

Developmental Trajectories of Physical Aggression from School Entry to Late Adolescence

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The developmental perspective applied to psychopathology has led to the concept of early- and late-onset disorders. This study explores the application of the early- and late-onset concepts of antisocial behavior to physical aggression. Are there two categories of chronically physically violent adolescents: those who are physically aggressive throughout childhood and those who start being physically aggressive during adolescence? The estimation of developmental trajectories for repeated measures of two different response variables—physical aggression in childhood as measured by teacher reports and physical aggression in adolescence as measured by self-reported violent delinquency—is achieved with a semi-parametric, group-based method. This new method is applied to a large sample of males from Montreal who have been assessed repeatedly since kindergarten. Several salient findings emerge from the analysis. First, we find considerable change in the levels of childhood and adolescent physical aggression. Thus, there is little evidence of stability of behavior in an absolute sense. A second key finding concerns the connection of childhood aggression to adolescent aggression. Boys with higher childhood physical aggression trajectories are far more likely to transition to a higher-level adolescent aggression trajectory than boys from lower childhood physical aggression trajectories. However, for all childhood physical aggression trajectory levels the modal transition is to a relatively low-level adolescent aggression trajectory. Third, we find little evidence of “late onset” of high-level physical aggression. Specifically, the joint trajectory analysis finds no evidence of transition from a low physical aggression trajectory in childhood to a high trajectory in adolescence.

Keywords: Adolescence, aggression, child development, violence.

Abbreviations: BIC: Bayesian Information Criterion.

Introduction

Over the past decade the use of a developmental psychopathology perspective has led investigators to look for the age of “onset” of specific disorders. A rapid consensus was reached that there were two categories of cases: those who initiated that kind of behavior during childhood and those who initiated it during adolescence (e.g., American Psychiatric Association, 1994; Moffitt, Caspi, Dickson, Silva, & Stanton, 1996; Patterson, DeBaryshe, & Ramsey, 1989). The consensus is surprising because the two categories solution aggregates a large variety of antisocial phenomena that could have different etiologies and developmental trajectories, and thus would probably need different prevention and treatment strategies.

Within 14 years the DSM classification of conduct disorder went from five categories (DSM-III: under-

socialized aggressive, undersocialized nonaggressive, socialized aggressive, socialized nonaggressive, atypical), to three (DSM-III-R: group, solitary aggressive, undifferentiated), to two (DSM-IV: childhood-onset, adolescent-onset). The major loss in this simplification process has been the differentiation between antisocial behavior with and without physical aggression. This is an especially surprising orientation, since physical aggression is probably the main reason the general public and funding agencies support research on antisocial behavior. Most courts of law will treat differentially a juvenile who physically aggressed and juveniles who shoplifted, ran away from home, or used marijuana. There is good evidence that the mean frequency of physical aggression increases during the first year after birth, and then decreases steadily from the third year after birth (Goodenough, 1931; Nagin & Tremblay, 1999; Restoin et al., 1985; Tremblay et al., 1996, 1999). One would expect that running away from home, shoplifting, and marijuana use would not follow the same trajectory as physical aggression.

Most tests of the early- and late-onset antisocial behavior classification aggregated different forms of antisocial behavior (e.g., Hodgins, 1994; Moffitt et al., 1996; Nagin & Farrington, 1992; Tibbetts & Piquero,

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1999; Tolan & Thomas, 1995). However, Lahey et al. (1998), using retrospective data to differentiate childhood- and adolescent-onset CD, found that the childhood-onset cases were characterized by high levels of physical aggression. Childhood-onset conduct disorder may capture a group of children who fail to learn to inhibit physical aggression during childhood, whereas adolescent-onset conduct disorder may be capturing individuals who have difficulties learning to regulate other types of behaviors that become possible only once the child has developed the physical and psychological skills, and acquired the liberty of movement without adult supervision, required to engage in such delinquent activities as use of drugs and alcohol, burglary, or running away from home. If this were the case, childhood- and adolescent-onset CD would not be the same disorder starting at different points during development, but different disorders starting at different developmental stages. Their relation would be similar to the relation between autism and schizophrenia.

This paper concentrates on the development of physical aggression from school entry to late adolescence. A recent cross-sectional study of a large representative sample of Canadian children found that maternal reports of physical aggression declined in those children between the ages of 2 and 11 years whereas the frequency of indirect aggression increased from the ages of 4 to 11 years (Tremblay et al., 1996). From a developmental perspective this result is not surprising. One would expect that the capacity to inflict bodily harm on others would precede the capacity to inflict mental or emotional harm and that these behaviors are very likely to evolve over time in different ways. The acquisition of the motor skills that allow toddlers to hit, kick, or bite their peers generally pre-dates their ability to talk. More importantly, a child's development of the physical capacity to attack others long precedes the development of the intellectual and social capacity to inflict mental or emotional harm by verbal aggression or social exclusion.

Only a few studies have traced the developmental origins of physical aggression but that evidence which is available suggests that, on average, it peaks at a very young age—perhaps as young as 2 years (Tremblay, 2000). Cairns, Cairns, and colleagues (Cairns & Cairns, 1994; Cairns, Cairns, Ferguson, Neckerman, & Gariépy, 1989) found that physical aggression, on average, decreased rather steadily from ages 10 to 18 years. Tremblay et al. (1999) report a steady decline in physical aggression in a sample of Montreal males from ages 6 to 15 years. Similar results are found in a Pittsburgh, PA-based longitudinal study (Loeber & Hay, 1994). Studies of physical aggression prior to age 6 are even rarer but the little evidence that is available suggests that humans begin physically aggressing as soon as they have the physical capacity to do so (Tremblay et al., 1999).

Still, average tendencies may conceal the late emergence of physical aggression among subpopulations. However, Nagin and Tremblay (1999) find no evidence of such late-emerging physical aggression. They utilized a semi-parametric, group-based methodology, described by Nagin (1999), which is specifically designed to identify distinctive groupings of developmental trajectories within the population. Four such distinct trajectory groups were identified; all had either stable or declining trajectories of physical aggression from age 6 onward. There was no evidence of the onset of physical aggression after age 6. A follow-up study involving five additional prospective

longitudinal studies—one more from Canada, two from New Zealand, and two from the U.S.—again found no evidence of onset of physical aggression after age 6 years (Broidy et al., 1999).

Even if late onset of childhood physical aggression is highly unusual, this does not rule out the possibility that a sizable fraction of adolescents who were not physically aggressive as young children become physically violent during adolescence. Adolescence is a critical period in personal development. Parental control and influence generally diminishes and children take important steps toward independence. Unstructured time with peers increases, opportunities to organize life's activities without adult supervision grow, and experience with the successes and failures that determine life chances become more prominent. In various ways, each of these changes in life circumstances has been implicated in the onset of delinquency.

This study builds from the findings of Nagin and Tremblay (1999) and Broidy et al. (1999), by exploring the linkage between trajectories of physical aggression in childhood and adolescence. The key question we address is whether there is any substantial evidence of onset of physical aggression in adolescents among individuals with no history of physical aggression during the elementary school years, and if there is, whether that physical violence is chronic and sustained rather than episodic.

We also have a methodological objective. Specifically, we develop an important extension to the semiparametric, group-based method for identifying and analyzing developmental trajectories described in a number of recent articles (Land, McCall, & Nagin, 1996; Nagin, 1999; Nagin & Land, 1993; Nagin & Tremblay, 1999; Roeder, Lynch, & Nagin, 1999). Prior applications of the method analyzed repeated measures of a single response variable (e.g., the number of convictions from ages 10 to 32). Here we extend the method to permit the estimation of trajectories for repeated measures of two different response variables—physical aggression in childhood as measured by teacher reports and physical aggression in adolescence as measured by self-reported violent delinquency.

We offer this method to complement the conventional approach for measuring stability of behavior that uses measures of association—such as correlation coefficients—to index the strength of the relationship between the measured behavior of the same individuals at two points in time (see, e.g., Backteman & Magnusson, 1981; Farrington, 1991; Huesmann, Eron, Lefkowitz, & Walder, 1984; Loeber & LeBlanc, 1990; Olweus, 1979). In our judgement, stability coefficients suffer from several important limitations. First, the magnitude of a stability coefficient is not easily interpreted. What, for example, does a stability coefficient of +0.6 imply about the proportion of individuals who exhibit behavioral continuity in comparison to the proportion of individuals who exhibit behavioral change? How should we interpret a stability coefficient of .3 in comparison to a stability coefficient of .6? Clearly, one is larger but how much larger? Second, the size of stability coefficients are quite sensitive to inclusion of outlier data from highly skewed distributions such as those often encountered in research on crime and antisocial behavior (Moffitt, 1993). Third, stability coefficients are based on measurements at two points in time and, thus, make inefficient use of longitudinal data with more than two assessment periods. If

one wishes to investigate stability for more than two periods, it is necessary to calculate multiple stability coefficients. Even more fundamentally, stability coefficients may be sensitive to the choice of assessment periods used in their calculation. Fourth, the usual and customary interpretation of a correlation coefficient assumes that it applies equally to all individuals within the population under study. However, research showing substantial heterogeneity in the development of antisocial behavior over the life span calls into question the plausibility of such an assumption (e.g. the theories of Moffitt, 1993; and Patterson et al., 1989).

The method we use here has several noteworthy features that avoid these problems. First, it allows us to identify—in concrete, visual terms—the proportion of individuals who exhibit behavioral continuity and the proportion of individuals who exhibit behavioral change. Second, because the approach is based on mixtures of simple, but realistic, probability distributions, it provides a basis for identifying population heterogeneity in developmental trajectories. Relatedly, this feature also allows us to distinguish between random noise and systematic population variation in patterns of childhood physical aggression and adolescent violence. This avoids an important pitfall associated with constructing groups based on subjective or ad hoc classification rules—overfitting the data with the creation of groups that reflect only random variation. Third, it makes use of all the available data, not just assessments at two periods in time.

Methods

Sample and Instruments

The data used in this analysis were obtained from a long-term longitudinal study of 1161 white males who were enrolled in kindergarten classes in 53 low socioeconomic status neighborhood schools in Montreal. Only those boys whose biological parents were born in Canada and whose parents' primary language was French were included in the study. After applying these criteria and eliminating individuals who refused to participate or who could not be located, a sample of 1037 subjects remained.

The first wave of data collection occurred in 1984, when all of the boys were approximately 6 years old. At ages 6, 10, 11, 12, and 13 the boys were rated by their teachers on the Social Behavior Questionnaire (Tremblay et al., 1991). For purposes of our analysis, we are interested in the distribution of the physical aggression measures in this instrument. At each wave of data collection, a physical aggression index was created by combining data on three items: (1) kicks, bites, hits other children; (2) fights with other children; and (3) bullies or intimidates other children. The final index ranges from 0 to 6 at each wave of data collection. The internal consistency index (Cronbach's alpha) ranges from .78 to .87.

Our analysis also relies on a measure of self-reported physical aggression that was collected from each boy at ages 13, 14, 15, 16, and 17. The internal consistency index (Cronbach's alpha) ranges from .62 to .75. To obtain this information, each boy was asked to report the frequency with which he had committed each of the following acts within the previous 12 months: (1) gang fighting; (2) using a deadly weapon; (3) attacking someone who had done nothing to you; and (4) throwing rocks, bottles, or other objects at someone. Response options included: (0) never, (1) once or twice, (2) sometimes, and (3) often. Thus, the combined measure at each wave is an integer index of the frequency of physical aggression over the preceding year. This index does not control for the seriousness of the incident.

However, we have conducted our analysis with different subsets of the items and our findings do not materially differ.

A small number of the 1037 boys had missing data on either all of the childhood or adolescent aggression outcomes. After deleting these boys from the data set, we were left with a final analysis sample of 926 boys. While some of the 926 boys had missing data at some waves, we allowed each of them to contribute information to the analysis for each wave in which they were observed. For additional details about these data, see Tremblay, Pihl, Vitaro, and Dobkin (1994) and Tremblay et al. (1991).

Statistical Analyses

In this section, we provide an overview of our analysis methods. A more detailed discussion is presented in the Appendix. The statistical model advances prior work of Nagin and colleagues in the use of finite mixture models to identify distinctive developmental trajectories within the population. As developed in Nagin (1999), this modeling strategy is particularly well suited for analyzing individual-level developmental trends in which development does not vary regularly and smoothly across population members. Rather, the population is viewed as being comprised of distinct clusters of developmental trajectories.

Mixture models assume that the population is comprised of a finite number of unobserved groups of individuals. The groups are defined by an expected developmental trajectory that relates the expected level of the behavior of interest with age. Technically, we model this linkage between expected behavior and age by up to a second-order polynomial equation. The parameters of this relationship are allowed to vary freely across groups. This provides for great flexibility in describing the developmental trajectory of each group. In addition to estimating a parametric representation of each group's trajectory, the proportion of the population comprising each trajectory group is also estimated.

The mixture model framework applied here is designed to combine trajectories of distinct but related behaviors—in this case trajectories of physical aggression from ages 6 to 13 years based on teacher reports are combined with trajectories of physical aggression from ages 13 to 17 years based on self-reports. Each group is characterized by two separate trajectories—one for childhood aggression and the other for adolescent aggression. The trajectories are the product of a joint estimation procedure that estimates each group's trajectories in combination. In addition to the two trajectories, which in combination specify the developmental course of physical aggression from ages 6 to 17 years, an estimate of the proportion of the population following this developmental course is also produced.

Model estimation is achieved by maximization of the likelihood that is derived in the Appendix. This likelihood brings together earlier mixture model work that was designed to accommodate special features of the data to be analyzed. Nagin and Tremblay (1999) develop a mixture model based on the censored normal distribution. The censored normal is well suited to accommodate a common feature of psychometric scale data such as the childhood physical aggression data analyzed here. Typically a sizable contingent of the sample exhibits none of the behaviors measured by the scale. The result is a clustering of data at the scale minimum. Also, there is usually a smaller contingent that exhibits all of the behaviors measured by the scale. The result is another cluster of data at the scale maximum. Nagin and Land (1993), Land et al. (1996), and Roeder et al. (1999) develop a mixture model based on the Poisson distribution and its more general relative, the zero-inflated Poisson distribution. This Poisson-based model is designed to estimate trajectory models in which the response variable is an integer-valued index or count and is used to model self-reported physical aggression during adolescence.

In addition to a depiction of the shapes of a group's joint behavioral trajectories and estimation of the proportion of the population following such a joint trajectory, another important output is an estimate of the probability that each individual belongs to each of the groups. This probability is calculated on the basis of the data and the maximum likelihood parameter estimates associated with the mixture; we call it the posterior probability of group membership. Using this probability, individuals can be assigned to the group to which they have the highest probability of belonging.

Final model selection requires a determination of the number of groups that best describes the data. As described in Nagin (1999), a conventional chi-squared-based test of goodness-of-fit cannot be used to test whether the addition of a group results in a significant improvement in explanatory power. Instead we follow the recommendation of Kass and Raftery (1995) and Raftery (1995) to use the Bayesian Information Criterion (BIC) as a basis for selecting the optimal model. For any given model BIC is calculated as: $BIC = -2 \log(L) + \log(n) * (k)$, where L is the model's maximized likelihood, n is the sample size, and k is the number of parameters in the model.

Results

To introduce the joint trajectory analysis we begin by reporting results for separate trajectory models for childhood and adolescent aggression, respectively. Based on the BIC criterion a three-group model was found to best fit the childhood aggression data. For the adolescent aggression data a six-group model was found to best fit the data. However, here we describe the four-group model because the results from this more parsimonious solution are qualitatively similar. Figure 1 presents the results of this analysis.

The left panel of Fig. 1 shows the forms of the three childhood physical aggression trajectories. The largest group, an estimated 50% of the population, is defined by a low and declining aggression trajectory; the next largest group, about 30% of the population, is described by a medium and generally declining trajectory; and the

smallest group, about 20% of the population, by a trajectory of high aggression. These findings generally conform with Nagin and Tremblay (1999). However, in addition to the three groups identified here, they also found a small group of boys who showed no sign of desistance from their high level of physical aggression. This chronic group emerges with the use of physical aggression measurements made at ages 14 and 15. To avoid overlap with the adolescent violent data these measurements were not used in this analysis.

The right panel of Fig. 1 reports the trajectories for adolescent physical aggression. The largest group (64%) self-reports very little physical aggression over the observation period. The smallest group (5%) reports high levels of aggression from ages 13 to 17 years old. In between are two groups of about equal size, an estimated 15% of the population each, that display opposite trajectories. One is a desistance trajectory in which group members start off with a high level of physical aggression at age 13 but by age 17 have desisted from such behavior. The other is a rising trajectory group that starts off reporting no physical aggression at age 13 but by age 17 is reporting modest levels.

We turn now to the results of the joint analysis in which the trajectories of physical aggression in childhood are linked with those in adolescence. Based on the BIC criterion, a seven-group model was found to best fit the data. The posterior probabilities of group membership also suggest that the fit is good. These probabilities provide a quantitative and objective basis for assigning individuals to the trajectory group that best matches their behavior. For example, an individual who displayed a high level of physical aggression in childhood but who ceased being violent in adolescence would probably be assigned to a group with a comparable predicted trajectory. Ideally, for each individual this probability should be one for the group to which they are assigned and thereby zero for all others. To the degree that there are large numbers of individuals whose behavior is not well matched by a trajectory group, assignment proba-

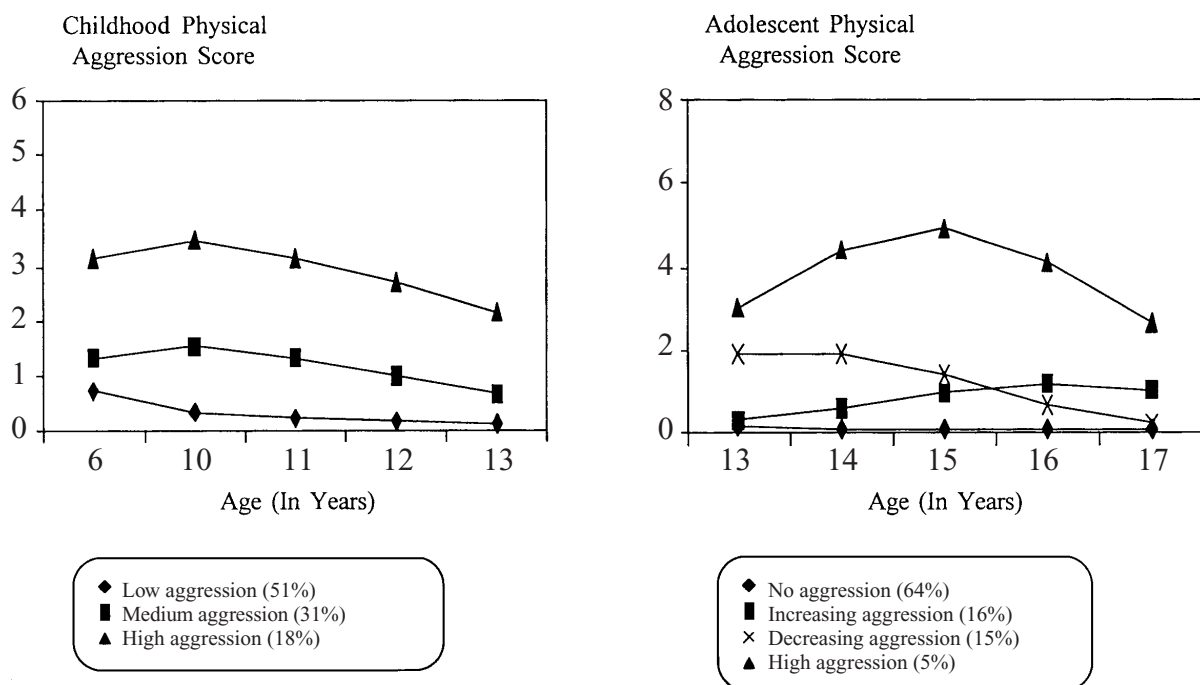


Figure 1. Marginal trajectories of childhood physical aggression and adolescent physical aggression ($n = 926$).

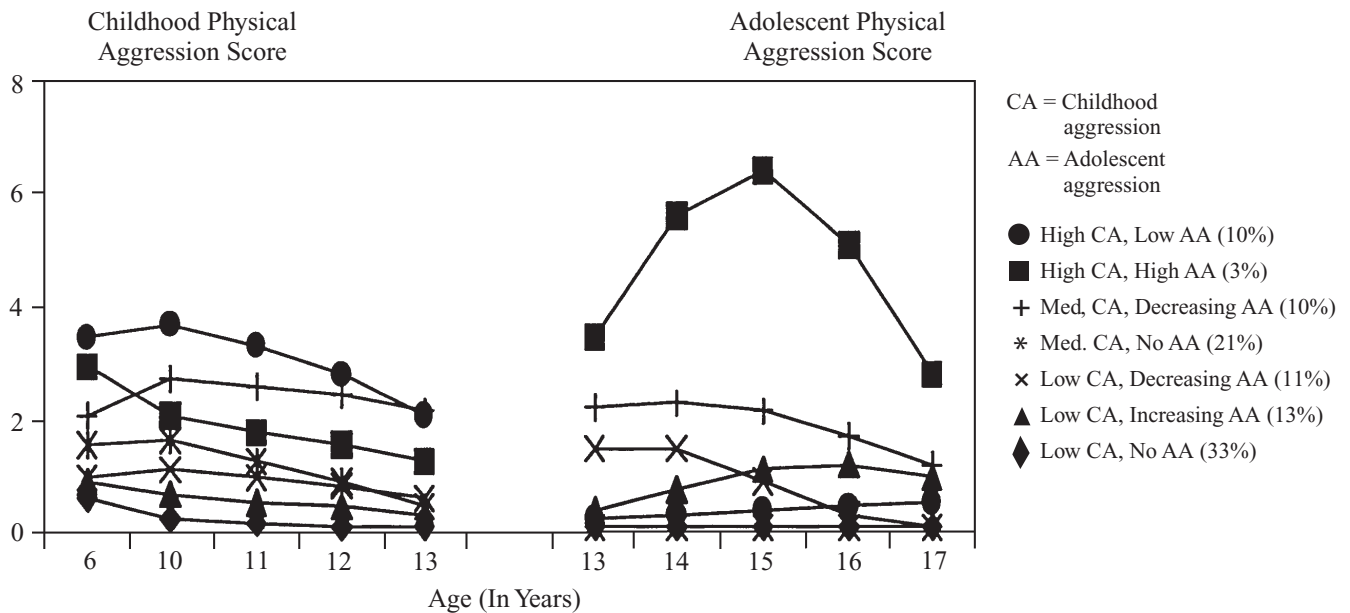


Figure 2. Joint trajectories of childhood physical aggression and adolescent physical aggression ($n = 926$).

bilities to the best-fitting group will be low. For the seven-group model, mean assignment probabilities for the best-fitting group averaged .82 and ranged from .73 to .95. Although there is no formal statistical criterion for evaluating these summary measures, we conclude that our group-based model does a more than adequate job of capturing individual differences in the developmental course of physical aggression.

Figure 2 presents the results of this bivariate system of childhood and adolescent physical aggression trajectories. This figure shows seven distinct trajectory patterns—one for each of the groups included in the model specification. In order to simplify the presentation of these results, Figures 3a–c display the trajectories of groups with similar developmental patterns of childhood aggression but divergent trajectories of adolescent aggression.

Figure 3a reports a cluster of three groups with low and steadily declining physical aggression in childhood. The largest group, which is estimated to account for 33% of the population, self-reports virtually no physical aggression in adolescence. We call this category of individuals the low childhood aggression/no adolescent aggression group. A second group has a trajectory of adolescent physical aggression that starts off low at age 13 but thereafter increases to a moderate level by ages 16–17. We call this category the low childhood aggression/increasing adolescent aggression group. By contrast, the third group depicted in Fig. 3a starts off with a moderate level of self-reported aggression at age 13 but in the ensuing years their violence decreases gradually to a near-zero level. We call this category the low childhood aggression/decreasing adolescent aggression group. Both groups are of about equal size, about 11% to 13% of the population, respectively.

Figure 3b depicts a two-group cluster with generally medium but declining levels of childhood physical aggression. The larger of the two groups, estimated to comprise 21% of the population, reports virtually no physical aggression during adolescence. The other group, estimated to account for about 10% of the population, reports a relatively high but declining level of physical aggression during adolescence.

Lastly, Fig. 3c displays trajectories for another two-group cluster in which both groups display a consistently high level of physical aggression from ages 6 to 13. Despite the similarity of their childhood aggression trajectories, however, these two groups display markedly different trajectories of aggression in adolescence. One group, which we call the high childhood aggression/high adolescent aggression group, is estimated to account for about 3% of the population. At age 13, the self-reported physical aggression of this group is higher than that of any other group at any age. Their violence rises steadily to a peak at age 15 and thereafter declines. This single-peaked pattern conforms to conventional findings based on aggregate data on the relationship of age and crime (Farrington, 1986; Hirschi & Gottfredson, 1983). Criminal involvement as measured by arrest rises steadily through adolescence and then begins a steady decline thereafter. It is noteworthy, however, that this is the only single-peaked individual level trajectory identified in this analysis. The second group is comprised of individuals who, despite their high aggression in childhood, report a negligible level of violence in their youth. This group is estimated to comprise 10% of the population.

Consider the implication of these trajectory plots for the continuity of physical aggression. One definition of continuity is that behavior remains stable over time. By this definition, the results provide little evidence of stability. All seven of the childhood physical aggression trajectories are generally declining. For the adolescent trajectories two are declining, one is rising, and one is hump shaped. Another definition of continuity is that population members maintain their relative standing over time. In this group-based modeling approach, relative stability is supported by trajectories not intersecting; intersection implies change in the relative standing of groups vis-à-vis the measured behavior. By this definition there is very substantial evidence of continuity. Inspection of Fig. 2 reveals that there are only two instances of intersection in the childhood trajectories. Among the adolescent trajectories, there is only one trajectory that intersects others. Still, the other six trajectories maintain their relative positions throughout the observation period. Overall, the results provide strong evidence of

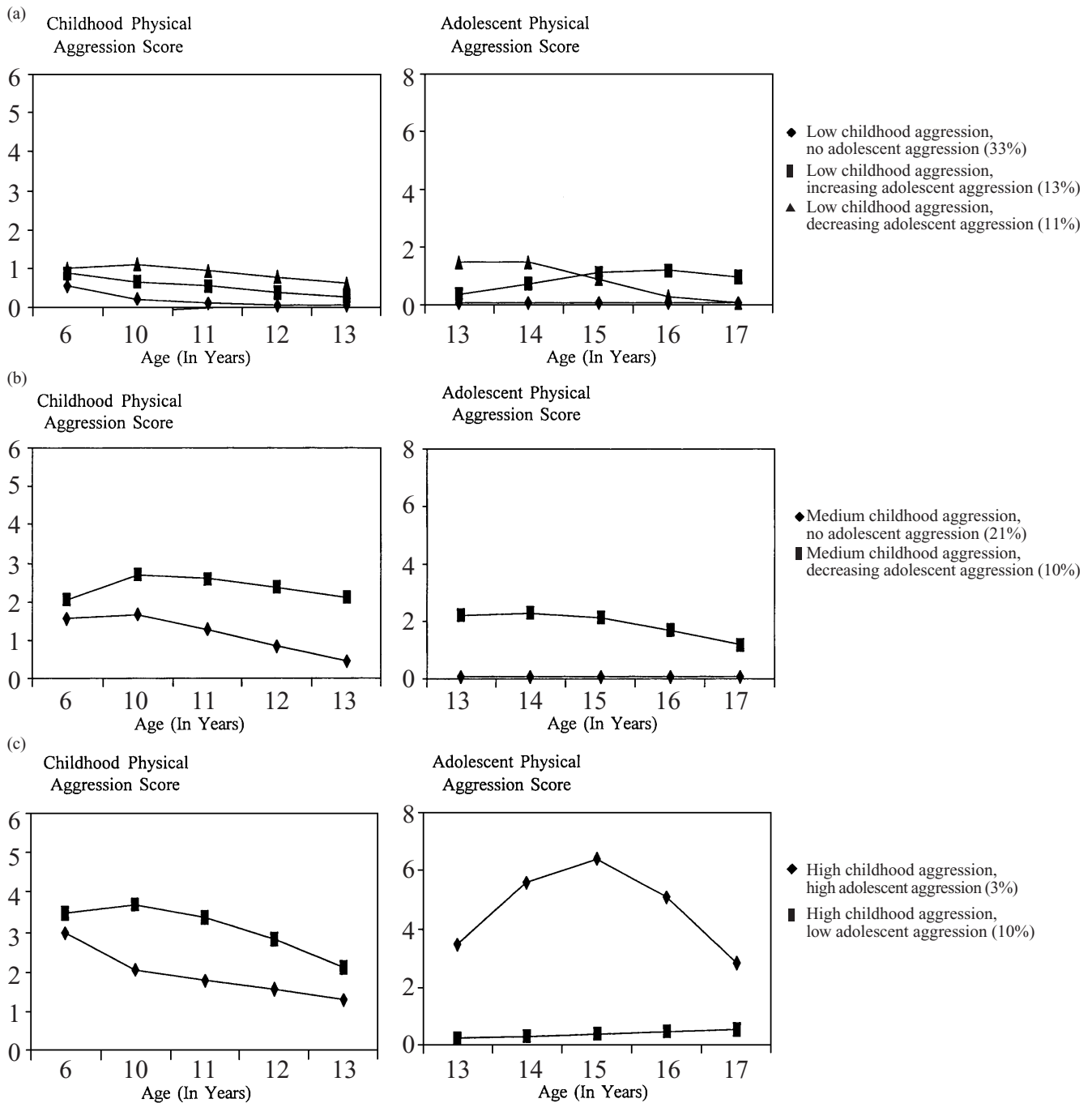


Figure 3. Joint trajectories of childhood physical aggression and adolescent physical aggression. a: Low Childhood Aggression. b: Medium Childhood Aggression. c: High Childhood Aggression.

continuity, in terms of relative standing but not in terms of absolute levels of aggression.

We now consider continuity across the two life course stages—childhood and adolescence. A striking feature of the adolescent aggression plots in Figs. 3a–c is the variability of adolescent outcomes for groups with similar trajectories of childhood physical aggression. Consider the two high childhood aggression groups (Fig. 3c). One displays a clear form of continuity—their high childhood physical aggression is followed by high adolescent physical aggression. However, the other group with comparably high childhood physical aggression goes on to report virtually no physical aggression in adolescence. This group is three times larger than the high adolescent aggression group. Thus, even among those individuals who were highly physically aggressive in their childhood,

the probability of their engaging in little or no adolescent aggression is still very high—about .77 ($.77 = .10 / [.03 + .10]$).

Next, consider the two middle childhood aggression trajectories (Fig. 3b). One group displays a clear form of behavioral continuity and goes on to exhibit considerable adolescent aggression. However, this group is half the size of the counterpart group that goes on to self-report virtually no physical aggression during adolescence.

Finally, consider the low childhood aggression cluster (Fig. 3a). The group with the majority of cases reports virtually no physical aggression in adolescence. A second group proceeds to display a pattern of adolescent physical aggression that rises to a moderate level, while the third group gives a mirror image; physical aggression is moderate at age 13 and decreases with age. These three

Table 1

Joint Distribution of Childhood and Adolescent Physical Aggression Trajectories Based on Classify-Analyze Method on Marginal Outcomes

Adolescent physical aggression trajectories	Childhood aggression trajectory #1 (low aggression)		Childhood aggression trajectory #2 (medium aggression)		Childhood aggression trajectory #3 (high aggression)		Total	
	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%
T ₁ : No aggression	358	75.9	167	57.6	66	40.2	591	63.8
T ₂ : Increasing aggression	60	12.7	50	17.2	36	22.0	146	15.8
T ₃ : Decreasing aggression	46	9.8	54	18.6	40	24.4	140	15.1
T ₄ : High aggression	8	1.7	19	6.6	22	13.4	49	5.3
Total	472	51.0	290	31.3	164	17.7	926	100.0

$\gamma = +.462$; $p < .05$.

Since γ is an ordinal measure of association, we calculate it after combining the adolescent aggression T₂ and T₃ trajectory groups into a single group.

groups are respectively estimated to account for 30%, 13%, and 11% of the population. Thus, for those who display low levels of physical aggression during childhood, the probability of their going on to follow a rising trajectory of physical aggression in adolescence, even only to a moderate level, is a low .23 (.23 = .13/[.13 + .11 + .33]). The counterpart probabilities for the declining and never adolescent aggression trajectories are .19 and .58, respectively. Again, a wide variety of adolescent aggression trajectories attend to comparable trajectories of childhood aggression.

Another salient aspect of the change captured by the joint trajectories is that change is commonly toward less physical aggression. About 13% of the population are estimated to belong to the two high childhood aggression trajectory groups. About 75% of these individuals go on to belong to the trajectory group that reports virtually no physical aggression in adolescence. Similarly, for the two middle childhood aggression trajectories and for the three low childhood aggression trajectories the modal transition is to the nonviolent adolescent trajectory group.

The joint trajectory model combines trajectories of childhood and adolescent physical aggression. An alternative approach allows for a probabilistic transition from the three childhood physical aggression trajectories identified depicted in Fig. 1 to the four adolescent trajectories also depicted in that figure. Specifically, we examine the overlap of group membership between the childhood and adolescence trajectory groups. For example, we measure the proportion of individuals in the high childhood aggression trajectory group who go on to follow a high-level trajectory of physical aggression in adolescence. To compute these transition probabilities we first assign individuals to the childhood and adolescence physical aggression trajectory groups based on the posterior probability of group membership. The transition probabilities are computed by cross-tabulating the childhood and adolescent trajectory group assignments.

Table 1 reports these transition probabilities and in addition reports a conventional measure of association, $\gamma = .462$, for ordinal contingency tables. Consistent with expectations, the trajectories for childhood and adolescent aggression are not independent. For all childhood aggression groups—including the high aggression group—the modal transition probability is to the no-aggression trajectory in adolescence. This finding matches the pattern observed in the joint analysis—a general tendency

to transition to less physical aggression. That said, the probability of transitioning to the no adolescent aggression group declines from .75 for the low childhood aggression trajectory to .40 for the high childhood aggression trajectory. Also, the probability of transitioning into the high adolescent aggression group rises from .02 for the low childhood aggression group to .13 for the high childhood aggression group. This finding is also mirrored in the joint analysis—children with a history of aggression are much more likely to be aggressive as adolescents. Conversely, the analysis suggests that adolescent initiation of high levels of sustained physical aggression among those without a history of childhood physical aggression is a rare event. Only 1.7% of the individuals in the low childhood aggression group make the transition to the high physical aggression group in adolescence. Those individuals from the low childhood aggression group who go on to engage in some physical aggression during adolescence most commonly follow the two moderate level adolescent aggression groups.

The distribution of responses to the individual items that comprise the adolescent physical aggression scale provides further perspective on the prevalence of sustained physical aggression in adolescence among the childhood physical aggression groups. For any given item (e.g., attacked someone with a weapon), the individual had four response options—never in the past year, one to two times, occasionally, and frequently. We counted the number of individuals by childhood aggression group who in any year from ages 13 to 17 responded that they frequently engaged in any of the violent acts in our index. Only 3% of the individuals in the low childhood physical aggression group responded that they frequently engaged in any of these violent behaviors at any time from ages 13 to 17 whereas 8% and 17% of the middle and high aggression groups gave at least one affirmative reply.

Discussion

The objective of this analysis was to examine the linkage between childhood and adolescent physical aggression. Our study advances research on this issue in two important ways. First, we have focused exclusively on physical aggression. We have maintained this focus because physical violence is arguably the most socially destructive form of antisocial behavior. Also, the developmental course of physical aggression may be different than for other forms of antisocial behavior

including nonphysical aggression (Crick, Casas, & Ku, 1999; Nagin & Tremblay, 1999; Tremblay, 2000; Tremblay et al., 1999). A second key contribution of this study is that it links trajectories of distinct but analogous behaviors—teacher-rated childhood physical aggression and self-reported adolescent physical aggression. Previous research has used a static analytic approach in which behavior at one point in time is associated with behavior at a later point in time. This analytical strategy does not adequately capture the developmental course of the behavior of interest.

Several salient findings have emerged from the analysis. First, we find considerable change in the levels of childhood and adolescent physical aggression within different groups. Thus, there is little evidence of stability of behavior in an absolute sense. Instead we find strong evidence of stability only in a more narrow sense of the term—the relative ranking of the groups. Our findings on the stability of relative standing closely conform with much prior research. Understanding the mechanisms that underlie the changes in absolute levels of physical aggression for the different groups should help identify more effective interventions to prevent physical violence.

A second key finding concerns the connection of childhood aggression to adolescent aggression. Boys with higher childhood physical aggression trajectories are far more likely to transition to a higher-level adolescent aggression trajectory than boys from lower childhood physical aggression trajectories. However, for all childhood physical aggression trajectory levels the modal transition is to a relatively low-level adolescent aggression trajectory. This finding is reminiscent of Robins' (1978, p. 611) observation that "adult antisocial behavior virtually requires childhood antisocial behavior [yet] most antisocial children do not become antisocial adults". Since our results apply only to physical violence, future research should try to identify the specific antisocial behaviors for which this statement is not valid. This knowledge would be extremely useful for targeting the appropriate type of preventive intervention to the appropriate age group.

A noteworthy result from a theoretical and practical perspective is that we find little evidence of "late onset" of high-level physical aggression. The joint trajectory analysis finds no evidence of transition from a low physical aggression trajectory in childhood to a high trajectory in adolescence. Within the three-group cluster of low childhood physical aggression individuals (Fig. 3a), a majority of the boys report no physical aggression in adolescence. For the minority who do indicate some physical aggression, self-reported levels are moderate, not high. The results of the "classify-analyze" procedure reported in Table 1 also reveals little evidence of late onset of physical aggression. The boys assigned to the low aggression trajectory constitute only about 15% of the population of the high adolescent physical aggression group.

Thus, by any standard our analysis suggests that individuals without any substantial history of physical aggression during the elementary school years are a small minority of adolescents who engage in high levels of physical aggression. This conclusion calls into question the applicability of theories that implicate late onset in their explanation of physical violence.

That said, we are not suggesting that adolescents without a history of physical aggression in childhood never commit acts of serious violence. We are, however, not comfortable with the use of the term "onset" to

describe such incidents. Onset is meant to imply the emergence of an enduring pattern of behavior. We would not use the word onset to describe events that are episodic and without real continuity. For example, we do not use the term "onset of flu" to describe a person's first bout with the flu. Periodic bouts with the flu are part of the human condition, not an enduring syndrome or ongoing pattern of related events. Adolescence is commonly a tumultuous period in human development. For the first time, physically but not socially mature individuals have ample time to socialize without supervision. It should not be surprising that the physical aggression that virtually all individuals display in the first years of life (Tremblay et al., 1999) might emerge sporadically in the turbulent and largely idiosyncratic circumstances of adolescence. Thus, we view these unusual instances of aggression among the individuals with no history of childhood physical aggression (from age 6 onward) as incidents that do not reflect an enduring behavioral pattern. Whether we can predict and prevent these incidents will need to be specifically investigated.

Finally, contrary to widespread belief, our results clearly indicate that frequent use of physical aggression is relatively uncommon during adolescence, even in a sample of males who started school in low socioeconomic areas of a large North American city. The chronic cases of physical aggression during adolescence had chronic problems with physical aggression at least since kindergarten, and most probably since infancy (Tremblay et al., 1999). The identification of the different developmental trajectories should help identify the reasons why with age these boys fail to reduce their use of physical aggression, while most of their peers do.

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References

- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.
- Bakteman, G., & Magnusson, D. (1981). Longitudinal stability of personality characteristics. *Journal of Personality, 49*, 148–160.
- Broidy, L., Brame, R., Fergusson, D., Dodge, K., Laird, R., Loeber, R., Lynam, D., Nagin, D., & Tremblay, R. (1999). *Trajectories of childhood problem behavior and adolescent delinquency: Results from a six site international study*. Working Paper: Carnegie Mellon University.
- Cairns, R. B., & Cairns, B. D. (1994). *Life lines and risks: Pathways of youth in our time*. New York: Cambridge University Press.
- Cairns, R. B., Cairns, B. D., Neckerman, H. J., Ferguson, L. L., & Gariépy, J. L. (1989). Growth and aggression: 1. Childhood to early adolescence. *Developmental Psychology, 25*, 320–330.
- Crick, N. R., Casas, J. F., & Ku, H.-C. (1999). Relational and physical forms of peer victimization in preschool. *Developmental Psychology, 35*, 376–385.
- Farrington, D. P. (1986). Age and crime. In M. Tonry & N. Morris (Eds.), *Crime and justice: An annual review of research*. Vol. 7 (pp. 189–250). Chicago: University of Chicago Press.

- Farrington, D. P. (1991). Childhood aggression and adult violence: Early precursors and later-life outcomes. In D. J. Pepler & K. H. Rubin (Eds.), *The development and treatment of childhood aggression* (pp. 5–29). Hillsdale, NJ: Lawrence Erlbaum.
- Goodenough, F. L. (1931). *Anger in young children*. Westport, CT: Greenwood Press.
- Hirschi, T., & Gottfredson, M. R. (1983). Age and the explanation of crime. *American Journal of Sociology*, 89, 552–584.
- Hodgins, S. (1994). Status at age 30 of children with conduct problems. *Studies on Crime and Crime Prevention*, 3, 41–62.
- Huesmann, L. R., Eron, L. D., Lefkowitz, M. M., & Walder, L. O. (1984). Stability of aggression over time and generations. *Developmental Psychology*, 20, 1120–1134.
- Kass, R. E., & Raftery, A. E. (1995). Bayes factors and model uncertainty. *Journal of the American Statistical Association*, 90, 773–795.
- Lahey, B. B., Loeber, R., Quay, H. C., Applegate, B., Shaffer, D., Waldman, I., Hart, E. L., McBurnett, K., Frick, P. J., Jensen, P. S., Dulcan, M. K., Canino, G., & Bird, H. R. (1998). Validity of DSM-IV subtypes of conduct disorder based on age of onset. *Journal of the American Academy of Child and Adolescent Psychiatry*, 37, 435–442.
- Land, K. C., McCall, P. L., & Nagin, D. S. (1996). A comparison of Poisson, negative binomial, and semiparametric mixed Poisson regression models with applications to criminal careers data. *Sociological Methods and Research*, 24, 387–441.
- Loeber, R., & Hay, D. H. (1994). Developmental approaches to aggression and conduct problems. In M. Rutter & D. H. Hay (Eds.), *Development through life: A handbook for clinicians* (pp. 488–515). Oxford: Blackwell.
- Loeber, R., & LeBlanc, M. (1990). Toward a developmental criminology. *Crime and Justice*, 12, 375–437.
- Moffitt, T. E. (1993). Adolescence-limited and life-course persistent antisocial behavior: A developmental taxonomy. *Psychological Review*, 100, 674–701.
- Moffitt, T. E., Caspi, A., Dickson, N., Silva, P. S., & Stanton, W. (1996). Childhood-onset versus adolescent-onset antisocial conduct problems in males: Natural history from ages 3 to 18 years. *Development and Psychopathology*, 8, 399–424.
- Nagin, D. S. (1999). Analyzing developmental trajectories: A semi-parametric, group-based approach. *Psychological Methods*, 4, 139–177.
- Nagin, D. S., & Farrington, D. P. (1992). The onset and persistence of offending. *Criminology*, 30, 501–523.
- Nagin, D. S., & Land, K. C. (1993). Age, criminal careers, and population heterogeneity: Specification and estimation of a nonparametric, mixed Poisson model. *Criminology*, 31, 327–362.
- Nagin, D. S., & Tremblay, R. (1999). Trajectories of boys' physical aggression, opposition, and hyperactivity on the path to physically violent and non-violent juvenile delinquency. *Child Development*, 70, 1181–1196.
- Olweus, D. (1979). Stability of aggressive reaction patterns in males: A review. *Psychological Bulletin*, 86, 852–875.
- Patterson, G. R., DeBaryshe, B. D., & Ramsey, E. (1989). A developmental perspective on antisocial behavior. *American Psychologist*, 44, 329–335.
- Raftery, A. E. (1995). Bayesian model selection in social research. *Sociological Methodology*, 25, 111–164.
- Restoin, A., Montagner, H., Rodriguez, D., Girardot, J. J., Laurent, D., Kontar, F., Ullmann, V., Casagrande, C., & Talpain, B. (1985). Chronologie des comportements de communication et profils de comportement chez le jeune enfant. In R. E. Tremblay, M. A. Provost, & F. F. Strayer (Eds.), *Ethologie et développement de l'enfant* (pp. 93–130). Paris: Editions Stock/Laurence Peroude.
- Robins, L. N. (1978). Sturdy childhood predictors of adult antisocial behavior: Replication from longitudinal studies. *Psychological Medicine*, 8, 611–622.
- Roeder, K., Lynch, K., & Nagin, D. S. (1999). Modeling uncertainty in group membership using latent-class models: A case study in criminology. *Journal of the American Statistical Association*, 94, 766–776.
- Tibbetts, S. G., & Piquero, A. (1999). The influence of gender, low birth weight, and disadvantaged environment in predicting early onset of offending: A test of Moffitt's Interactional Hypothesis. *Criminology*, 37, 843–878.
- Tolan, P. H., & Thomas, P. (1995). The implications of age of onset for delinquency risk II: Longitudinal data. *Journal of Abnormal Child Psychology*, 23, 157–181.
- Tremblay, R. E. (2000). The development of aggressive behaviour during childhood: What have we learned in the past century? *International Journal of Behavioral Development*, 24, 129–141.
- Tremblay, R. E., Boulerice, B., Harden, P. W., McDuff, P., Pérusse, D., Pihl, R. O., & Zoccolillo, M. (1996). Do children in Canada become more aggressive as they approach adolescence? In Human Resources Development Canada & Statistics Canada (Ed.), *Growing up in Canada: National longitudinal survey of children and youth* (pp. 127–137). Ottawa: Statistics Canada.
- Tremblay, R. E., Japel, C., Pérusse, D., Boivin, M., Zoccolillo, M., Montplaisir, J., & McDuff, P. (1999). The search for the age of "onset" of physical aggression: Rousseau and Bandura revisited. *Criminal Behavior and Mental Health*, 9, 24–39.
- Tremblay, R. E., Loeber, R., Gagnon, C., Charlebois, P., Larivée, S., & LeBlanc, M. (1991). Disruptive boys with stable and unstable high fighting behavior patterns during junior elementary school. *Journal of Abnormal Child Psychology*, 19, 285–300.
- Tremblay, R. E., Pihl, R. O., Vitaro, F., & Dobkin, P. L. (1994). Predicting early onset of male antisocial behavior from preschool behavior. *Archives of General Psychiatry*, 51, 732–738.

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Appendix

In this Appendix, we provide the details of our joint trajectory modeling procedure. For details on the univariate trajectory model see Nagin (1999). Let c_{it} denote the childhood aggression score associated with individual i at time t and let a_{it} denote the adolescent aggression score associated with individual i at time t . In the special case where c_{it} and a_{it} are independent and conditional upon membership in group j , we can write their joint probability distribution as the product of two independent probability distributions:

$$p(c_{it}, a_{it} | \alpha_{it}^j, \beta_{it}^j) = f(c_{it} | \alpha_{it}^j) h(a_{it} | \beta_{it}^j)$$

where α_{it}^j and β_{it}^j denote the parameters that govern the probability distribution for c_{it} and a_{it} , $f(\cdot)$ and $h(\cdot)$, respectively.

For this application c_{it} is assumed to follow the censored normal distribution and a_{it} is assumed to follow the Poisson distribution.

For each class j , we assume the parameter governing the childhood aggression score for individual i at time t is given by

$$\alpha_{it}^j = \alpha_0^j + \alpha_1^j t + \alpha_2^j t^2,$$

where t can range from ages 6 to 13. Similarly, the parameter governing the probability mass function for the adolescent aggression distribution is given by

$$\beta_{it}^j = \exp(\beta_0^j + \beta_1^j t + \beta_2^j t^2)$$

where t can range from ages 13 to 17.

Let C_i and A_i denote each individual's longitudinal sequence

of measurement of c_{it} and a_{it} . Again conditional on group membership we assume c_{it} and a_{it} are independently distributed over time. Thus,

$$P(C_i, A_i | j) = \prod_t f(c_{it} | \alpha_{it}^j) h(a_{it} | \beta_{it}^j).$$

Because group membership is not observed, construction of the unconditional likelihood of A_i and C_i requires that we sum

over the J conditional likelihood functions and weight each by π_j , the probability of membership in class j :

$$P(A_i, C_i) = \sum_j \pi_j P(C_i, A_i).$$

Finally, the likelihood function that is used for estimation of the model parameters, α and β , is constructed as the product of $P(A_i, C_i)$ over the $I = 1, 2, \dots, N$ individuals comprising the estimation sample.