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AN INTRODUCTION TO THE ACER CONQUEST SOFTWARE FOR ITEM RESPONSE ANALYSES

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ABSTRACT

ACER ConQuest is a generalized Rasch-type item response modelling software. It is widely used in the fields of measurement, psychometrics, and educational assessment. This paper introduces ConQuest's functions, the analysis models fitted, and its applications. An analysis example is shown for investigating psychometric properties of a psychological instrument with a multidimensional item response theory (MIRT) model. The paper displays preparation of the input files and the main analysis outputs. Finally, a number of useful studies and resources have been provided for users to conduct more comprehensive analyses with ConQuest.

Keywords: *Applications of ACER ConQuest software, use of software, multidimensional item response analysis*

INTRODUCTION

Item response theory (IRT) and the Rasch model (Rasch, 1960) have been widely used in designing psychometric measures and large-scale educational assessments since the 1980s. Compared to classical test theory, the Rasch model and IRT models have several advantages though they require strong assumptions – unidimensionality (measuring one underlying latent trait) and local independence (performance on a test item is statistically independent of performance on other items): interval-scale logit positions, sample-free item difficulty calibrations, and item-free estimation of person ability. In this paper, the term "IRT" is used to refer to all item response methods that calibrate the relationship of person ability and item difficulty.

The logistic Rasch model (Rasch, 1960/1980) is the simplest item response model used for assessments that consist of dichotomous items. Based on this Rasch model, researchers derived numerous model extensions which have been applied to large-scale educational assessment programs. Also, a variety of software packages have been developed for analyses with these models, such as ConQuest (Adams et al., 2020), Winsteps (Linacre, 2022), Facets (Linacre, 2022), and RUMM2010 (Andrich, 2001). The Australian Council for Educational Research's (ACER) ConQuest is well known by its powerful and flexible features that can be employed with a wide range of sophisticated item response models and latent regression models. The present paper introduces the functions of the ConQuest software, the analysis models fitted, and its applications. Users will learn about how to use ConQuest and select appropriate analysis models for their data and studies.

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ACER ConQuest is generalized item response modelling software that supports a comprehensive set of Rasch-type item response models. Unlike other software that is limited to only unidimensional Rasch models, ConQuest enables us to analyze both unidimensional and multidimensional models. ConQuest was built on strong statistical methodologies and the practical administration of large-scale educational assessments. The first version of the ConQuest computer program was released by ACER in 1998. The emergence of ConQuest was the product of two research programs conducted by researchers at ACER and the University of California, Berkeley (Wu, Adams, & Wilson, 1998). The first research program was required to develop advanced tools and methods for analyzing data collected from large international assessments: the International Association for Evaluation of Educational Achievement's Third International Mathematics and Science Study (TIMSS) and the Organization for Economic Co-operation and Development's Program for International Student Assessment (PISA). The second research program created the generalized item response model that was flexible enough to fit an extensive array of Rasch-type item response models (Adams, Wilson, & Wang, 1997; Wang, 1994). The ConQuest software has been upgraded continuously with respect to the most up-to-date psychometric methods. In 2020, ACER released the latest ConQuest package, the 5th version.

CONQUEST SOFTWARE, THE MANUAL, AND THE MODELS FITTED

To order a ConQuest package, users can find information on the ACER ConQuest website (www.acer.org/au/conquest). Several editions of the ConQuest package (standard, student, multiple, instructor, or extended licenses) are available for both Windows and MacOS. They also provide a 30-day trial version with limited functions and for less than 100 items. ConQuest has two types of user interfaces: the graphical user interface (GUI, for Windows only) and the simple command line, or console, interface (CMD, for Windows and MacOS). The GUI is more user friendly and can produce a wide array of graphical outputs (see Figure 1). The CMD interface runs substantially faster than the GUI, which is very important for conducting complex analyses and processing very large-scale datasets, like the data collected from the TIMSS and the PISA assessments. The installation of ConQuest is very simple. First, users download the ConQuest package from the ACER ConQuest website. Then, users double click the installer file ("*ACER ConQuest VX.msi*" for Windows users) or open the installer disk image ("ConQuest_X_YY_Z.dmg" for MacOS users) and install the package following the installation guidance.

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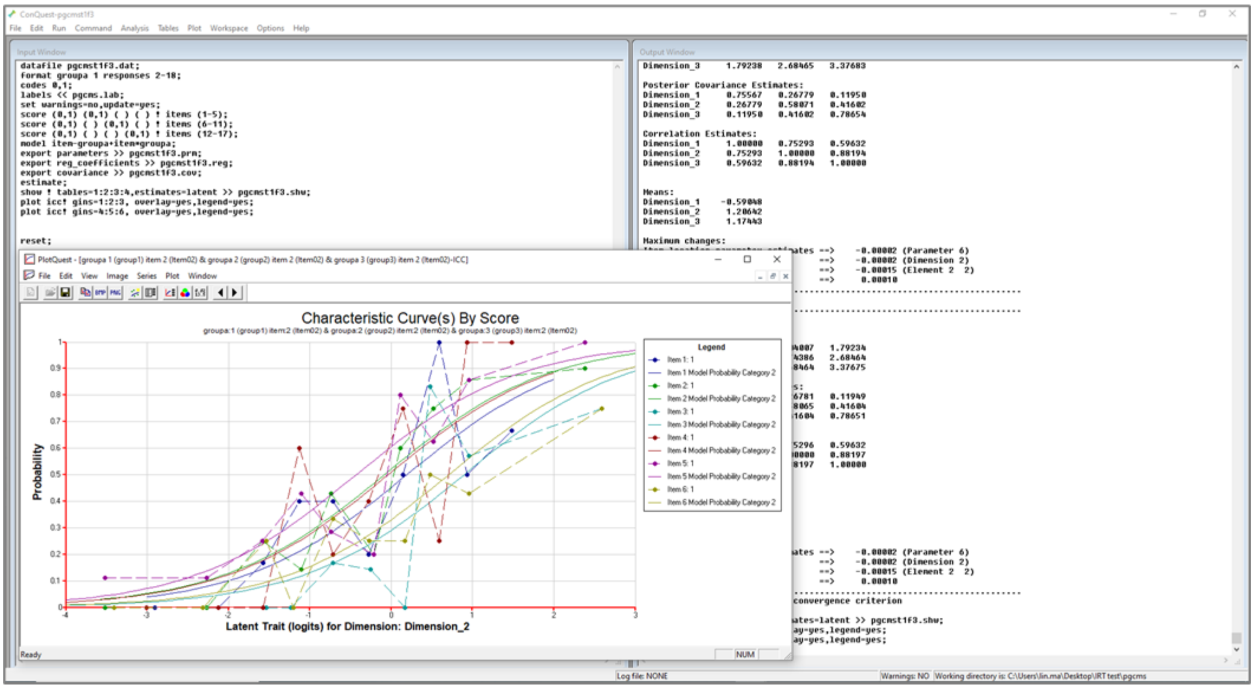

Figure 1. ConQuest Graphical User Interface (GUI) – Windows of Input, Output, and Plot

The ACER ConQuest Manual (Adams et al., 2022) is a great source for users to start analyses with IRT models and ConQuest. It provides examples and tutorials in detail, with data, scripts, analysis outputs, and explanations for each type of analysis model. Table 1 summarizes the main IRT models and latent regression models that are covered by ConQuest. The analysis models can be used to calibrate test items in different formats, with dichotomous-category responses or polytomous-category responses. With respect to assessment projects, users can evaluate measurement dimensions and person abilities with unidimensional models, multidimensional models, or multifaceted models (items, students, and raters). The estimation methods for item parameters and person parameters include marginal maximum likelihood, joint maximum likelihood, and Bayesian Markov Chain Monte Carlo estimation. The features of ACER ConQuest allow users to flexibly choose analysis methods and models with comprehensive estimates according to their study purposes. For the detailed implementations of each IRT model, please refer to the articles written by the authors.

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Table 1
Item Response Models and Latent Regression Models Fitted with ConQuest

	Item Response Model	Notes of Item Type and Analysis Model
1	Rasch's (1960) Simple Logistic Model	Items in a common two-category response format (dichotomous response): yes/no, true/false, agree/disagree
2	Andrich's (1978) Rating Scale Model	Items in a common multiple-category response format: Likert scale, 1 – 5 points
3	Masters' (1982) Partial Credit Model	Items have more than 2 levels of responses: 2-category response and multiple-category response
4	Wilson's (1992) Ordered Partition Model	Many-to-one correspondence between item response categories and scores: a 4-category item with 3 different score levels
5	Fischer (1983) Linear Logistic Test Model (LLTM)	Item difficulty is estimated by the linear combinations of sub-elements for dichotomous and polytomous response items
6	Linacre's (1989/1994) Multifaceted Models (extension of LLTM)	A item response determined by 3 facets: person, item, and rater
7	Generalized Unidimensional Models	Flexibly fit all above unidimensional models according to users' specifications
8	Multidimensional Item Response Models (Adams, Wilson, & Wang, 1997; Wang, 1994)	Fit up to 10 latent dimensions: multidimensional between-item tests; multidimensional within-item tests
9	Latent Regression Models (Adams, Wilson, & Wu, 1997)	Estimate regression models directly from item response data, instead of from mean scores

Note. The source is from the ACER ConQuest Manual (Adams et al., 2022).

APPLICATIONS OF CONQUEST

ACER ConQuest produces a series of analysis outputs. For each analysis mode, the ConQuest Manual provides examples of tutorials with detailed explanations for the command scripts and the main analysis outputs. The analysis results can be saved in SPSS, Excel, or text files. The latest ConQuest 5 allows R program users to directly read the generated analysis output files through the *conquestr* library. The analysis outputs provide parameters and graphs for users to examine model fit, psychometric properties of test items and measures, persons' abilities and performances on the assessments and items, and differences of groups' performances.

First, users can test the relative fit of analysis models through comparing differences in the deviance parameter between models. ConQuest produces a goodness-of-fit parameter – *Deviance* (*D = -2log(likelihood)*) for each analysis model. Users can check the distribution of the Chi-squared statistic by comparing the deviance values and the numbers of parameters of two nested models (*Chi-square = D1 – D2, df = N1 - N2*). The smaller deviance values indicate a better model fit (Bobbitt, 2021; Howell, 2021). In the ConQuest tutorial of multi-facets and hierarchical model analysis, an analysis example is demonstrated for users to compare the fit of competing models using the deviance statistics.

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Second, for item analyses, users can calibrate items and response categories with a set of parameters such as item difficulties, estimate errors, weighted or un-weighted fit indices, Cronbach's alpha coefficients of reliability, separation reliability values, item and test information functions, distractor analyses for multiple choice questions, and item response category analyses. Users can investigate the relationships of latent dimensions with the correlation parameters. Also, users can examine differential item functioning and test the equality and invariance of assessment items across respondent groups, times, and multiple booklets. Extensions to ConQuest are available via *conquest*, including properties of Likert-type items (rating scale model), information for tests containing items with multiple-category responses (partial credit model or ordered partition model), and difficulties and correlations of cognitive subtasks (linear logistic test model).

Third, ConQuest produces estimates for persons' and groups' abilities and performances on individual items and latent attributes. One of ConQuest's big advantages is that for the multiple IRT models, the generated item-person map displays the distributions of all test items and participants on multiple latent dimensions on a single logit scale (see Appendix 5). This map clearly exhibits the relative difficulties of test items, gaps in measures, the persons' abilities, and the groups' performances on each latent trait. These analysis results with other graphs are helpful for users to quickly identify issues in measures, refine test items, or to target some participants' abilities.

Fourth, ConQuest can be employed to investigate multifaceted models. It generates parameters for examining the propensities of raters, such as the grading consistency and variations in the harshness or leniency of raters. In addition, from each analysis model, Conquest can draw plausible values – person ability estimates with their error distributions. These values are useful for analysts to analyze data collected from large assessments with complex matrix sampling designs.

DATA ANALYSIS WITH THE MULTIDIMENSIONAL ITEM RESPONSE MODEL

To operate data analyses with ConQuest, users need to prepare three files for analyses: a *data* file, a *variable label* file, and a *command* file. The data file includes all data for an analysis. ACER ConQuest version 5 allows users to read analysis data directly from a SPSS data file or a CSV text file (e.g., Excel). The variable label file specifies the labels for the individual variables. The command file includes the scripts that define the input files, the response values, the measurement dimensions, the analysis models and methods, and the output parameters, plots, and files. For most analyses, the command scripts are simple and straightforward. The ConQuest Manual provides detailed explanations for the scripts and main analysis outputs for each analysis mode.

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This paper provides an example of using a multidimensional item response model to investigate the psychometric properties of a psychological instrument – the Philadelphia Geriatric Center Morale Scale (PGCMS: Lawton, 1975). The example files prepared for the analysis are provided. Multidimensional item response theory (MIRT) is an extension of unidimensional IRT models. Unidimensionality of measurement is one of the important assumptions for using the Rasch model. However, in practice, many instruments cannot meet this strict assumption. Researchers found that MIRT models can provide more accurate estimation for assessments with multiples latent attributes (Adams et al., 1997; Briggs & Wilson, 2003; Spencer, 2004). ConQuest allows users to investigate multidimensional instruments using MIRT models.

The data used in the sample analysis are from a study of senior care receiver's self-efficacy (Cox et al., 2006). In the study, the PGCMS was applied to measure the participants' self-efficacy before and after receiving the interventions. There were three participant groups: an individually-delivered intervention (Group 1), a group-delivered intervention (Group 2), and a case management comparison group (Group 3). The 17-items PGCMS consists of three sub-factors: Agitation (6 items), Attitude Toward Own Aging (5 items), and Lonely Dissatisfaction (6 items). All items are dichotomous response items, scored as 0 (response = No/Worse/Not Satisfied/A Lot) or 1 (response = Yes/Better/Satisfied/Not Much).

The collected data are saved in a data file (*pgcmsf3.dat*) or a text file (*pgcmsf3.txt*) as those exhibited in the Appendix 1 – File 1 Data File. Each line records the data of one participant. Column 1 indicates each participant's group number, 1 to 3. Columns 2 to 18 represent each participant's responses to the 17 items (value = 0 or 1). The labels of the three groups and the 17 items are specified in the variable label file (*pgcms.lab*, see Appendix 1 – File 2). The third input file for the analysis is the command file (*pgcms_cmd.cqc*). See Appendix 1 – File 3 and the notes about the command scripts. This file indicates the analysis data, the variable labels, the three dimensions of the PGCMS, the item response model used, the analysis methods, and the analysis outputs. In one command file, using the "*reset*;" statement, users can fit the same analysis data to different analysis models and analysis methods. After the three input files have been prepared, users need to save these files in one folder. Following that, users open the command file through the ConQuest software and run all scripts. The analysis results and plots will be generated and saved into the output files specified. Appendix 2 – Analysis Output 1 summarizes the statistical estimation regarding analysis method, model, data, and model fit – deviance. Appendix 3 displays the parameter estimates of items, groups, and their interactions (item*group). Appendix 4 reports the population parameter estimates: the mean, correlation, and reliability of the three latent sub-scales. Appendix 5 – the Item-Person Map displays the distributions of the PGCMS items and all participants on the three latent dimensions on a single logit scale. Users can compare test items, such as item difficulties, redundant items, assessment gaps among items. From this map, users also can compare participants' abilities or performances on the three latent factors. This

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example shows that the participants performed better on the scales of Factor 2 (Attitude Toward Own Aging) and Factor 3 (Lonely Dissatisfaction) than on the scale of Factor 1 (Agitation).

Overall, the ConQuest command statements are straightforward. However, the "simple" statements represent sophisticated item response methods behind them. The Command Reference section in the ConQuest Manual provides detailed interpretations for every command statement and relative requirements. A user may need to refer to this section frequently to effectively choose suitable analysis methods and command scripts. ACER online resources provided some notes of the fitted models and research papers by the ConQuest authors and their colleagues (see ACER Notes and Tutorials). They are great sources for users to manipulate the ConQuest software.

Meanwhile, the ConQuest software can produce a series of analysis results according to users' specifications. For the main outputs of each sample analysis, the ConQuest Manual provides the detailed explanations. However, the ConQuest program covers a comprehensive range of item response models. Many models were built on advanced statistical methodologies. The manual can't show all details of underlying methodologies. Thus, it assumes that ConQuest users already have knowledge about the relative functions and applications of these sophisticated analysis models. To better understand analysis models that ConQuest fits, it is recommended that users refer to articles by authors who originally developed the item response models and latent regression models, such as Rasch's (1960/1980) simple logistic model for dichotomously scored items, Andrich's (1978) rating scale model for items in a common, multiple-category response format, Fischer's (1983) linear logistic test model for estimating item difficulty parameters through linear combinations of more fundamental attributes, the multidimensional item response models developed by Adams, Wilson, and Wang (1997), and the latent regression models created by Adams, Wilson, and Wu (1997) (see Table 1). Also, as a valuable guidebook, Wu and Adams' (2007) book – *Applying the Rasch model to Psycho-Social Measurement: A Practical Approach* – is recommended for users to understand the fundamentals of measurement, Rasch models, developing tests from IRT perspectives, analyzing items with ConQuest, and how to examine analysis results. In addition, for applications of MIRT models, users can refer to Briggs and Wilson's (2003) introduction to multidimensional measurement using Rasch Models and Immekus, Snyder, and Ralston's (2019) study of the instrument's factor structure using MIRT.

CONCLUSION

ConQuest software is well maintained by ACER with up-to-date item response methods. Its powerful functions attract users in the fields of measurement, psychometrics, and educational assessment. ConQuest integrates a comprehensive range of advanced item response models (unidimensional and multidimensional Rasch models) and latent regression models in a single software package. It has become one of the popular computer packages for IRT analyses. With

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it, users can flexibly analyze their data and deeply investigate their assessments, measures and items, respondents, and raters using appropriate methods and parameters. Meanwhile, to implement ConQuest properly for different analyses, it is recommended that users learn about relative analysis models and their applications in advance. This paper has introduced ConQuest's applications and demonstrated a sample analysis with a MIRT model. Moreover, the paper has provided some useful sources that users can refer to for their studies.

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Appendix 1. Three Input Files for the Analysis with ConQuest

File 1 – The Data File (pgcmsf3.dat): *Participants' Group (Column 1) and Responses to the 17 Items (Column 2-18)*

```
100000111111111011
111110101111011011
101110000001011101
100000100110000100
111110111111111111
111110100111111111
100000000001101100
2111 1101111111111
211111101111111111
201011101111111111
200000101000111101
211110101111111110
301000111011100011
300111100111111111
300010111110111111
310111111011011111
300001101110111101
301000101111101011
300000110010001000
```

Note. 19 participants' data are shown here. Each line represents one participants' data. Group numbers (1 – 3) refer to Treatment 1 – individually-delivered, Treatment 2 – group-delivered, and no treatment. The values of response are 0 (response = No/Worse/Not Satisfied/A Lot) or 1 (response = Yes/Better/Satisfied/Not Much).

File 2 – The Variable Label File (pgcms.lab)

```
===> group
1	group1
2	group2
3	group3
===> item
1	Item01
2	Item02
3	Item06
4	Item08
5	Item10
6	Item03
7	Item05
8	Item09
9	Item11
10	Item14
11	Item15
12	Item04
13	Item07
14	Item12
15	Item13
16	Item16
17	Item17
```

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File 3 – The Command File (pgcms_cmd.cqc)

```
1  datafile pgcmsf3.dat;
2  format group 1 responses 2-18;
3  codes 0,1;
4  labels << pgcms.lab;
5  set warnings=no, update=yes;
6  score (0,1) (0,1) ( ) ( ) ! items (1-5);
7  score (0,1) ( ) (0,1) ( ) ! items (6-11);
8  score (0,1) ( ) ( ) (0,1) ! items (12-17);
9  model item;
10 estimate;
11 show ! estimates=latent >> pgcmsf3-output1.shw;
12
13 reset;
14 datafile pgcmsf3.dat;
15 format group 1 responses 2-18;
16 codes 0,1;
17 labels << pgcms.lab;
18 set warnings=no, update=yes;
19 score (0,1) (0,1) ( ) ( ) ! items (1-5);
20 score (0,1) ( ) (0,1) ( ) ! items (6-11);
21 score (0,1) ( ) ( ) (0,1) ! items (12-17);
22 model item-group+item*group;
23 export parameters >> pgcmsf3.prm;
24 export reg_coefficients >> pgcmsf3.reg;
25 export covariance >> pgcmsf3.cov;
26 estimate! method=montecarlo,nodes=2000,conv=.005,stderr=quick;
27 show ! tables=1:2:3:4,estimates=latent >> pgcmsf3-output2.shw;
28 plot icc! gins=1:2:3, overlay=yes, legend=yes;
29 plot icc! gins=4:5:6, overlay=yes, legend=yes;
```

Note.

Line 1: Indicate the data file.
Line 2: Indicate the column numbers for the group variable and the responses to the 17 items.
Line 3: Specify the item response values, 0 and 1.
Line 4: Indicate the variable label file.
Line 5: Indicate no warnings when update the export files of parameter estimates.
Line 6-8: Specify the items that are included in one of the three dimensions of the PGCMS.
Line 9: Indicate the analysis model: use the simple logistic model here.
Line 10: Use default settings (a Gauss-Hermite method) to analyze the model.
Line 11: Specify output file of analysis results.
Line 13: Reset the data to fit to another analysis model (see the changes in Line 22 to Line 29).
Line 22: The second analysis model includes two facets – item and group, and their interaction.
Line 23-25: Indicate the estimated parameters that are exported to a separated file.
Line 26: Specify the analysis method, using the Monte Carlo method.
Line 27: Save the analysis results in another output file. Display output Tables 1 to 4.
Line 28-29: Produce the item characteristic curve plots.

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Appendix 2. Analysis Outputs 1 – Analysis Estimation Summary

```
================================================================================================
ConQuest: Generalised Item Response Modelling Software     Tue Mar 07 22:18 2022
SUMMARY OF THE ESTIMATION
================================================================================

Estimation method was: Gauss-Hermite Quadrature with 3375 nodes
Assumed population distribution was: Gaussian
Constraint was: DEFAULT
The Data File: pgcmsf3.dat
The format:  group 1 responses 2-18
The regression model:
Grouping Variables:
The item model: item-group+item*group
Sample size: 177
Final Deviance:     3144.44881
Total number of estimated parameters: 53
The number of iterations: 115
Termination criteria:  Max iterations=1000, Parameter Change= 0.00010
                       Deviance Change= 0.00010
Iterations terminated because the deviance convergence criteria was reached
Random number generation seed:    1.00000
Number of nodes used when drawing PVs: 2000
Number of nodes used when computing fit: 200
Number of plausible values to draw: 5
Maximum number of iterations without a deviance improvement: 100
Maximum number of Newton steps in M-step: 10
Value for obtaining finite MLEs for zero/perfects:    0.30000
================================================================================
```

Note. Test model fit by comparing the values of deviance (*D*) and the numbers of parameters (*df*). A smaller deviance values indicate a better model fit.

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Appendix 3. Analysis Outputs 2 – Estimates of Parameters: Item, Group, and Item*Group

```
=====================================================================================================
ConQuest: Generalised Item Response Modelling Software     Tue Mar 07 22:18 2022
TABLES OF RESPONSE MODEL PARAMETER ESTIMATES
================================================================================
TERM 1: item
------------------------------------------------------------------------------------------
   VARIABLES                                  UNWEIGHTED FIT              WEIGHTED FIT
---------------                          -----------------------    -----------------------
     item             ESTIMATE  ERROR^   MNSQ        CI         T   MNSQ        CI         T
------------------------------------------------------------------------------------------
 1   Item01             0.335   0.135    0.79 ( 0.79, 1.21) -2.1    0.88 ( 0.82, 1.18) -1.3
 2   Item02             0.081   0.134    1.22 ( 0.79, 1.21)  1.9    1.08 ( 0.83, 1.17)  0.9
 3   Item06             0.216   0.134    1.29 ( 0.79, 1.21)  2.5    1.02 ( 0.83, 1.17)  0.3
 4   Item08            -0.950   0.133    0.87 ( 0.79, 1.21) -1.2    0.89 ( 0.84, 1.16) -1.4
 5   Item10             0.317*  0.268    0.95 ( 0.79, 1.21) -0.4    1.02 ( 0.83, 1.17)  0.3
 6   Item03            -0.832   0.156    0.66 ( 0.79, 1.21) -3.6    0.84 ( 0.75, 1.25) -1.3
 7   Item05             1.420   0.140    1.63 ( 0.79, 1.21)  5.0    1.32 ( 0.83, 1.17)  3.5
 8   Item09            -0.433   0.151    0.89 ( 0.79, 1.21) -1.0    1.03 ( 0.78, 1.22)  0.3
 9   Item11             0.197   0.145    0.83 ( 0.79, 1.21) -1.6    0.89 ( 0.81, 1.19) -1.1
 10  Item14             0.292   0.144    0.80 ( 0.79, 1.21) -2.0    0.92 ( 0.81, 1.19) -0.8
 11  Item15            -0.644*  0.329    1.01 ( 0.79, 1.21)  0.1    0.94 ( 0.77, 1.23) -0.5
 12  Item04             0.198   0.139    0.92 ( 0.79, 1.21) -0.7    1.02 ( 0.81, 1.19)  0.2
 13  Item07             0.211   0.138    1.02 ( 0.79, 1.21)  0.2    1.05 ( 0.81, 1.19)  0.5
 14  Item12            -0.939   0.148    0.95 ( 0.79, 1.21) -0.5    1.07 ( 0.75, 1.25)  0.6
 15  Item13            -0.210   0.141    0.88 ( 0.79, 1.21) -1.1    1.04 ( 0.80, 1.20)  0.4
 16  Item16             0.417   0.137    0.88 ( 0.79, 1.21) -1.1    0.95 ( 0.82, 1.18) -0.6
 17  Item17             0.323*  0.315    0.85 ( 0.79, 1.21) -1.5    0.93 ( 0.82, 1.18) -0.7
--------------------------------------------------------------------------------
An asterisk next to a parameter estimate indicates that it is constrained
Separation Reliability =  0.951
Chi-square test of parameter equality =     261.91,  df = 14,  Sig Level = 0.000
^ Quick standard errors have been used

================================================================================
TERM 2: (-)group
------------------------------------------------------------------------------------------
   VARIABLES                                  UNWEIGHTED FIT              WEIGHTED FIT
---------------                          -----------------------    -----------------------
    group             ESTIMATE  ERROR^   MNSQ        CI         T   MNSQ        CI         T
------------------------------------------------------------------------------------------
 1   group1             0.043   0.061    1.01 ( 0.60, 1.40)  0.1    1.00 ( 0.59, 1.41)  0.0
 2   group2             0.246   0.057    1.05 ( 0.67, 1.33)  0.3    1.10 ( 0.65, 1.35)  0.6
 3   group3            -0.289*  0.083    1.03 ( 0.63, 1.37)  0.2    1.02 ( 0.62, 1.38)  0.1
--------------------------------------------------------------------------------
An asterisk next to a parameter estimate indicates that it is constrained
Separation Reliability =  0.830
Chi-square test of parameter equality =      19.11,  df = 2,  Sig Level = 0.000
^ Quick standard errors have been used

================================================================================
TERM 3: item*group
------------------------------------------------------------------------------------------------------------
          VARIABLES                                          UNWEIGHTED FIT              WEIGHTED FIT
-------------------------------                         -----------------------    -----------------------
     item           group            ESTIMATE  ERROR^   MNSQ        CI         T   MNSQ        CI         T
------------------------------------------------------------------------------------------------------------
 1   Item01     1   group1            -0.099    0.176    1.04 ( 0.60, 1.40)  0.3    1.03 ( 0.67, 1.33)  0.2
 2   Item02     1   group1            -0.074    0.173    0.98 ( 0.60, 1.40) -0.0    1.02 ( 0.68, 1.32)  0.1
 3   Item06     1   group1            -0.210    0.171    0.87 ( 0.60, 1.40) -0.6    0.94 ( 0.68, 1.32) -0.3
 4   Item08     1   group1             0.176    0.170    0.83 ( 0.60, 1.40) -0.8    0.84 ( 0.68, 1.32) -1.0
 5   Item10     1   group1             0.206*   0.345    0.85 ( 0.60, 1.40) -0.7    0.93 ( 0.66, 1.34) -0.4
.......
 1   Item01     2   group2            -0.173    0.159    0.71 ( 0.67, 1.33) -1.8    0.81 ( 0.73, 1.27) -1.5
 2   Item02     2   group2            -0.265    0.157    1.07 ( 0.67, 1.33)  0.4    1.04 ( 0.74, 1.26)  0.2
 3   Item06     2   group2             0.487    0.158    1.81 ( 0.67, 1.33)  4.0    1.11 ( 0.71, 1.29)  0.8
 4   Item08     2   group2            -0.184    0.156    0.93 ( 0.67, 1.33) -0.4    0.92 ( 0.72, 1.28) -0.6
.......
 15  Item13     3   group3             0.115*   0.244    0.86 ( 0.63, 1.37) -0.7    1.08 ( 0.66, 1.34)  0.5
 16  Item16     3   group3             0.182*   0.238    0.85 ( 0.63, 1.37) -0.8    0.91 ( 0.69, 1.31) -0.6
 17  Item17     3   group3            -0.064*   0.546    0.52 ( 0.63, 1.37) -3.1    0.71 ( 0.68, 1.32) -1.9
--------------------------------------------------------------------------------
An asterisk next to a parameter estimate indicates that it is constrained
Separation Reliability =  0.414
Chi-square test of parameter equality =      47.46,  df = 28,  Sig Level = 0.012
^ Quick standard errors have been used
================================================================================
```

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Appendix 4. Analysis Outputs 3 – Population Parameter Estimates of Three Latent Variables: Mean, Covariance, Correlation, and Reliability

```
===============================================================================================
ConQuest: Generalised Item Response Modelling Software     Tue Mar 07 22:18 2022
TABLES OF POPULATION MODEL PARAMETER ESTIMATES
================================================================================
REGRESSION COEFFICIENTS

                                              Dimension
                         ---------------------------------------------------
Regression Variable           Dimension 1      Dimension 2      Dimension 3

CONSTANT                    -0.590 ( 0.123)   1.206 ( 0.125)   1.174 ( 0.138)
---------------------------------------------------------------------------------
An asterisk next to a parameter estimate indicates that it is constrained
=================================================================================
COVARIANCE/CORRELATION MATRIX

                                  Dimension
                         --------------------------|
Dimension                     1         2         3

 Dimension 1                          2.040     1.792
 Dimension 2                0.753               2.685
 Dimension 3                0.596     0.882
----------------------------------------------------
Variance                    2.675     2.744     3.377
----------------------------------------------------
An asterisk next to a parameter estimate indicates that it is constrained
Values below the diagonal are correlations and values above are covariances
====================================================

RELIABILITY COEFFICIENTS
------------------------

Dimension: (Dimension 1)
-----------------------
 MLE Person separation RELIABILITY:  Unavailable
 WLE Person separation RELIABILITY:  Unavailable
 EAP/PV RELIABILITY:                  0.731
------------------------
Dimension: (Dimension 2)
-----------------------
 MLE Person separation RELIABILITY:  Unavailable
 WLE Person separation RELIABILITY:  Unavailable
 EAP/PV RELIABILITY:                  0.808
------------------------
Dimension: (Dimension 3)
-----------------------
 MLE Person separation RELIABILITY:  Unavailable
 WLE Person separation RELIABILITY:  Unavailable
 EAP/PV RELIABILITY:                  0.784
------------------------
```

Note. Dimensions 1 to 3 represent three latent factors: Factor 1 – Agitation, Factor 2 – Attitude Toward Own Aging, and Factor 3 – Lonely Dissatisfaction.

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Appendix 5. Analysis Outputs 4 – Item-Person Map of The Latent Variables for The Three-Dimensional Model.

```
==============================================================================================================
ConQuest: Generalised Item Response Modelling Software     Tue Mar 07 22:18 2022
MAP OF LATENT DISTRIBUTIONS AND RESPONSE MODEL PARAMETER ESTIMATES
================================================================================
             Dimension                            Terms in the Model (excl Step terms)
-------------------------------------
    Dimension1 Dimension2 Dimension3        +item                  -group                  +item*group
--------------------------------------------------------------------------------------------------------------
                 |         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
   8             |         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
   7             |         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
   6             |         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
                 |        X|         |                      |                      |                      |
                 |         |         |                      |                      |                      |
   5             |         |         |                      |                      |                      |
                 |        X|        X|                      |                      |                      |
                 |       XX|       XX|                      |                      |                      |
                 |       XX|      XXX|                      |                      |                      |
   4             |       XX|     XXXX|                      |                      |                      |
                 |     XXXX|      XXX|                      |                      |                      |
                 |      XXX|      XXX|                      |                      |                      |
                X|     XXXX|    XXXXX|                      |                      |                      |
   3             |    XXXXX|      XXX|                      |                      |                      |
               XX|  XXXXXXX|   XXXXXX|                      |                      |                      |
               XX|  XXXXXXX| XXXXXXXX|                      |                      |                      |
              XXX|XXXXXXXXX|  XXXXXXX|                      |                      |                      |
   2          XXX|  XXXXXXX|    XXXXX|                      |                      |                      |
              XXX| XXXXXXXX|   XXXXXX|                      |                      |                      |
             XXXX| XXXXXXXX|  XXXXXXX|7                     |                      |                      |
   1       XXXXXX| XXXXXXXX|  XXXXXXX|                      |                      |                      |
          XXXXXXX|  XXXXXXX|XXXXXXXXX|                      |                      |10.3                  |
          XXXXXXX|   XXXXXX| XXXXXXXX|13 17                 |                      |15.1 3.2 13.2         |
           XXXXXX|  XXXXXXX| XXXXXXXX|1 3 5 9 10 12         |2                     |4.1 5.1 6.1 8.1       |
   0       XXXXXX|    XXXXX|     XXXX|2 16                  |1                     |2.1 7.1 9.1 1.2       |
         XXXXXXXX|    XXXXX|    XXXXX|15                    |3                     |1.1 3.1 10.1          |
          XXXXXXX|     XXXX|   XXXXXX|8                     |                      |11.1 14.1 17.1        |
        XXXXXXXXX|     XXXX|    XXXXX|6 11                  |                      |15.2 6.3              |
  -1      XXXXXXX|      XXX|     XXXX|4 14                  |                      |                      |
        XXXXXXXXX|    XXXXX|       XX|                      |                      |                      |
         XXXXXXXX|       XX|       XX|                      |                      |                      |
            XXXXX|       XX|        X|                      |                      |                      |
  -2      XXXXXXX|       XX|       XX|                      |                      |                      |
             XXXX|        X|        X|                      |                      |                      |
            XXXXX|         |        X|                      |                      |                      |
            XXXXX|         |        X|                      |                      |                      |
  -3           XX|         |        X|                      |                      |                      |
               XX|         |         |                      |                      |                      |
               XX|         |        X|                      |                      |                      |
  -4            X|         |         |                      |                      |                      |
                X|         |         |                      |                      |                      |
                X|         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
  -5             |         |         |                      |                      |                      |
                X|         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
  -6             |         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
                 |         |         |                      |                      |                      |
  -7             |         |         |                      |                      |                      |
==============================================================================================================
Each 'X' represents   1.3 cases
Some parameters could not be fitted on the display
==============================================================================================================
```

Note. Dimensions 1 to 3 represent three latent factors: Factor 1 – Agitation, Factor 2 – Attitude Toward Own Aging, and Factor 3 – Lonely Dissatisfaction.