be considered as a representative cross-section of the population. As the longitudinal data collection period covers six years, and the cross-sectional data collection in 1991 covers the age cohorts from 12 to 25, this design allows the longitudinal modeling of developmental curves from ages 12 to 31.

The 1991 sample of 3,393 Dutch adolescents aged 12 to 23 was drawn from an existing panel of 10,000 households. 't Hart (1994) checked whether the first wave sample was representative by comparing it with population data published by the Dutch Central Statistics Office (CBS). No differences were found between the sample and the CBS data with regard to district, urbanization level, educational level, and religious affiliation. The sample was therefore regarded as representative of the Dutch indigenous adolescent population of the early 1990s.

To reduce costs, only a part of respondents were followed over the total period of six years. Therefore, in 1994 a smaller but still considerable random selection of 1,966 subjects was taken from the 1991 sample. A total of 1,781 respondents participated in 1997. The sample was replenished in 1994 and 1997 with new respondents between 12 and 15 years of age. As a consequence of this resampling, the design combined different cohorts simultaneously with overlapping developmental periods, allowing the study of period differences. Over all waves, there were 3,954 participants in this study, of which 3,393 were sampled in 1991, 335 in 1994, and 226 in 1997. Although the 3,393 subjects of the first wave gave their informed consent to remain participants in the longitudinal study, 822 of the selected participants eventually refused to partake in the second and third wave, and the response rate between waves 1 and 3 was 76%.

Measurement. The adolescents were interviewed in their homes by trained interviewers. After the interview, respondents were given another questionnaire to fill out on their own and return to the research organization. For this study, delinquency is assessed as one or more offenses that are committed in the past year (see Appendix). This measure is more practical when using complex models than frequency measures that vary widely and, in the case of delinquency, deviate largely from the normal distribution. This measure allows the authors to study the age-dependent differentiation in male and female participation in delinquency. The self-report questionnaire includes 23 nonviolent offenses, ranging from “riding a bus without buying a ticket” to “car theft,” and six violent offenses, ranging from “illegal possession of a weapon” to “violent assault.” An estimate of the reliability of the scale is .65 (Cronbach’s alpha).
The object of the present research is to determine the relation between age and the proportion of respondents who have reported at least one delinquent act in the year previous to their interview. The authors use the differential autoregressive model to test the hypothesis that sex differences in delinquency are invariant across age; that is, whether the same parameters apply for males as well as females.

RESULTS

To handle the data as efficiently as possible, all cohorts were divided into data groups, with either one, two, or three measurements. Some of these groups containing very few subjects (1 through 3) were discarded, because of lack of variance. In most cases, these invariant groups consisted of a single respondent, and only 52 respondents had to be discarded from the analysis. All other data were analyzed. The next step was to integrate the data on a single-time axis of 20 years.

Before analyzing the integrated data set, the authors tested whether the parameters of cohorts of equal age but from different historical periods could be considered as being equal. As a result of the resampling, it was found that 1,349 respondents were of the same age, but lived in different periods. The authors found neither a period effect \( F(2, 1337) = 1.7, \text{n.s.} \), nor an interaction effect between age and period \( F(6, 1337) = 1.7, \text{n.s.} \). Next, we looked into the possible problem of instrumentation. As a consequence of resampling on the second measurement in 1994, 70 of the adolescents who were 15 years old had completed the questionnaire three years ago, whereas 55 adolescents of the same age group had no previous experience. Comparing these two groups indicated no significant instrumentation effect \( F(1, 123) = 1.3, \text{n.s.} \). On the third measurement in 1997, 32 adolescents who were 15 years old experienced the questionnaire for the first time, and 43 for the second time. Again, there were no significant differences in self-reported delinquency \( F(1, 73) = 0.07, \text{n.s.} \). In 1997, there were also adolescents who were 18 years old who experienced the questionnaire for the second (36 respondents) or third time (48 respondents). Again, no significant differences \( F(1, 83) = 0.02, \text{n.s.} \) were found.

Model fit. We started with the comparison of the parameters for males and females (Table 1). The parameters \( \gamma_0 \) (initial mean), \( a \) (drift), and \( b \) (constant change) are significantly different for males and females. Next, the authors compared a null model (0) with all parameters
equal for both sexes, with the optimal model (1) with $\gamma_0$, $a$, and $b$ free, and a model (2) with no constraints concerning the sex differences (Table 2).

Model 1 shows a large and significant improvement in comparison to the null model. The unconstrained model 2 shows that the three parameters $\sigma^2_0$, $c$, and $g$ combined still offer a significant improvement in comparison to model 1. As can be expected from Table 1, when these parameters are entered separately, none of the parameters are significant (not shown). From the fit results, one can conclude that model 1 is the most parsimonious.

Figure 1 shows the raw observed percentage for each age group and the outcome of model 1. For every age, the $R^2$ or squared multiple correlation for the 20 time points can be calculated (Table 3). Clearly, the explained variance starts low (44%), and then the model shows an increase (69% at age 16), whereas after age 18, the amount of variance explained decreases rapidly. It is therefore concluded that the explained variance is dependent on the size of the active delinquent group with increasing age.

### Table 1. Parameter estimates for males and females

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Males</th>
<th>Females</th>
<th>Difference</th>
<th>95% interval of difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial mean ($\bar{y}_0$)</td>
<td>.440</td>
<td>.269</td>
<td>.171</td>
<td>.064 / .277</td>
</tr>
<tr>
<td>Initial variance ($\sigma^2_0$)</td>
<td>.257</td>
<td>.232</td>
<td>.025 - .067 / .118 n.s.</td>
<td></td>
</tr>
<tr>
<td>Drift $a$</td>
<td>-4.17</td>
<td>-5.01</td>
<td>.084</td>
<td>.002 / .169 n.s.</td>
</tr>
<tr>
<td>Constant change $b$</td>
<td>.353</td>
<td>.280</td>
<td>.073</td>
<td>.014 / .133 n.s.</td>
</tr>
<tr>
<td>Constant change with time $c$</td>
<td>-0.17</td>
<td>-0.13</td>
<td>- .004</td>
<td>- .0007 / .000 n.s.</td>
</tr>
<tr>
<td>Diffusion $g$</td>
<td>.439</td>
<td>.471</td>
<td>- .032</td>
<td>- .073 / .008 n.s.</td>
</tr>
</tbody>
</table>

n.s.: difference not significant

### Table 2. Testing absolute and relative fit of parameters for sex differences

<table>
<thead>
<tr>
<th>Model 0</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{y}_0$, $\sigma^2_0$, a, b, c, g</td>
<td>$\sigma^2_0$, c, g</td>
<td>$\sigma^2_0$, a, b, c, g</td>
</tr>
<tr>
<td>Chi-squared fit of model</td>
<td>807.22</td>
<td>639.64</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>505</td>
<td>502</td>
</tr>
<tr>
<td>Probability</td>
<td>.000</td>
<td>.015</td>
</tr>
<tr>
<td>AIC</td>
<td>-202.79</td>
<td>-430.98</td>
</tr>
<tr>
<td>Test of $X^2$ improvement</td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.02</td>
</tr>
</tbody>
</table>
Figure 1. Observed and expected delinquency for males and females

Table 3. $R^2$ for every time point / age

<table>
<thead>
<tr>
<th>Time point</th>
<th>Age</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>0.44</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>0.57</td>
</tr>
<tr>
<td>3</td>
<td>14</td>
<td>0.64</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>0.68</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>0.69</td>
</tr>
<tr>
<td>6</td>
<td>17</td>
<td>0.68</td>
</tr>
<tr>
<td>7</td>
<td>18</td>
<td>0.66</td>
</tr>
<tr>
<td>8</td>
<td>19</td>
<td>0.63</td>
</tr>
<tr>
<td>9</td>
<td>20</td>
<td>0.60</td>
</tr>
<tr>
<td>10</td>
<td>21</td>
<td>0.57</td>
</tr>
<tr>
<td>11</td>
<td>22</td>
<td>0.53</td>
</tr>
<tr>
<td>12</td>
<td>23</td>
<td>0.50</td>
</tr>
<tr>
<td>13</td>
<td>24</td>
<td>0.46</td>
</tr>
<tr>
<td>14</td>
<td>25</td>
<td>0.42</td>
</tr>
<tr>
<td>15</td>
<td>26</td>
<td>0.38</td>
</tr>
<tr>
<td>16</td>
<td>27</td>
<td>0.34</td>
</tr>
<tr>
<td>17</td>
<td>28</td>
<td>0.30</td>
</tr>
<tr>
<td>18</td>
<td>29</td>
<td>0.26</td>
</tr>
<tr>
<td>19</td>
<td>30</td>
<td>0.22</td>
</tr>
<tr>
<td>20</td>
<td>31</td>
<td>0.18</td>
</tr>
</tbody>
</table>
DISCUSSION

Hirschi and Gottfredson (1994) have stated that the basic differences in delinquency between sexes seem to be invariant across age. In our data, the percentage of the self-reported delinquency for males is approximately 1.5 that for females. But males reach a peak at a considerably higher level, and the changes over age are also more prominent. Most importantly, the difference between the percentages diminishes after the peak age of 16. The modeled curve does reflect a significant difference in maturation or growth: females are constantly less delinquent than males, but male involvement in delinquency changes faster. The results of this study are not entirely in line with the Hirschi-Gottfredson thesis of invariance, as the rate of change is higher for males than for females. Basically, we interpret these results as disconfirmation of the view that the differences between males and females are invariant over age. At the same time, it must be recognized that these developments are neither easily measured, nor easily modeled. Unexplained variance is considerable, especially at later ages. Roughly, the percentage grows and declines at about the same ages, and in this respect the results of this study do not contradict the findings of D'Unger, Land, and McCall (2002), who also found similar patterns for males and females, but a much higher involvement in delinquency for males.

In another respect the curve seems to be equal for both sexes: the modeled peak ages are the same. In view of the fact that females have a slight lead in development during adolescence and tend to associate with males who are somewhat older (Harrington Cleveland, 2003), it is a bit surprising that this developmental difference is not reflected in delinquency data. Further research is needed on this point.

APPENDIX A

Items of the self-report questionnaire

In the past year, have you
1. taken a ride on the bus, tram, or underground without a valid ticket?
2. taken a ride on the train without a valid ticket?
3. driven a car, motorcycle, or moped without a valid driver's license or insurance?
4. painted graffiti on walls, buses, or bus stops?
5. set fire to something that did not belong to you?
6. damaged or destroyed things?
7. stolen money from a call box or a vending machine?
8. stolen something from a shop?
9. stolen something in school?
10. stolen something from home?
11. stolen something from your work?
12. stolen a motorcycle, moped, or bicycle?
13. stolen a car?
14. stolen something from or in a car?
15. pickpocketed someone?
16. stolen a handbag or suitcase from someone?
17. broken into a house or building or entered without permission?
18. stolen something else?
19. bought something while you knew it was stolen?
20. sold something that had been stolen?
21. carried a knife or other weapon?
22. threatened to hurt someone to obtain money or valuable goods?
23. been involved in fights, for instance in football stadiums, during demonstrations, or on the street?
24. seriously molested someone outside your family, so that a visit to the hospital was necessary?
25. seriously molested someone of your family, so that a visit to the hospital was necessary?
26. hurt someone with a knife or other weapon?
27. used marihuana or hashish?
28. used hard drugs, such as heroin, cocaine, lsd, or speed?
29. used beer, wine, or liquor while you were too young?

REFERENCES


