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Trajectories of Boys' Physical Aggression, Opposition, and Hyperactivity on the Path to Physically Violent and Nonviolent Juvenile Delinquency

Daniel Nagin and Richard E. Tremblay

A semi-parametric mixture model was used with a sample of 1,037 boys assessed repeatedly from 6 to 15 years of age to approximate a continuous distribution of developmental trajectories for three externalizing behaviors. Regression models were then used to determine which trajectories best predicted physically violent and nonviolent juvenile delinquency up to 17 years of age. Four developmental trajectories were identified for the physical aggression, opposition, and hyperactivity externalizing behavior dimensions: a chronic problem trajectory, a high level near-desister trajectory, a moderate level desister trajectory, and a no problem trajectory. Boys who followed a given trajectory for one type of externalizing problem behavior did not necessarily follow the same trajectory for the two other types of behavior problem. The different developmental trajectories of problem behavior also led to different types of juvenile delinquency. A chronic oppositional trajectory, with the physical aggression and hyperactivity trajectories being held constant, led to covert delinquency (theft) only, while a chronic physical aggression trajectory, with the oppositional and hyperactivity trajectories being held constant, led to overt delinquency (physical violence) and to the most serious delinquent acts.

INTRODUCTION

In their review of the development of violent behavior, the National Research Council's Panel on Understanding and Preventing Violence (Reiss & Roth, 1993) observed: "it is clear that aggressive children tend to become violent teenagers and adults" (p. 358). Indeed, a number of longitudinal studies in countries as different as England, Finland, French-Canada, New Zealand, Sweden, and the United States have shown that boys' childhood disruptive or troublesome behavior is one of the best predictors of adolescent and adult criminality, including violent crimes (Farrington, 1994; Haapasalo & Tremblay, 1994; Huesmann, Eron, Lefkowitz, & Walder, 1984; Pulkkinen & Tremblay, 1992; Stattin & Magnusson, 1989; White, Moffitt, Earls, Robins, & Silva, 1990).

From the perspective of understanding the development of physically violent behavior, however, there are several important limitations with extant research. Over the past 4 decades, it has been repeatedly suggested that studies of children's aggressive behavior distinguish different types of aggression (Buss, 1961; Crick & Grotpeter, 1995; Feshbach, 1984; Lagerspetz, Bjorkqvist, & Peltonen, 1988; Tremblay, 1991). More often than not this suggestion has not been heeded; the majority of developmental studies continue to confound physical aggression with verbal aggression, indirect aggression, opposition, hyperactivity, and other disruptive or troublesome behaviors. For example, the Pupil Evaluation Inventory peer rating instrument (Pekarik, Prinz, Liebert, Weintraub, & Neale, 1976) and the Peer Nominated Index of Aggression (Lefkowitz, Eron, Walder, & Huesmann, 1977) are commonly used in longitudinal studies of the development of aggression (Huesmann et al., 1984; Serbin, Peters, & Schwartzman, 1996; Vitaro, Tremblay, Kerr, Pagani, & Bukowski, 1997). Both have only two physical aggression items in their 10-item "aggression" scales. Similarly, the frequently used Child Behavior Checklist (CBCL) aggression scale for parent or teacher rating of children's behavior (Achenbach & Edelbrock, 1983; Hawkins, Von Cleve, & Catalano, 1988; McFadyen-Ketchum, Bates, Dodge, & Pettit, 1996) has only 3 of the 23 items that refer to physical aggression. Thus, based on these very broadly defined "aggression scales," it is only possible to conclude that disruptive or troublesome behavior during childhood predicts later violent behavior, not that physical aggression during childhood per se is a distinct risk factor for physical violence in adolescence or adulthood.

To be sure, much research has documented overlap in externalizing behaviors—physically aggressive children also tend to be in opposition, hyperactive, and otherwise troublesome (Hinshaw, Lahey, & Hart, 1993; Hinshaw, Zupan, Simmel, Nigg, & Melnick, 1997; Kerr, Tremblay, Pagani-Kurtz, & Vitaro, 1997; Tremblay, Mâsse, Pagani, & Vitaro, 1996). Still, this does not mean that these other problem behaviors are equivalently predictive of physical violence later in life. An answer to the question of whether physical aggression is a distinct risk factor for later physical violence is important for at least two reasons. First, an

affirmative finding would be valuable for targeting youth at greatest risk for becoming physically violent adults. A screening strategy that focused on chronic physical aggression rather than on generic troublesome behavior could increase predictive accuracy. This would help to narrow the target population of high-risk youth. Second, a finding that physical aggression is a distinct risk factor for adult physical violence speaks directly to a central question in developmental research on violence: Does physical violence in adults have distinct developmental antecedents in childhood physical aggression or is it simply a manifestation of a general potential for antisocial behavior? Alternatively, as stated in *Understanding and Preventing Violence* (Reiss & Roth, 1993), a key question is:

> What constructs underlie aggressive and violent behavior, and how general or specific should they be? Should we assume that all persons can be ordered on a dimension of violence potential at any given age, or can they be ordered on a more general dimension such as antisocial personality or "potential for antisocial behavior"? (p. 361)

A number of developmental models address these questions. Some argue for a single pathway to all criminal behavior, some argue for specific pathways to specific types of criminal behavior, and others argue for multiple pathways to a general tendency for criminal behavior. For example, in their general theory of crime, Gottfredson and Hirschi (1990) argue for a single pathway model. According to this model, children who fail to learn to control their impulses (i.e., those with low self-control), are most at risk of being unable to resist the temptations of any criminal behavior. From this model one would expect that chronically hyperactive children, characterized by low impulse control, are at greatest risk for all forms of criminal behavior during adolescence and adulthood. Loeber and colleagues (Loeber, 1991; Loeber et al., 1993) proposed models with different developmental pathways leading to different types of offending in adolescence and adulthood. For example, an overt behavior problem pathway starts with minor problems such as annoying others, leads to physical fighting, and is followed by serious violence such as strong-arm robbery and rape. By contrast, a covert behavior problem pathway starts with minor problems such as lying, leads to property damage, and is followed by serious covert delinquent acts such as fraud and burglary. Yoshikawa (1994) suggested still another model, a cumulative effects model, in which the accumulation of problems during childhood leads to a general propensity for criminal behavior. From this model, one would expect that any combination of hyperactive, oppositional, and physically aggressive developmental trajectories will increase the risk of any form of criminal behavior.

A second problem with research linking childhood aggression and adult violence is that most longitudinal studies from childhood to adolescence and adulthood have assessed behavior problems at only one or two points in time during childhood. Whereas such limited measurements may be sufficient for predictive purposes, it is insufficient for analyzing developmental trajectories of behavior problems from childhood to adolescence, and for linking such trajectories to criminal behavior. The few studies that have assessed changes in physical aggression on population samples with multiple assessments during childhood indicate that as children grow older they resort less and less frequently to physical aggression (Cairns, Cairns, Neckerman, Ferguson, & Gariépy, 1989; Tremblay, Boulerice, et al., 1996). In other words, they learn to use other means of problem solving. There is clear evidence, however, that not all children follow this developmental trajectory (Haapasalo & Tremblay, 1994; Loeber, Tremblay, Gagnon, & Charlebois, 1989). Some children appear never to engage in physical aggression, some are clearly chronic cases, and others are desistors. Thus, developmental researchers commonly create taxonomies of developmental trajectories using ad hoc, albeit reasonable, categorization procedures based on factors such as age of onset and the seeming chronicity of the behavior (Haapasalo & Tremblay, 1994; Loeber et al., 1989; Moffitt, 1993; Patterson, DeBaryshe, & Ramsey, 1989).

In the past decade, major advances have been made in methodology for analyzing individual level developmental trajectories that allow researchers to move beyond the use of such categorization procedures for studying developmental trajectories. The two main branches of methodology are hierarchical modeling (Bryk & Raudenbush, 1987, 1992; Goldstein, 1995), and growth curve modeling (Meredith & Tisak, 1990; Muthen, 1989; Willett & Sayer, 1994). A third alternative for analyzing individual level development is semi-parametric and is designed to identify distinctive groups of developmental trajectories within the population (Land & Nagin, 1996; Nagin, 1999; Nagin, Farrington, & Moffitt, 1995; Nagin & Land, 1993; Roeder, Lynch, & Nagin, 1999).

One of the principle advantages of this third approach is that it is well suited to analyzing questions about developmental trajectories that are inherently categorical—do certain types of people tend to have distinctive developmental trajectories? In contrast, because hierarchical and latent growth curve model-

ing assume a continuous distribution of trajectories within the population, it is difficult to designate distinct regions of the response surface (e.g., the chronic region versus the desister region). Consequently, it would be awkward to use these methods to address research questions that contrast categories of developmental trajectories (e.g., Moffitt, 1993). Another useful feature of the trajectory estimation method is that it is well suited for identifying heterogeneity in types of developmental trajectories rather than assuming them.

In this article, we generalize the semi-parametric mixture model method by adapting it for the analysis of psychometric scale data. We apply this generalized method to repeated measures of externalizing behavior problems during childhood for the purposes of identifying different developmental trajectories of physical aggression, opposition, and hyperactivity, and examining to what extent the different trajectories lead to different levels of involvement in physically violent and nonviolent delinquent behavior during adolescence. From the numerous studies that have linked hyperactivity to delinquency (see Lahey, McBurnett, & Loeber, in press) as well as from Gottfredson and Hirchi's (1990) self-control model, we expect that a chronic hyperactivity trajectory will lead to higher levels in both physically violent and nonviolent delinquent behavior involvement. From Loeber's model (Loeber, 1991; Loeber et al., 1993) we expect that a trajectory of chronic physical aggression will lead to higher levels of physically violent criminal behavior involvement, and that a trajectory of chronic oppositional behavior will lead to higher levels in nonviolent delinquent behavior involvement. From Yoshikawa's (1994) cumulative effect model, we expect that the accumulation of opposition, hyperactive, and physical aggression trajectories will increase the risk of both physically violent and nonviolent delinquent behavior involvement.

METHOD

Participants and Procedures

In the spring of 1984, all teachers of kindergarten classes at 53 schools in low socioeconomic areas in Montréal, Québec, Canada, were asked to rate the behavior of each boy in their classroom. A total of 1,161 boys were rated by 87% of the kindergarten teachers. To control for cultural effects, the boys were included in the longitudinal study only if both their biological parents were born in Canada and their parents' mother tongue was French. Thus a homogeneous White, French-speaking sample was created. After applying these criteria, and eliminating those who refused to participate, and those who could not be traced, the sample was reduced to 1,037. The boys were then assessed annually in the spring by their classroom teachers, between the ages of 10 and 15 years. Each spring the boys also were met at school and asked to complete a questionnaire.

When they were assessed in kindergarten, 67% lived with both of their parents, 24% lived only with their mothers, and 5% lived with their mother and a man other than their father; the rest lived in other family arrangements. The mean age of the parents at the birth of the child was 25.4 years (SD = 4.8) for mothers and 28.4 years for fathers (SD = 5.6). The mean age at the birth of their first child was 23.8 years (SD = 4.1) for mothers and 26.4 years (SD = 5.1) for fathers. The mean number of school years completed by the parents was 10.5 (SD = 2.8) for the mothers and 10.7 (SD = 3.2) for the fathers. The mean score on the Canadian socioeconomic index for occupations (Blishen, Carroll, & Moore, 1987) was 38.15 for mothers and 39.19 for fathers.

Measures

Teachers' behavioral ratings of externalizing behavior problems. Physical aggression, opposition, and hyperactivity were rated by the boys' classroom teachers in the spring of each year using the Social Behavior Questionnaire (Tremblay et al., 1991). Physical aggression was assessed with three items: kicks, bites, hits other children; fights with other children; and bullies or intimidates other children. The internal consistency index (Cronbach's α) for the physical aggression scale ranges from .78 to .87 (M = .84) for assessments between age 6 and 15 years. Opposition was assessed with five items: doesn't share materials, irritable, disobedient, blames others, and inconsiderate. The internal consistency index ranged from .81 to .84 (M = .83). Hyperactivity was assessed with two items: squirmy, fidgety; and doesn't keep still. The internal consistency index ranged from .85 to .89 (M = .86).

Self-reported delinquency. Questions concerning the boys' delinquent behavior over the past 12 months at 15, 16, and 17 years of age were used to create a physically violent behavior scale, a serious delinquency scale, and a nonviolent (property offense) delinquent behavior scale. The physically violent scale included fist fighting, gang fighting, carrying/using a deadly weapon, threatening or attacking someone, and throwing an object at someone. The internal consistency index (Cronbach's α) for that scale ranged from .76 to .81 (M = .79). The serious delinquency scale included breaking and entering, arson, attacking someone, de-

stroying property, stealing something worth more than $100, and carrying or using a deadly weapon. The internal consistency index for the scale ranged from .73 to .79 (M = .77). The property offense scale included stealing from a store, keeping objects worth more than $10, stealing something worth more than $100, entering without paying admission, stealing money from home, stealing a bicycle, stealing something worth between $10 and $100, buying stolen goods, being in an unauthorized place, and breaking and entering. The internal consistency index for the scale ranged from .86 to .87 (M = .87).

Juvenile infractions. Youths in the province of Québec are considered juveniles by the courts up to their 18th birthday. Following the 18th birthday of each participant, we searched the files of each juvenile court in the province of Québec and recorded all their infractions. Although some participants may have been arrested outside the province of Québec, these would be exceptional cases. Between ages 16 and 17 we identified three subjects who were living outside of the province of Québec, and five others whose addresses were unknown. Cumulative juvenile infractions for all offense types averaged 1.1 (SD = 4.6) with about 14% of the sample having at least one infraction. Less than 5% of the sample had infractions for property offenses and even fewer for violent offenses. Due to the very low prevalence of infractions for violent and property offenses, meaningful analysis of offense-specific juvenile infractions was not possible.

Statistical Methodology

Developmental trajectory models were estimated for physical aggression, opposition, and hyperactivity. Recall that the scales are based on teacher ratings made at about ages 6, 10, 11, 12, 13, 14, and 15 years. For all three scales, the trajectory estimation method described below identified four distinct groups. Figures 1, 2, and 3 graph the actual versus predicted trajectories by group for each of the problem behaviors. Before commenting substantively on the

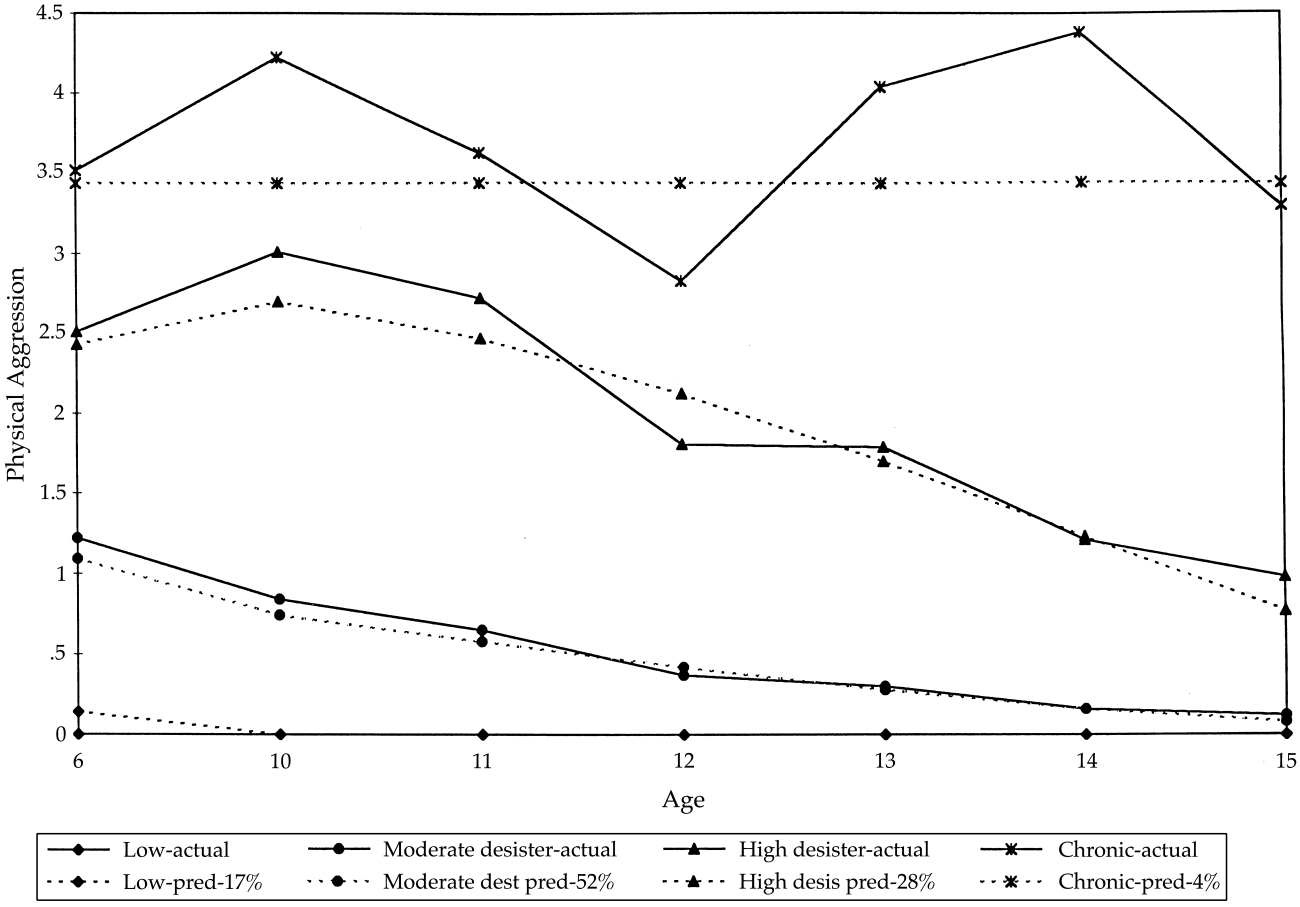

Figure 1 Trajectories of physical aggression.

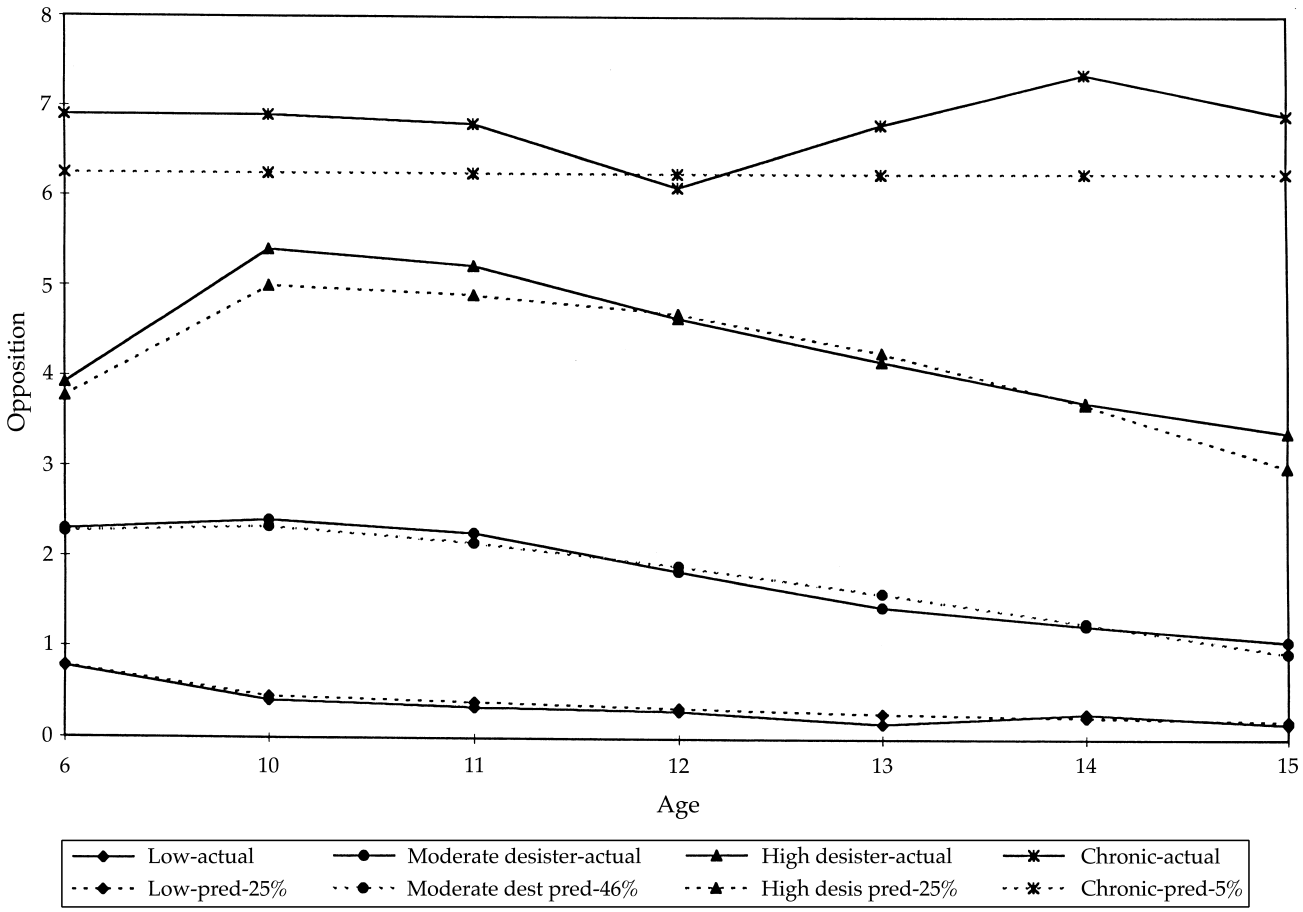

Figure 2 Trajectories of opposition.

figures, we describe the statistical procedure used to estimate them.

Like hierarchical and latent curve modeling, we use a polynomial relationship to model the link between age and behavior. Specifically, we use a quadratic equation:

$$y_{it}^{*j} = \beta_0{}^j + \beta_1{}^j \text{Age}_{it} + \beta_2{}^j \text{Age}^2{}_{it} + \varepsilon \qquad (1)$$

where y_{it}^{*j} is a latent variable characterizing the behavior (e.g., physical aggression) of subject i at time t given membership in group j, Age_{it} is subject i's age at time t, $\text{Age}^2{}_{it}$ is the square of subject i's age at time t, and ϵ is a disturbance assumed to be normally distributed with zero mean and constant variance σ^2.[1] The model's coefficients, $\beta_0{}^j$, $\beta_1{}^j$, and $\beta_2{}^j$, determine the shape of the trajectory and are superscripted by j to denote that the coefficients are not constrained to be the same across the j groups. By freeing the model parameters to differ across groups, the estimation procedure allows for cross-group differences in the shape of developmental trajectories. This flexibility is a key feature of the model, because it allows for easy identification of population heterogeneity not only in the level of behavior at a given age but also in its development over age. In principal we could use an even higher order polynomial to model the relationship between y_{it}^{*j} and Age_{it}. Typically, this would be difficult due to the high intercorrelation of the age terms raised to various powers.

Figure 4 illustrates two hypothetical possibilities. A single peaked trajectory is implied if $\beta_1 > 0$ and $\beta_2 < 0$. Thus, if data collection began at age 1 year old, the trajectory would imply that for this group the problem behavior rose steadily until age 6 and then began a steady decline. Alternatively, if data collection began at age 6, as is the case with the data used in this study, generally it would be inappropriate to extrap-

[1] We use the term *latent variable* to describe y_{it}^{*j} because, as discussed below, it is not fully observed. Thus, our use of the term "latent" is different from that in the psychometric literature, where the term *latent factor* refers to an unobservable construct that is assumed to give rise to multiple manifest variables.

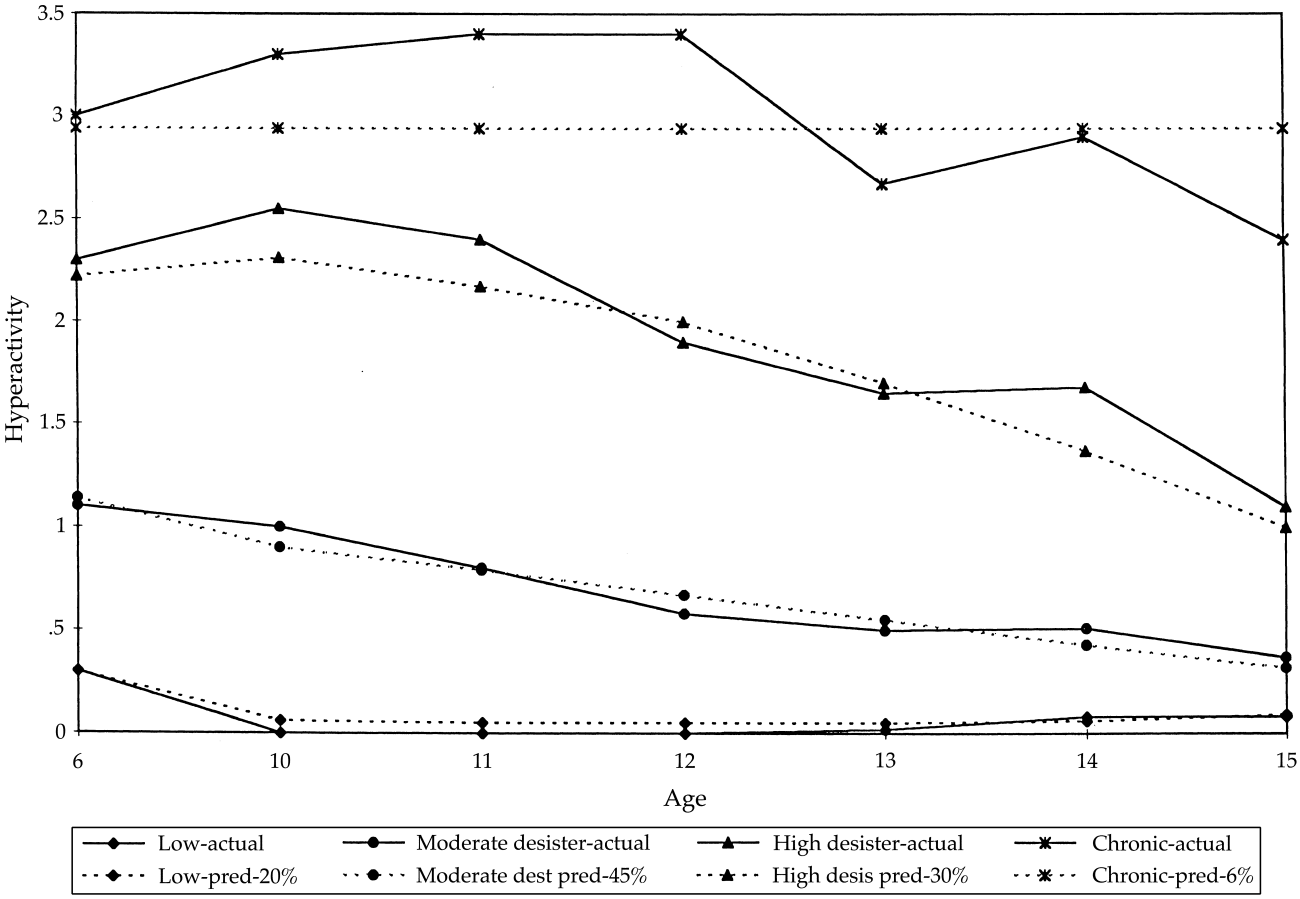

Figure 3 Trajectories of hyperactivity.

olate backward to a younger age outside the period of measurement. Thus, for a model based on data from age 6 onward, this trajectory would imply a steady decline in the behavior following the initial assessment. Such a trajectory would typify desistance from the problem behavior. The second trajectory depicted in Figure 4 has no curvature; rather, it remains constant over age. This trajectory is implied if $\beta_1 = 0$ and $\beta_2 = 0$. If that stable level of the behavior is high, this trajectory would typify a group that chronically engages in the problem behavior.

The trajectories depicted in Figures 1, 2, and 3 are the product of maximum likelihood estimation. The likelihood function linking y_{it} to the latent constructs y_{it}^{*j} is specified to capture an important feature of data from developmental studies such as that used in this analysis—the distribution of measured behavior, y_{it}, is usually censored. Commonly, a sizeable contingent of the sample exhibit none of the problem behaviors measured by the scale. The result is a clustering of data at the scale minimum. Also, there is usually a smaller contingent that exhibit all of the behaviors measured by the scale. The result is another cluster of data at the scale maximum. We take advantage of long-established results on the censored normal distribution (Greene, 1990; Maddala, 1983) to accommodate this censoring problem. A derivation of the likelihood is reported in the Appendix.

Here we briefly describe key outputs of model estimation. One is the shape of each group's trajectory as determined by the parameter estimates of Equation 1. A second key output is the estimated proportion of the population belonging to each trajectory group. A third important output is the "posterior probability" of group membership for each individual in the estimation sample. Specifically, for each individual, the model's coefficient estimates can be used to calculate the probability that the individual belongs to each group. Based on these calculations, individuals can be assigned to the group that best conforms to their observed behavior. For example, consider a person who started high on the problem behavior but who subsequently desisted. Based on the posterior probability calculations, this individual

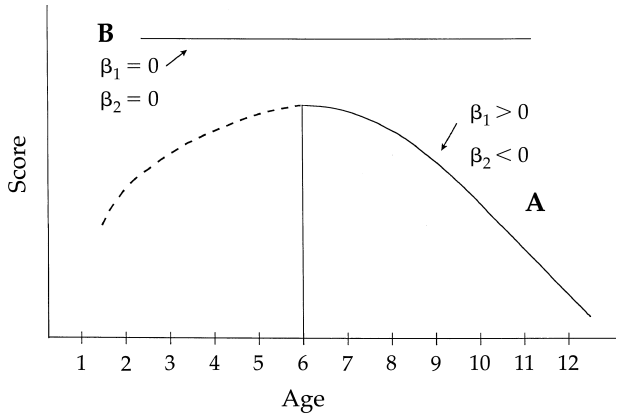

Figure 4 Two hypothetical trajectories.

would most likely be assigned to a trajectory group exhibiting a declining rate of problem behavior rather than to a group exhibiting chronic problem behavior.

Final model selection requires a determination of the number of groups that best describes the data. Determination of the optimal number of groups is a difficult statistical problem. The conventional likelihood ratio test cannot be used to test whether the addition of a group results in a significant improvement in explanatory power (Ghosh and Sen, 1985). Thus, we follow the lead of D'Unger, Land, McCall, and Nagin (1998) and use the Bayesian Information Criterion (BIC) as a basis for selecting the optimal model. Kass and Raftery (1995) and Raftery (1995) argue that BIC can be used for comparison of both nested and unnested models under fairly general circumstances. When prior information on the correct model is limited, they recommend selection of the model with the largest BIC. For any given model, BIC is calculated as:

$$\text{BIC} = -2\log(L) + \log(n)\cdot(k),$$

where L is the model's maximized likelihood, n is the sample size, and k is the number of parameters in the model. As Kass and Raftery note, the BIC rewards parsimony. For this application the BIC criterion will tend to favor models with fewer groups.

Before turning to the results, we briefly speak to the issue of the use of groups to approximate an underlying continuous phenomenon. Our model assumes that the population is comprised of a mixture of distinct groups defined by their developmental trajectory. This assumption, of course, is not literally correct. Unlike biological or physical phenomena in which populations may be comprised of literally distinct groups such as different types of animal or plant species, population differences in developmental trajectories of behavior are unlikely to reflect such bright-line differences (although biology has a long tradition of debates concerning classification; see Appel, 1987). To be sure, there are many taxonomic theories that predict different trajectories of development across sub-populations (e.g., Belsky, Steinberg, & Draper, 1991; Kandel, 1975; Loeber, 1991; Moffitt, 1993; Patterson et al., 1989), but the purpose of such taxonomies is generally to draw attention to differences in the causes of distinct developmental trajectories within the population rather than to suggest that the population is comprised of literally distinct groups.

Thus, we use trajectory groups to approximate an unspecified but possibly continuous distribution of population heterogeneity in developmental trajectories. In so doing, we adopt a standard procedure in non-parametric and semi-parametric statistics of approximating a continuous distribution by a discrete mixture (Follman & Lambert, 1989; Heckman & Singer, 1984; Lindsay, 1995). Thus the trajectory groups exist only as approximations.

The idea of using a discrete mixture to approximate a continuous distribution is easily illustrated with an example. Suppose Figure 5A depicts the population distribution of some behavior z. In Figure 5B, this same distribution is replicated and overlaid with a histogram that approximates its shape. Figure 5B

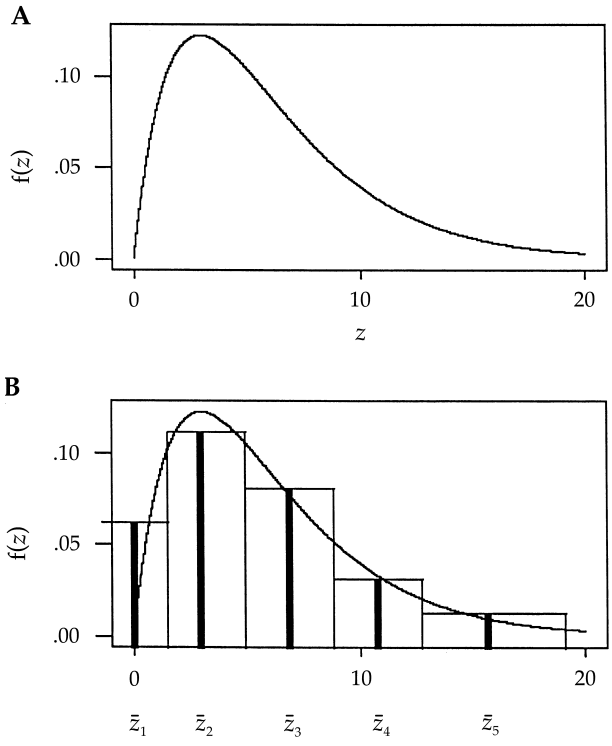

Figure 5 Approximating a continuous distribution.

illustrates that any continuous distribution with finite end-points can be approximated by a discrete distribution (i.e., a histogram) or alternatively by a finite number of "points of support" (i.e., the dark shaded "pillars").

Why use groups to approximate what we acknowledge is probably a continuous population distribution of developmental trajectories? The answer is that we have no good empirical or theoretical basis for specifying that distribution. This brings us to the key distinction between the approach developed here and the two more widely known and used approaches to modeling developmental trajectories—hierarchical modeling and latent growth curve modeling. All three approaches model individual trajectories with a polynomial relationship that links age to behavior. The approaches differ in their modeling strategy for incorporating population heterogeneity in the growth curve parameters that for the quadratic model are β_0, β_1, and β_2. In hierarchical and latent growth curve modeling, these parameters are assumed to be normally distributed in the population. In the semi-parametric approach developed here, no assumption is made about this distribution. Instead it is approximated by trajectory groups.

The cost of approximation is obvious. Approximations are just that—there is a loss of accuracy. Balanced against this are gains in generality and flexibility. Generally, we have no empirical or theoretical basis for specifying the distribution of the growth curve parameters within the population. Although for some phenomenon a normal assumption may be reasonable, for others it is questionable. For example, the distribution of problem behaviors is very skewed in the population and developmental trajectories seemingly quite varied. In these circumstances the assumption that the growth curve parameters are trivariate normally distributed is suspect, if only because of the skew in the data.

Furthermore, and perhaps even more important, the semi-parametric, group-based approach is a flexible and easily applied method for identifying vastly different trajectories of behaviors within the population. Trajectories can vary greatly across groups both in terms of the level of behavior at the outset of the measurement period and in the rate of growth and decline over age. For research questions about developmental trajectories that are categorical in nature, the flexibility of the method for identifying differences across groups is ideal. For example, Moffitt's (1993) developmental theory predicts that chronic offenders are likely to suffer from various neurological deficits, whereas adolescent-limited offenders who desist from delinquency as young adults are not. Within our semi-parametric framework, this hypothesis is readily tested by comparing the prevalence and severity of neurological problems in the group whose behavior most closely corresponds to chronic behavior with that of the group whose behavior corresponds with a desistance-like decay in problem behavior. In contrast, because hierarchical and latent growth curve modeling assume a continuous distribution of trajectories within the population, it is difficult to designate distinct regions of the response surface (e.g., the chronic region versus the desister region). Consequently, it would be awkward to use these methods to address research questions that contrast categories of developmental trajectories.

Finally, this method provides an alternative to using assignment rules based on subjective categorization criteria to construct typologies of developmental trajectories. For example, Haapasalo and Tremblay (1994), Loeber et al. (1989), Séguin, Pihl, Harden, Tremblay, and Boulerice (1995), as well as Tremblay et al. (1991), subjectively defined a cut-off point to identify high physically-aggressive boys in each of the assessment years, and then created trajectories of physical aggression based on the timing and number of years an individual had reached the high fighting criterion. Although such assignment rules are generally reasonable, there are limitations and pitfalls attendant to their use. One is that the existence of the various developmental trajectories that underlie the taxonomic theory cannot be tested; they must be assumed a priori. A related pitfall of constructing groups with subjectively defined classification procedures is "overfitting" the data by creating clusters of trajectories that reflect only random variation. Second, ad hoc rules provide no basis for calibrating the precision of individual classifications to the various groups that comprise the taxonomy. The semi-parametric, group-based method avoids each of these limitations. It provides a formal basis for testing the existence of various developmental trajectories and also provides an explicit metric, the posterior probability of group membership, for evaluating the precision of group assignments.

RESULTS

Identification of Trajectories

For each of the externalizing problem behaviors, Table 1 reports BIC scores for models with two, three, and four groups. BIC scores for two four-group models are reported—one in which all four groups follow the quadratic trajectory described by Equation 1 (Model 4a) and a second (Model 4b) in which the tra-

Table 1 Bayesian Information Criterion (BIC) by Model Type

	Problem Behaviors		
Model	Physical Aggression	Opposition	Hyperactivity
Two group	−7704.1	−11825.1	−8324.4
Three group	−7668.1	−11693.2	−8276.5
Four group			
Model 4a	−7667.6	−11694.0	−8277.0
Model 4b	−7667.4	−11685.5	−8279.3

jectory of the fourth group is constrained to be constant over age. This is accomplished by defining the trajectory for this group in terms of a single parameter (β_0, the constant term of Equation 1, and thereby setting both β_1 and β_2 equal to zero). Thus, Model 4b saves two parameters compared to 4a. Inspection of Table 1 shows that for physical aggression and opposition, BIC is maximized (i.e., is least negative) for Model 4b. For hyperactivity, BIC is minimized for the three group model.

The analyses reported below are based on Model 4b for all three externalizing behaviors. We use Model 4b for hyperactivity to err on the side of caution in testing the different theoretical models. The three group hyperactivity model does not identify a chronic hyperactivity group, whereas Model 4b does find such a group. We note, however, that our conclusions are not affected by this choice.

Inspection of Figures 1, 2, and 3 shows that for each externalizing problem behavior the trajectories are very similar. Specifically, there is a group we call "lows" who rarely display the problem behavior to any substantial degree. Depending on the problem behavior, the lows are estimated to account for about 15% to 25% of the sampled population. A second group, which comprises about 50% of the population for each behavior, is best characterized as "moderate-level desisters." At age 6 they manifested modest levels of the externalizing problem behavior, but by age 10 to 12 they have largely desisted from displays of that behavior. A third group, comprising about 20% to 30% of the population, start off scoring relatively high on the problem behavior at age 6, but by age 15 score far lower. We call this group "high-level near desisters." Finally, there is a small group of "chronics" who comprise less than 5% of the population for each externalizing problem behavior. They start off scoring high on the behavior and continue to score high throughout the observation period. It should be noted that for each of the externalizing problem behaviors, we did not identify a late onset group.

The similarity of the trajectory groups across the externalizing behavior types would seem to suggest that although the behaviors—physical aggression, opposition, and hyperactivity—are different, they are driven by a common developmental process. Statistics on group overlap reported in Table 2 suggest, however, that this conclusion is premature. Panel A of this table reports the percentage of individuals in each of the groups defined by physical aggression who are also members of the counterpart group defined by opposition and hyperactivity, respectively. For example, of the 298 individuals assigned to the

Table 2A Overlap in Group Membership of Physical Aggression Groups with Counterpart Opposition and Hyperactivity Groups

	Physical Aggression Group			
	Lows (n = 191)	Moderate-Level Desister (n = 518)	High-Level Desister (n = 298)	Chronic (n = 30)
Opposition	76.4%	67.7%	65.8%	46.7%
Hyperactivity	56.8%	58.7%	58.1%	13.3%

Table 2B Overlap in Group Membership of Opposition Groups with Counterpart Hyperactivity Groups

	Opposition Group			
	Lows (n = 254)	Moderate-Level Desister (n = 484)	High-Level Desister (n = 260)	Chronic (n = 39)
Hyperactivity	55.1%	63.5%	65.4%	23.1%

high-level near desister physical aggression group, 65.8% and 58.1% were also, respectively, assigned to this counterpart group for oppositional behavior and hyperactivity. Panel B reports the percentage of individuals in each of the groups defined by opposition who are also members of the counterpart group defined by hyperactivity. Although the overlap percentages are high, they are not near 100%, particularly for the group of greatest concern, the chronics. Only about half of the chronic physical aggressives are also in the chronic opposition group and only 13% are also chronically hyperactive. Overlap between the chronic opposition and chronic hyperactive groups is similarly small; only 23% of those in the chronic opposition group are also in the chronic hyperactive group.

Delinquent Outcomes of the Trajectories

Table 3 reports summary statistics on self-reported serious delinquency, physical violence, and theft at age 17 by group for each of the three externalizing problem behaviors. The entries are the average number of self-reported events over the past year. Note that these self-reports were elicited 2 years after the final wave of assessments upon which the trajectories themselves were based. Observe that for all but the chronic groups, the average number of events of physical violence, serious delinquency, or theft are very similar across the problem behavior types. For example, the moderate-level physical aggression desister group, on average, reported one event of physical violence at age 17. The counterpart average for the moderate-level desister group for opposition is 1.28 and for hyperactivity is 1.25. The chronic group defined by physical aggression seems, however, to have distinctly higher levels of physical violence (3.6 events), serious delinquency (2.0 events), and theft (6.1 events) than the chronic group defined by opposition behavior (2.4, 1.2, and 4.3 events of physical violence, serious delinquency, and theft, respectively) or by hyperactivity (2.4, .9, and 3.3 events, respectively). The average number of juvenile infractions by age 18 also are reported. Average cumulative infractions of the chronic physical aggression group, 7.2, is far greater than the average for the chronic hyperactivity group, 2.3. The average infraction rate for the chronic opposition group of 6.4, however, is only slightly smaller.

Explanatory Power of the Three Externalizing Problem Behavior Trajectories

Even though this study used a large sample size of inner city boys, it is not feasible to make meaningful statistical contrasts of non-overlapping chronic groups, due to small sizes of these groups (e.g., persons who are chronically hyperactive but not chronically physically aggressive versus those who are chronically physically aggressive but not chronically hyperactive).

Table 3 Self-Reported Physical Violence, Serious Delinquency, and Theft Events at Age Seventeen Years and Lifetime Juvenile Infractions by Trajectory Group for Each Problem Behavior

Group	Physical Aggression	Opposition	Hyperactivity
Physical violence (average no. of events)			
Low	.72	.60	.98
Moderate-level desister	1.03	1.28	1.25
High-level near-desister	1.95	1.88	1.71
Chronic	3.58	2.38	2.39
Serious delinquency (average no. of events)			
Low	.28	.15	.10
Moderate-level desister	.44	.60	.57
High-level near-desister	.91	.89	.83
Chronic	1.95	1.21	.91
Theft (average no. of events)			
Low	1.36	1.20	.97
Moderate-level desister	2.14	2.30	2.32
High-level near-desister	2.52	2.76	2.80
Chronic	6.05	4.33	3.26
Cumulative juvenile infractions (average no. of infractions) up to 18th birthday			
Low	.06	.01	.33
Moderate-level desister	.50	.76	.64
High-level near-desister	2.21	1.88	2.03
Chronic	7.17	6.38	2.34

Furthermore, such comparisons treat the group designations as unambiguous identifications, rather than as approximations based on the estimated group membership probabilities. In some circumstances the inherent uncertainty in classification can seriously undermine inference based on conventional methods of statistical inference that assume no classification error (Roeder et al., 1999). Thus, to test the comparative explanatory power of the three childhood externalizing problem behaviors in explaining self-reported theft, physical violence, serious delinquency, and total infractions, we estimated the following two regression models. Model 1 includes only the probabilities for opposition and hyperactivity, whereas Model 2 also includes the physical aggression probabilities. Our testing strategy is to examine whether physical aggression adds significantly to the explanatory power of the model, controlling for opposition behavior and hyperactivity, and whether these variables continue to provide independent explanatory power if physical aggression is controlled for. We perform these tests using the likelihood ratio test. Use of the test in this application is appropriate because the models are nested.

Because the response variable measures a count (i.e., number of events) the models were estimated using a generalization of the standard Poisson regression procedure, the negative binomial model. Like the Poisson model, the negative binomial regression model is designed for analysis of count data. It generalizes the Poisson by accounting for the "over-dispersion" problem, a common phenomenon in highly skewed data such as counts of individual criminal events (Land, McCall, & Nagin, 1996). The results are reported in Table 4. Without controls for the physical aggression group membership probabilities (Model 1), the probabilities defining opposition group membership have a jointly significant (5% level) relationship to physical violence, serious delinquency, and theft for each of the 3 assessment years. The hyperactivity probabilities are never jointly significant.

With the addition of the physical aggression probabilities (Model 2), the results for theft are little changed. The physical aggression probabilities never contribute significantly to the model's explanatory power, whereas opposition continues to make a distinctly significant contribution in 2 of 3 years, ages 15 and 16. The addition of the physical aggression probabilities, however, does materially change the results for physical violence and serious delinquency. For physical violence the opposition probabilities are only jointly significant at the 5% level at age 15, and for serious delinquency joint significance is only achieved at age 17. In contrast, for physical violence the physical aggression probabilities are jointly significant at age 15 and 16 and nearly significant at age 17 ($p = .06$). For serious delinquency the physical aggression group membership probabilities are jointly significant at age

Table 4 The Statistical Significance (5% level) of Physical Aggression, Opposition, and Hyperactivity in Explaining Physical Violence, Serious Delinquency, Theft, and Juvenile Infractions

	17 y		16 y		15 y	
Behavior	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Self-reported violence						
Opposition	S	*ns*	S	*ns*	S	S
Hyperactivity	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Physical aggression	—	S	—	S	—	S
Self-reported serious delinquency						
Opposition	S	S	S	*ns*	S	*ns*
Hyperactivity	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Physical aggression	—	*ns*	—	S	—	S
Self-reported theft						
Opposition	S	S	S	S	S	*ns*
Hyperactivity	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Physical aggression	—	*ns*	—	*ns*	—	*ns*
	Model 1	Model 2				
Cumulative juvenile infractions						
Opposition	S	S				
Hyperactivity	*ns*	*ns*				
Physical aggression	—	S				

Note: S = significant; *ns* = not significant.

15 and 16 but fall short of significance at age 17 (p = .08). Thus, physical aggression seems to be a distinct predictor of self-reported physical violence and serious delinquency, but not of theft. In this latter case, opposition seems to be the distinct predictor.

Consider finally the results for cumulative contacts with the juvenile justice system. Both the physical aggression and opposition group membership probabilities make a significant contribution to explaining variation in contacts with the juvenile justice system. In light of our findings that physical aggression is a distinct predictor of violence and serious delinquency and opposition a distinct predictor of theft, the result that both predict juvenile infractions is not surprising.

The results reported in Table 4 are based on the entire sample and thus include large numbers of persons who never displayed high levels of any of the three externalizing problem behaviors. Such individuals populate the low and moderate-level desister groups. Inspection of Table 3 shows that, on average, these individuals report few incidents of violence and serious delinquency. We also performed an analysis in which the sample is restricted to persons assigned to the chronic or high-level near-desister group for one or more of the three externalizing problem behaviors (n = 475). Because of this sample restriction, we limit the explanatory variables in the regression to the probability of membership in each of the three chronic groups. At all ages the probability of membership in the chronic physical aggression groups is positively and significantly related to self-reported physical violence. In 2 of 3 years it is also significantly related to serious delinquency. By contrast, the counterpart probabilities for opposition behavior and hyperactivity are never significantly related to these behaviors controlling for probability of chronic physical aggression. These findings strengthen our conclusion from Table 4 that physical aggression seems to be a distinct risk factor for violence and serious delinquency. For this restricted sample, however, opposition was no longer a distinct risk factor for theft.

DISCUSSION

From the results it is clear that as boys grow older they generally show less and less physical aggression, opposition, and hyperactivity. The results for physical aggression replicate previous studies and contradict the popular belief that as boys become older they increase the frequency of their oppositional and physically-aggressive behavior (Cairns & Cairns, 1994; Tremblay, Boulerice, et al., 1996). The oppositional and physically aggressive adolescents were oppositional and physically aggressive children. Contrary to the idea that there is a group of males who have a late onset trajectory of problem behaviors (Haapasalo & Tremblay, 1994; Moffitt, 1993; Patterson et al., 1989), we did not identify such a group. There were, however, clearly many boys with high levels of externalizing behavior problems when they started school who became better adjusted as they grew older. Two decades ago, Robins (1978) observed that "adult antisocial behavior virtually requires childhood antisocial behavior [yet] most antisocial children do not become antisocial adults" (p. 611). For each type of externalizing problem behavior, the relative size of the high-level near-desister group compared to the chronic group provides still further evidence of "Robins' Maxim." For example, for physical aggression, about 28% of the sample was estimated to be in the high level near-desister group, but only 4% was estimated to be in the chronic group. Thus, of the boys who displayed elevated levels of physical aggression in kindergarten, only 1 in 8, that is, 4/(28 + 4), continued to exhibit elevated levels of physical aggression in later adolescence.

In the second stage of the analysis, the model coefficient estimates were used to compute the posterior probability of group membership for each individual in the estimation sample. These probabilities created the basis for examining the differences in annual self-reports of delinquent behavior between ages 15 and 17 for groups of boys who showed different developmental trajectories between 6 and 15 years of age. Our purpose was to test different models of the paths from childhood externalizing problem behaviors to juvenile delinquency.

Results clearly indicated that boys who show high levels of hyperactive behavior from kindergarten to high school are much less at risk of juvenile delinquency than those who show high levels of physical aggression or opposition. This finding suggests that studies that have found hyperactivity to be a good predictor of juvenile delinquency had failed to control for physical aggression and opposition (Farrington, Loeber, & Van Kammen, 1990; Satterfield, Hoppe, & Schell, 1982; Weiss & Hechtman, 1993). Lahey et al. (in press) came to the same conclusion concerning the developmental links between attention deficit hyperactivity disorder (ADHD) and conduct disorder. Our findings also suggest that Gottfredson and Hirschi's (1990) hypothesis of low self-control as the underlying cause of most criminal and delinquent behavior must be reconsidered. Only 13% of the chronically physically aggressive and 23% of the chronically oppositional were chronically hyperactive. Many chronically antisocial boys are not among the most impulsive, and many chronically impulsive are not chronically antisocial.

As there were few additive effects in the regression, Yoshikawa's hypothesis that childhood problem behaviors accumulate to increase the risk of all forms of delinquent behavior also did not get strong support from our results. It was the hypothesis of specific pathways to overt and covert delinquency (Loeber, 1991; Loeber et al., 1993) that was most strongly supported by our results. A chronic oppositional trajectory, with the physical aggression and hyperactivity trajectories being held constant, led to covert delinquency (theft) only, whereas a chronic physical aggression trajectory, with the oppositional and hyperactivity trajectories being held constant, led to overt delinquency (physical violence) and to the most serious delinquent acts.

Loeber's (Loeber, 1991; Loeber & Hay, 1994; Loeber, Keenan, & Zhang, 1997) model suggested that the overt pathway starts in early childhood with oppositional behavior, leads to physically aggressive behavior during middle childhood, and is transformed into violent delinquency during adolescence. Our results do not support the idea that chronic physical aggression appears after oppositional behavior, because we did not have a late onset group for physical aggression. It could be argued that our study, which began during the kindergarten year, started too late to observe the path from opposition to physical aggression. The available data on physical aggression before entry in a kindergarten indicates, however, that the frequency of physical aggression reaches its peak around age 2 and then slowly declines up to adolescence (Restoin et al., 1985; Tremblay, Boulerice, et al., 1996). It is most likely that the boys in the high level and chronic physically aggressive trajectories were already highly physically aggressive by age 2 (Cummings, Iannotti, & Zahn-Waxler, 1989; Keenan & Shaw, 1994). For opposition to be antecedent to physical aggression we would probably need to be referring to opposition in the first year of life.

We have the impression that the boys on the overt delinquency or physical aggression path are those who did not learn to regulate the physically aggressive reactions that approximately 50% of boys manifest from the middle of their 2nd year of life to the middle of their 3rd year of life (Tremblay, Boulerice, et al., 1996). This behavioral trajectory appears to start with physical aggression as soon as the child is sufficiently coordinated to do so. The changes in behavior are probably changes in the frequency, means, context, victims, and consequences of his physical aggression, which are probably related to his physical, cognitive, emotional, and social development.

Our results for the oppositional trajectory appear to confirm that subjects who follow Loeber et al.'s (1993) covert pathway from pre- to late adolescence start with early childhood oppositional behavior (Loeber's authority conflict pathway). Thus, the chronic covert behavior problem trajectory would start with preschool oppositional behavior problems. Future longitudinal studies of preschool children should focus on the factors that put some children on the chronic oppositional trajectory and others on the chronic physical aggression trajectory. Early temperamental characteristics certainly need to be taken into account (e.g., Kagan & Snidman, 1991; Tremblay, Pihl, Vitaro & Dobkin, 1994), but complex early interactions among biopsychosocial factors are probably major determinants of these chronic trajectories (see Raine, Farrington, Brennan, & Mednick, in press).

This study is different from previous studies of the trajectories leading to juvenile delinquency for a number of reasons. It used a large sample of inner city, nonimmigrant, culturally homogeneous White males. Seven annual assessments over a 10-year period, starting in kindergarten, were used to assess the developmental trajectory of problem behaviors with a specific focus on the differences between the three major externalizing behaviors: physical aggression, opposition, and hyperactivity. Three annual assessments of offending during the peak juvenile delinquency years (15 to 17 years) were used. Data were collected from different sources. Assessments of behavior problems were obtained from different teachers over the 10-year period, delinquency was assessed from self-reports and official files. Finally, the study demonstrates a new semi-parametric method for estimating developmental trajectories that combines the strengths of categorical and continuous data analyses. This method adapts prior work based on mixtures of zero-inflated Poisson distributions to the analysis of psychometric scale data. It accommodates missing data so that individuals with incomplete assessment histories do not have to be dropped from the analysis. Also, time between assessment periods do not have to be equally spaced.

There also are limitations to the study. Because it was restricted to boys with a specific set of characteristics, replications will be needed with other populations to verify to what extent the results are generalizable. It will be especially important to replicate the study with samples of females. Although the sample was large compared to most studies, it was still not sufficient to create and compare groups of subjects with specific characteristics such as chronically physically aggressives who were or were not also in chronic opposition. Our use of three annual assessments of self-reported delinquency during the peak antisocial years was more extensive than in most developmen-

tal studies. Notwithstanding, the variation of results over the years indicates that an extended period of repeated measures would provide a clearer picture of the long-term trajectories of overt and covert delinquency. In 1984, when the study started, assessments of externalizing behavior problems from kindergarten teachers appeared to be early enough to understand the onset of the paths toward violent juvenile delinquency (Eron, 1990). The results from the present study and others (e.g., Eron, 1990; Stattin & Klackenberg-Larsson, 1993; Tremblay, Mâsse et al., 1996; White et al., 1990), however, indicate that we need longitudinal studies of behavioral development starting in the first year of life to understand the early development of chronic physically violent and nonviolent antisocial behavior. We will also need to wait at least another decade to trace the paths through adult criminal behavior.

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ADDRESSES AND AFFILIATIONS

Corresponding author: Daniel Nagin, 2105 Hamburg Hall, Carnegie Mellon University, Pittsburgh, PA 15213; e-mail: dn03@andrew.cmu.edu. Richard Tremblay is at the University of Montréal.

APPENDIX

As described in the main text, the form of the likelihood for each individual i is:

$$P(Y_i) = \sum_j \pi_j P^j(Y_i)$$

where $P(Y_i)$ is the unconditional probability of observing individual i's longitudinal sequence of behavioral measurements—Y_i, $P^j(Y_i)$ is the probability of Y_i given membership in j, and π_j is the probability of j. Thus, the likelihood for the entire sample of N individuals is:

$$L = \prod^N P(Y_i)$$

For given j, conditional independence is assumed for the sequential realizations of the elements of Y_i, y_{it} over the T ages of measurement. Thus,

$$P^j(Y_i) = \prod^T p^j(y_{it})$$

where $p^j(Y_{it})$ is the probability distribution function of y_{it} given membership in group j.

For the censored normal, $p^j(Y_{it})$ equals:

$$p^j(y_{it} = S_{\min}) = \Phi\left(\frac{S_{\min} - \beta^j x_{it}}{\sigma}\right),$$

$$p^j(y_{it}) = \frac{1}{\sigma}\phi\left(\frac{y_{it} - \beta^j x_{it}}{\sigma}\right) \quad for \quad S_{\min} \le y_{it} \le S_{\max},$$

and $$p^j(y_{it} = S_{\max}) = 1 - \Phi\left(\frac{S_{\max} - \beta^j x_{it}}{\sigma}\right).$$

where ϕ and Φ are, respectively, the density function and cumulative distribution function of a normal random variable with mean $\beta^j x_{it} = \beta_0{}^j + \beta_1{}^j \mathrm{Age}_{it} + \beta_2{}^j \mathrm{Age}_{it}{}^2$ and standard deviation, σ, Age_{it} is individual i's age at time t, and $S_{\min}$ and $S_{\max}$ are, respectively, the scale minimum and maximum.

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