Example 41g — Two-level multinomial logistic regression (multilevel)

Description

We demonstrate two-level multinomial logistic regression with random effects by using the following data:

```
. use https://www.stata-press.com/data/r17/gsem_lineup
(Fictional suspect identification data)
. describe
Contains data from https://www.stata-press.com/data/r17/gsem_lineup.dta
Observations: 6,535 Fictional suspect identification data
Variables: 6
29 Mar 2020 10:35
(_dta has notes)
```

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Storage type</th>
<th>Display format</th>
<th>Value label</th>
<th>Variable label</th>
</tr>
</thead>
<tbody>
<tr>
<td>suspect</td>
<td>int</td>
<td>%9.0g</td>
<td></td>
<td>Suspect ID</td>
</tr>
<tr>
<td>suswhite</td>
<td>byte</td>
<td>%9.0g</td>
<td></td>
<td>Suspect is white</td>
</tr>
<tr>
<td>violent</td>
<td>byte</td>
<td>%9.0g</td>
<td></td>
<td>Violent crime</td>
</tr>
<tr>
<td>location</td>
<td>byte</td>
<td>%14.0g</td>
<td>loc</td>
<td>Lineup location</td>
</tr>
<tr>
<td>witmale</td>
<td>byte</td>
<td>%9.0g</td>
<td></td>
<td>Witness is male</td>
</tr>
<tr>
<td>chosen</td>
<td>byte</td>
<td>%9.0g</td>
<td>choice</td>
<td>Individual identified in lineup by witness</td>
</tr>
</tbody>
</table>

Sorted by: suspect

```
. notes
_dta:
2. Data contain repeated values of variable suspect. Each suspect is viewed by multiple witnesses and each witness (1) declines to identify a suspect, (2) chooses a foil, or (3) chooses the suspect.
```

```
. tabulate location
Lineup location | Freq. | Percent | Cum. |
----------------|-------|---------|------|
Police_station  | 2,228 | 34.09   | 34.09|
Suite_1         | 1,845 | 28.23   | 62.33|
Suite_2         | 2,462 | 37.67   | 100.00|
Total           | 6,535 | 100.00  |      |
```

1
. tabulate chosen

<table>
<thead>
<tr>
<th>Individual identified in lineup by witness</th>
<th>Freq.</th>
<th>Percent</th>
<th>Cum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>2,811</td>
<td>43.01</td>
<td>43.01</td>
</tr>
<tr>
<td>Foil</td>
<td>1,369</td>
<td>20.95</td>
<td>63.96</td>
</tr>
<tr>
<td>Suspect</td>
<td>2,355</td>
<td>36.04</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Total | 6,535 | 100.00 |

In what follows, we re-create results similar to those of Wright and Sparks (1994), but we use fictional data. These data resemble the real data used by the authors in proportion of observations having each level of the outcome variable chosen, and the data produce results similar to those presented by the authors.

See Structural models 6: Multinomial logistic regression and Multilevel mixed-effects models in [SEM] Intro 5 for background.

For additional discussion of fitting multilevel multinomial logistic regression models, see Skrondal and Rabe-Hesketh (2003).

Remarks and examples

Remarks are presented under the following headings:

- Two-level multinomial logistic model with shared random effects
- Two-level multinomial logistic model with separate but correlated random effects
- Fitting the model with the Builder

Two-level multinomial logistic model with shared random effects

We wish to fit the following model:
This model concerns who is chosen in a police lineup. The response variables are 1.chosen, 2.chosen, and 3.chosen, meaning chosen = 1 (code for not chosen), chosen = 2 (code for foil chosen), and chosen = 3 (code for suspect chosen). A foil is a stand-in who could not possibly be guilty of the crime.

We say the response variables are 1.chosen, 2.chosen, and 3.chosen, but 1.chosen does not even appear in the diagram. By its omission, we are specifying that chosen = 1 be treated as the base mlogit category. There are other ways we could have drawn this; see [SEM] Example 37g.

In these data, each suspect was viewed by multiple witnesses. In the model, we include a random effect at the suspect level, and we constrain the effect to be equal for chosen values 2 and 3 (selecting the foil or the suspect).

We can fit this model with command syntax by typing
. gsem (i.chosen <- i.location i.suswhite i.witmale i.violent M1[suspect]@1), 
> mlogit

Fitting fixed-effects model:
Iteration 0: log likelihood = -6914.9098
Iteration 1: log likelihood = -6696.7136
Iteration 2: log likelihood = -6694.0006
Iteration 3: log likelihood = -6693.9974
Iteration 4: log likelihood = -6693.9974

Refining starting values:
Grid node 0: log likelihood = -6705.0919

Fitting full model:
Iteration 0: log likelihood = -6705.0919 (not concave)
Iteration 1: log likelihood = -6654.5724
Iteration 2: log likelihood = -6653.5717
Iteration 3: log likelihood = -6653.5671
Iteration 4: log likelihood = -6653.5671

Generalized structural equation model
Number of obs = 6,535
Response: chosen
Base outcome: 1
Family: Multinomial
Link: Logit
Log likelihood = -6653.5671

( 1) [2.chosen]M1[suspect] = 1
( 2) [3.chosen]M1[suspect] = 1

| Coefficient Std. err. | z    | P>|z| | [95% conf. interval] |
|-----------------------|------|------|----------------------|
| 1.chosen (base outcome)|      |      |                      |
| 2.chosen
| location Suite_1      | .3867066 | .1027161 | 3.76 | 0.000 | .1853868 | .5880264 |
| Suite_2                | .4915675 | .0980312 | 5.01 | 0.000 | .2994299 | .6837051 |
| 1.suswhite             | -.0275501 | .0751664 | -0.37 | 0.714 | -.1748736 | .1197734 |
| 1.witmale              | -.0001844 | .0680803 | -0.00 | 0.998 | -.1336193 | .1332505 |
| 1.violent             | .0356477 | .0773658 | 0.46 | 0.645 | -.1159864 | .1872819 |
| M1[suspect] 1 (constrained) | | | | |
| _cons                 | -1.002334 | .099323 | -10.09 | 0.000 | -1.197003 | -.8076643 |

3.chosen
| location Suite_1      | -.2832042 | .0936358 | -3.02 | 0.002 | -.4667271 | -.0996814 |
| Suite_2                | .1391796 | .0863473 | 1.61 | 0.107 | -.0300581 | .3084172 |
| 1.suswhite             | -.2397561 | .0643075 | -3.73 | 0.000 | -.3657965 | -.1137158 |
| 1.witmale              | .1419285 | .059316 | 2.39 | 0.017 | .0256712 | .2581857 |
| 1.violent             | -1.376579 | .0885126 | -15.55 | 0.000 | -1.55006 | -1.203097 |
| M1[suspect] 1 (constrained) | | | | |
| _cons                 | .1781047 | .0833393 | 2.14 | 0.033 | .0147627 | .3414468 |

| var( M1[suspect]) | .2538014 | .0427302 | 18.24673 | 35.30228 |

4 Example 41g — Two-level multinomial logistic regression (multilevel)
Notes:

1. We show the interpretation of mlogit coefficients in [SEM] Example 37g.

2. The estimated variance of the random effect is 0.2538, implying a standard deviation of 0.5038. Thus a 1-standard-deviation change in the random effect amounts to a \( \exp(0.5038) = 1.655 \) change in the relative-risk ratio. The effect is both practically significant and, from the output, statistically significant.

3. This is not the model fit by Wright and Sparks (1994). Those authors did not constrain the random effect to be the same for chosen equal to 2 and 3. They included separate but correlated random effects, and then took that even a step further.

**Two-level multinomial logistic model with separate but correlated random effects**

The model we wish to fit is

![Diagram of the model](image)

This is one of the models fit by Wright and Sparks (1994), although remember that we are using fictional data.

We can fit this model with command syntax by typing

```
. gsem (2.chosen <- i.location i.suswhite i.witmale i.violent M1[suspect]) ///
> (3.chosen <- i.location i.suswhite i.witmale i.violent M2[suspect]), ///
> mlogit
```

We did not even mention the assumed covariance between the random effects because latent exogenous variables are assumed to be correlated in the command language. Even so, we can specify the `cov()` option if we wish, and we might do so for emphasis or because we are unsure whether the parameter would be included.
Example 41g — Two-level multinomial logistic regression (multilevel)

```
. gsem (2.chosen <- i.location i.suswhite i.witmale i.violent M1[suspect])
>     (3.chosen <- i.location i.suswhite i.witmale i.violent M2[suspect]),
>     cov(M1[suspect]*M2[suspect]) mlogit
Fitting fixed-effects model:
Iteration 0:  log likelihood = -6914.9098
Iteration 1:  log likelihood = -6696.7136
Iteration 2:  log likelihood = -6694.0006
Iteration 3:  log likelihood = -6693.9974
Iteration 4:  log likelihood = -6693.9974
Refining starting values:
Grid node 0:  log likelihood = -6793.4228
Fitting full model:
Iteration 0:  log likelihood = -6793.4228  (not concave)
Iteration 1:  log likelihood = -6717.7507  (not concave)
Iteration 2:  log likelihood = -6684.6592
Iteration 3:  log likelihood = -6660.1404
Iteration 4:  log likelihood = -6652.1368
Iteration 5:  log likelihood = -6651.7841
Iteration 6:  log likelihood = -6651.7819
Iteration 7:  log likelihood = -6651.7819
Generalized structural equation model  Number of obs = 6,535
Response: chosen
Base outcome: 1
Family: Multinomial
Link: Logit
Log likelihood = -6651.7819
( 1) [2.chosen]M1[suspect] = 1
( 2) [3.chosen]M2[suspect] = 1

| Coefficient | Std. err. | z    | P>|z| | [95% conf. interval] |
|-------------|-----------|------|------|----------------------|
| 1.chosen    | (base outcome) |
|             |           |      |      |                      |
| 2.chosen    |           |      |      |                      |
| location    |           |      |      |                      |
| Suite_1     | 0.3881676 | 0.1004754 | 3.86 | 0.000 | 0.1912394 | 0.5850958 |
| Suite_2     | 0.48938   | 0.0960311 | 5.10 | 0.000 | 0.3011625 | 0.6775974 |
| 1.suswhite  | -0.0260152 | 0.0749378 | -0.35 | 0.728 | -0.1728906 | 0.1208602 |
| 1.witmale   | -0.0007652 | 0.0679187 | -0.01 | 0.991 | -0.1338833 | 0.132353  |
| 1.violent   | 0.0369381  | 0.0771594 | 0.48  | 0.632 | -0.1142915 | 0.1881677 |
| M1[suspect] | 1 (constrained) |
| _cons       | -1.000382 | 0.0992546 | -10.08 | 0.000 | -1.194918 | -0.8058469 |
| 3.chosen    |           |      |      |                      |
| location    |           |      |      |                      |
| Suite_1     | -0.2904225 | 0.0968578 | -3.00 | 0.003 | -0.4802604 | -0.1005847 |
| Suite_2     | 0.1364246  | 0.089282 | 1.53  | 0.127 | -0.0385649 | 0.3114142 |
| 1.suswhite  | -0.2437654 | 0.0647275 | -3.77 | 0.000 | -0.370629  | -0.1169018 |
| 1.witmale   | 0.139826   | 0.0596884 | 2.34  | 0.019 | 0.0228389  | 0.256813   |
| 1.violent   | -1.388013  | 0.0891863 | -15.56 | 0.000 | -1.562815  | -1.213212  |
| M2[suspect] | 1 (constrained) |
| _cons       | 0.1750622  | 0.0851614 | 2.06  | 0.040 | 0.008149   | 0.3419754  |
```
Example 41g — Two-level multinomial logistic regression (multilevel) 7

<table>
<thead>
<tr>
<th>var(</th>
<th>M1[suspect])</th>
<th>.2168248</th>
<th>.0549321</th>
<th>.131965</th>
<th>.3562533</th>
</tr>
</thead>
<tbody>
<tr>
<td>var(</td>
<td>M2[suspect])</td>
<td>.2978104</td>
<td>.0527634</td>
<td>.2104416</td>
<td>.421452</td>
</tr>
<tr>
<td>cov(</td>
<td>M1[suspect], M2[suspect])</td>
<td>.2329749</td>
<td>.0438721</td>
<td>5.31</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Notes:
1. The estimated variances of the two random effects are 0.2168 and 0.2978, which as explained in the second note of above example, are both practically and statistically significant.
2. The covariance is estimated to be 0.2300. Therefore, $0.2300 / \sqrt{0.2168 \times 0.2978} = 0.9052$ is the estimated correlation.
3. Wright and Sparks (1994) were interested in whether the location of the lineup mattered. They found that it did, and that foils were more likely to be chosen at lineups outside of the police station (at the two “specialist” suites). They speculated the cause might be that the police at the station strongly warn witnesses against misidentification, or possibly because the specialist suites had better foils.

Fitting the model with the Builder

Use the first diagram in Two-level multinomial logistic model with shared random effects above for reference.

1. Open the dataset.
   In the Command window, type
   ```
   . use https://www.stata-press.com/data/r17/gsem_lineup
   ```

2. Open a new Builder diagram.
   Select menu item Statistics > SEM (structural equation modeling) > Model building and estimation.

3. Put the Builder in gsem mode by clicking on the $\infty$ button.

4. Create the independent variables.
   Select the Add observed variables set tool, and then click near the bottom of the diagram about one-third of the way in from the left.
   In the resulting dialog box,
   a. select the Select variables radio button (it may already be selected);
   b. include the levels of the factor variable location by clicking on the button next to the Variables control. In the resulting dialog box, select the Factor variable radio button, select Main effect in the Specification control, and select location in the Variables control for Variable 1. Click on Add to varlist, and then click on OK;
   c. type 1.suswhite 1.witmale 1.violent in the Variables control after i.location (typing 1.varname rather than using the button to create them as i.varname factor variables prevents rectangles corresponding to the base categories for these binary variables from being created);
5. Create the rectangles for the possible outcomes of the multinomial endogenous variable.

Select the Add observed variables set tool, “set”, and then click in the diagram about one-third of the way in from the right and one-fourth of the way up from the bottom.

In the resulting dialog box,

a. select the Select variables radio button (it may already be selected);

b. check Make variables generalized responses;

c. select Multinomial, Logit in the Family/Link control;

d. select chosen in the Variable control;

e. under Levels, remove 1b to prevent the rectangle corresponding to the base category from being created;

f. select Vertical in the Orientation control;

g. select the Distances tab;

h. select .5 (inch) from the from the Distance between variables control;

i. click on OK.

6. Create the paths from the independent variables to the rectangles for outcomes chosen = 2 and chosen = 3.

a. Select the Add path tool, “”.

b. Click in the right side of the 1b.location rectangle (it will highlight when you hover over it), and drag a path to the left side of the 2.chosen rectangle (it will highlight when you can release to connect the path).

c. Continuing with the “” tool, click in the right side of each independent variable and drag a path to both the 2.chosen and 3.chosen rectangles.

7. Create the suspect-level latent variable.

a. Select the Add multilevel latent variable tool, “”, and click near the right side of the diagram, vertically centered between 2.chosen and 3.chosen.

b. In the Contextual Toolbar, click on the “” button.

c. Select the nesting level and nesting variable by selecting 2 from the Nesting depth control and selecting suspect > Observations in the next control.

d. Specify M1 as the Base name.

e. Click on OK.

8. Create the paths from the multilevel latent variable to the rectangles for outcomes chosen = 2 and chosen = 3.

a. Select the Add path tool, “”.

b. Click in the upper-left quadrant of the suspect_{1} double oval, and drag a path to the right side of the 2.chosen rectangle.
c. Continuing with the tool, click in the lower-left quadrant of the suspect\textsubscript{1} double oval, and drag a path to the right side of the 3.chosen rectangle.

9. Place constraints on path coefficients from the multilevel latent variable.

Use the Select tool, , to select the path from the suspect\textsubscript{1} double oval to the 2.chosen rectangle. Type 1 in the # box in the Contextual Toolbar and press Enter. Repeat this process to constrain the coefficient on the path from the suspect\textsubscript{1} double oval to the 3.chosen rectangle to 1.

10. Clean up the location of the paths.

If you do not like where the paths have been connected to the rectangles, use the Select tool, , to click on the path, and then simply click on where it connects to a rectangle and drag the endpoint.

11. Estimate.

Click on the Estimate button, , in the Standard Toolbar, and then click on OK in the resulting GSEM estimation options dialog box.

12. If you wish to fit the model described in Two-level multinomial logistic model with separate but correlated random effects, use the Select tool to select the path from the suspect\textsubscript{1} double oval to the 3.chosen rectangle in the diagram created above. Select Object > Delete from the SEM Builder menu.

Using the Select tool, select the suspect\textsubscript{1} double oval and move it up so that it is parallel with the rectangle for 2.chosen.

13. Create the multilevel latent variable corresponding to the random effects of suspect in the 3.chosen equation.

a. Select the Add multilevel latent variable tool, , and click near the right side of the diagram, next to the 3.chosen rectangle.

b. In the Contextual Toolbar, click on the button.

c. Select the nesting level and nesting variable by selecting 2 from the Nesting depth control and selecting suspect > Observations in the next control.

d. Specify M2 as the Base name.

e. Click on OK.

14. Draw a path from the newly added suspect-level latent variable to 3.chosen.

Select the Add path tool, click in the left of the suspect\textsubscript{2} double oval, and drag a path to the right side of the 3.chosen rectangle.

15. Create the covariance between the random effects.

a. Select the Add covariance tool, .

b. Click in the bottom-right quadrant of the suspect\textsubscript{1} double oval, and drag a covariance to the top right of the suspect\textsubscript{2} double oval.

16. Clean up paths and covariance.

If you do not like where a path has been connected to its variables, use the Select tool, , to click on the path, and then simply click on where it connects to a rectangle and drag the endpoint. Similarly, you can change where the covariance connects to the latent variables by clicking on the covariance and dragging the endpoint. You can also change the bow of the covariance by
clicking on the covariance and dragging the control point that extends from one end of the
selected covariance.

17. Estimate again.

Click on the **Estimate** button, ![Estimate button](image), in the Standard Toolbar, and then click on **OK** in the resulting
**GSEM estimation options** dialog box.

You can open a completed diagram for the first model in the Builder by typing
```
.webgetsem gsem_mlmlogit1
```

You can open a completed diagram for the second model in the Builder by typing
```
.webgetsem gsem_mlmlogit2
```

**References**


**Also see**

[SEM] Example 37g — Multinomial logistic regression

[SEM] Example 38g — Random-intercept and random-slope models (multilevel)

[SEM] Intro 5 — Tour of models

[SEM] gsem — Generalized structural equation model estimation command