Web-based Supporting Materials for “Joint Modeling of Multiple Repeated Measures and Survival Data Using Multidimensional Latent Trait Linear Mixed Model” by Jue Wang and Sheng Luo

Table 1: The ALSFRS items and scores

Items	**0 - Extreme**	**1 - Severe**	**2 - Moderate**	**3 - Mild**	**4 - Normal**
(1) Speech	Loss of useful speech	Speech combined with nonvocal communication	Intelligible with repeating	Detectable speech disturbance	Normal speech processes
(2) Salivation	Marked drooling; requires constant tissue or handkerchief	Marked excess of saliva with some drooling	Moderately excessive saliva; may have minimal drooling	Slight but definite excess of saliva in mouth; may have nighttime drooling	Normal
(3) Swallowing	NPO (exclusively parenteral or enteral feeding)	Needs supplemental tube feeding	Dietary consistency changes	Early eating problems-occasional choking	Normal eating habits
(4) Handwriting	Unable to grip pen	Able to grip pen but unable to write	Not all words are legible	Slow or sloppy; all words are legible	Normal
(5) Cutting food and handling utensils (with or without gastrostomy)	Needs to be fed	Food must be cut by someone, but can still feed slowly	Can cut most foods, although clumsy and slow; some help needed	Somewhat slow and clumsy, but no help needed	Normal
(6) Dressing and hygiene	Total dependence	Needs attendant for self-care	Intermittent assistance or substitute methods	Independent and complete self-care with effort or decreased efficiency	Normal function
(7) Turning in bed and adjusting bed clothes	Helpless	Can initiate, but not turn or adjust sheets alone	Can turn alone or adjust sheets, but with great difficulty	Somewhat slow and clumsy, but no help needed	Normal
(8) Walking	No purposeful leg movement	Non-ambulatory functional movement only	Walks with assistance	Early ambulation difficulties	Normal
(9) Climbing stairs	Cannot do	Needs assistance	Mild unsteadiness or fatigue	Slow	Normal
(10) Breathing	Significant difficulty, considering using mechanical respiratory support	Occurs at rest, difficulty breathing when either sitting or lying	Occurs with one or more of the following: eating, bathing, dressing (ADL)	Occurs when walking	None

Table 2: Simulation Setting I: additional simulation results from the JM and RM when data are simulated from the JM.

	JM				RM			
	BIAS	SE	SD	CP	BIAS	SE	SD	CP
$a_{31} = 1$	0.009	0.186	0.173	0.935	0.004	0.183	0.174	0.940
$a_{41} = 2$	-0.004	0.220	0.218	0.950	0.009	0.213	0.219	0.955
$a_{51} = 0.8$	0.040	0.185	0.183	0.935	0.022	0.184	0.183	0.935
$a_{61} = 0.5$	0.009	0.133	0.139	0.970	0.012	0.138	0.139	0.955
$a_{71} = 0.3$	0.011	0.173	0.178	0.955	0.011	0.174	0.179	0.940
$a_{81} = 0.6$	0.012	0.157	0.146	0.935	0.006	0.163	0.145	0.940
$a_{91} = 1.2$	0.021	0.134	0.132	0.970	0.017	0.139	0.131	0.955
$a_{10,1} = 1.5$	0.024	0.181	0.182	0.945	0.017	0.181	0.182	0.935
$a_{12} = 1$	-0.001	0.052	0.058	0.965	0.003	0.055	0.058	0.965
$a_{22} = 1$	0.007	0.064	0.063	0.945	0.009	0.063	0.063	0.945
$a_{32} = 2$	0.019	0.199	0.177	0.900	0.017	0.194	0.178	0.910
$a_{42} = 3$	0.006	0.233	0.229	0.945	0.018	0.227	0.230	0.950
$a_{52} = 1.8$	0.053	0.185	0.188	0.950	0.040	0.182	0.187	0.945
$a_{62} = 1.5$	0.009	0.146	0.140	0.945	0.017	0.150	0.141	0.935
$a_{72} = 1.3$	0.022	0.179	0.179	0.960	0.025	0.175	0.180	0.955
$a_{82} = 1.6$	0.024	0.152	0.148	0.935	0.019	0.155	0.147	0.905
$a_{92} = 2.2$	0.026	0.132	0.136	0.980	0.024	0.136	0.136	0.970
$a_{10,2} = 2.5$	0.026	0.187	0.189	0.930	0.020	0.188	0.188	0.925
$a_{13} = 2.5$	0.010	0.072	0.082	0.970	0.017	0.075	0.082	0.965
$a_{23} = 2.5$	0.008	0.090	0.087	0.945	0.016	0.091	0.087	0.930
$a_{33} = 3.5$	0.031	0.210	0.192	0.925	0.026	0.208	0.193	0.935
$a_{43} = 4.5$	0.012	0.258	0.251	0.930	0.028	0.254	0.253	0.940
$a_{53} = 3.3$	0.064	0.192	0.204	0.935	0.046	0.188	0.203	0.950
$a_{63} = 3$	0.025	0.163	0.152	0.935	0.033	0.164	0.152	0.920
$a_{73} = 2.8$	0.025	0.202	0.191	0.930	0.029	0.192	0.192	0.930
$a_{83} = 3.1$	0.032	0.158	0.160	0.945	0.028	0.160	0.160	0.945
$a_{93} = 3.7$	0.032	0.151	0.152	0.960	0.031	0.157	0.151	0.945
$a_{10,3} = 4$	0.033	0.204	0.208	0.940	0.024	0.208	0.207	0.955
$a_{14} = 5$	0.013	0.108	0.119	0.960	0.017	0.116	0.120	0.950
$a_{24} = 5$	0.011	0.131	0.124	0.965	0.026	0.129	0.125	0.950
$a_{34} = 6$	0.047	0.255	0.232	0.920	0.035	0.258	0.233	0.905
$a_{44} = 7$	0.013	0.311	0.301	0.925	0.033	0.316	0.304	0.920
$a_{54} = 5.8$	0.084	0.241	0.248	0.950	0.063	0.233	0.247	0.955
$a_{64} = 5.5$	0.033	0.194	0.187	0.930	0.042	0.197	0.188	0.940
$a_{74} = 5.3$	0.040	0.237	0.228	0.935	0.037	0.228	0.229	0.950
$a_{84} = 5.6$	0.043	0.191	0.198	0.950	0.041	0.197	0.198	0.950
$a_{94} = 6.2$	0.042	0.194	0.194	0.950	0.038	0.205	0.194	0.935
$a_{10,4} = 6.5$	0.043	0.244	0.253	0.945	0.032	0.246	0.252	0.950

Table 3: Simulation Setting I: additional simulation results from the JM and RM when data are simulated from the JM (continued).

	JM				RM			
	BIAS	SE	SD	CP	BIAS	SE	SD	CP
$b_2^{(1)} = 0.1$	0.010	0.087	0.093	0.955	0.023	0.083	0.095	0.955
$b_3^{(1)} = 1.5$	0.015	0.075	0.077	0.950	0.017	0.078	0.077	0.950
$b_4^{(1)} = 2$	0.003	0.093	0.096	0.945	0.007	0.097	0.096	0.945
$b_5^{(1)} = 0.1$	0.021	0.144	0.149	0.960	0.037	0.135	0.151	0.960
$b_6^{(1)} = 1.2$	0.007	0.057	0.054	0.925	0.011	0.056	0.054	0.920
$b_7^{(1)} = 1.6$	0.013	0.073	0.078	0.965	0.015	0.075	0.078	0.960
$b_8^{(1)} = 0.2$	0.013	0.105	0.112	0.950	0.026	0.100	0.114	0.955
$b_9^{(1)} = 0.3$	0.013	0.089	0.094	0.955	0.025	0.086	0.096	0.960
$b_{10}^{(1)} = 0.4$	0.016	0.133	0.140	0.960	0.032	0.129	0.142	0.960
$b_3^{(2)} = 0.4$	0.003	0.031	0.031	0.955	−0.001	0.030	0.031	0.950
$b_4^{(2)} = 0.1$	−0.001	0.028	0.031	0.965	−0.002	0.028	0.031	0.970
$b_5^{(2)} = 1.6$	0.022	0.073	0.076	0.940	0.012	0.070	0.075	0.960
$b_6^{(2)} = 0.2$	0.001	0.023	0.022	0.910	−0.001	0.023	0.022	0.925
$b_7^{(2)} = 0.3$	0.001	0.029	0.030	0.955	−0.002	0.029	0.030	0.955
$b_8^{(2)} = 1.2$	0.008	0.055	0.052	0.925	0.005	0.054	0.052	0.940
$b_9^{(2)} = 1$	0.006	0.040	0.043	0.975	0.002	0.041	0.043	0.970
$b_{10}^{(2)} = 1.5$	0.009	0.066	0.069	0.955	0.002	0.066	0.068	0.965

Table 4: Simulation Setting II: additional simulation results from the JM and RM when data are simulated from the RM.

	JM				RM			
	BIAS	SE	SD	CP	BIAS	SE	SD	CP
$a_{31} = 1$	0.012	0.152	0.145	0.925	0.021	0.151	0.144	0.920
$a_{41} = 2$	0.010	0.196	0.186	0.935	0.017	0.192	0.186	0.950
$a_{51} = 0.8$	0.013	0.151	0.148	0.930	0.018	0.154	0.148	0.920
$a_{61} = 0.5$	0.013	0.116	0.115	0.955	0.010	0.115	0.115	0.960
$a_{71} = 0.3$	0.016	0.143	0.146	0.925	0.020	0.147	0.145	0.925
$a_{81} = 0.6$	−0.005	0.123	0.118	0.950	−0.003	0.124	0.118	0.935
$a_{91} = 1.2$	0.010	0.111	0.109	0.935	0.011	0.113	0.109	0.930
$a_{10,1} = 1.5$	0.010	0.149	0.150	0.970	0.013	0.149	0.150	0.975
$a_{12} = 1$	−0.002	0.051	0.054	0.975	−0.000	0.051	0.054	0.975
$a_{22} = 1$	0.004	0.056	0.057	0.955	0.003	0.057	0.056	0.955
$a_{32} = 2$	0.024	0.164	0.150	0.920	0.030	0.161	0.150	0.915
$a_{42} = 3$	0.024	0.213	0.198	0.930	0.031	0.205	0.198	0.940
$a_{52} = 1.8$	0.025	0.156	0.154	0.935	0.028	0.158	0.154	0.915
$a_{62} = 1.5$	0.012	0.124	0.118	0.935	0.010	0.124	0.118	0.935
$a_{72} = 1.3$	0.023	0.152	0.149	0.935	0.028	0.159	0.148	0.910
$a_{82} = 1.6$	0.005	0.119	0.121	0.950	0.009	0.119	0.121	0.955
$a_{92} = 2.2$	0.018	0.112	0.115	0.970	0.018	0.114	0.115	0.960
$a_{10,2} = 2.5$	0.016	0.153	0.159	0.960	0.017	0.153	0.159	0.965
$a_{13} = 2.5$	0.008	0.075	0.078	0.940	0.008	0.073	0.078	0.940
$a_{23} = 2.5$	0.005	0.081	0.080	0.945	0.005	0.080	0.080	0.965
$a_{33} = 3.5$	0.030	0.181	0.167	0.925	0.038	0.182	0.166	0.920
$a_{43} = 4.5$	0.035	0.245	0.222	0.900	0.038	0.236	0.222	0.920
$a_{53} = 3.3$	0.027	0.165	0.170	0.945	0.034	0.168	0.171	0.945
$a_{63} = 3$	0.025	0.141	0.131	0.930	0.021	0.140	0.131	0.940
$a_{73} = 2.8$	0.025	0.174	0.162	0.915	0.028	0.178	0.161	0.900
$a_{83} = 3.1$	0.016	0.128	0.135	0.965	0.019	0.126	0.135	0.970
$a_{93} = 3.7$	0.018	0.135	0.131	0.935	0.019	0.135	0.131	0.950
$a_{10,3} = 4$	0.026	0.172	0.178	0.950	0.026	0.172	0.178	0.945
$a_{14} = 5$	0.005	0.110	0.116	0.955	0.006	0.108	0.116	0.955
$a_{24} = 5$	0.012	0.118	0.119	0.970	0.014	0.120	0.119	0.950
$a_{34} = 6$	0.047	0.229	0.206	0.905	0.051	0.227	0.206	0.910
$a_{44} = 7$	0.041	0.294	0.273	0.920	0.050	0.286	0.274	0.930
$a_{54} = 5.8$	0.044	0.214	0.214	0.955	0.050	0.217	0.214	0.950
$a_{64} = 5.5$	0.033	0.173	0.166	0.945	0.021	0.168	0.166	0.960
$a_{74} = 5.3$	0.032	0.212	0.199	0.915	0.035	0.219	0.198	0.925
$a_{84} = 5.6$	0.032	0.174	0.173	0.955	0.032	0.169	0.174	0.955
$a_{94} = 6.2$	0.025	0.179	0.173	0.935	0.031	0.178	0.174	0.940
$a_{10,4} = 6.5$	0.034	0.206	0.223	0.965	0.032	0.205	0.223	0.965

Table 5: Simulation Setting II: additional simulation results from the JM and RM when data are simulated from the RM (continued).

	JM				RM			
	BIAS	SE	SD	CP	BIAS	SE	SD	CP
$b_2^{(1)} = 0.1$	0.012	0.086	0.092	0.950	0.011	0.090	0.094	0.950
$b_3^{(1)} = 1.5$	0.021	0.074	0.074	0.950	0.021	0.073	0.074	0.940
$b_4^{(1)} = 2$	0.016	0.090	0.091	0.950	0.015	0.090	0.091	0.960
$b_5^{(1)} = 0.1$	0.019	0.142	0.147	0.950	0.018	0.148	0.150	0.960
$b_6^{(1)} = 1.2$	0.011	0.052	0.052	0.930	0.007	0.051	0.051	0.955
$b_7^{(1)} = 1.6$	0.014	0.068	0.073	0.965	0.013	0.071	0.074	0.960
$b_8^{(1)} = 0.2$	0.013	0.106	0.111	0.945	0.011	0.110	0.113	0.955
$b_9^{(1)} = 0.3$	0.016	0.091	0.093	0.955	0.014	0.094	0.095	0.945
$b_{10}^{(1)} = 0.4$	0.018	0.133	0.139	0.950	0.016	0.139	0.141	0.945
$b_3^{(2)} = 0.4$	0.001	0.029	0.028	0.965	0.002	0.028	0.028	0.970
$b_4^{(2)} = 0.1$	−0.002	0.027	0.029	0.955	−0.000	0.027	0.028	0.950
$b_5^{(2)} = 1.6$	0.012	0.067	0.070	0.965	0.013	0.069	0.070	0.960
$b_6^{(2)} = 0.2$	−0.000	0.022	0.020	0.930	−0.000	0.020	0.020	0.950
$b_7^{(2)} = 0.3$	−0.000	0.027	0.027	0.935	−0.000	0.026	0.027	0.960
$b_8^{(2)} = 1.2$	0.006	0.050	0.048	0.935	0.007	0.049	0.048	0.935
$b_9^{(2)} = 1$	0.002	0.038	0.040	0.980	0.003	0.039	0.040	0.965
$b_{10}^{(2)} = 1.5$	0.007	0.061	0.064	0.955	0.007	0.060	0.064	0.950

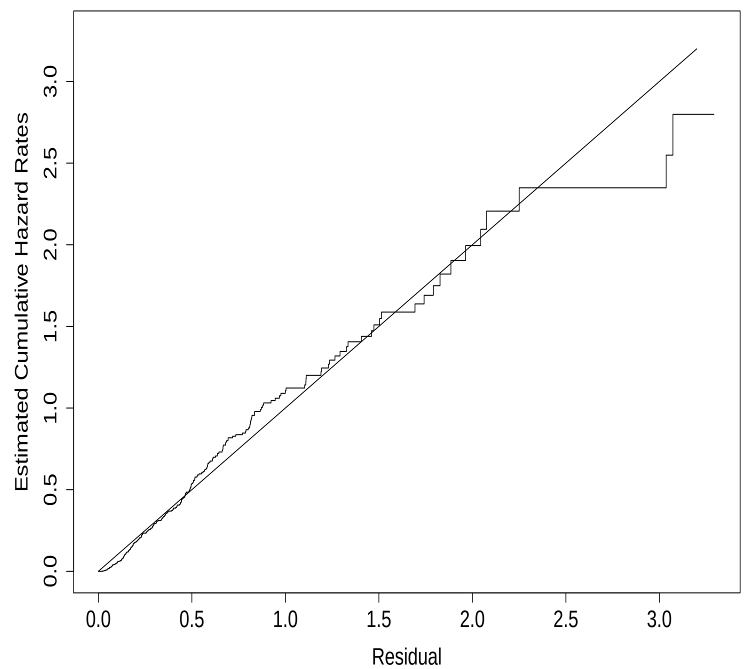

Figure 1: Cox-Snell residual plot from the JM_{3LV} model for the Ceftriaxone study.

Table 6: Parameters for covariance matrix from the JM_{3LV} model for the Ceftriaxone study.

	Mean	SD	2.5%	97.5%
σ_1	5.310	0.243	4.863	5.819
σ_2	3.899	0.198	3.507	4.296
σ_3	4.564	0.188	4.197	4.945
σ_4	4.235	0.200	3.845	4.632
σ_5	4.773	0.204	4.371	5.198
σ_6	4.430	0.224	3.997	4.888
ρ_{12}	−0.071	0.055	−0.179	0.033
ρ_{13}	0.071	0.050	−0.031	0.169
ρ_{14}	0.085	0.049	−0.010	0.184
ρ_{15}	−0.205	0.046	−0.293	−0.110
ρ_{16}	0.061	0.051	−0.036	0.160
ρ_{23}	0.110	0.050	0.013	0.208
ρ_{24}	0.732	0.031	0.665	0.787
ρ_{25}	0.120	0.050	0.017	0.212
ρ_{26}	0.672	0.035	0.600	0.740
ρ_{34}	0.002	0.051	−0.100	0.103
ρ_{35}	0.377	0.042	0.291	0.454
ρ_{36}	0.073	0.050	−0.023	0.174
ρ_{45}	0.049	0.050	−0.050	0.141
ρ_{46}	0.807	0.025	0.755	0.853
ρ_{56}	−0.009	0.052	−0.114	0.090

Table 7: Parameters $\boldsymbol{a}$ from the JM_{3LV} model for the Ceftriaxone study.

	Mean	SD	2.5%	97.5%
Speech: Extreme	0.000	-	-	-
Salivation: Extreme	−2.164	0.091	−2.343	−1.983
Swallowing: Extreme	−0.915	0.089	−1.089	−0.739
Handwriting: Extreme	−1.014	0.098	−1.199	−0.816
Cutting food: Extreme	0.000	-	-	-
Dressing and hygiene: Extreme	0.755	0.104	0.557	0.959
Turning in bed: Extreme	0.245	0.093	0.071	0.426
Walking: Extreme	0.000	-	-	-
Climbing stairs: Extreme	6.594	0.224	6.165	7.052
Breathing: Extreme	−1.883	0.073	−2.025	−1.740
Speech: Severe	2.855	0.113	2.635	3.074
Salivation: Severe	−0.814	0.079	−0.963	−0.653
Swallowing: Severe	0.743	0.086	0.568	0.908
Handwriting: Severe	0.432	0.100	0.242	0.632
Cutting food: Severe	4.239	0.120	4.006	4.476
Dressing and hygiene: Severe	3.714	0.128	3.469	3.959
Turning in bed: Severe	2.576	0.101	2.375	2.770
Walking: Severe	4.190	0.143	3.915	4.472
Climbing stairs: Severe	10.914	0.305	10.326	11.524
Breathing: Severe	−0.451	0.058	−0.568	−0.341
Speech: Moderate	6.205	0.169	5.880	6.527
Salivation: Moderate	0.779	0.079	0.625	0.937
Swallowing: Moderate	2.780	0.102	2.573	2.966
Handwriting: Moderate	2.012	0.106	1.803	2.215
Cutting food: Moderate	6.474	0.157	6.176	6.785
Dressing and hygiene: Moderate	7.282	0.174	6.938	7.617
Turning in bed: Moderate	5.117	0.128	4.877	5.377
Walking: Moderate	10.432	0.272	9.919	10.989
Climbing stairs: Moderate	11.899	0.320	11.281	12.547
Breathing: Moderate	0.882	0.059	0.769	0.994
Speech: Mild	10.318	0.253	9.816	10.826
Salivation: Mild	3.036	0.094	2.848	3.220
Swallowing: Mild	5.453	0.133	5.192	5.721
Handwriting: Mild	6.109	0.152	5.815	6.406
Cutting food: Mild	9.584	0.211	9.181	10.005
Dressing and hygiene: Mild	10.393	0.216	9.982	10.818
Turning in bed: Mild	8.218	0.167	7.896	8.535
Walking: Mild	14.391	0.352	13.722	15.095
Climbing stairs: Mild	14.481	0.374	13.792	15.236
Breathing: Mild	1.504	0.062	1.381	1.626

Table 8: Parameters $\boldsymbol{b}$ from the $\mathrm{JM}_{3\mathrm{LV}}$ model for the Ceftriaxone study.

	Mean	SD	2.5%	97.5%
Factor loading on bulbar function				
Speech	1.000	-	-	-
Salivation	0.436	0.016	0.405	0.468
Swallowing	0.554	0.020	0.515	0.594
Handwriting	−0.046	0.008	−0.061	−0.030
Cutting food	0.000	-	-	-
Dressing and hygiene	−0.037	0.008	−0.053	−0.022
Turning in bed	0.021	0.007	0.008	0.035
Walking	0.000	-	-	-
Climbing stairs	0.027	0.010	0.009	0.046
Breathing	0.095	0.006	0.083	0.107
Factor loading on fine motor function				
Speech	0.000	-	-	-
Salivation	−0.005	0.008	−0.022	0.012
Swallowing	0.030	0.009	0.012	0.048
Handwriting	0.742	0.026	0.694	0.793
Cutting food	1.000	-	-	-
Dressing and hygiene	0.673	0.023	0.630	0.720
Turning in bed	0.388	0.015	0.359	0.416
Walking	0.000	-	-	-
Climbing stairs	0.065	0.012	0.042	0.090
Breathing	0.045	0.007	0.031	0.059
Factor loading on gross motor function				
Speech	0.000	-	-	-
Salivation	−0.051	0.008	−0.067	−0.035
Swallowing	0.054	0.009	0.037	0.071
Handwriting	−0.047	0.009	−0.065	−0.030
Cutting food	0.000	-	-	-
Dressing and hygiene	0.206	0.011	0.184	0.228
Turning in bed	0.360	0.014	0.333	0.387
Walking	1.000	-	-	-
Climbing stairs	0.910	0.036	0.840	0.980
Breathing	0.104	0.007	0.090	0.119

Stan code for fitting the JM_{3LV} model

```
data {
  int<lower=0> N;
  int<lower=0> obs;
  int subject[obs]; // subject ID
  int<lower=0> K; // number of outcomes
  int<lower=0> Y[obs, K];
  int<lower=0> n_ordi;
  int<lower=0> n_theta;
  int<lower=0> n_rho;
  vector[n_theta*2] zero;
  real<lower=0> time[obs];
  int<lower=0> treat[obs];
  real<lower=0> fvc[obs];
  // survival data
  int<lower=0> treat_pts[N];
  real<lower=0> fvc_pts[N];
  int<lower=0> event[N];
  int IO[N, 3];
  real dt1[N, 3];
}
parameters {
  vector[5] beta[n_theta];

  vector[n_theta*2] U[N];
  real<lower=0> Var[n_theta*2];
  real<lower=-1, upper=1> rho[n_rho];
  vector[obs] e[n_theta];
  real<lower=0> Var_e[n_theta];

  real a_random[K-n_theta];
  vector[n_theta] b_random[K-n_theta];
  vector<lower=0>[n_ordi-2] delta[K];
  // survival parameters
  real gam[2];
  real nu[n_theta*2];
  real<lower=0> g[3];
}
transformed parameters {
  cov_matrix[n_theta*2] Sigma_U;
  vector[n_ordi-1] a[K];
  vector[n_theta] b[K];
  vector[n_theta] theta[obs];
  real<lower=0, upper=1> psi[obs, K, n_ordi];
  vector<lower=0, upper=1>[n_ordi] prob_y[obs, K];
  real<lower=0> sig[n_theta*2];
  real<lower=0> sd_e[n_theta];

  // construct the probability vector for the ordinal variables
  for (k in 1:n_theta) {
    a[k, 1] <- 0;
    for (l in 2:(n_ordi-1)) {
      a[k, l] <- a[k, l-1] + delta[k, l-1] ;
    }
  }
  for (k in (n_theta+1):K) {
    a[k, 1] <- a_random[k-n_theta];
    for (l in 2:(n_ordi-1)) a[k, l] <- a[k, l-1] + delta[k, l-1];
  }

  for (k1 in 1:(n_theta-1)) {
    for (k2 in (k1+1):n_theta) {
      b[k1, k2] <- 0; // upper triangle = 0
      b[k2, k1] <- 0; // lower triangle = 0
    }
```

```
  }
  for (k in 1:n_theta)
    b[k, k] <- 1; // diag = 1
    for (k in (n_theta+1):K)
      b[k] <- b_random[k-n_theta];

    // construct the latent variable theta
    for (p in 1:n_theta) {
      for (i in 1:obs) {
        theta[i, p] <- beta[p, 1] + beta[p, 2]*treat[i] + beta[p, 3]*time[i] + beta[p, 4]*treat[i]*time[i] +
         beta[p, 5]*fvc[i] + U[subject[i], 2*p-1] + U[subject[i], 2*p]*time[i] + e[p, i];
      }
    }

    for (i in 1:obs) {
      for (k in 1:K) {
        for (l in 1:(n_ordi-1)) {
          psi[i, k, l] <- inv_logit(a[k, l] - to_row_vector(b[k])*theta[i]); // b[k, 1]*theta[i, 1] + b[k, 2]*theta[i, 2]
        }
        psi[i, k, n_ordi] <- 1;

        prob_y[i, k, 1] <- psi[i, k, 1];
        for (l in 2:n_ordi) {prob_y[i, k, l] <- psi[i, k, l] - psi[i, k, l-1];}
      }
    }

    // construct the variance-covariance matrix
    for (p in 1:(n_theta*2)) {
      sig[p] <- sqrt(Var[p]);
      Sigma_U[p, p] <- Var[p];
    }
    Sigma_U[1,2] <- rho[1]*sig[1]*sig[2];
    Sigma_U[2,1] <- Sigma_U[1,2];
    Sigma_U[1,3] <- rho[2]*sig[1]*sig[3];
    Sigma_U[3,1] <- Sigma_U[1,3];
    Sigma_U[1,4] <- rho[3]*sig[1]*sig[4];
    Sigma_U[4,1] <- Sigma_U[1,4];
    Sigma_U[1,5] <- rho[4]*sig[1]*sig[5];
    Sigma_U[5,1] <- Sigma_U[1,5];
    Sigma_U[1,6] <- rho[5]*sig[1]*sig[6];
    Sigma_U[6,1] <- Sigma_U[1,6];
    Sigma_U[2,3] <- rho[6]*sig[2]*sig[3];
    Sigma_U[3,2] <- Sigma_U[2,3];
    Sigma_U[2,4] <- rho[7]*sig[2]*sig[4];
    Sigma_U[4,2] <- Sigma_U[2,4];
    Sigma_U[2,5] <- rho[8]*sig[2]*sig[5];
    Sigma_U[5,2] <- Sigma_U[2,5];
    Sigma_U[2,6] <- rho[9]*sig[2]*sig[6];
    Sigma_U[6,2] <- Sigma_U[2,6];
    Sigma_U[3,4] <- rho[10]*sig[3]*sig[4];
    Sigma_U[4,3] <- Sigma_U[3,4];
    Sigma_U[3,5] <- rho[11]*sig[3]*sig[5];
    Sigma_U[5,3] <- Sigma_U[3,5];
    Sigma_U[3,6] <- rho[12]*sig[3]*sig[6];
    Sigma_U[6,3] <- Sigma_U[3,6];
    Sigma_U[4,5] <- rho[13]*sig[4]*sig[5];
    Sigma_U[5,4] <- Sigma_U[4,5];
    Sigma_U[4,6] <- rho[14]*sig[4]*sig[6];
    Sigma_U[6,4] <- Sigma_U[4,6];
    Sigma_U[5,6] <- rho[15]*sig[5]*sig[6];
    Sigma_U[6,5] <- Sigma_U[5,6];
    for (p in 1:n_theta)
      sd_e[p] <- sqrt(Var_e[p]);
}
model {
```

```
  real h[N];
  real S[N];
  real LL[N];
  vector[3] h0[N];
  vector[3] gt[N];

  // construct random effects and random errors
  U ~ multi_normal(zero, Sigma_U);
  for (p in 1:n_theta)
    e[p] ~ normal(0, sd_e[p]);

  for (i in 1:obs) {
    for (k in 1:K) {
      Y[i, k] ~ categorical(prob_y[i, k]);
    }
  }

  // construct survival part
  for (i in 1:N) {
    for (k in 1:3) {
      h0[i,k] <- g[k]*I0[i,k];
      gt[i,k] <- g[k]*dt1[i,k];
    }

    h[i] <- exp(gam[1]*treat_pts[i] + gam[2]*fvc_pts[i] + nu[1]*U[i, 1] + nu[2]*U[i, 2] + nu[3]*U[i, 3] +
                nu[4]*U[i, 4] + nu[5]*U[i, 5] + nu[6]*U[i, 6])*sum(h0[i]);
    S[i] <- exp(-(exp(gam[1]*treat_pts[i] + gam[2]*fvc_pts[i] + nu[1]*U[i, 1] + nu[2]*U[i, 2] + nu[3]*U[i, 3] +
                nu[4]*U[i, 4] + nu[5]*U[i, 5] + nu[6]*U[i, 6])*sum(gt[i])));
    LL[i] <- log(pow(h[i],event[i])*S[i]);  // event=1 for event; 0 for censored

  }
  increment_log_prob(LL);

  // construct the priors
  for (k in 1:K) {
    for (l in 1:(n_ordi-2)) {
      delta[k, l] ~ normal(0, 10) T[0,] ;
    }
  }
  for (k in 1:(K-n_theta)) {
    b_random[k] ~ normal(0, 10);
  }
  a_random ~ normal(0, 10);

  for (p in 1:n_theta) {
    beta[p] ~ normal(0, 10);
  }
  Var ~ inv_gamma(0.01, 0.01);
  rho ~ uniform(-1, 1);
  Var_e ~ inv_gamma(0.01, 0.01);

  gam ~ normal(0, 10);
  nu ~ normal(0, 10);
  g ~ gamma(0.01, 0.01);
}
```