

Running head: DEVELOPMENTAL IMPACT OF PREVENTIVE INTERVENTIONS

The Developmental Impact of Two First Grade Preventive Interventions  
on Aggressive/Disruptive Behavior in Childhood and Adolescence:  
An Application of Latent Transition Growth Mixture Modeling

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## Abstract

We examine the impact of two universal preventive interventions in first grade on the growth of aggressive/disruptive behavior in grades 1-3 and 6-12 through the application of a latent transition growth mixture model (LT-GMM). Both the classroom-centered and family-centered interventions were designed to reduce the risk for later conduct problems by enhancing the child behavior management practices of teachers and parents, respectively. We first modeled growth trajectories in each of the two time periods with separate GMMs. We then associated latent trajectory classes of aggressive/disruptive behavior across the two time periods using a transition model for the corresponding latent class variables. Subsequently, we tested whether the interventions had direct effects on trajectory class membership in grades 1-3 and 6-12. For males, both the classroom-centered and family-centered interventions had significant direct effects on trajectory class membership in grades 6-12, whereas only the classroom-centered intervention had a significant effect on class membership in grades 1-3. Significant direct effects for females were confined to grades 1-3 for the classroom-centered intervention. Further analyses revealed that both the classroom-centered and family-centered intervention males were significantly more likely than control males to transition from the high trajectory class in grades 1-3 to a low class in grades 6-12. Effects for females in classroom-centered interventions went in the hypothesized direction but did not reach significance.

*Keywords:* latent transition, growth mixture, aggression, conduct problems, prevention

The Developmental Impact of Two First Grade Preventive Interventions on Aggressive/Disruptive Behavior in Childhood and Adolescence: An Application of Latent Transition Growth Mixture Modeling

Substance abuse, depression, and antisocial behavior are among the most common and serious mental health problems we presently face in the United States (Kessler et al., 1994). Their untoward impact and costs extend well beyond the affected individuals to their families, friends, neighbors, co-workers, and the community at large. Although advances continue to be made in the behavioral and psychopharmacological treatment of these disorders, particularly in terms of depression (Clarkin, Pilkonis, & Magruder, 1996; Thase & Kupfer, 1996) and substance abuse (Crits-Cristoph & Siqueland, 1996; O'Brien, 1996; Schuckit, 1996), the general consensus among mental health professionals, and likely the lay population as well, is that effective preventive interventions would be highly preferable (Mrazek & Haggerty, 1994; Institute of Medicine [IOM], 1994).

Yet despite substantial evidence that the antecedents of these disorders may be apparent as early as first grade, there have been relatively few randomized control studies of universal preventive interventions aimed at these early antecedents (Hawkins et al., 1992, Kellam et al., 1994; Reid, Eddy, Fetrow, & Stoolmiller, 1999), and currently only two of these studies have reported outcomes beyond first grade (Hawkins et al., 1992, 2001; Kellam et al., 1994; Kellam et al., 2008; Petras et al., 2008). Importantly, these studies reported beneficial—albeit modest—impact into the middle school years (Hawkins et al., 1992; Kellam et al., 1994) and young adulthood (Hawkins et al., 2001; Kellam et al., 2008; Petras et al., 2008). The relative dearth of randomized control studies such as these is somewhat surprising given that the Woodlawn study (Kellam, Branch, Agrawal, & Ensminger, 1975), as well as others, showed that learning problems predict psychiatric distress, particularly depressed mood and depressive disorder (Shaffer et al., 1979), whereas aggressive behavior, as early as first grade, predicts

later antisocial behavior, criminality, and heavy substance use (Kellam et al., 2008; Petras et al., 2008; Robins, 1978).

In response to the lack of well-controlled, longitudinal evaluations of preventive interventions targeting the early antecedents of substance abuse, depression, and antisocial behavior, the Johns Hopkins Prevention Intervention Research Center (JHU PIRC) has mounted two first grade universal preventive intervention trials in collaboration with the Baltimore City Department of Education. Our use of the term “universal” preventive intervention reflects the fact that we intervened with an entire population of first grade school children (IOM, 1994). This second generation of preventive trials builds on the foundation laid by the JHU PIRC's initial classroom-based, universal preventive intervention trials, which were fielded in 19 Baltimore City schools with two consecutive cohorts of first graders in the 1985-86 and 1986-87 school years (Kellam et al., 2008).

In the second generation field trials (Ialongo, Werthamer, Brown, Kellam, & Wai, 1999), the two classroom-based interventions used in the initial JHU PIRC trials were revised to enhance their effectiveness, which included combining the two protocols into one. This revised intervention protocol thus featured a focus on both poor achievement and aggressive and shy behavior. The decision to focus on both achievement and behavior was driven by the evidence from the first generation trial in 1985-86 that, while Mastery Learning intervention had a beneficial impact on early achievement, it had only a modest to moderate crossover, or indirect, effect on aggression. Similarly, the Good Behavior Game intervention had a beneficial impact on aggressive and shy behavior, but not on achievement. Each intervention thus appeared to be specific to its proximal target. Consequently, if we were to reduce the later risk for substance abuse, depression, and antisocial behavior, both early aggression and achievement needed to be targeted.

In addition to combining the two classroom interventions in the second generation trial, a universal family-centered intervention was developed to contrast with the combined classroom

intervention. Like the classroom-centered intervention, the proximal targets of the family-centered intervention were poor achievement and aggressive and shy behaviors. The family-centered intervention sought to reduce these early risk behaviors by enhancing family-school communication and parenting practices associated with learning and behavior. As described in detail in Ialongo et al. (1999), the conceptual basis for the interventions was derived from the life course/social field framework (Kellam et al., 2008) and its integration with the model of the development of antisocial behavior expounded by Patterson, Reid, and Dishion (1992).

### **Present Study**

This paper seeks to describe patterns of change in aggressive behavior in a sample of predominately minority urban youth from grades 1-3 to grades 6-12. In particular, the study was motivated by two research goals. The first goal was to describe the longitudinal patterns or trajectory profiles of aggressive behavior during the two important time periods (i.e., grades 1-3 and grades 6-12) as well as individual transition patterns between the time periods. Thus, it was of interest to quantify the relative frequencies of individual aggressive behavior trajectory profile continuities and shifts from grades 1-3 to grades 6-12. The second goal was to test the influences of the two preventive interventions (classroom- and family-centered) on the aggression trajectory profile membership during each of the two time periods, as well as test their effects on the transition probabilities.

The analysis in this paper serves as a novel application of a statistical hybrid model, one that combines use of a growth mixture model (GMM) and latent transition analysis, for the evaluation of proximal and distal effects of a preventive intervention. Essentially, two or more latent class variables, each measured or characterized by distinct growth processes, are specified. The resultant latent class variables are then associated with each other using a latent transition model. An earlier version of this model, without intervention effects, was described by Muthén, Khoo, Francis, and Boscardin (2003) as a flexible method for investigating the influence of an early developmental

process on a later process. The motivation for utilizing a multisegmented or multiphase approach for modeling developmental outcomes over a more extended period of time is that it does not require one to assume the same metric or meaning of the outcome over time, as conventional growth modeling does. Instead, a broad-span developmental process is viewed in phases, with each phase having its own growth model, one phase leading to another, and all modeled simultaneously.

The motivation for using a growth *mixture* model for each phase, rather than a conventional random-effects growth model, is threefold.<sup>1</sup> First the use of both a latent class variable and within-class random growth factors permits greater flexibility in characterizing individual differences in growth trajectories for each developmental phase. Second, the use of a latent transition model, reliant on the trajectory classes for each time period, permits a more adaptable model for developmental continuities and discontinuities in growth patterns than would not be possible with just a regression of random effects across phases. Third, the flexibility described in the first two advantages enables a more nuanced investigation of the effects of the interventions on each of the developmental phases as well as on the association between the phases.

For this paper, two developmental phases for aggressive/disruptive behavior are defined: grades 1-3 and grades 6-12. The first phase encompasses the period of early childhood, which is considered to be a critical period in the development of many foundational skills in all areas of development. The second phase captures the time of adolescence, which is characterized by significant changes in physical and sexual maturity and cognitive development as well as the onset of antisocial and delinquent behavior. A GMM is specified for each phase, and individuals are permitted to transition between latent classes from the first phase to the second. Intervention status may

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<sup>1</sup> In concert with the growing popularity of data-driven, group-based methods for studying developmental trajectories and evaluating preventive interventions have come active and spirited ontological discussions about the nature of trajectory groups as well as the statistical assumptions inherent in these methods (e.g., Bauer & Curran, 2003, 2004; Muthén, 2004; Nagin & Tremblay, 2005; Petras & Masyn, 2010). These discussions are ongoing and an in-depth consideration is beyond the scope of this paper.

influence growth class membership in the first phase and the second phase and may also impact transitions between growth classes from the first phase to the second. For this study, all analyses will be conducted separately by gender because of documented gender differences in the development of aggression (Schaeffer et al., 2006, Bradshaw et al., 2010) as well as differences in their response to universal preventive interventions (Petras et al., 2008).

## Method

### Participants

A total of 678 children and families, representative of the entering cohort of first graders in nine Baltimore City public elementary schools, were available for participation in the fall of 1993. Of the 678 students, 12 students were excluded due to missing data on all of the aggression ratings. Of the remaining 666 students, 54.1% were female, more than two-thirds (68.3%) received subsidized school lunch, and the majority were African American (86.6%). No differences were detected between the selected and the unselected sample in terms of gender, lunch status, or fall-of-first-grade aggression. For males,  $\chi^2 (1, N=678) = 7.75, p < .01$  and females  $\chi^2 (1, N=678) = 7.02, p < .01$ , African Americans were more likely not to be selected than non-African Americans. Given that only a small portion (1.8%) of the original sample was excluded, the bias introduced to the sample composition is considered minimal. For this paper, four assessment points were used during the elementary school years (i.e., fall of 1<sup>st</sup>, spring of 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> grade) and seven during the middle and high school years (i.e., spring of 6<sup>th</sup>, 7<sup>th</sup>, 8<sup>th</sup>, 9<sup>th</sup>, 10<sup>th</sup>, 11<sup>th</sup>, and 12<sup>th</sup> grade

### Missing Data

The estimates of parameters in the models were adjusted for attrition. Mplus (Muthén & Muthén, 1998-2010) uses full information maximum likelihood estimation under the assumption that the data were missing at random. Missing at random assumes that the reason for the missing data is either random or random after incorporating other variables measured in the study (Arbuckle, 1996;

Little, 1995). Full information maximum likelihood, used in the present study, is widely accepted as an appropriate way of handling missing data (Muthén & Shedden, 1999; Schafer & Graham, 2002).

Among males, 27.5% had complete data, 42.2% had ten of the eleven and 58.9% had nine of the eleven time points used in the analyses. The bivariate data coverage ranged from 75.8% to 40.3%.

Among females, 41.5% had complete data, 56.2 had ten out of the eleven and 67.3 had nine of the eleven time points used in the analyses. The bivariate data coverage ranged from 97.7% to 55.9%.

## **Design**

A randomized block design was used, with schools serving as the blocking factor. Three first grade classrooms in each of nine urban elementary schools were randomly assigned to one of the two intervention conditions or a control condition. Teachers and children were randomly assigned to intervention conditions with balancing for gender. The gender balance was accomplished by establishing the ratio of males and females for the entire first grade classrooms prior to randomization, followed by weighing the sample prior to randomization to insure roughly the same proportion of males and females in a section within a school. The interventions were provided over the first grade year, following a pretest assessment in the early fall. The intervention impact has been documented in several manuscripts. Regarding the prevalence of conduct problems and mental health service need and utilization in middle school, the classroom centered intervention appeared to be more effective than the family centered intervention (Ialongo et al., 1999, 2001). In terms of the timing to initial use of tobacco & illicit substances in middle school, Storr et al. (2002) reported modest attenuation in the risk of first use of tobacco for youth in both intervention conditions (see also Wang et al., 2008). In addition, Furr-Holden et al. (2004) reported that the classroom centered intervention was associated with a reduced risk of starting to use other illegal drugs (i.e., heroin, crack, and cocaine powder) by early adolescence. Lastly, Bradshaw et al. (2009) found that the classroom centered intervention was

associated with higher scores on standardized achievement tests as well as greater odds of high school graduation and college attendance.

We accounted for the clustering of students within classrooms by computing robust standard errors using a sandwich estimator (White, 1980).

## The Interventions

**The Classroom-Centered Intervention.** The classroom-centered intervention consisted of three components: curriculum enhancements, enhanced behavior management practices, and back-up strategies for children not performing adequately. Each classroom-centered intervention class was divided into three heterogeneous groups, providing the underlying structure for the curricular and behavioral components of the classroom intervention. The existing Baltimore City Public Schools curriculum in language arts and mathematics was enhanced through the addition of new and supplementary curricular materials designed to increase critical thinking, composition, and listening and comprehension skills. The existing math curriculum was replaced with the Mimosa mathematics program (Irons & Trafron, 1993), which implemented the most recent National Council of Teachers of Mathematics standards at the time. Current behavior management practices were enhanced by a weekly classroom meeting that was used to promote child social problem solving within a group context (Johnson & Johnson, 1987; Kellam et al., 1975) and the Good Behavior Game (Dolan, Turkkan, Werthamer-Larsson, & Kellam, 1989). CC classrooms were identified as either high- or low-implementing, based on scores obtained from a three-phase CC implementation measurement procedure (see Ialongo et al., 1999). Each CC intervention was assigned a score from 0 to 100, which represented the percentage of the CC intervention implemented with a high level of fidelity. Classrooms/schools at or below 50% were classified as low-implementing, whereas those above 50% were classified as high implementing. Five of the nine CC classrooms were identified as high-implementation classrooms.

**The Family-Centered Intervention.** The family-centered intervention was designed to improve achievement and reduce early aggression, shy behavior, and concentration problems by enhancing parent-teacher communication and providing parents with effective teaching and child behavior management strategies. The major mechanisms for achieving those aims were 1) training for teachers and other relevant school staff in parent-teacher communication and partnership building, 2) weekly home-school learning and communication activities, and 3) a series of nine workshops for parents led by the first grade teacher and the school psychologist or social worker. The Parents on Your Side program (Canter & Canter, 1991) formed the basis for training teachers in partnership building and parent-teacher communication. The program included a 3-day seminar with follow-up supervisory visits and an explicit training manual accompanied by videotape training aides. In terms of the FSP implementation/participation, parents/caregivers attended (on average) 4.02 ( $SD = 2.38$ , median 5.0, range 0-7) of the seven core parenting sessions offered in the Fall of first grade, or 57.14%. Around 13% (12.7%) of the parents/caregivers failed to attend any of the workshops, whereas 35.3% of the parents attended at least six of the seven sessions.

## Measures

**Teacher Observation of Classroom Adaptation-Revised (TOCA-R).** The TOCA-R (Werthamer-Larsson, Kellam, & Wheeler, 1991) is designed to assess each child's adequacy of performance on the core tasks in the classroom as rated by the teacher. It involves a structured interview administered by a trained member of the assessment staff. The interviewer follows a script precisely and responds in a standardized way to issues the teacher initiates. Teachers rate the child's adaptation on a frequency scale from 1 to 6 (1 = not at all, 6 = always). The authority acceptance, or aggressive/disruptive behavior, scale includes items such as breaks rules, harms property, and fights. For this analysis the total item average score was used. The TOCA-R was assessed in the fall and spring of first and second grades and in the spring of third grade.

**Teacher Report of Classroom Behavior-Checklist Form (TRCB-CF).** The TRCB-CF is designed to obtain teacher reports of child conduct problems. It was based on the standardized teacher interview developed by Werthamer-Larsson et al. (1991) and described above. With respect to the conduct disorder subscale, teachers respond to seven items corresponding to *Diagnostic and Statistical Manual of Mental Disorders-IV* (American Psychiatric Association, 1994) criteria for Conduct Disorder (e.g., starts physical fights with classmates, lies, hurts others physically, steals, damages other people's property on purpose, skips school, and bullies classmates into getting his own way). Coefficient alpha for the TRCB-CF Conduct Problems scale in grades 6-12 was .88 or higher. For this analysis the total item average score was used. The TRCB-CF was assessed in the spring of each year from sixth through twelfth grade.

### **Analysis**

To study the impact of a classroom-centered and a family-centered intervention on youth transitions from early (in grades 1-3) to later (in grades 6-12) aggressive/disruptive behavior, the traditional latent transition model was combined with a GMM across two time periods (see Figure 1). Latent transition analysis is a longitudinal extension of latent class analysis that explores individual-level change or transitions in latent class membership across time. At its core, latent class analysis uses the joint distribution of observed responses across all individuals on a set of items to characterize an underlying categorical latent variable that subdivides the given population into K mutually exclusive and exhaustive groups or classes. Latent transition analysis has been used extensively to study the onset and progression of substance use in children and adolescents and the effectiveness of prevention programs (Collins, Graham, Rousculo, & Hansen, 1997; Kaplan, 2008; Lanza & Collins, 2002). Traditionally, in latent class analysis and latent transition analysis, the indicators of the latent class variables are observed categorical indicators, each measured at the same fixed point in time. In

other words, the measurement model for the latent class variable at each time point represents a cross-sectional “snapshot” of responses to a set of manifest variables.

In this paper, each latent class variable is characterized not by a set of measures obtained at a fixed point in time but rather by a continuous longitudinal process during a specified time period. For each of the two time periods (grades 1-3 and grades 6-12), a latent GMM with two random effects and a latent class variable is used to capture individual heterogeneity in the change process (Muthén et al., 2002; Muthén & Shedden, 1999). The latent class variables are essentially characterized by clusters of individuals with similar growth trajectories, parameterized by the latent growth factors and allowing for normal variability in those factors within class. Given trajectory class membership during the first time period, the proportion of individuals who stay in a comparable trajectory class or transition to a different class during the second time period is expressed in terms of transition probabilities. Marginal class probabilities for each time period as well as these transition probabilities are allowed to vary as a function of covariates (e.g., intervention status). All models are estimated using the Mplus software (Muthén & Muthén, 1998-2010).

### **Model Building**

The following model building strategy was employed separately for males and females in the sample. The separate analysis was motivated by documented gender differences in the course of aggressive behavior as well as in response to interventions.

Using exploratory descriptive analyses as a point of departure, a nested series of conventional single-class growth models were estimated to determine the functional form of aggressive behavior. In order to accommodate the fact that the two interventions took place in first grade, we excluded the pre-intervention assessment in the fall of first grade from the measurement model—that is, the growth model for the grades 1-3 time period—and used it as a predictor of class membership during the first

time period instead. Thus, the growth model for the first time period was based on outcome measures concurrent with or subsequent to treatment, adjusting for baseline (pre-treatment) levels of aggression in fall of first grade.

The growth models in the first time period were centered so that the intercept growth factor represented aggression levels in spring of third grade. The growth model for the second time period was centered in sixth grade.<sup>2</sup> Chi-square testing as well as traditional structural equation modeling fit statistics (Tucker-Lewis Index [TLI], Comparative Fit Index [CFI], and Root Mean Square Error of Approximation [RMSEA], Standardized Root Mean Square Residual [SRMR]) were used for model comparison (see Hu and Bentler, 1999; Marsh, Wen, & Hau, 2004). For males and females and in both time periods, a model with an intercept and slope as random effects fit the data the best (see Table 1). There was no evidence for nonlinearity in the change process over time for both time periods as judged by changes in chi-square when a quadratic slope was added to the model.

Building upon the measurement model, we explored evidence for population heterogeneity by sequentially adding trajectory classes for both outcomes during the two time periods. All mixture models were estimated using multiple starting values to avoid local optima. Using fit indices appropriate for finite mixture models (e.g., Bayesian Information Criterion [BIC], Vuong-Lo-Mendell-Rubin Likelihood-Ratio Test [VLMR-LRT], Bootstrapped Likelihood-Ratio Test [BLRT]), it was determined that two latent growth classes with normal random effects within each class were sufficient to capture heterogeneity in the developmental course of aggression for both genders at each of the two time periods, offering improvements over the one-class models. When allowing the

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<sup>2</sup> These two centering decisions ensured that the two intercepts are adjacent across the two time segments. In a non-mixture setting, this offers the opportunity to investigate whether it is the end point of the first segment that influences growth in the second segment or whether the pattern of change in the first segment, apart from the end point, was related to growth in the second segment. Extending this idea to the mixture context, classes are now defined by heterogeneity in the end point and growth in the first segment predicts classes defined by heterogeneity in the start point and growth in the second segment.

residual variances to vary in the low class (i.e., 2-class, M1), the model fit of a 2-class model was superior when compared to a three class model. Adding classes to the model resulted in a non-significant slope variance in the first time period and it was consequently constrained to zero to avoid convergence issues (i.e., 2-class, M2). While some support for a three class solution existed, only a 2-class model provided sufficient class sizes to study transition probabilities (see Table 2).

### Testing of Intervention Impact

In order to evaluate the impact of the intervention at the level of the latent classes across time, models in a sequence, depicted with structural path diagrams and corresponding marginal and conditional relative frequency tables in Figure 2, were estimated and compared. The initial model, Model 0, seeks to confirm that there is indeed an across-time association between latent growth class membership,  $C1$ , in the first time period and latent class growth membership,  $C2$ , in the second time period among those in the control group.

The second two models, Model 1A and 1B, evaluate the evidence of a marginal impact of treatment on latent growth class membership during the first and second time period, respectively. In the models that include treatment, intervention status is treated as a three-category latent class variable,  $CG$ , with known membership for all individuals. That is, each individual had known membership in the classroom-centered intervention class, the family-centered intervention class, or the control class. Model 1A estimates the *proximal* marginal impact of intervention status on latent growth class membership. Model 1B estimates the *distal* marginal impact of intervention status on latent growth class membership. For Models 1A and 1B, as well as all subsequent models, we elected to allow the intervention only to have effects on trajectory class membership and not within-class, class-specific effects on the growth factors. As a result,  $C1$  and  $C2$  were characterized solely by

heterogeneity in growth trajectories and not by individual differences in response to the intervention within the time period (Nylund & Masyn, 2008; Petras & Masyn, 2010).

Model 2 combines Models 0 and 1A for the full sample. In this model, intervention status is allowed to have a proximal direct effect on latent growth class membership in the first time period, transitions between latent classes from the first to the second time period are permitted, and intervention status may have an indirect distal impact on latent growth class membership in the second time period via the impact on  $C1$ .

Model 3 adds a direct effect from intervention status to latent class membership in the second time period so that the total impact of the intervention on  $C2$  would be a combination of the direct effect on  $C2$  and the indirect effect on  $C2$  via  $C1$ . Notice that, for both Model 2 and Model 3, the transition probabilities (i.e., the probabilities for  $C2$  conditional on  $C1$ ) are the same for each level of  $CG$ .

In the final model, Model 4, the transition probabilities between latent growth classes for the two time periods can themselves be influenced by intervention status, which is essentially equivalent to an interaction between intervention and class membership in the first time period. Intervention status still has a direct effect on  $C1$  and  $C2$  in addition to a moderating effect on the association between  $C1$  and  $C2$ . For example, based on the report by Ialongo et al. (1999) of the more immediate impact of the classroom-centered and family-centered interventions, we hypothesized that members of the high class of aggressive/disruptive behavior over grades 1-3 who received the interventions would be more likely to transition to a low class of aggressive/disruptive behavior in grades 6-12. Thus their likelihood of transitioning to a lower-aggressive class during the second time period as a function of intervention status was moderated by their class membership during the first time period.

## Results

### Developmental Course of Aggressive/Disruptive Behavior

For males and females (see Figure 3), two developmental trajectory classes were identified between grades 1-3 and grades 6-12. During the first time period (i.e., first-third grade), 49.7% of males and 59.7% of females displayed an elevated level of aggressive/disruptive behavior. On average, males in this trajectory class had higher initial levels of aggressive behavior in the spring of first grade and tended to increase more steeply compared to females. Among males, 50.3% displayed low, increasing developmental aggression trajectories, compared to 40.3% of females who displayed stable low levels of aggression.

During the second time period (i.e., grades 6-12), 48.9% of males and 31.5% of females showed a high, decreasing development of aggression. As found in the first period, males in this group, on average, started at a higher initial level in sixth grade compared to females. Alternatively, 51.1% of males and 68.5% of females displayed a stable low level and development of aggressive behavior.

### **Association Between Latent Growth Class Membership Across Time Periods**

A precondition for testing impact of the two preventive interventions on the developmental course of aggressive behavior is the association between class membership in the first and second time periods among the non-treated population. Among males, it was found that individuals in the high class had 8.5 the odds to transition to the high class at the second time period compared to individuals in the low class at Time 1 ( $Est.=2.141$ ,  $S.E.=0.564$ ,  $p<0.05$ ,  $OR=8.5$ ). In comparison, females in the high class at Time 1 had 47 times the odds to transition to the high class, but this did not reach the required significance level ( $Est. =3.854$ ,  $S.E. =3.159$ ,  $ns$ ,  $OR=47.2$ ). The most likely explanation for this non-significant finding and high odds ratio is the fact that 98.3% of females in the low class at Time 1 remained in the low class at Time 2.

### **Testing for a Proximal Marginal Intervention Impact**

Given this association among individuals in the control population (albeit non-significant for females), we then proceeded to test whether individuals' class membership at the first time period varied as a function of intervention status; thus, we tested for a proximal marginal intervention impact. In the first time period, males who received the classroom-centered intervention had three times the odds of being in the low class (*Est.* =1.137, *S.E.* =0.423, *p*<0.01, *OR*=3.117), and no significant differences were found for the family-centered intervention (*Est.* =0.047, *S.E.* =0.373, *ns*, *OR*=1.048). In comparison, females in the classroom-centered intervention had three times the odds to be in the low class (*Est.* =1.118, *S.E.* =0.477, *p*<0.05, *OR*=3.059), and no significant results were found for the family-centered intervention (*Est.* =0.479, *S.E.* =0.432, *ns*, *OR*=1.614).

### **Testing for a Distal Marginal Intervention Impact**

Testing for a distal effect of the intervention was motivated by the question whether the proximal impact of the classroom-centered intervention was sustained into the middle school years, an important characteristic of effective intervention programs. In addition, it was of interest to probe for so-called sleeper effects of an intervention; that is, the effects of an intervention might materialize at times of later risk. Males who received the classroom-centered intervention or the family-centered intervention had half the odds to be in the high class during the second time period compared to control males (classroom-centered: *Est.* = -0.699, *S.E.* =0.227, *p*<0.01, *OR*=0.497; family-centered: *Est.* = -0.593, *S.E.* =0.235, *p*<0.05, *OR*=0.553). In comparison, no evidence of a significant distal impact was found among females (classroom-centered: *Est.* =0.163, *S.E.* =0.337, *ns*; family-centered: *Est.* =-0.186, *S.E.* =0.308, *ns*).

### **Intervention Impact on Trajectory Class Membership Transition Probabilities Across Time Periods**

Given the significant differences for the proximal effect of the classroom-centered intervention among males and females, as well as for the distal effect of both interventions for males, we now focused on the potential mechanisms which might explain the proximal and distal differences among males. To this end, we compared three competing models (see Figure 2, Models 2, 3, and 4). Model 2, which allows for a proximal direct effect on class membership in the first time period, was used as the base model. In comparison, in Model 3 a direct effect on  $C2$ —that is, an effect on growth trajectory membership over grades 6-12—was added. Model 4 also allowed the transition probabilities to vary by intervention status.

This impact on transition probabilities resembles an interaction between intervention status and class membership in the first time period. Recall the example given earlier, where we hypothesized that members of the high class of aggressive/disruptive behavior over grades 1-3 who received the interventions would be more likely to transition to a low class of aggressive/disruptive behavior in grades 6-12.

For females, both Model 3 (vs. M2:  $LRTS=2.677, df=2, p=0.262$ ) and Model 4 (vs. M3:  $LRTS=0.739, df=2, p=0.691$ ; vs. M2:  $LRTS=1.998, df=4, p=0.736$ ) were clearly rejected at the .05 level. Thus, there was no direct effect on growth trajectory membership in grades 6-12 as a function of intervention status, nor was there evidence of an intervention effect on the transition between growth trajectory membership between grades 1-3 and 6-12.

With respect to males, when comparing Model 3 to Model 2—that is, testing whether intervention effects on growth trajectory membership over grades 6-12 were a result of a direct effect of the intervention in addition to the indirect effect on  $C1$ —a marginally significant chi-square difference was found ( $LRTS=5.324, df=2, p=0.070$ ). The comparison of Model 4 and Model 3—that is, testing for the interaction of intervention status and class membership (or intervention effects on

the transition between growth trajectory membership in grades 1-3 and 6-12)—yielded a non-significant chi-square difference ( $LRTS=4.466$ ,  $df=2$ ,  $p=0.107$ ). Finally, when using an omnibus test—that is, probing whether the interaction effect as well as the direct effect on  $C2$  were simultaneously zero (i.e., comparing Model 4 to Model 2), a significant difference was found ( $LRTS=9.970$ ,  $df=4$ ,  $p=0.041$ ).

Given that tests of interaction typically suffer from lower statistical power than tests of main effects at the same  $\alpha$ -level (Aiken & West, 1991), it is not uncommon for researchers to relax the standard significance level and accept evidence for interactions on the .1 level to improve power. Thus, we elected to present and interpret the results of Model 4 with the interaction for males while noting that the evidence suggesting differences in transition probabilities across intervention levels was marginal.

For both the classroom-centered and family-centered interventions, increases in probabilities to transition to a lower-aggression class were found (see Table 3). In the control condition, 88.3% of males remained in a higher-aggression class, and consequently 11.7% transitioned to a lower-aggression class. In comparison, among males who received the classroom-centered intervention, 76.2% remained in a higher-aggression class, and 23.8% transitioned to a lower-aggression class. This pattern is reflected in the transition probability ratio<sup>3</sup> for shifting out of the high-aggression class from grades 1-3 to grades 6-12 of 2.034, when comparing males in the high class who received the classroom-centered intervention to the ones in the control condition (see Table 3).

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<sup>3</sup> In order to assess the differences in transitional probabilities of the two intervention groups in relation to the control group, we transformed the transitional probabilities into transitional probability ratios using the control group as the reference category. For example, the transitional probability ratio for males who transitioned from the high- to the low-aggression class in the classroom-centered intervention compared to the control group who show the same transition is  $0.238/0.117=2.034$ .

A stronger effect was found among males who received the family-centered intervention. While 65.6% remained in a higher-aggression class, 34.4% transitioned to a lower-aggression group. This pattern translated into a transition probability ratio for shifting out of the high-aggression class from grades 1-3 to grades 6-12 of 2.940 when comparing males in the high class who received the family-centered intervention to the ones in the control condition (see Table 3).

It is worth noting that there is negligible difference in transition probabilities across intervention groups for those in the low, stable-aggression trajectory class in grades 1-3, implying an intervention effect beyond *C1* only for those in the high-aggression class in grades 1-3. The lack of effect of intervention in the low, stable class could explain, in part, the only marginally significant test for the interaction between *CG* and *C1*.

While Model 4 for females was clearly rejected, we chose to present the results in order to determine any similarities between males and females regarding the intervention impact. When inspecting the transition probabilities by condition (see Table 4), females in the low-aggression group tended to have a considerably greater probability to remain in the low class when transitioning to middle school compared to males. The transition probabilities range from 0.929 to 0.936. However, the transition probability ratio for the classroom- and the family-centered intervention were close to 1, indicating no effect (see Table 4). For females who started out in the high-aggression class (i.e., class 1) in elementary school, the transition probabilities varied by intervention condition. While the family-centered intervention showed no effect, a similar, but smaller, effect as compared to males was seen for the classroom-centered intervention: 78.4% of females in the high-aggression class transitioned to the low class, which translated into a transition probability ratio of 1.371 (see Table 4).

## Discussion

This paper presented a novel application of a statistical hybrid model that combines growth mixture modeling and latent transition analysis. This LT-GMM was used to evaluate the impact of two universal preventive interventions on patterns of change in aggressive behavior in a sample of predominately minority urban youth from grades 1-3 to grades 6-12. We argue that the LT-GMM is highly attractive for intervention impact analyses since it allows for the simultaneous modeling of separate, but linked, developmental phases, which does not require the different phases to have the same metric. Importantly, this model allows for testing of not only a proximal and distal impact, but also of an impact on the association between developmental phases.

To investigate the malleability of the aggressive/disruptive behavior trajectories, two randomized preventive interventions (namely the classroom-centered and the family-centered) were employed. Following traditional impact testing strategy, we first focused on testing proximal and distal main effects. It was found that both males and females who received the classroom-centered intervention showed significantly higher odds of being in the low-aggressive/disruptive behavior trajectory in grades 1-3. The family-centered intervention did not show a proximal, but only a significant distal effect among males. Regarding the distal impact, it was found that for males, but not for females, the beneficial impact of the classroom-centered intervention was significantly sustained into the middle and high school years.

The proximal results for males and females in the classroom-centered intervention are consistent with the results by Dolan et al. (1993) and provide further support for the belief that early aggressive/disruptive behavior is malleable in response to universal preventive intervention efforts targeting teacher behavior management and instructional practices. Moreover, consistent with Petras et al. (2008), we also found evidence—albeit tentative—that improvements in early

aggressive/disruptive behavior in the elementary school years were associated with lower levels of such behavior in adolescence and early adulthood, particularly for males.

The relative lack of intervention effects for girls versus boys in terms of distal impact is consistent with the results from our first generation trial (e.g., Kellam et al., 2008; Petras et al., 2008). Also consistent with our prior studies, the effects of the interventions appear to be greatest for those who manifest moderate to higher levels of aggressive/disruptive behavior over the elementary school years. The lack of significant distal effects for girls may simply be because that there are fewer girls than boys who manifest moderate to high levels of aggressive/disruptive behavior in the middle to high school years. It is important to note that, as in Petras et al. (2008), the intervention effects on girls' aggressive/disruptive class membership were generally in the expected direction. Clearly, future universal preventive intervention studies of the kind reported here will need larger sample sizes in order to provide a true test of intervention impact on aggressive/disruptive behavior in girls, particularly in the adolescent years.

As noted, we found proximal as well as distal impact for boys in the classroom-centered intervention condition, whereas only distal impact was found for boys in the family-centered condition. In regard to these "sleeper effects" of the family-centered intervention, it is important to note that parents in the family-centered condition were offered a total of seven 2-hour workshops on child behavior management, versus 40 hours of training and on-site coaching for teachers in the classroom-centered condition. It may simply be the case that the rate of acquisition and implementation of effective child behavior management practices was slower for parents in the family-centered condition than for teachers in the classroom-centered condition. As a result, we did not see family-centered intervention effects for boys until grades 6-12.

Given these results, particularly for males, we probed whether the impact of the two interventions moderated the transitions in trajectory class membership across the two time periods. We found statistically weak support for such an interaction effect, indicating that both the classroom- and family-centered interventions worked particularly well among males who started elementary school with elevated levels of aggressive/disruptive behavior. This finding—that the intervention works particularly well among individuals with higher levels of the risk factors—is a common finding in studies of universal interventions (Petras et al., 2008). Despite non-significant results for females, the results for females went in the hypothesized direction. That is, females receiving the classroom-centered intervention were more likely to transition to the low-aggression class. Once again, the lack of significant effects for girls as opposed to boys may simply be because that there are fewer girls than boys who manifest moderate to high levels of aggressive disruptive behavior during the elementary school years.

### **Limitations and Extensions**

With respect to limitations of the study itself, we relied in this article solely on teacher ratings of behavior. Youth, parent, peer, and criminal arrest records data—particularly in grades 6-12—would have increased confidence in the findings presented with regard to the effects of the interventions. The inclusion of parenting practices, deviant peer affiliation, and other theoretically relevant mediators and moderators of developmental course would have permitted a further explication of the mechanisms of intervention effects. Finally, a larger sample size would have provided a more powerful test of the effects of the interventions on girls and intervention effects in general. In addition, the use of only three time points for the first time period limited our ability to detect a nonlinear development in aggressive behavior and in the mixture context, to estimate the slope as a random effect.

Despite the limitations of this study, the modeling approach illustrated herein has clear utility for understanding pathways of influence on developmental processes through multiple phases of the lifespan. Interesting extensions of this approach could be used to examine mechanisms of influence. It would be possible to include mediated paths from intervention status to the growth class variables. In this example, perhaps parenting practices or deviant peer affiliation mediate the impact of the family-based and classroom-based interventions, respectively. It would also be possible to examine potential moderators of proximal and distal intervention effects. In this example, intervention fidelity or adherence may moderate both the proximal and distal intervention impacts, but perhaps have more of an effect with respect to the distal impact; that is, those individuals with lower intervention adherence may show less of an intervention impact at later developmental phases.

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**Table 1***Model Fit Statistics for Fitting a Conventional Growth Curve Model*

Model	Chi-Square (df)	p-value	CFI <sup>a</sup>	TLI <sup>b</sup>	RMSEA <sup>c</sup> (p-value)	SRMR <sup>d</sup>
<b>Males, Grades 1-3 (n=349)</b>						
Unstructured	155.033 (3)	0.0000	0.000	0.000	0.381 (0.000)	0.267
Intercept	27.341 (4)	0.0000	0.846	0.885	0.129 (0.002)	0.084
Intercept + Slope	1.206 (1)	0.2722	0.999	0.996	0.024 (0.456)	0.016
<b>Males, Grades 6-12 (n=322)</b>						
Unstructured	627.029 (21)	0.0000	0.000	0.000	0.299 (0.000)	0.397
Intercept	138.208 (26)	0.0000	0.815	0.856	0.116 (0.000)	0.092
Intercept + Slope	41.350 (23)	0.0108	0.970	0.972	0.050 (0.474)	0.047
<b>Females, Grades 1-3 (n=300)</b>						
Unstructured	111.946 (3)	0.0000	0.000	0.000	0.348 (0.000)	0.231
Intercept	19.095 (4)	0.0008	0.861	0.896	0.112 (0.018)	0.073
Intercept + Slope	1.070 (1)	0.3009	0.999	0.998	0.015 (0.462)	0.016
<b>Females, Grades 6-12 (n=275)</b>						
Unstructured	395.980 (21)	0.0000	0.000	0.000	0.255 (0.000)	0.332
Intercept	144.383 (26)	0.0000	0.684	0.745	0.129 (0.000)	0.201
Intercept + Slope	59.789 (23)	0.0000	0.902	0.910	0.076 (0.034)	0.121

<sup>a</sup> Cumulative Fit Index (Critical value: greater than or equal to 0.96)<sup>b</sup> Tuckey Lewis Index (Critical value: greater than or equal to 0.95)<sup>c</sup> Root Mean Square Error of Approximation (Critical value: less than or equal to 0.05)<sup>d</sup> Standardized Root Mean Square Residual (Critical value: less than or equal 0.07)

**Table 2***Model Fit Statistics for Fitting a Growth Mixture Model*

Model	LL <sup>a</sup>	# of free parameters	BIC <sup>b</sup>	VLMR-LRT <sup>c</sup>	BLRT <sup>d</sup>	Entropy	Smallest class f (r.f.) <sup>e</sup>
<b>Males, Grades 1-3</b>							
1-class	-1222.547	8	2491.934	na	na	na	349 (100%)
2-class	-1167.587	11	2399.580	p<0.05	p<0.0001	0.887	57.5 (16.5%)
2-class, M1*	-1052.610	14	2187.191	na	na	0.741	165.6 (47.5%)
2-class, M2	-1054.126	12	2178.542	na	na	0.745	165 (47.3%)
3-class	-1136.078	14	2354.126	p<0.05	p<0.0001	0.910	14.8 (4.3%)
3-class, M1	Non convergence						
<b>Males, Grades 6-12</b>							
1-class	-1578.752	12	3226.798	na	na	na	322 (100%)
2-class	-1543.103	15	3172.824	p<0.001	p<0.0001	0.805	54.8 (17%)
2-class, M1	-1371.422	22	2869.884	na	na	0.799	157.5 (48.9%)
3-class*	-1519.192	18	3142.327	p<0.05	p<0.0001	0.829	21 (6.5%)
3-class, M1	Non convergence						
<b>Females, Grades 1-3</b>							
1-class	-850.202	8	1746.033	na	na	na	300 (100%)
2-class	-789.233	11	1641.208	p<0.05	p<0.0001	0.932	31.9 (10.6%)
2-class, M1**	-567.431	14	1214.715	na	na	0.880	177.4 (59.1%)
2-class, M2	-568.731	12	1205.908	na	na	0.882	179.2 (59.7%)
3-class*	-746.565	14	1572.984	ns	p<0.0001	0.951	9 (3.1%)
3-class, M1	Non-convergence						
<b>Females, Grades 6-12</b>							
1-class	-925.000	12	1917.401	na	na	na	275 (100%)
2-class*	-875.808	15	1835.868	p<0.01	p<0.0001	0.939	28.2 (10.3%)
2-class, M1	-674.255	22	1418.080	na	na	0.824	86.8 (31.5%)
3-class*	-860.230	18	1821.561	ns	p<0.0001	0.929	11.1 (4.0%)
3-class, M1	Non convergence						

\* Problem with the Psi Matrix, \*\* Problem with the Theta Matrix

ns stands for non-significant; na stands for non applicable

M1: Modified model, which allowed the residual variances to be free in the low class.

M2: Modified model, which constrained the slope variance to zero.

<sup>a</sup> Loglikelihood <sup>b</sup> Bayesian Information Criterion<sup>c</sup> Vuong-Lo-Mendell-Rubin Likelihood Ratio Test p-value<sup>d</sup> Bootstrap Likelihood Ratio Test p-value<sup>e</sup> Model based estimated frequency and relative frequency

Table 3

*Transition Probabilities (Transition Probability Ratio) by Intervention Condition among Males based on Model 4*

		Grades 6-12						
		Classroom-centered (n=128)		Family-centered (n=120)		Control condition (n=112)		
		Class 1 (high): 53.6% <sup>a</sup>	Class 2 (low): 58.2%	Class 1 (high): 44.2%	Class 2 (low): 55.8%	Class 1 (high): 55.9%	Class 2 (low): 44.1%	
Grades 1-3	Class 1 (high): 43.4%	.762 <sup>b</sup> (0.863) <sup>c</sup>	.238 (2.034)	Class 1 (high): 54.3%	.656 (0.743)	.344 (2.940)	Class 1 (high): 49.4%	.883 (Ref.)
	Class 2 (low): 56.6%	.268 (1.103)	.732 (0.967)	Class 2 (low): 45.7%	.255 (1.049)	.745 (0.984)	Class 2 (low): 50.6%	.243 (Ref.)

<sup>a</sup> This number indicates the estimated class prevalence.

<sup>b</sup> This number indicates the transition probability. For each row and condition, the transition probabilities add up to one.

<sup>c</sup> This number expresses the four transition probabilities in the two intervention groups in reference to the four transition probabilities of the control group.

Table 4

*Transition Probabilities (Transition Probability Ratio) by Intervention Condition among Females based on Model 4*

		Grades 6-12								
		Classroom-centered (n=97)				Family-centered (n=107)				Control condition (n=102)
		Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	
		(high):	(low):	(high):	(low):	(high):	(low):	(high):	(low):	
Grades 1-3	Class 1 (high): 50.6%	34.9% <sup>a</sup>	65.1%	27.7%	72.3%	29.8%	70.2%			
	(0.505) <sup>c</sup>	0.216 <sup>b</sup>	0.784	58.8%	(2.336)	(0.000)		0.428	0.572	
	Class 2 (low): 49.4%	0.064	0.936	41.2%	0.071	0.929	35.9%	0.068	0.932	
		(0.941)	(1.004)		(1.044)	(0.997)		(Ref.)	(Ref.)	

<sup>a</sup> This number indicates the estimated class prevalence.

<sup>b</sup> This number indicates the transition probability. For each row and condition, the transition probabilities add up to one.

<sup>c</sup> This number expresses the four transition probabilities in the two intervention groups in reference to the four transition probabilities of the control group.

### Figure Captions

Figure 1. Conceptual path diagram of the latent transition growth mixture model (LT-GMM).

Figure 2. Structural diagrams for Models 0-4 with corresponding marginal and conditional relative frequency tables assuming two latent classes for C1 (i.e., spring, grades 1-3), C2 (i.e., spring, grades 6-12), and CG (i.e., classroom centered condition or family-centered condition).

Figure 3. Development of aggressive behavior (spring, grades 1-3) and conduct problems (spring, grades 6-12) among males (n=360) and females (n=306).

Figure 1

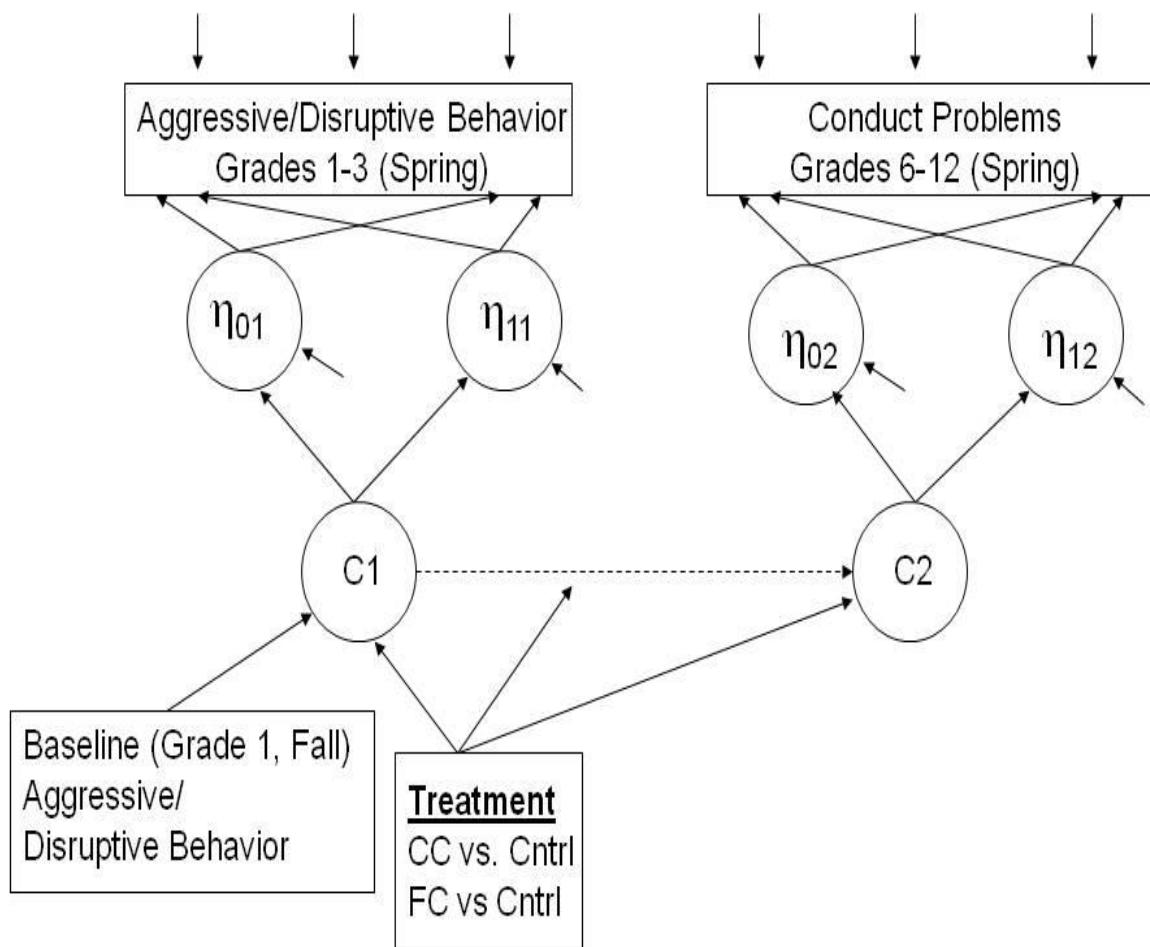
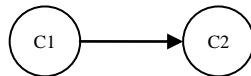


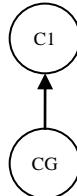
Figure 2

Model 0:  
Transitions from C1 classes  
to C2 classes in control  
group only.



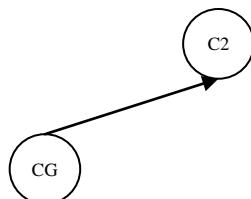
	$P(C2=1 C1)$	$P(C2=2 C1)$	$P(C1)$
$C1=1$	a	$1-a$	d
$C1=2$	b	$1-b$	$1-d$
$P(C2)$	c	$1-c$	1

Model 1A:  
Proximal marginal Tx (CG)  
impact on C1 class  
membership only.



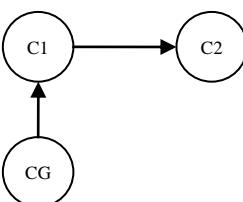
$CG=1$	$P(C1)$	$CG=2$	$P(C1)$
$C1=1$	$d_1$	$C1=1$	$d_2$
$C1=2$	$1-d_1$	$C1=2$	$1-d_2$

Model 1B:  
Distal marginal Tx (CG)  
impact on C2 class  
membership only.



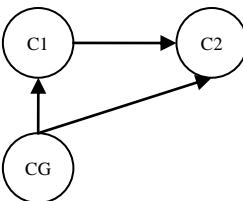
$CG=1$	$C2=1$	$C2=2$	$CG=2$	$C2=1$	$C2=2$
$P(C2)$	$c_1$	$1-c_1$	$P(C2)$	$c_2$	$1-c_2$

Model 2:  
Transitions from C1 classes  
to C2 classes ; Direct Tx  
(CG) impact on C1 class  
membership; Indirect  
Tx(CG) impact on C2 class  
membership via C1.



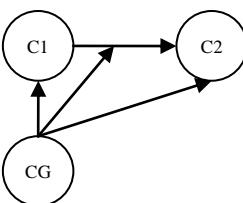
$CG=1$	$P(C2=1 C1)$	$P(C2=2 C1)$	$P(C1)$	$CG=2$	$P(C2=1 C1)$	$P(C2=2 C1)$	$P(C1)$
$C1=1$	a	$1-a$	$d_1$	$C1=1$	a	$1-a$	$d_2$
$C1=2$	b	$1-b$	$1-d_1$	$C1=2$	b	$1-b$	$1-d_2$
$P(C2)$	c	$1-c$	1	$P(C2)$	c	$1-c$	1

Model 3:  
Transitions from C1 classes  
to C2 classes ; Direct Tx  
(CG) impact on C1 class  
membership; Indirect  
Tx(CG) impact on C2 class  
membership via C1; Direct  
Tx (CG) impact on C2 class  
membership.



$CG=1$	$P(C2=1 C1)$	$P(C2=2 C1)$	$P(C1)$	$CG=2$	$P(C2=1 C1)$	$P(C2=2 C1)$	$P(C1)$
$C1=1$	a	$1-a$	$d_1$	$C1=1$	a	$1-a$	$d_2$
$C1=2$	b	$1-b$	$1-d_1$	$C1=2$	b	$1-b$	$1-d_2$
$P(C2)$	$c_1$	$1-c_1$	1	$P(C2)$	$c_2$	$1-c_2$	1

Model 4:  
Tx (CG) impact on  
transitions from C1 classes  
to C2 classes ; Direct Tx  
(CG) impact on C1 class  
membership.



$CG=1$	$P(C2=1 C1)$	$P(C2=2 C1)$	$P(C1)$	$CG=2$	$P(C2=1 C1)$	$P(C2=2 C1)$	$P(C1)$
$C1=1$	$a_1$	$1-a_1$	$d_1$	$C1=1$	$a_2$	$1-a_2$	$d_2$
$C1=2$	$b_1$	$1-b_1$	$1-d_1$	$C1=2$	$b_2$	$1-b_2$	$1-d_2$
$P(C2)$	$c_1$	$1-c_1$	1	$P(C2)$	$c_2$	$1-c_2$	1

Figure 3

