M3 Symposium: Multilevel Multivariate Survival Models For Analysis of Dyadic Social Interaction

Mike Stoolmiller:
stoolmil@uoregon.edu

University of Oregon

5/21/2013

Outline

- Example Research Questions
- Coding Dyadic (parent-child) Microsocial Interaction
- Structuring Microsocial Data for Analysis
- Introduction to Hazard Rates and Models
- Multivariate Multilevel Hazard Models
- Applied Example
- Summary & Future Directions

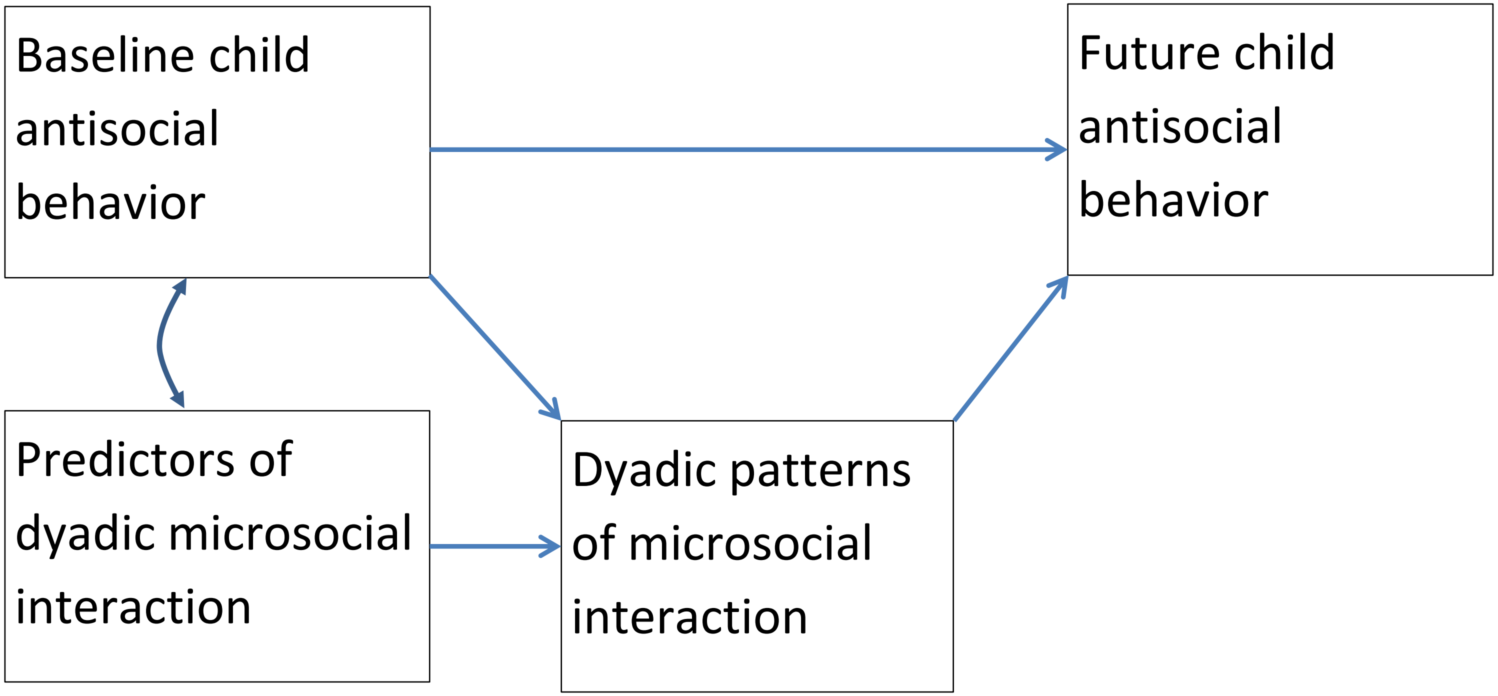
Example Dyad Level Research Questions

- Are antisocial children more likely to get angry when confronted by a negative parent? Does the strength of the tendency to get angry at the parent predict future antisocial behavior? (Coercive Process)
- If a best friend laughs when a teen talks about deviant behavior, does this predict the teen's future deviant behavior? (Peer Deviancy Training)
- Are spouses in distressed relationships more likely to reciprocate hostility from their partners, compared with those in happy relationships? Does this pattern predict divorce? (Coercive Process)

The Common Denominator

- The example research questions involve dyads and whether the typical response of one person to the behavior of another person is associated with either prior predictors or future outcomes.
- Focusing on social interaction between dyads in real time and coding the sequence and duration of individual behaviors of each dyad member is commonly called the study of microsocial interaction.
- Results typically used to inform behavioral interventions, e.g., parent training therapy for child antisocial behavior.

Heuristic Path Diagram: Dyad Level



Baseline child antisocial behavior

Future child antisocial behavior

Predictors of dyadic microsocial interaction

Dyadic patterns of microsocial interaction

Coding Microsocial Interaction In Contrast To:

- Observer global ratings and self-report.
- Observer watches an entire session of dyadic interaction and then makes global ratings at the end about typical patterns (e.g., during the session, did the child get angry when the parent tried to discipline him/her?).
- Dyad members think back and self-report about typical patterns of interaction (e.g., over the last 3 months, did your child get angry when you tried to discipline him/her?).

Example Research Dyads

- Dyads where patterns of microsocial interaction are thought to be important predictors of future outcomes include parent-child, husband-wife, therapist-client, child-best friend, supervisor-supervisee, siblings, etc.
- One dyad member could also be an experimental subject and the other “dyad member” could be the presentation of some experimental stimulus via a confederate or apparatus.
- Any time we have two or more streams of events in real time and events in one stream can effect events in the other stream, we can consider the use of MMSM.

Example Within Dyad Level Research Questions

- Does angry child affect tend to prime more angry affect?
- Does positive parent affect tend to damp angry child affect?
- Does watching actors smoke in movies trigger smoking in experimental subjects?

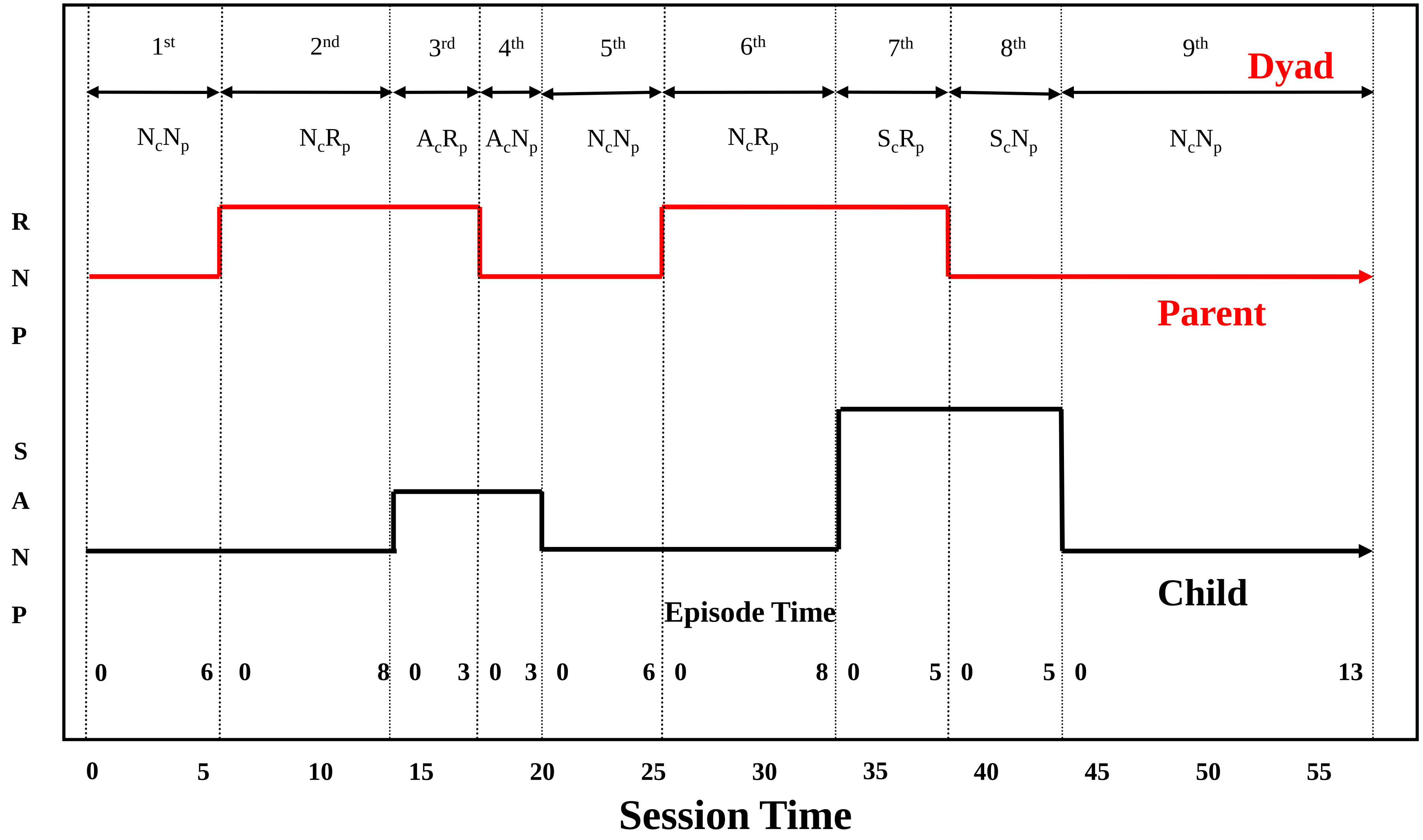
Combining Within Dyad and Between Dyad Research Questions

- Does watching actors smoke in movies trigger smoking in experimental subjects? (Within Dyad)
- Does the rate of “lighting up” in response to watching actors smoke predict relapse or failure in a smoking cessation program? (Between Dyad)

Coding Dyadic Interaction

- Two separate streams of event durations in proper temporal order, one for each dyad member but synchronized to a common time line.
- Coding system has exhaustive and mutually exclusive categories so the behavior of each dyad member is known at all times.
- Two streams can be merged to form a single stream for the dyad that categorizes the behavior of the dyad at all times.
- Coding system does not introduce artificial dependencies between the streams (e.g., single stream coding with precedence rules).

Schematic Event History Diagram



Restructuring Dyadic Data

- Starting from two separate streams in two separate files for one individual dyad:
- First, merge the two streams using standard database merging routines to get a dyadic stream.
- Second, fill in missing values arising from merge and compute dyadic state indicator.
- Third, use lead or lag functions to compute start and end state and start and end time for each dyadic state. Compute duration for each dyadic state, end time minus start time.
- Fourth, all individual dyadic files concatenated (stacked) in to one large file for entire sample.
- More operations are necessary on the stacked file but are explained later.

Time	Child
0	N
14	A
20	N
34	S
44	N
57	E

Time	Parent
0	N
6	R
17	N
26	R
39	N
57	E

Merge on Time

Time	Child	Parent
0	N	N
6		R
14	A	
17		
20	N	
26		R
34	S	
39		N
44	N	
57	E	E

Fill

Time	Child	Parent	Dyad
0	N	N	NcNp
6	N	R	NcRp
14	A	R	AcNp
17	A	N	AcNp
20	N	N	NcNp
26	N	R	NcRp
34	S	R	ScRp
39	S	N	ScNp
44	N	N	NcNp
57	E	E	EcEp

Lag

Start State	End State	Start Time	End Time	Duration
NcNp	NcRp	0	6	6
NcRp	AcNp	6	14	8
AcNp	AcNp	14	17	3
AcNp	NcNp	17	20	3
NcNp	NcRp	20	26	6
NcRp	ScRp	26	34	8
ScRp	ScNp	34	39	5
ScNp	NcNp	39	44	5
NcNp	EcEp	44	57	13

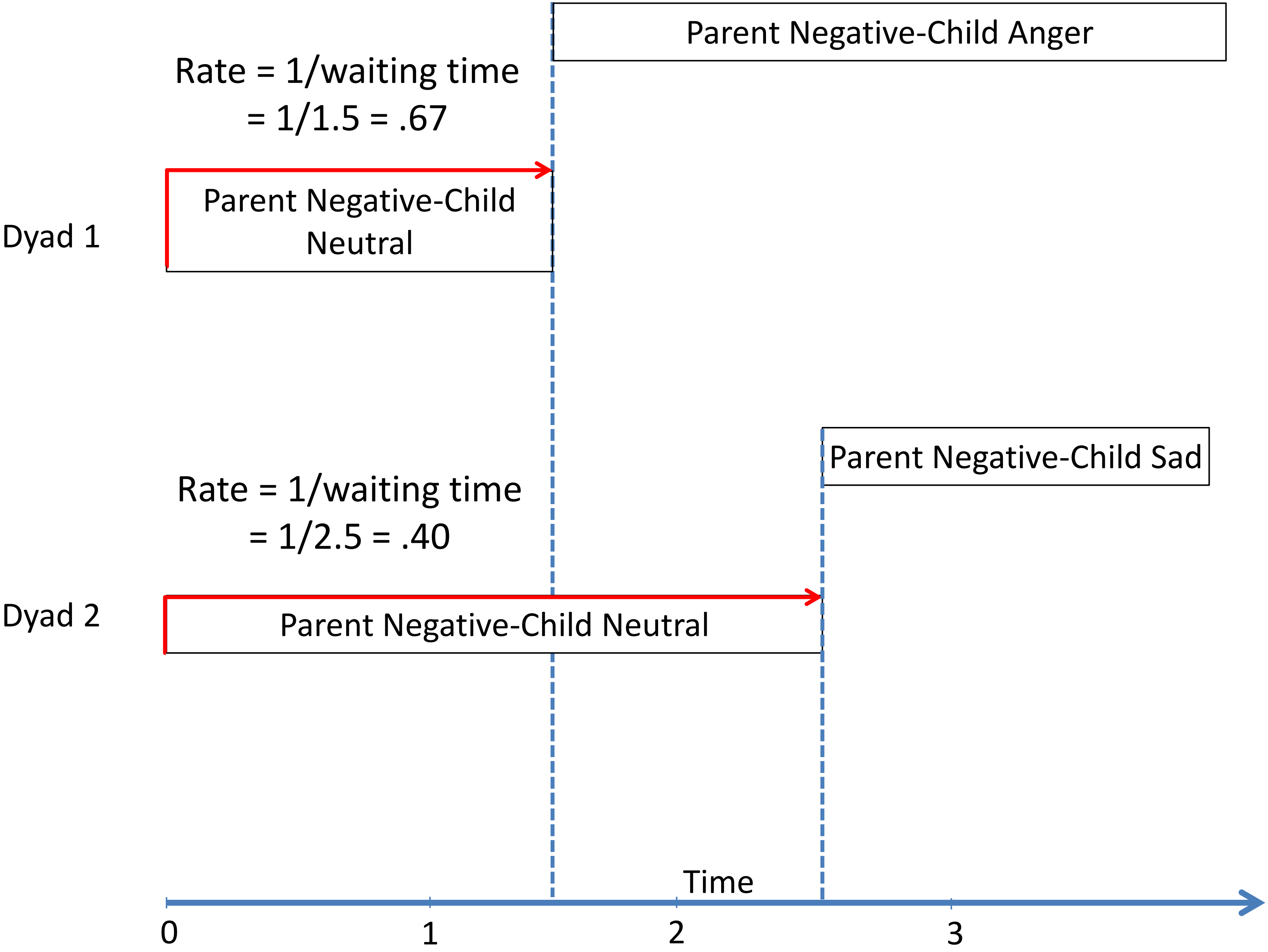
Stack

Censoring

- A waiting time is censored if we stop observing and do not know how much longer it took for the event to finally happen.
- In microsocial interaction, waiting times will be censored by the end of the observation period, equipment malfunction, if the subject moves out of sight of observer, etc.
- Waiting times for competing transitions are censored by the transition that actually happened, so called “competing risks”. (more on this later)

Hazard Rates For Dyadic Transitions

- The hazard rate is the time varying rate at which a dyadic state is terminated by a transition to a new and different dyadic state.
- Hazard rate is specific to a start state and an end state.
- Hazard rate can change during the waiting time.
- Individual hazard rates can be aggregated by ignoring the other dyad member and
  - ignoring start state (e.g., child anger initiation rate)
  - ignoring end state (e.g., child anger termination rate)



Parent Negative-Child Anger

Rate = 1/waiting time
= 1/1.5 = .67

Dyad 1

Parent Negative-Child Neutral

Parent Negative-Child Sad

Rate = 1/waiting time
= 1/2.5 = .40

Dyad 2

Parent Negative-Child Neutral

A Simple Single Level Hazard Model

- The hazard rate includes a baseline hazard function. A simple hazard rate model looks like this for the ith subject:
- $h_i(t) = h_0(t)\exp(b_1X_i)$.
- Estimation is usually on the log hazard scale:
- $\log(h_i(t)) = \log(h_0(t)) + b_1X_i$.
- The baseline hazard function, h_0 is a function of waiting time, t, and indicates how the hazard rate can vary across waiting time. It does not vary across subjects.
- The time fixed predictor X creates variation in the hazard rate across subjects but not across waiting time.
- The hazard rate stochastically determines the observed waiting times (durations).

Simulating A Simple Hazard Model

- Hazard functions are determined by probability distribution (df) and density (pdf) functions of the waiting time, t:
- $\frac{\mathrm{pdf}(t)}{1-\mathrm{df}(t)} = h(t) = h_0(t)\exp(b_1 X)$
- Suppose that the baseline hazard function is a constant value, a, wrt time, $\mathrm{h(t)} = a\exp(b_1 X)$.
- This corresponds to the exponential distribution for the waiting times. To get a single realization, we randomly generate one value from the exponential distribution with rate parameter h.

Multilevel Hazard Rates

- When each dyad can experience the same type of dyadic transition more than once during the session, the episodes are correlated. For a single hazard rate:
- $h_i(t) = h_0(t)\exp(b_1X_i + f_i)$ or on the log scale
- $\log(h_i(t)) = \log(h_0(t)) + b_1X_i + f_i$
- where f is a latent variable (random effect) typically assumed to be normally distributed with mean zero and variance, σ, which is estimated.

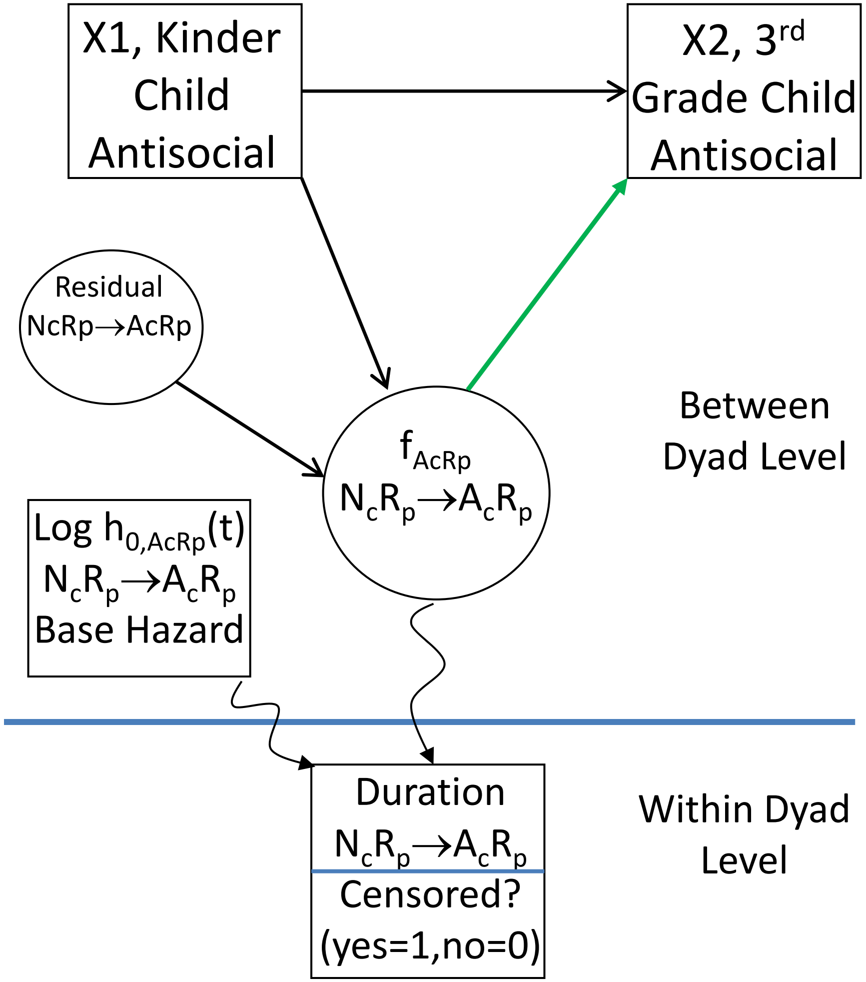
Proportional Hazards

- Mplus implements proportional hazards model, with non-, semi-, or fully parametric baseline hazard function.
- Baseline hazard function applies to all dyads and shows how population hazard rate varies across waiting time.
- Each dyad’s hazard rate differs from the baseline hazard function by a multiplicative constant.
- If proportional hazards is not reasonable, Mplus allows latent classes (i.e., population subgroups) to have differing baseline hazards.

Multivariate Multilevel Hazard Rates

- Many research questions about dyads involve more than 1 hazard rate as an outcome or predictor. A model with 2 hazard rates:
- $\log(h_{AcRp,i}(t)) = \log(h_{AcRp,0}(t)) + b_{AcRp,1}X_i + f_{AcRp,i}$
- $\log(h_{PcRp,i}(t)) = \log(h_{PcRp,0}(t)) + b_{PcRp,1}X_i + f_{PcRp,i}$
- Where f_{AcRp} and f_{PcRp} have a bivariate normal distribution with mean vector of $\mathbf{0}$ and covariance matrix, $\boldsymbol{\Sigma}$.

Path Diagram For A Multivariate Multilevel Dyadic States Model



X1, Kinder Child Antisocial

X2, 3^{rd} Grade Child Antisocial

Residual NcRp→AcRp

f_{AcRp} $N_cR_p \rightarrow A_cR_p$

Log $h_{0,AcRp}(t)$ $N_cR_p \rightarrow A_cR_p$ Base Hazard

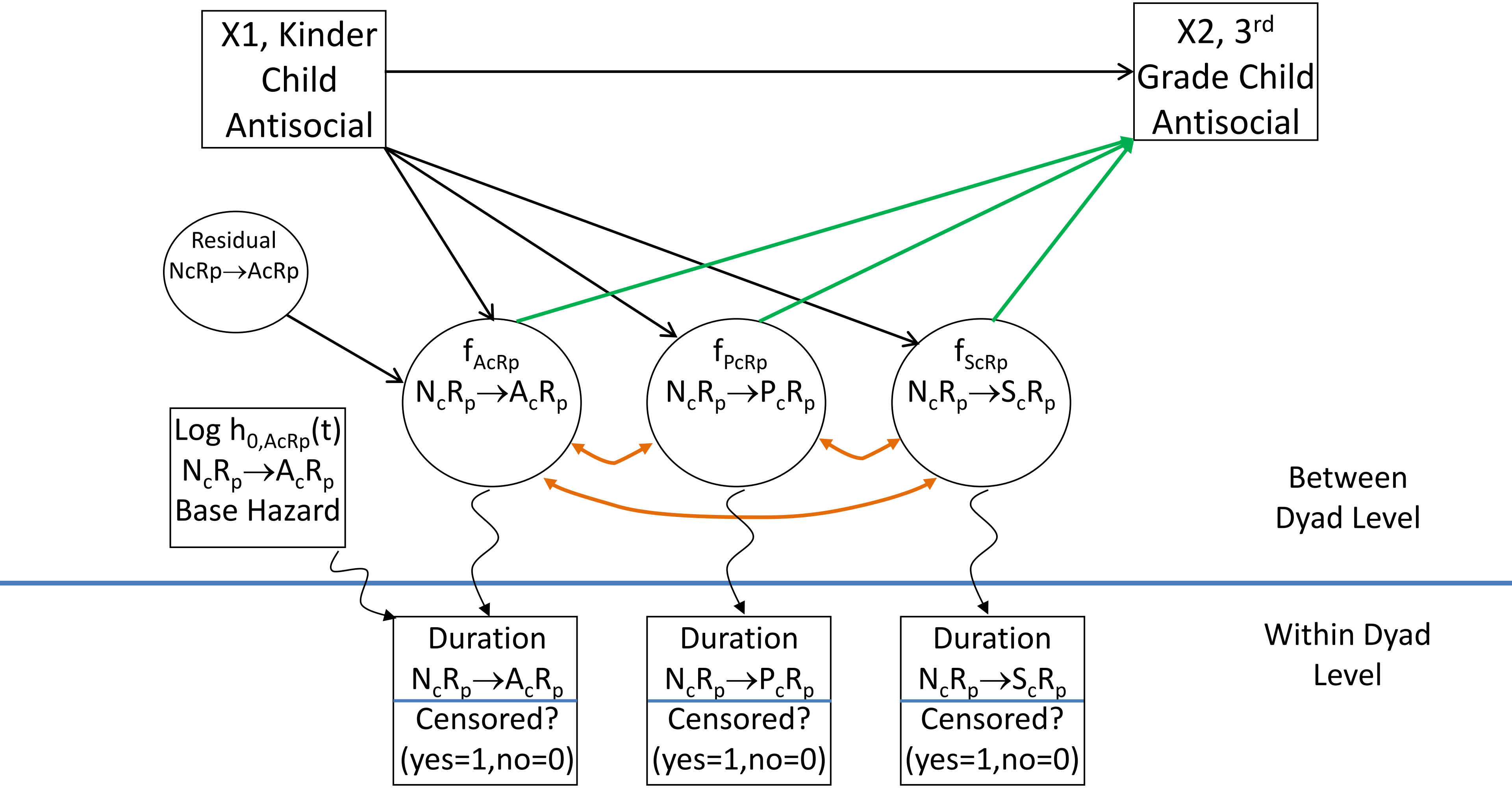
Between Dyad Level

Duration $N_cR_p \rightarrow A_cR_p$

Censored? (yes=1,no=0)

Within Dyad Level

Path Diagram For A Multivariate Multilevel Dyadic States Model



X1, Kinder Child Antisocial

X2, 3^{rd} Grade Child Antisocial

Residual NcRp→AcRp

f_{AcRp} $N_cR_p \rightarrow A_cR_p$

f_{PcRp} $N_cR_p \rightarrow P_cR_p$

f_{ScRp} $N_cR_p \rightarrow S_cR_p$

Log $h_{0,AcRp}(t)$ $N_cR_p \rightarrow A_cR_p$ Base Hazard

Between Dyad Level

Within Dyad Level

Duration $N_cR_p \rightarrow A_cR_p$ Censored? (yes=1,no=0)

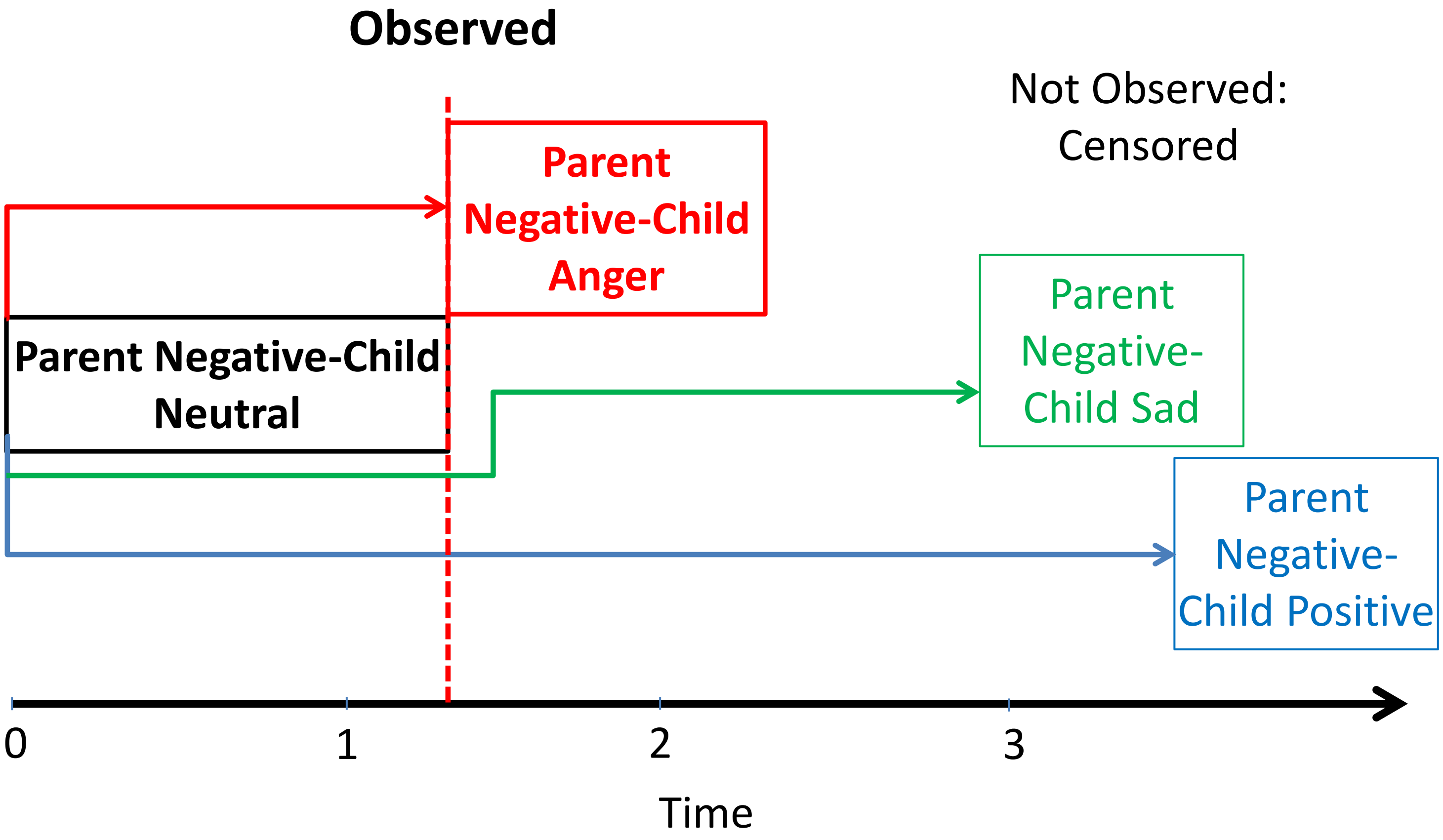
Duration $N_cR_p \rightarrow P_cR_p$ Censored? (yes=1,no=0)

Duration $N_cR_p \rightarrow S_cR_p$ Censored? (yes=1,no=0)

Competing Risks and Censoring Revisited

- In the previous model, the start state is the same but there are 3 possible transitions to 3 different end states.
- The actual transition that happens will censor the waiting times for the other 2 transitions.
- It is not known how long it would take for either of the other 2 transitions to happen, just longer than the transition that did happen.
- This is known as “competing risks” and is illustrated in the schematic diagram.

Schematic of Censoring In Competing Risks



Observed

Not Observed:
Censored

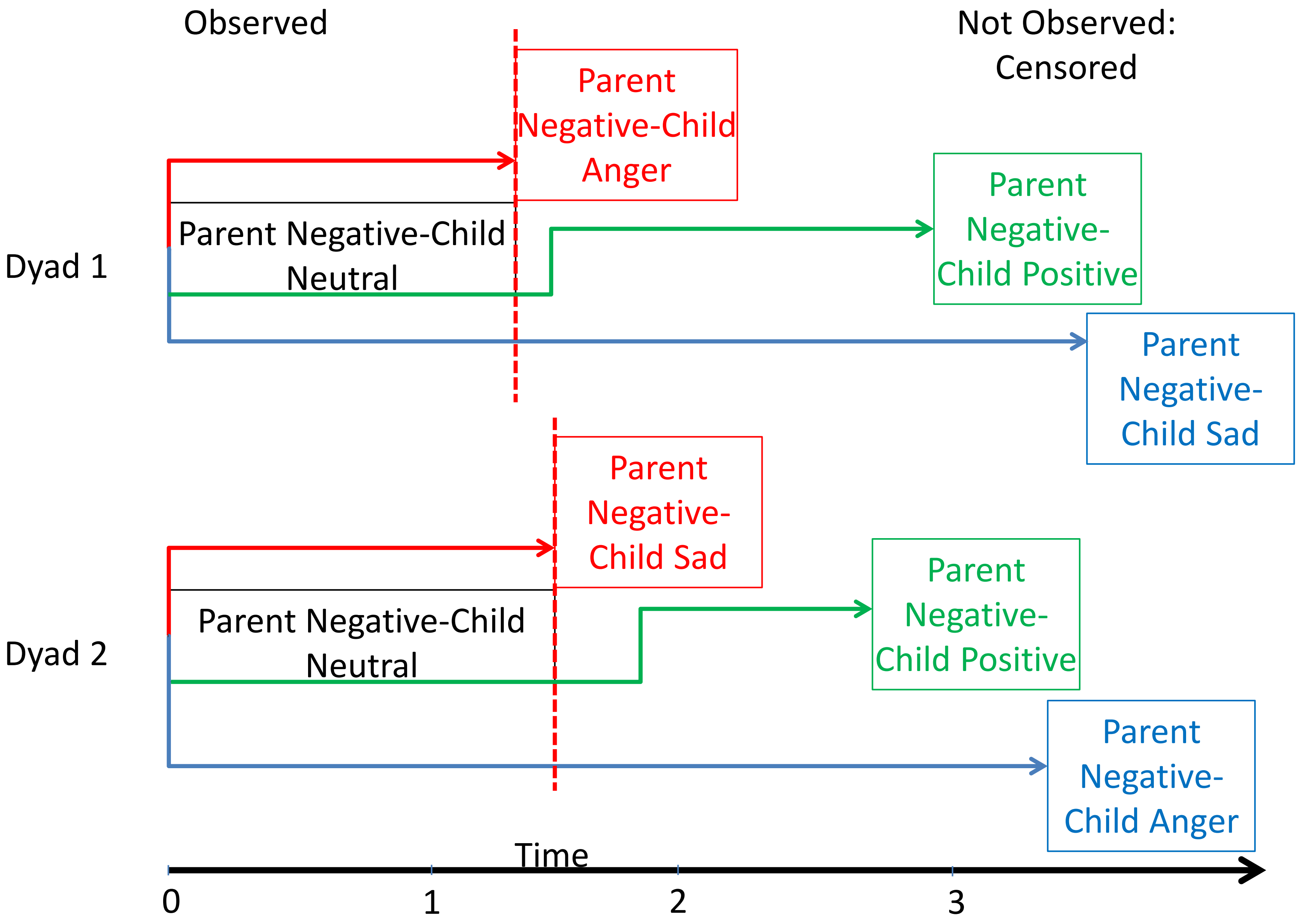
Parent Negative-Child Anger

Parent Negative-Child Neutral

Parent Negative-Child Sad

Parent Negative-Child Positive

Schematic of Censoring In Competing Risks



Observed

Not Observed:
Censored

Dyad 1

Parent Negative-Child
Neutral

Parent
Negative-Child
Anger

Parent
Negative-
Child Positive

Parent
Negative-
Child Sad

Dyad 2

Parent Negative-Child
Neutral

Parent
Negative-
Child Sad

Parent
Negative-
Child Positive

Parent
Negative-
Child Anger

Time

0
1
2
3

Time	Child
0	N
14	A
20	N
34	S
44	N
57	E

Time	Parent
0	N
6	R
17	N
26	R
39	N
57	E

Merge on Time

Time	Child	Parent
0	N	N
6		R
14	A	
17		
20	N	
26		R
34	S	
39		N
44	N	
57	E	E

Fill

Time	Child	Parent	Dyad
0	N	N	NcNp
6	N	R	NcRp
14	A	R	AcRp
17	A	N	AcNp
20	N	N	NcNp
26	N	R	NcRp
34	S	R	ScRp
39	S	N	ScNp
44	N	N	NcNp
57	E	E	EcEp

Lag

Start State	End State	Start Time	End Time	Duration
NcNp	NcRp	0	6	6
NcRp	AcRp	6	14	8
AcRp	AcNp	14	17	3
AcNp	NcNp	17	20	3
NcNp	NcRp	20	26	6
NcRp	ScRp	26	34	8
ScRp	ScNp	34	39	5
ScNp	NcNp	39	44	5
NcNp	EcEp	44	57	13

Stack

Final Mplus Data Structure: Censor Indicators

			Censor Indicators			
Start State	End State	Duration	AcRp	PcRp	ScRp	Family ID
NcNp	NcRp	6	1	1	1	123
NcRp	AcRp	8	0	1	1	123
AcRp	AcNp	3	1	1	1	123
AcNp	NcNp	3	1	1	1	123
NcNp	NcRp	6	1	1	1	123
NcRp	ScRp	8	1	1	0	123
ScRp	ScNp	5	1	1	1	123
ScNp	NcNp	5	1	1	1	123
NcNp	EcEp	13	1	1	1	123

Mplus Survival Syntax Cox Model

- DEFINE:
  - AcRp_dur = duration; PcRp_dur = duration;
  - ScAp_dur = duration;
- VARIABLES:
  - SURVIVAL = AcRp_dur (ALL) PcRp_dur (ALL) ScAp_dur (ALL);
  - TIMECENSOR = AcRp PcRp ScRp;
- ANALYSIS: basehazard = off;

The Research Design And Data

- Participants: 274 children (half boys), and their parents recruited at kindergarten from a low income, working class area.
- Parent-child dyads were videotaped on two, one-hour occasions (session 1 & 2 dyad N’s = 239 and 221). Interaction was coded for emotion using the SPAFF. Parent and child were coded separately but on a synchronized time line.
- 4 child states, angry, (A), neutral (N), positive (P), or Sad-Fear (S), 3 parent states, negative (R), neutral (N) or positive (P).
- Child Antisocial was based on parent CBC or teacher TRF from fall of kindergarten and then in spring of 3rd grade.
- Start state was child neutral-parent negative (NcRp).

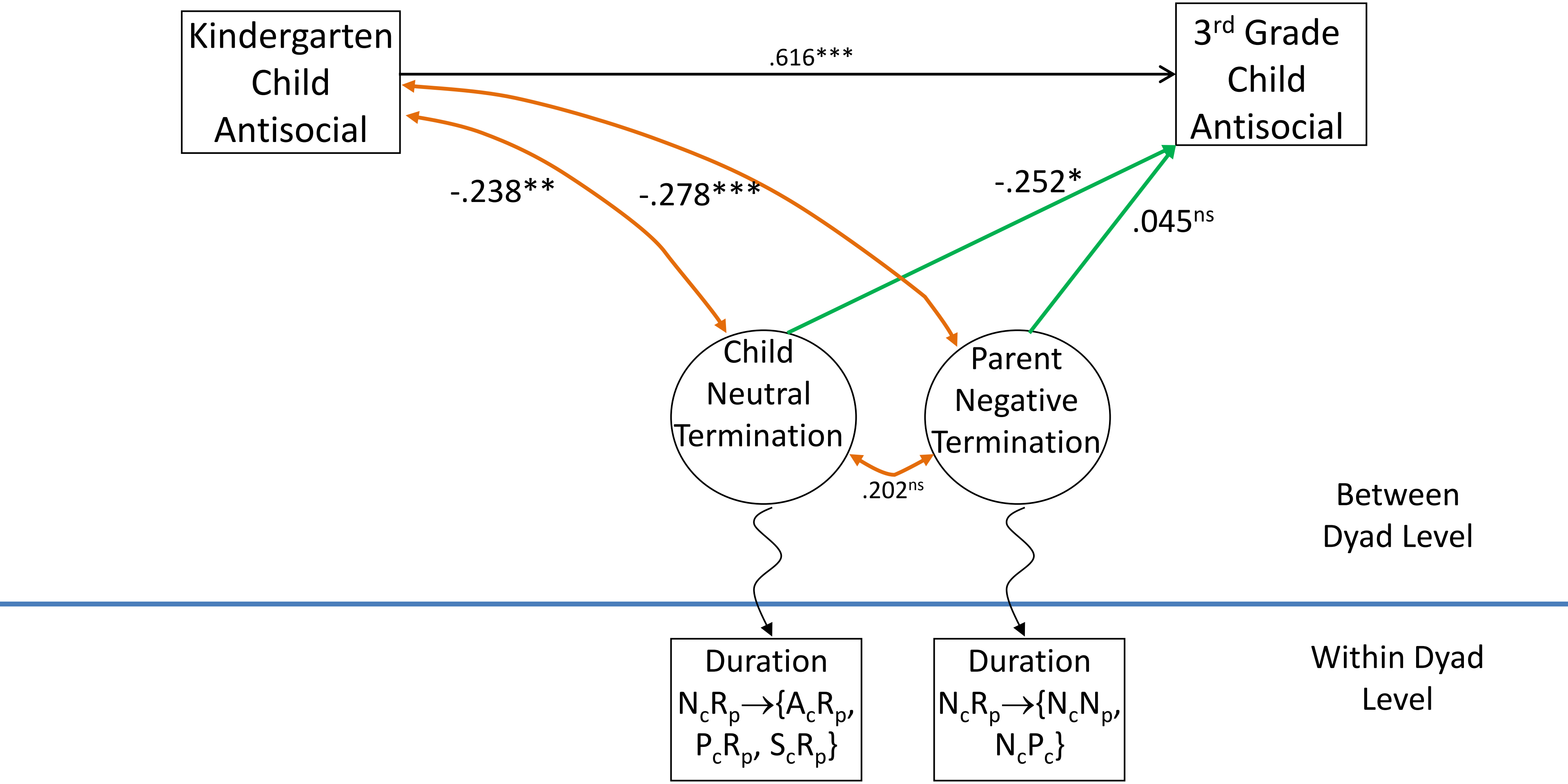
Transition Frequency Table

	Events	End State													
	Session 1+2	AcRp	AcNp	AcPp	NcRp	NcNp	NcPp	PcRp	PcNp	PcPp	ScRp	ScNp	ScPp	Total	Pro
	AcRp	0	175	23	259	2	0	8	0	0	28	0	0	495	0
	AcNp	224	1	528	2	2202	7	0	83	2	0	68	0	3116	0.01
	AcPp	25	411	1	0	6	394	0	0	68	0	0	14	918	0
	NcRp	219	1	1	2	6292	859	952	13	5	186	4	1	8533	0.02
	NcNp	2	2346	6	6673	1661	93264	9	45027	249	0	2111	7	149694	0.42
Start State	NcPp	0	6	299	642	93775	116	2	97	10052	1	4	275	105153	0.29
	PcRp	11	0	0	789	6	0	0	649	250	10	0	0	1715	0
	PcNp	0	111	0	4	45239	156	546	89	12177	0	85	0	58318	0.16
	PcPp	0	1	49	1	236	10172	188	12225	14	0	1	26	22899	0.06
	ScRp	12	0	0	156	2	0	11	0	0	1	269	45	495	0
	ScNp	0	66	0	4	1967	4	0	174	2	250	22	1375	3842	0.01
	ScPp	0	0	11	0	5	315	0	1	88	21	1303	1	1744	0

Transitions and Families: Starting From Child Neutral-Parent Negative

	End State						
Session 1+2	Child Angry Parent Neg	Child Sad Parent Neg	Child Pos Parent Neg	Child Neu Parent Neu	Child Neu Parent Pos	Total	Pro
Events	219	186	952	6292	859	8533	0.024
Families with 1+ transitions	98	89	208	238	197	240	1.000

Path Diagram For A Multivariate Multilevel Dyadic States Cox Model



Kindergarten Child Antisocial

3rd Grade Child Antisocial

.616***

-.238**

-.278***

-.252*

.045^{ns}

Child Neutral Termination

Parent Negative Termination

.202^{ns}

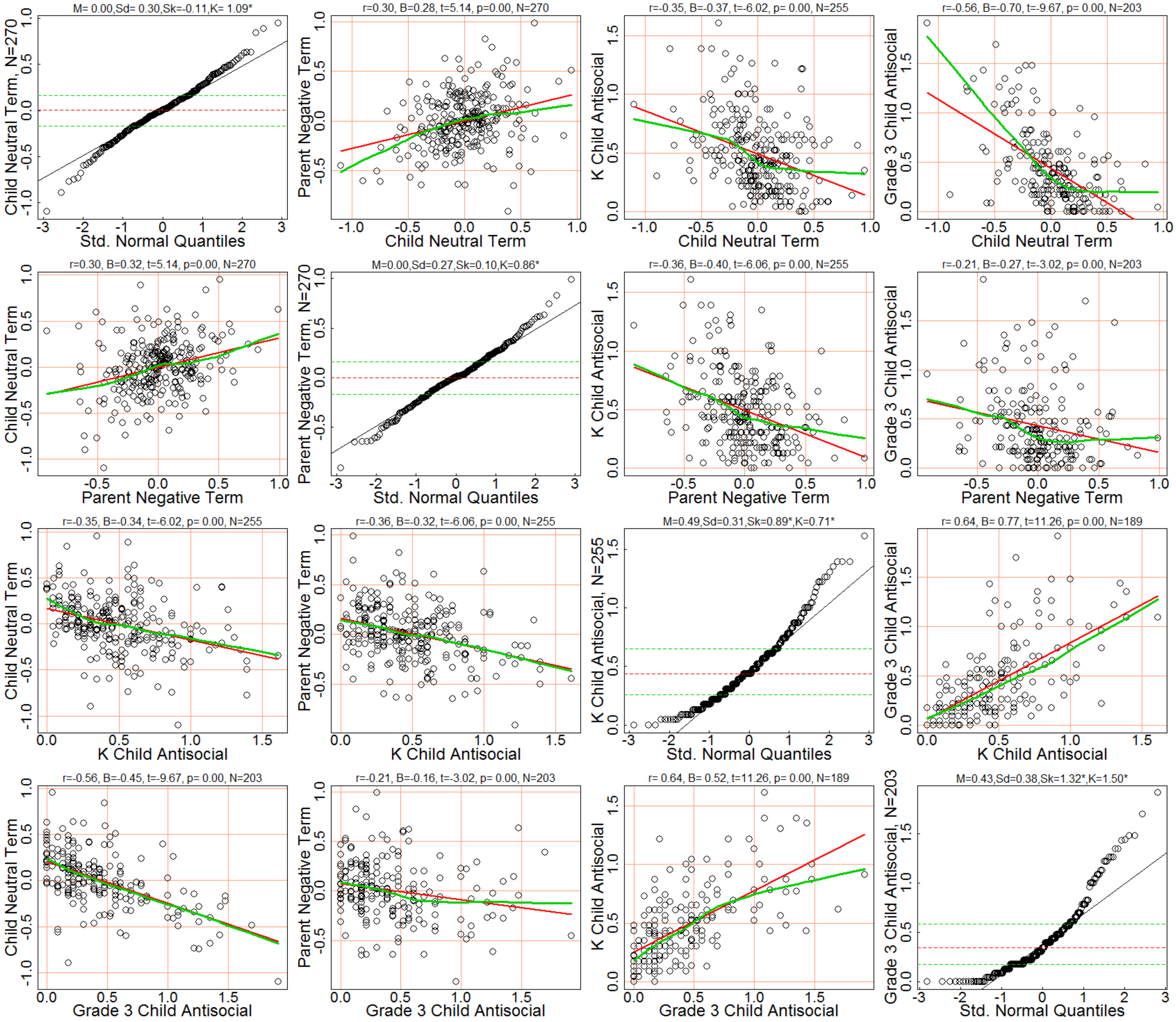
Between Dyad Level

Within Dyad Level

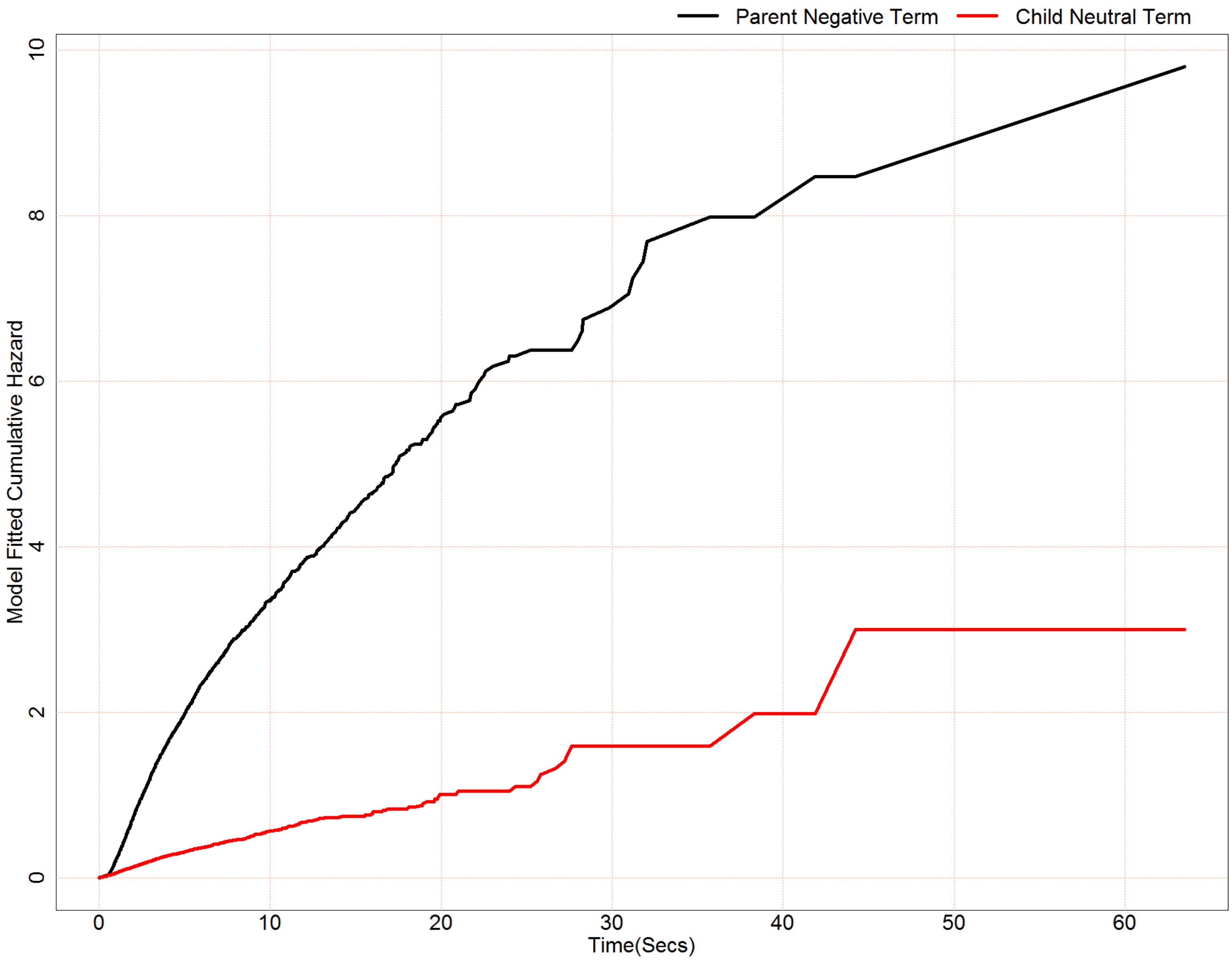
Duration
$N_cR_p \rightarrow \{A_cR_p, P_cR_p, S_cR_p\}$

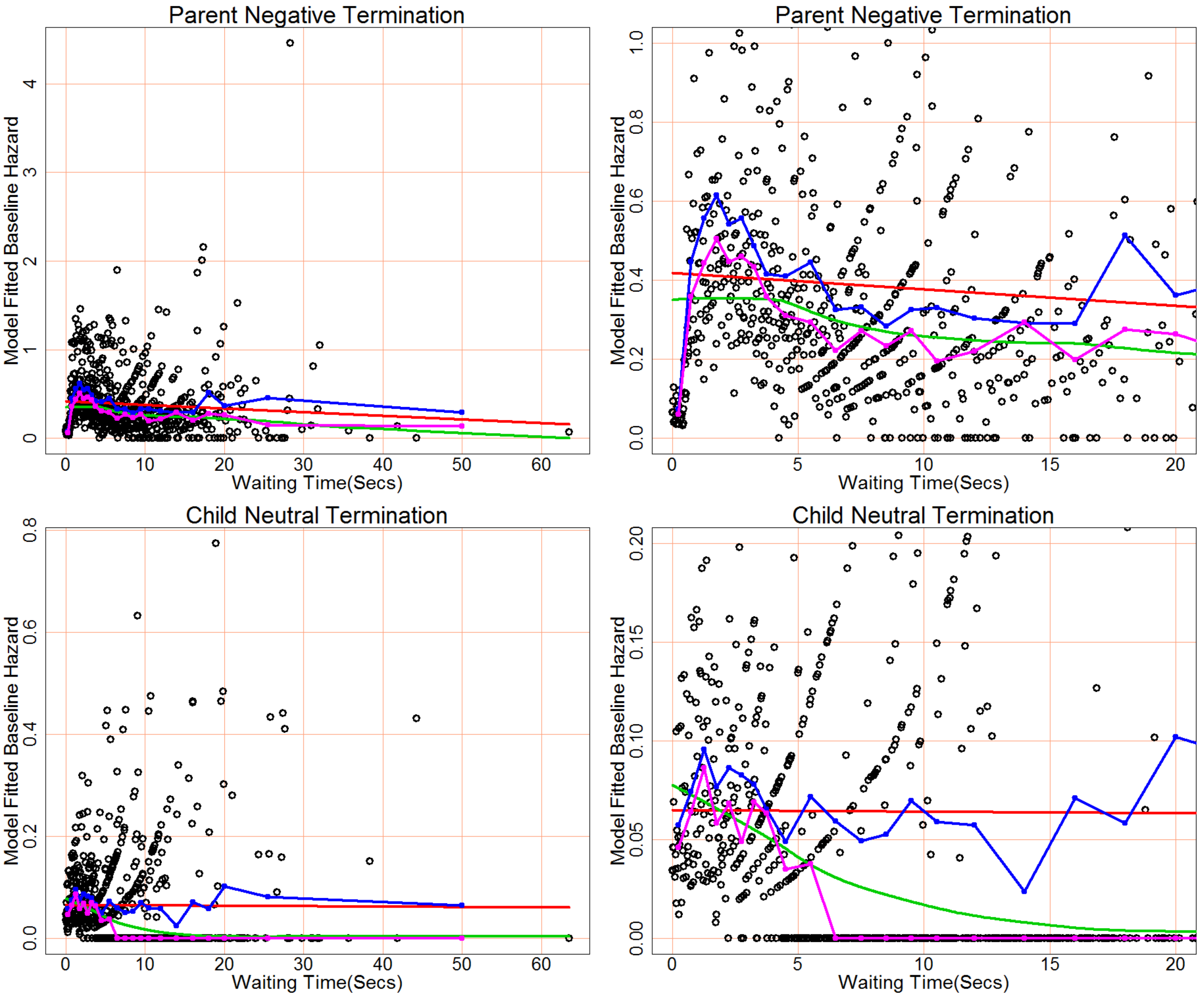
Duration
$N_cR_p \rightarrow \{N_cN_p, N_cP_c\}$

Cox model estimated factor scores



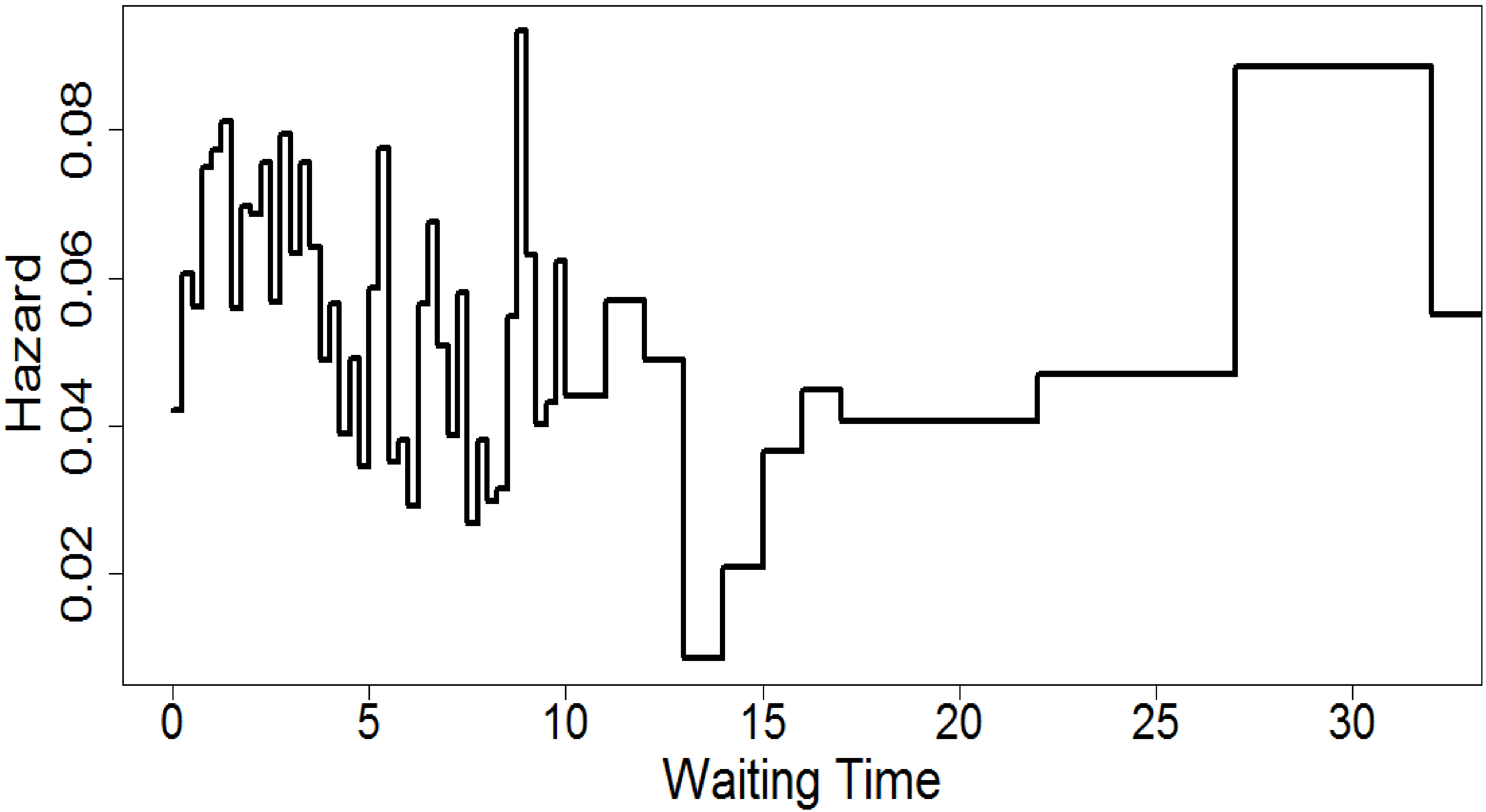
Cox Model Cumulative Hazards

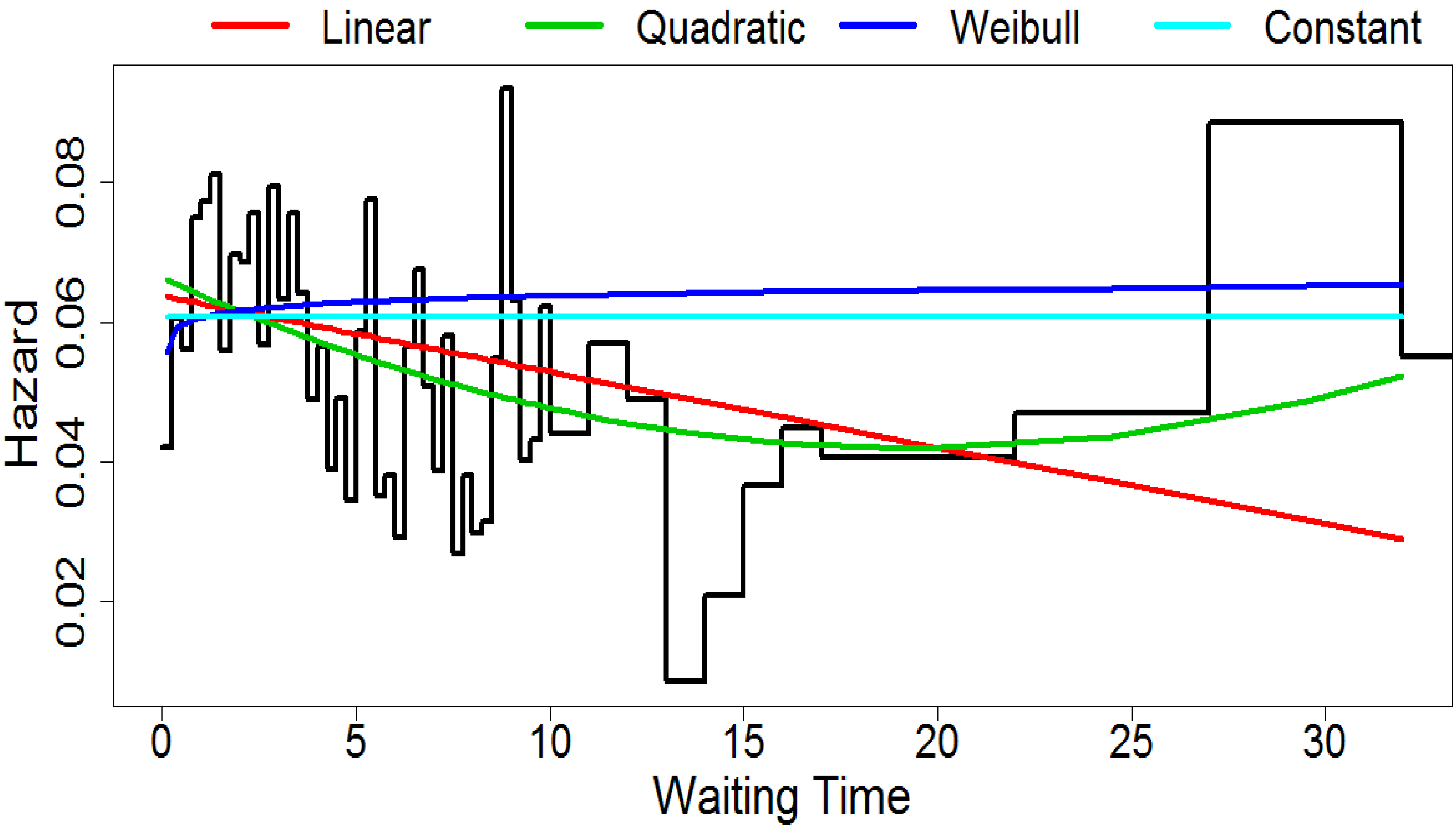



Parent Negative Termination
Model Fitted Baseline Hazard
0
1
2
3
4
Waiting Time(Secs)
0
10
20
30
40
50
60
Parent Negative Termination
Model Fitted Baseline Hazard
0.0
0.2
0.4
0.6
0.8
1.0
Waiting Time(Secs)
0
5
10
15
20
Child Neutral Termination
Model Fitted Baseline Hazard
0.0
0.2
0.4
0.6
0.8
Waiting Time(Secs)
0
10
20
30
40
50
60
Child Neutral Termination
Model Fitted Baseline Hazard
0.00
0.05
0.10
0.15
0.20
Waiting Time(Secs)
0
5
10
15
20

Other Models for Consideration

- Cox baseline hazards (over 600 time intervals)
- Baseline Hazard based on 51 time intervals
  - No constraints
  - Quadratic
  - Linear
  - Weibull
  - Constant (exponential)


Hazard
0.02
0.04
0.06
0.08
0
5
10
15
20
25
30
Waiting Time


Linear
Quadratic
Weibull
Constant
Hazard
0.02
0.04
0.06
0.08
0
5
10
15
20
25
30
Waiting Time

Model Comparisons For Different Baseline Hazards

	uncon	quad	linear	weibull	constant
loglikelihood	-5195.8	-5234.4	-5235.7	-5238.9	-5239.7
scaling factor	1.05	1.23	1.22	1.20	1.24
parameters	59	11	10	10	9
AIC	10510	10491	10491	10498	10497
adj BIC	10738	10533	10530	10537	10532
BIC	10926	10568	10562	10568	10561
Robust chi-sq		77.10	79.85	86.21	87.90
Df		48	49	49	50
p		0.005	0.004	0.001	0.001

Statistical/Methodological Issues

- Computing speed
  - Break model down in to smaller sub models
  - Get good start values
  - Minimize baseline hazard parameters
  - Get a supercomputer
- Statistical power
- Planned missingness designs to minimize cost
- Adequacy of large sample size assumptions both within and between dyads
- Non-proportional hazards models

The End

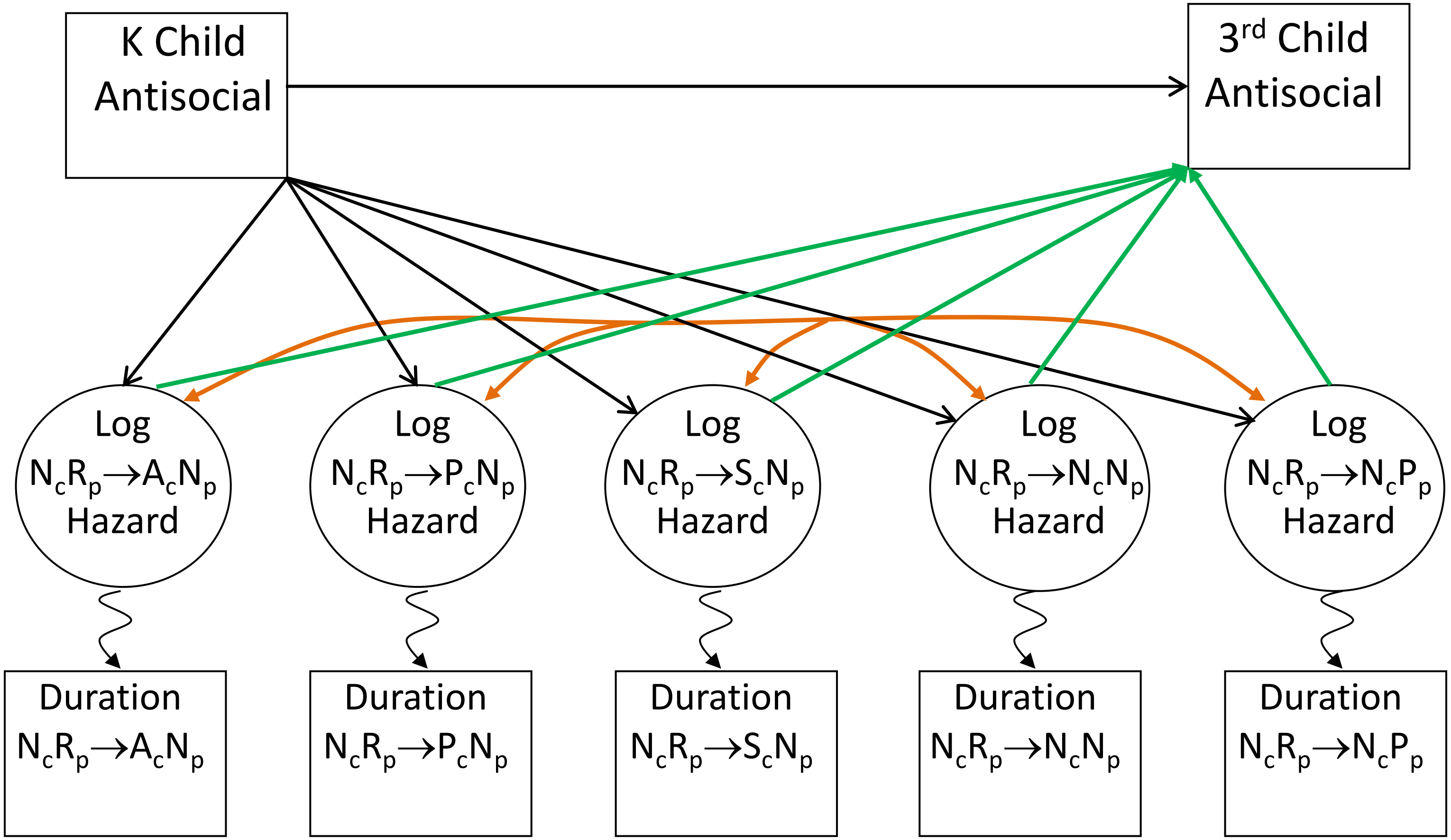
The Traditional Statistical Tool

- Sequential analysis focusing on the conditional probability of child anger or child sad-fear given parent negative behavior and whether these differed for high vs. low antisocial children (Wampold, 1984).
- Traditional sequential analysis, however, has two major limitations.

Major Limitations

- Traditional sequential analysis focused on conditional probabilities of one event following another but totally ignored amount of time or duration spent in a particular state (Gardner & Griffin, 1989).
- Traditional sequential analysis lacked a multi-level statistical framework.

Multivariate Multilevel Dyadic States Model



K Child Antisocial

3rd Child Antisocial

Log $N_cR_p \rightarrow A_cN_p$ Hazard

Log $N_cR_p \rightarrow P_cN_p$ Hazard

Log $N_cR_p \rightarrow S_cN_p$ Hazard

Log $N_cR_p \rightarrow N_cN_p$ Hazard

Log $N_cR_p \rightarrow N_cP_p$ Hazard

Duration $N_cR_p \rightarrow A_cN_p$

Duration $N_cR_p \rightarrow P_cN_p$

Duration $N_cR_p \rightarrow S_cN_p$

Duration $N_cR_p \rightarrow N_cN_p$

Duration $N_cR_p \rightarrow N_cP_p$