Using the Group-Based Dual Trajectory Model to Analyze Two Related Longitudinal Outcomes

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Introduction

Group-based models (GBM) (Nagin, 2005) have become an increasingly popular alternative method for longitudinal data analyses.

GBM assumes that the study population is made up of a finite number of sub-populations defined by distinctive patterns of growth. The objectives of this approach are to identify these sub-groups or latent classes, as well as to assess their association with individual-level covariates.

Unlike random-effects growth curve modeling, GBM is person or subject-centered (not variable centered), and group-based (not individual-based), akin to cluster analysis for longitudinal data.

GBM is also termed latent class growth analysis and regarded as a restricted version of growth mixture models (Muthen, 2004).

GBM has been extended in several ways recently (Jones & Nagin, 2007); the dual trajectory model is one of these advances.

This presentation will focus on the application of the group-based dual trajectory model by analyzing two important longitudinal outcomes from New Hampshire Dual Disorder study (Drake et al., 1998). The technical details will not be covered and are in Nagin's 2005 book.

Dual trajectory model

The standard group-based model is a "univariate model" analyzing a single longitudinal outcome. The dual model jointly estimates the trajectories of two distinct but related longitudinal outcome series.

The dual model can analyze the connection between the two outcome series, which may evolve contemporaneously (*comorbidity*), or evolve over different time periods (*heterotypic continuity*, or temporal interdependence).

The dual model can be further generalized to allow the linkage between the two outcome series as a function of individual characteristics and other background variables.

Dual trajectory model analysis can be implemented with the SAS procedure “PROC TRAJ” (version 9) developed by Jones & Nagin (2007).

Advantages of joint trajectory analysis

"Comorbidity" or "dual disorders" is very common in health research. The dual trajectory model provides a new window of opportunity to study this phenomenon.

The essence of the dual model is to investigate the interrelationship between the two longitudinal outcomes.

This longitudinal association can be assessed in conventional growth curve modeling too; however, the conventional growth model can only estimate the overall association between the two outcomes calculated over heterogeneous subpopulations. The underlying group heterogeneities are “averaged out” in this procedure.

By summarizing the interrelationships between the two outcome series across various trajectory groups, the dual model permits us to understand multidimensional and dynamic associations between the two outcomes.

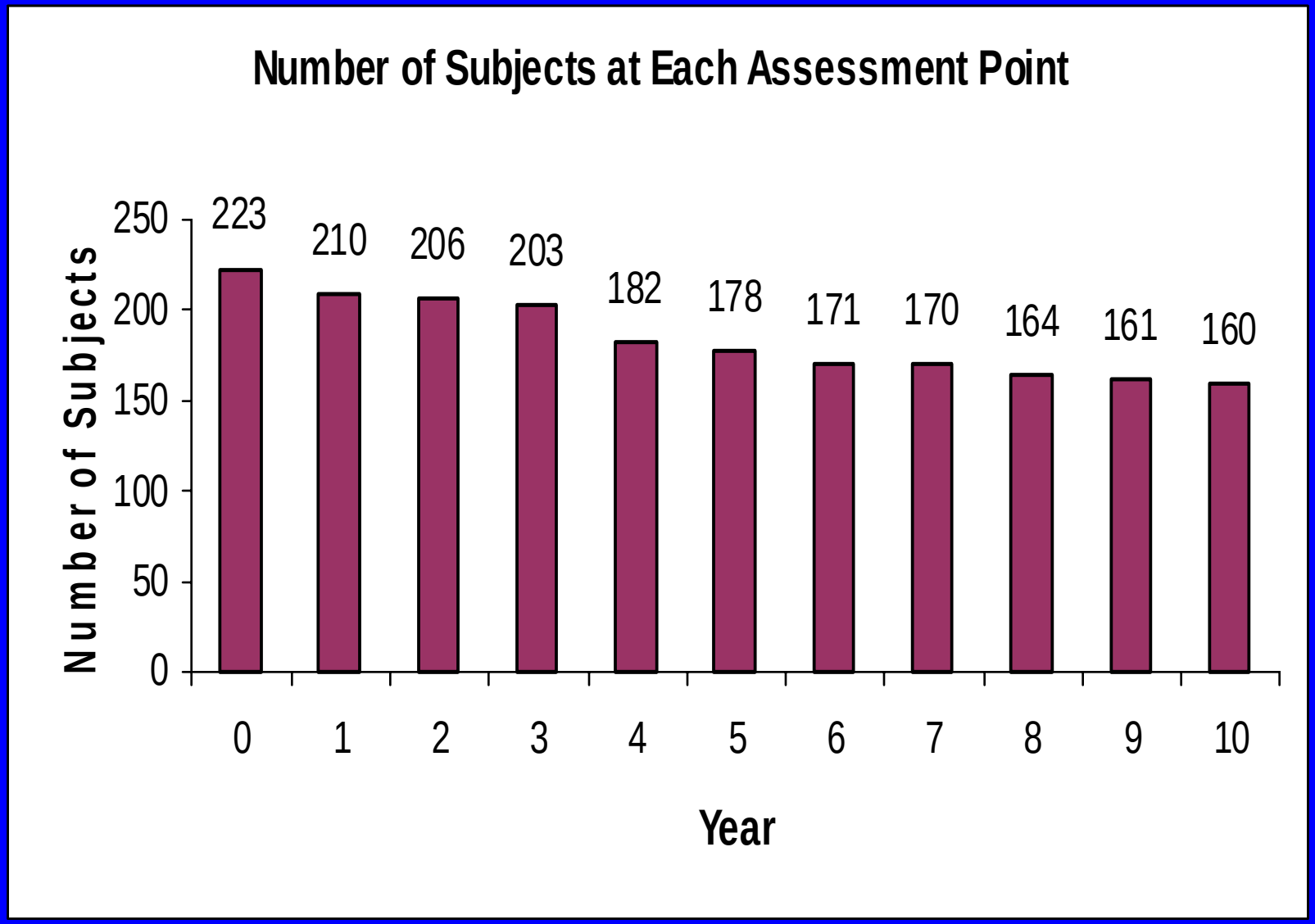
Illustration

Data source and variables

New Hampshire Dual Disorder Study (NHDD). Between 1989 and 1992, 223 persons with serious mental illness and co-occurring substance use disorders were randomized to one of two conditions for 3 years: Standard Case Management vs. Assertive Community Treatment. After 3 years, participants were released from experimental group assignments and followed up for 13 more years.

Assessment. Data were collected at baseline and every six months for the first 3 years and then yearly afterwards. For this analysis, yearly data from baseline to 10-year follow-up were used.

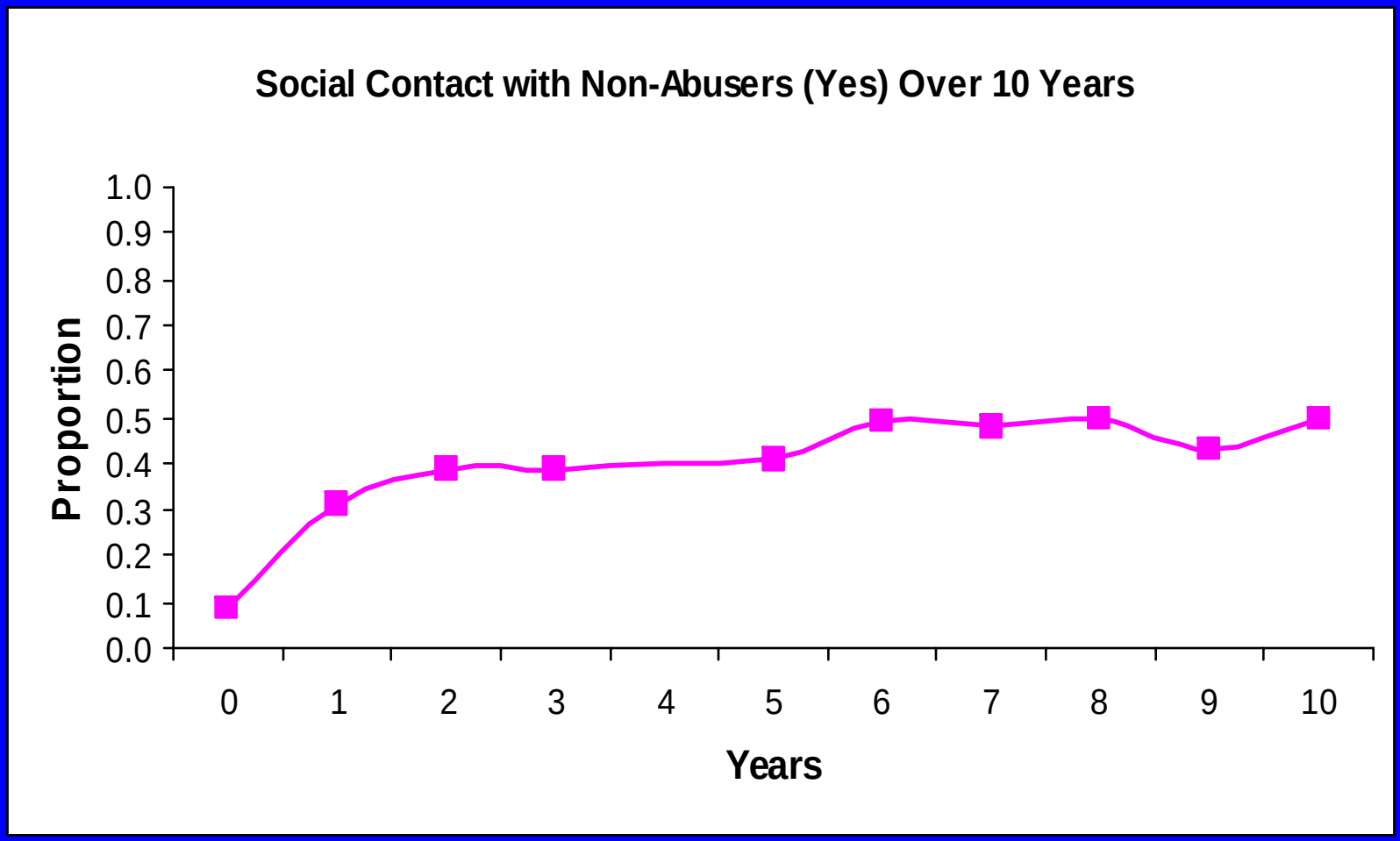
Attrition status. 223 participants were recruited and 160 completed 10-year follow-up. Attrition rate is 28%, which includes 19 deaths.

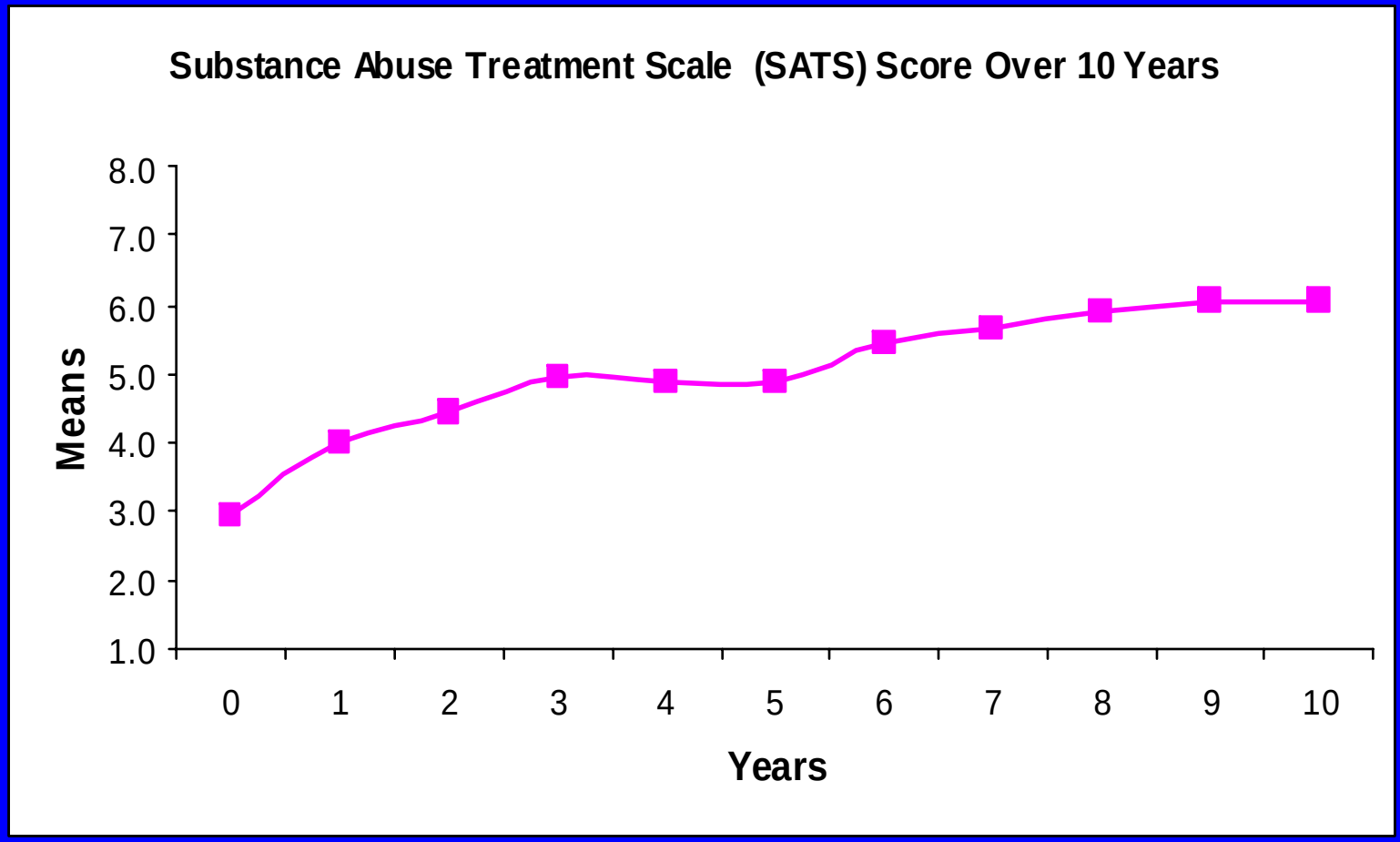


Variables. The two variables used for this analysis were: *the frequency of social contact with non-substance abusing friends* and *the Substance Abuse Treatment Scale (SATS)*.

The former is an ordinal variable but is recoded as dichotomy (yes vs. no) for this analysis; the latter is an 8-point scale measuring progression in substance abuse treatment, and it is treated as a continuous variable for this analysis.

Average trend and the association of the two longitudinal outcome variables





The plots show that both social contact and SATS have a rising trend over 10 years, with faster increase in the first 3 years.

Table 1 Selected Results of Mixed-Effects model (Outcome = SATS)

Covariance Parameter Estimates

Cov Parm	Subject	Standard Estimate	Error	Z Value	Pr Z
Intercept	ID	1.0766	0.1555	6.92	<.0001
time	ID	0.03078	0.007262	4.24	<.0001
time*time	ID	0.000151	0.000076	1.99	0.0233
Residual		1.8125	0.07139	25.39	<.0001

Solution for Fixed Effects

Effect	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept	3.2603	0.1016	418	32.08	<.0001
contact	0.2388	0.08690	1627	2.75	**0.0061**
time	0.5112	0.04083	1225	12.52	<.0001
time*time	-0.02639	0.003987	1000	-6.62	<.0001

The results for the mixed-linear model with random intercept, and random linear and quadratic time trend indicate that the two outcomes have a positive longitudinal relationship ($\beta = 0.24$, $p = 0.0061$).

Besides the average time trend (or growth trajectory) and the overall association between the two outcome series, we also want to know:

(1) If there are heterogeneous subgroups within each outcome that are distinguished by different patterns of change or growth.

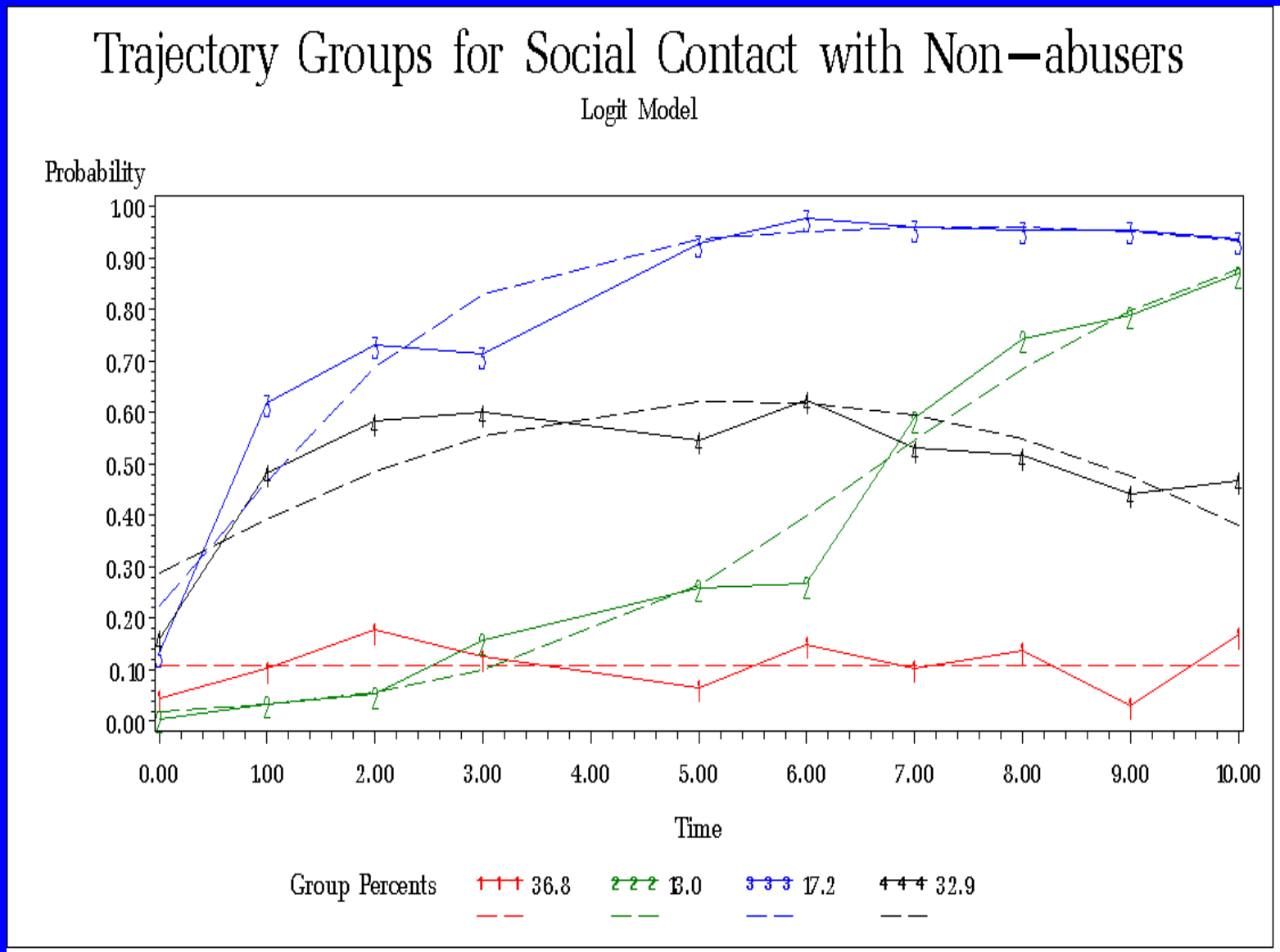
(2) If so, how are the two outcomes associated across different trajectory groups?

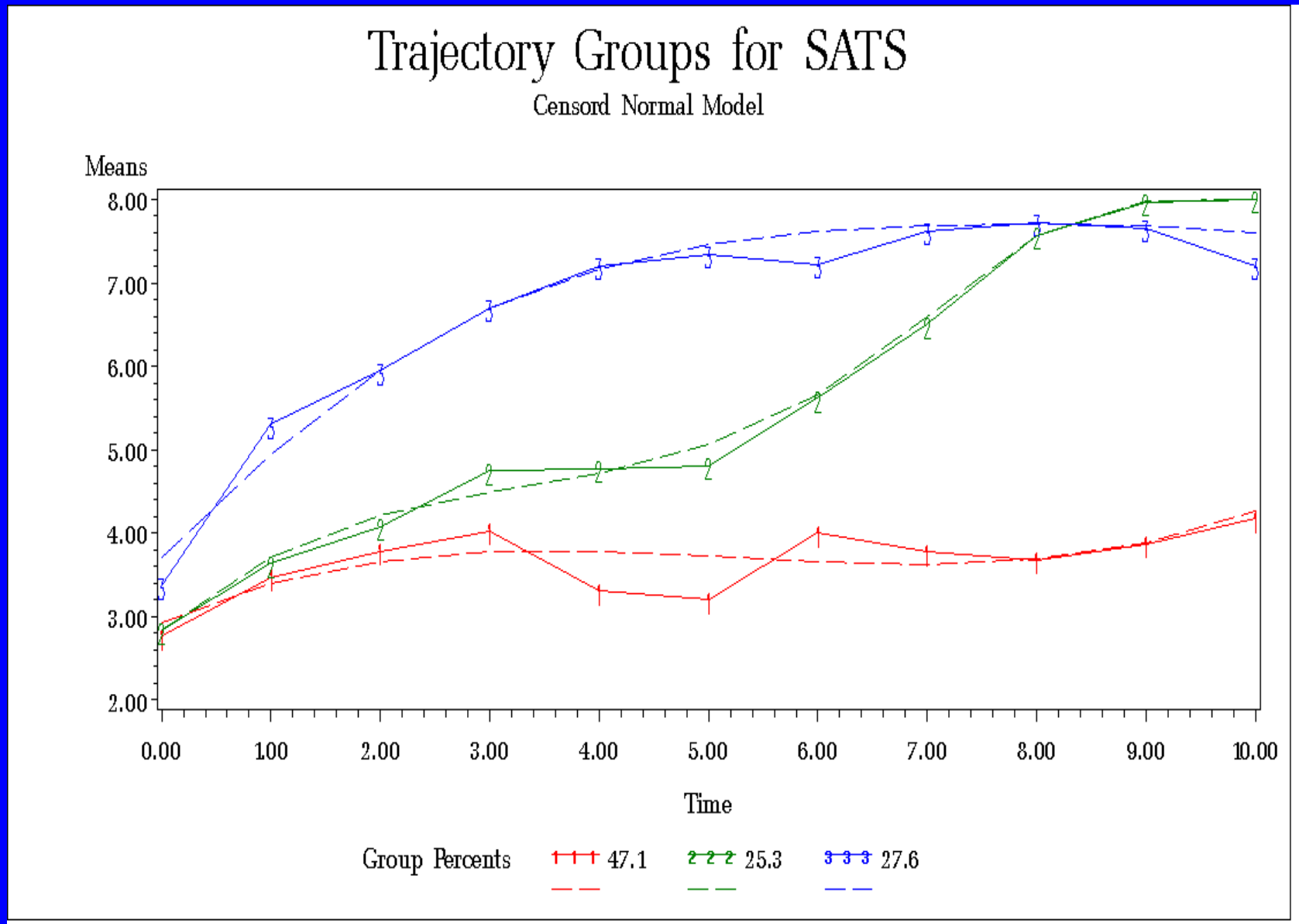
Identify the optimal number of latent trajectory groups for each outcome variable

Due to parameter proliferation with joint estimation in the dual model, it is recommended that identification of the optimal number of trajectory classes is based on a model for a single outcome variable (Nagin & Tremblay, 2001).

Thus, univariate models -- logit model for social contact and censored normal model for SATS -- were specified, and separate estimation is conducted first.

Four latent trajectory groups were identified for social contact, and three groups were identified for SATS.





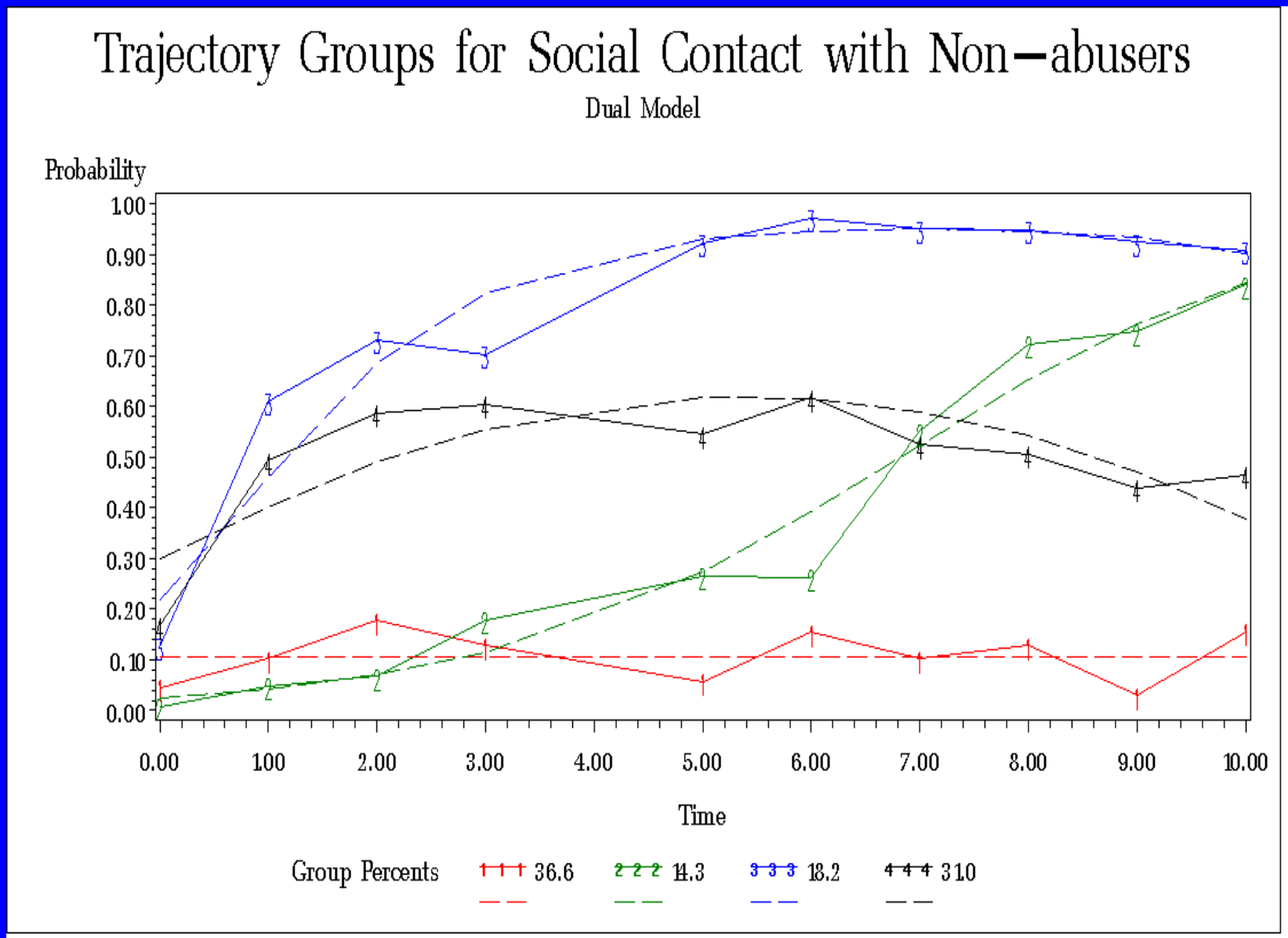
The four latent trajectory groups for social contact can be labeled as: 1-*low social contact group*, 2-*steady increase in social contact group* 3-*early increase in social contact group*, and 4-*moderate increase in social contact group.*

The three latent trajectory groups for SATS can be described as: 1-*slow improving group*, 2-*gradual improvement group* and 3-*quick improvement* group.

Dual trajectory model analysis

Number of group trajectories and probability of group membership

Number of trajectory groups identified from the joint model is the same as those from the univariate models. However, the probability of group membership is not exactly the same.



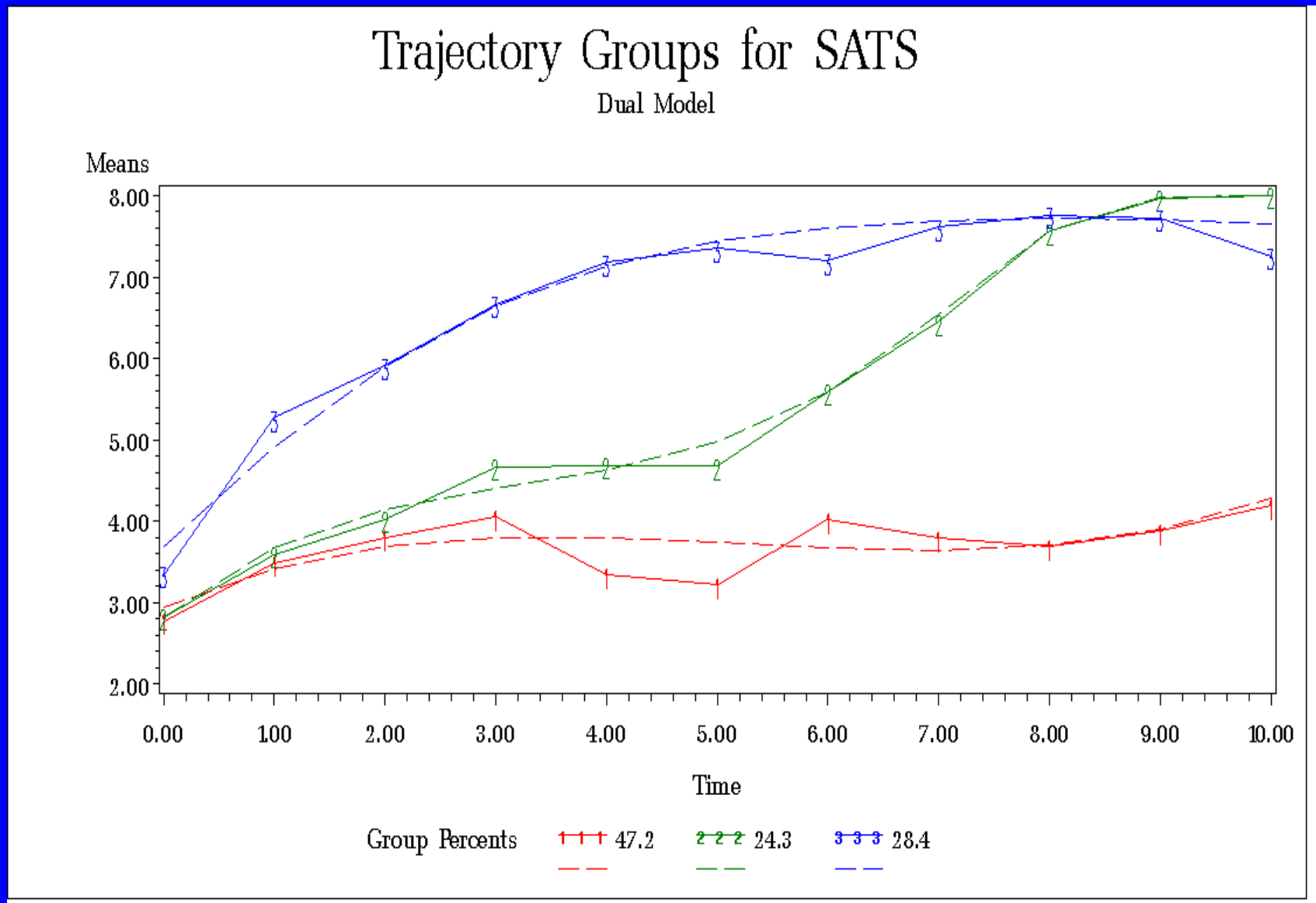


Table 2 Comparing Probability of Group Membership from Univariate Model and Dual Model

	Group Membership for Social Contact (%)			
	1	2	3	4
Univariate Model	36.8	13.0	17.2	32.9
Dual Model	36.6	14.3	18.2	31.0

	Group Membership for SATS (%)		
	1	2	3
Univariate Model	47.1	25.3	27.6
Dual Model	47.2	24.3	28.4

Interrelationship across the trajectory groups between the two outcomes.

These interrelationships were represented by estimated linkage probabilities in three alternative ways:

(1) probability of trajectory group membership in social contact conditional on SATS;

(2) probability of trajectory group membership in SATS conditional on social contact; and

(3) joint probabilities of trajectory group membership in both social contact and SATS.

Table 3 Probability of SATS Group Conditional on Social Contact Group

Social Contact Trajectory Group	*SATS Trajectory Group* 1-Slow Improving	2-Gradual Improvement	3-Quick Improvement	
1-Low Contact	**0.56**	0.32	0.12	1.00
2-Steady Increase	0.32	0.30	0.38	1.00
3-Early Increase	0.26	0.23	**0.51**	1.00
4-Moderate Increase	**0.56**	0.13	0.31	1.00

Table 4 Probability of Social Contact Group Conditional on SATS Group

Social Contact Trajectory Group	*SATS Trajectory Group*		
	1-Slow Improving	2-Gradual Improvement	3-Quick Improvement
1-Low Contact	**0.43**	**0.48**	0.15
2-Steady Increase	0.10	0.18	0.19
3-Early Increase	0.10	0.17	**0.33**
4-Moderate Increase	**0.37**	0.17	**0.33**
	1.00	1.00	1.00

Table 5 Joint Probability of Social Contact Group and SATS Group

Social Contact Trajectory Group	*SATS Trajectory Group* 1-Slow Improving	2-Gradual Improvement	3-Quick Improvement	
1-Low Contact	**0.21**	**0.12**	0.04	
2-Steady Increase	0.05	0.04	0.05	
3-Early Increase	0.05	0.04	0.09	
4-Moderate Increase	**0.17**	0.04	**0.10**	1.00

From these three kinds of linkage probabilities, we can conclude that there is a fair amount of overlap or temporal correspondence between social contact with non-abusers and SATS. That is, they are positively related: less social contact corresponds to slow improvement or staying in low stages in SATS, and more active social contact corresponds to quick improving or higher stage in SATS.

However, the picture for those middle-ground trajectory groups in both outcomes (*steady increase in social contact* and *gradual improvement group* in SATS) is mixed; they are not necessarily moving in the same direction.

Summary

The group-based trajectory model is an alternative way to analyze longitudinal data.

The dual trajectory model, an extension of the standard group-based approach, provides us the opportunity to analyze two distinct but related longitudinal outcomes simultaneously.

By being able to examine the dynamic linkage across all trajectory groups between the two longitudinal outcomes, the dual model approach provides a far richer, more comprehensive, and perhaps more realistic representation of the underlying relationship between the two longitudinal outcome variables under investigation.