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Transitions in Depressive Symptoms After 10 Years of Follow-up Using PROC LTA

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ABSTRACT

PROC LTA is by far the most popular and powerful SAS procedure for latent transition analysis used throughout a wide variety of scientific disciplines. However, few have reported easy-to-understand explanation with the example SAS code on examining transitions in latent statuses.

This paper provides an in-depth analysis, with some explanation of the SAS code, to examine transitions in latent statuses of depressive symptoms after 10 years of follow-up using PROC LTA. The author also examined whether clinical characteristics predicted membership in the different statuses and predicted transitions between latent statuses over time. Examples of using PROC LTA are drawn from the Baltimore Epidemiologic Catchment Area Study.

This paper gently guides all SAS users—even those with limited in statistics or who have never used SAS—through a step-by-step approach to using SAS for latent transition analysis and interpret the results. Moreover, this paper is ideally suited to students who are beginning their study of social and behavioral health sciences and to professors and research professionals who are researching in the fields in epidemiology, clinical psychology, or health services research.

CASE STUDY: BALTIMORE EPIDEMIOLOGIC CATCHMENT AREA FOLLOW-UP

The Baltimore Epidemiologic Catchment Area (ECA) Follow-up Study was a population-based longitudinal survey designed to measure the prevalence and incidence of psychiatric disorders over the adult life course (1-3).

Depressive symptoms were assessed for 1,023 adult household residents twice, in 1994 and 2004. The variables are as follows:

symptom1	is the 1st depressive symptom, dysphoria (1 = present; 2 = absent).
symptom2	is the 2nd depressive symptom, anhedonia (1 = present; 2 = absent).
symptom3	is the 3rd depressive symptom, changes in appetite (1 = present; 2 = absent).
symptom4	is the 4th depressive symptom, sleep disturbances (1 = present; 2 = absent).
symptom5	is the 5th depressive symptom, restlessness (1 = present; 2 = absent).
symptom6	is the 6th depressive symptom, tiredness (1 = present; 2 = absent).
symptom7	is the 7th depressive symptom, worthlessness (1 = present; 2 = absent).
symptom8	is the 8th depressive symptom, thinking problems (1 = present; 2 = absent).
symptom9	is the 9th depressive symptom, suicidal thoughts or behavior (1 = present; 2 = absent).
heart	1 = lifetime heart disease; 0 = no lifetime heart disease.
diabetes	1 = lifetime diabetes; 0 = no lifetime diabetes.
cancer	1 = lifetime cancer; 0 = no lifetime cancer.

Table 1 provides depressive symptoms in 2004 by depressive symptoms assessed in 1994.

Table 1. Depressive symptoms in 1994 vs. 2004 (*N* = 1,023)				
Had depressive symptom in 1994?	**Yes**	**Yes**	**No**	**No**
Had depressive symptom in 2004?	**Yes**	**No**	**Yes**	**No**
Dysphoria	147 (48%)	161 (52)	115 (16)	597 (84)
Anhedonia	38 (38)	62 (62)	46 (5)	870 (95)
Appetite	133 (51)	126 (49)	191 (25)	571 (75)
Sleep	128 (50)	127 (50)	165 (22)	602 (78)
Slow or Restless	27 (26)	77 (74)	70 (8)	847 (92)
Tired	69 (45)	86 (55)	129 (15)	737 (85)
Worthless	49 (38)	79 (62)	74 (8)	818 (92)
Thinking Problems	46 (38)	75 (62)	83 (9)	816 (91)
Suicidal Thoughts or Behavior	121 (49)	127 (51)	103 (13)	670 (87)

Note: Numbers in parentheses are row percentages, stratified by presence of a depressive symptom in 1994.

In general, depressive symptoms that were absent in 1994 were likely also to be absent in 2004. Of particular interest is that a substantial proportion of adults had persistent depressive symptoms over the 10-year period.

To study nine depressive symptoms as a pattern or set of latent variables in contrast to a focus on individual symptoms, we applied the latent transition model (4, 5). This model provides for simultaneous estimation: (i) latent status prevalences, (ii) item-response probabilities, and (iii) transition probabilities. In addition, latent transition analysis appears to be an informative model for examining predictors of transitions from one status of symptoms to another.

The likelihood ratio G^2 statistic, degree of freedom, Akaike Information Criterion (AIC), and Bayesian Information Criteria (BIC) (6) for models with two, three, and four latent statuses appear in **Table 2**. The BIC was used to compare non-nested models that differed in the number of latent statuses. A smaller value of BIC indicates a better model fit. The 3-status model is preferred over 2- and 4-status models based on the BIC (BIC_3 = 3730.53, BIC_4 = 3753.95, and BIC_2 = 4091.71) and model interpretability.

Table 2. Model fit information used in selecting the LTA model (*N* = 1,023).					
Number of Latent Statuses	**Number of Parameters Estimated**	**Likelihood Ratio G^2**	**Degree of Freedom**	**AIC**	**BIC**
2	21	3946.17	262122	3988.17	4091.71
3	**35**	**3487.96**	**262108**	**3557.96**	**3730.53**
4	51	3400.49	262092	3502.49	3753.95

Note: Bold font indicates the selected model.

Three parameter estimations (i.e., latent status prevalences, item-response probabilities, and transition probabilities) from the 3-status model of depressive symptoms appear in **Table 3**.

Table 3. Three-latent-status model of depressive symptoms (*N* = 1,023).			
	Latent status		
	None	**Mild**	**Severe**
Latent status prevalences			
1994	0.619	0.268	0.113
2004	0.574	0.331	0.094
Item-response probabilities*			
Dysphoria			
Yes	0.058	**0.501**	**0.915**
No	**0.943**[†]	0.499	0.085
Anhedonia			
Yes	0.001	0.081	**0.634**
No	**0.999**	**0.919**	0.366
Appetite			
Yes	0.094	0.477	**0.832**
No	**0.907**	**0.523**	0.168
Sleep			
Yes	0.058	0.474	**0.879**
No	**0.942**	**0.526**	0.121
Slow or Restless			
Yes	0.009	0.127	**0.527**
No	**0.991**	**0.873**	0.474
Tired			
Yes	0.013	0.293	**0.746**
No	**0.988**	**0.707**	0.254
Worthless			
Yes	0.008	0.152	**0.701**
No	**0.992**	**0.848**	0.299
Thinking Problems			
Yes	0.003	0.133	**0.777**
No	**0.997**	**0.868**	0.223
Suicidal Thoughts or Behavior			
Yes	0.067	0.375	**0.762**
No	**0.933**	**0.625**	0.238
Transition probabilities		*2004 latent status*	
1994 latent status			
None	**0.771**[‡]	0.194	0.036
Mild	0.334	**0.617**	0.049
Severe	0.067	0.410	**0.523**

*Constrained equal across waves.

[†]Item-response probabilities > 0.5 in bold to facilitate interpretation.

[‡]Diagonal transition probabilities in bold to facilitate interpretation.

Parameter restrictions were imposed so that the item-response probabilities are equal across the two times and the meaning of the latent statuses remains constant over time (5).

Item-response probabilities greater than 0.5 are in bold font in the second section of **Table 3**. Adults in the first latent status were likely to report that they have never experienced depressive symptoms. This overall pattern suggests that this latent status could be labeled "nondepressed." In contrast, adults in the third latent status were likely to report that they have experienced all nine symptoms, suggesting that this latent status could be labeled "severe depression." Patterns of depressive symptoms in the second latent status behaved somewhere between the two latent statuses above, suggesting that this latent status could be labeled "mild depression."

The prevalences of the three latent statuses appear in the first section of **Table 3**. In 1994, the nondepressed latent status (61.9%) was the most prevalent, followed by the mild and severe depression statuses (26.8% and 11.3%). The overall prevalences were similar in 2004.

Transition probability estimates are shown in the third section of **Table 3**. The probability that adults were in the same status at follow-up as at baseline was 0.771 for "nondepressed," 0.617 for "mild depression," and 0.523 for "severe depression." Adults in the severe depression latent status at baseline were the most likely to transition to another status across time (41% to mild depression and 6.7% to nondepressed status). Of particular interest is that 23% of the persons in the nondepressed latent status at baseline transitioned to the mild or severe depression statuses at follow-up.

Next, we examined whether clinical characteristics predicted membership in the different statuses in 1994. The three covariates were self-reported lifetime heart disease, lifetime diabetes, and lifetime cancer (results are shown below in **Table 4**).

Table 4. Odds ratio for predictors of latent status membership in 1994 (*N* = 1,023).

	Latent status		
Covariate	**None**	**Mild**	**Severe**
heart disease	Reference	1.75	1.79
diabetes	Reference	1.20	1.39
cancer	Reference	1.00	1.10

Note: All covariates entered simultaneously as predictors of 1994 latent status membership.

We found that adults who reported lifetime heart disease, diabetes, or cancer were 79%, 39%, and 10% more likely, respectively, to be in the severe depression latent status relative to the nondepressed status. Similarly, adults with lifetime heart disease or diabetes were 75% and 20% more likely to be in the mild depression latent status relative to the nondepressed status. As shown below in **Table 5**, however, lifetime diabetes (p = 0.61) and lifetime cancer (p = 0.98) were not significant predictors of 1994 latent status membership. Lifetime heart disease was marginally significant (p = 0.07).

Table 5. Hypothesis tests for predictors of membership in latent statuses of depressive symptoms in 1994 (*N* = 1,023).

Covariate	**l Removing Covariate**	**Likelihood-Ratio Statistic**	**Degree of Freedom**	***P***
heart disease	-6,210.96	5.21	2	0.07
diabetes	-6,208.84	0.98	2	0.61
cancer	-6,208.37	0.03	2	0.98

Additionally, we examined whether the clinical characteristics are significant predictors of transitions between latent statuses of depressive symptoms. Estimates of odds ratios for the transitions from the nondepressed latent status into the severe or mild depression statuses appear in **Table 6**.

Table 6. Odds ratios reflecting the effects of medical conditions on transition from nondepressed latent status in 1994 to severe or mild depression latent statuses in 2004 (*N* = 1,023).

	Latent status		
Covariate	**None**	**Mild**	**Severe**
heart disease	Reference	3.23	0.59
diabetes	Reference	1.04	0.67
cancer	Reference	1.91	1.15

Note: All covariates entered simultaneously as predictors of 1994 latent status membership and transition probabilities.

The largest odds ratio, 3.23, was associated with lifetime heart disease as a predictor of membership in the mild depression latent status in 2004 relative to membership in the nondepressed status in 2004 for adults from the nondepressed status in 1994. Stated differently, among adults who were in the nondepressed latent status in 1994, those who reported lifetime heart disease were about three times as likely to be in the mild depression status in 2004 relative to the nondepressed status than were the adults who did not report lifetime heart disease.

Cancer is also associated with an increased odds of transitioning from the nondepressed status to the mild depression status relative to remaining in the same nondepressed status over time (odds ratio = 1.91).

STATISTICAL ANALYSIS USING SAS

Here is the code for analyzing the latent transition models with PROC LTA for the Baltimore ECA data:

```
* ==========  Table 2  ========== *;
PROC LTA DATA=stat2;
    nstatus 2;
    *nstatus 3;
    *nstatus 4;
    ntimes 2;
    items   symptom11-symptom19
            symptom21-symptom29;
    categories 2 2 2 2 2 2 2 2 2;
    measurement times;
    seed 592667;
RUN;


* ==========  Table 3  ========== *;
PROC LTA DATA=stat2;
    nstatus 3;
    ntimes 2;
    items   symptom11-symptom19
            symptom21-symptom29;
    categories 2 2 2 2 2 2 2 2 2;
    measurement times;
```

```
    seed 592667;
RUN;


* ==========  Table 4 – Table 5  ========== *;
PROC LTA DATA=stat2;
    nstatus 3;
    ntimes 2;
    items   symptom11-symptom19
            symptom21-symptom29;
    categories 2 2 2 2 2 2 2 2 2;
    covariates1 heart diabetes cancer;
    reference1 2; /* ref = nondepressed */
    measurement times;
    seed 592667;
RUN;

* ==========  Table 6  ========== *;
PROC LTA DATA=stat2;
    nstatus 3;
    ntimes 2;
    items   symptom11-symptom19
            symptom21-symptom29;
    categories 2 2 2 2 2 2 2 2 2;
    covariates2 heart diabetes cancer;
    reference2 2; /* ref = nondepressed */
    measurement times;
    beta prior = 1;
    seed 592667;
RUN;
```

The BETA PRIOR statement was used in **Table 6** to invoke a stabilizing prior distribution on the β parameters so that it solves most sparseness-related estimation problems (7).

DISCUSSION

Recent decades have seen tremendous applications of latent transition analysis in various academic fields. However, few have reported step-by-step instructions to perform each technique in SAS. In this paper, we examined whether clinical characteristics were more or less likely to predict membership in the different statuses of depressive symptoms and predict transitions between latent statuses over time using the PROC LTA procedure in SAS. The emphasis is on statistical tools and model interpretations which are useful in social and behavioral health studies.

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