How important is the General Factor of Personality?

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Contents

Is there a general factor of personality?

A recurring question in the assessment of cognitive and non-cognitive dimensions of personality is what is the appropriate number of factors/dimensions to extract from a data set and what is the structure of these factors. Hierarchical models have been used frequently in the cognitive domain (Carroll, 1993; Horn & Cattell, 1966, 1982) and less frequently in the non-cognitive domain. Hierarchical models of anxiety (Zinbarg & Barlow, 1996; Zinbarg, Barlow, & Brown, 1997) show lower order factors as well as a higher order

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one. Few have applied this procedure to the entire domain of non-cognitive personality. Recently Philippe Rushton and his colleagues (Rushton & Irwing, 2008; Rushton, Bons, & Hur, 2008; Rushton & Irwing, 2008 (in press)) have done so. Their seemingly startling finding is that there is indeed a higher order factor (the "General Factor of Personality") to be found in at least four major personality inventories.

Their work is carefully done and does indeed show a general factor. But is this surprising or important? Perhaps, but only if we think that the higher order factor is as important as such general factors are in the intelligence or anxiety domain.

How does one evaluate the importance of a higher order factor? Typically this is done by examining the direct effect of the second or third order factor not on the lower order factors, but on the variables themselves (Holzinger & Swineford, 1937; Jensen & Weng, 1994; Reise, Morizot, & Hays, 2007; Schmid & Leiman, 1957). Hierarchical models are found merely by allowing the first order factors to correlate and then finding a second order factor to account for their correlations. These hierarchical models can be transformed into a bi-factor model (Holzinger & Swineford, 1937) directly from the hierachical solution by using the transformation introduced by Schmid and Leiman (1957). All of these procedures are available in the open source, public domain computer system R (R Development Core Team, 2008), using the **psych** package (Revelle, 2009). It is, of course, also possible to model bifactor solutions using structural equation modeling procedures such as the **sem** package in R.

The Digman Big 5

Although the "Big 5" model of non-cognitive aspects of personality is partly credited to John Digman's influential chapter in the Annual Review (Digman, 1990), Digman also proposed a higher order structure of two super factors (Digman, 1997). As is clear from inspection of the correlation matrices of the Big 5 reviewed by Digman, the five factors are not orthogonal. In a meta-analysis of the Digman study, Rushton and Irwing (2008) have presented both median and weighted average correlation matrices. Using these correlations, a two factor solution can be extracted, rotated obliquely using `oblimin`, with the resulting two correlated factors accounted for by a higher order factor. Because there are just two factors, the higher order factor loadings are fixed to be equal (Figure 1a). Although done using an exploratory algorithm, this result is in good agreement with that done by Rushton and Irwing (2008) using confirmatory procedures.

An alternative solution, using the procedure of Schmid and Leiman (1957) is to calculate the g loadings from the hierarchical solution, extract the general factor, and the find the residual loadings on the remaining orthogonal factors (Figure 1b). The amount of general factor saturation, McDonald's coefficient $\omega_{hierarchical}$ (McDonald, 1999; Revelle & Zinbarg, 2009; Zinbarg, Revelle, Yovel, & Li, 2005), is found by squaring the sum of the general factor loadings and dividing by the sum of the total correlation matrix. The resulting value, .35, is the percentage of variance accounted for by the general factor.

(Table 1).

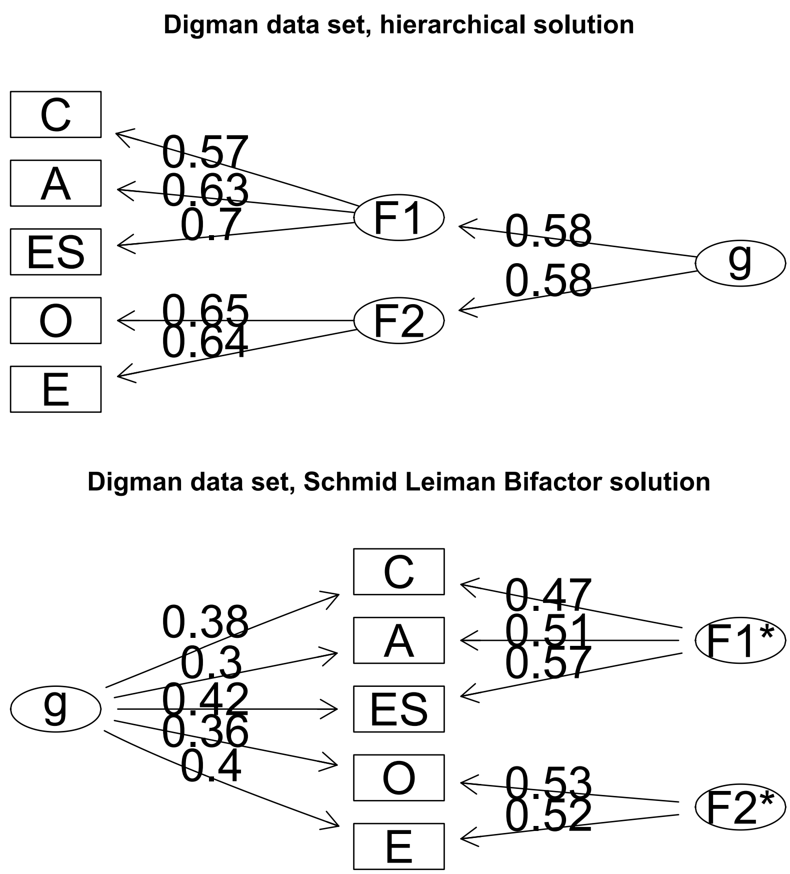

Figure 1. Hierarchical (top panel) and Bi-factor (lower panel) solution to the median Digman data set.

Is 35% a large or small amount? Is it more useful to consider the General Factor or think in terms of the two lower order factors (Digman's α and β)?. One way to make this decision is in terms of the group factor saturation at the lower levels. This can be found using the ICLUST (Item Cluster Analysis) algorithm (Revelle, 1979)). (See Cooksey and Soutar (2006) for a discussion of the use of ICLUST in an applied setting). Revelle's β coefficient is defined as the worst split half reliability and is an estimate of the general factor saturation of a test. For the five scales, $\beta = .36$ which is in good agreement with the ω_h estimate of .35. More importantly, the $beta_i$ for the lower level constructs (Agreeableness + Conscientiousness +Emotional Stability or Digman's α and Openness + Extraversion

Table 1: Schmid Leiman bifactor solution to the median correlations from the 14 Digman studies (median from Rushton & Irwing, 2008). Because there are only five variables, the original factor solution is limited to two factors.

```
> rush.med

     O     C     E     A    ES
O  1.00 0.190 0.420 0.070 0.120
C  0.19 1.000 0.175 0.350 0.425
E  0.42 0.175 1.000 0.085 0.230
A  0.07 0.350 0.085 1.000 0.410
ES 0.12 0.425 0.230 0.410 1.000

> omega(rush.med,2)

Omega
Alpha:  0.62
Lambda.6:   0.61
Omega Hierarchical:   0.35
Omega Total   0.71

Schmid Leiman Factor loadings:
      g  F1*  F2*   h2   u2
O  0.36 0.02 0.53 0.42 0.58
C  0.38 0.47 0.07 0.37 0.63
E  0.40 0.03 0.52 0.43 0.57
A  0.30 0.51 0.08 0.36 0.64
ES 0.42 0.57 0.03 0.50 0.50

With eigenvalues of:
   g  F1*  F2*
0.70 0.81 0.56

general/max  0.87   max/min =   1.43
```

or Digman's β) are .62 and .59 respectively. That is, 62% of the α factor and 59% of the β factor represent variance in common with items within those group factors. Combining these two into one super factor reduces the amount of common variance to 36% (Figure 2).

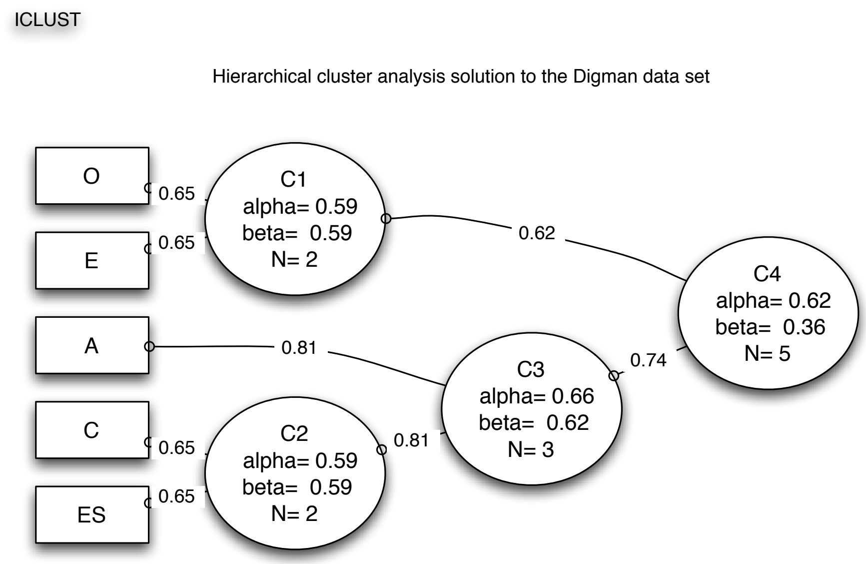

Figure 2. A hierarchical cluster analysis of the Digman median correlation matrix shows the hierarchical structure quite clearly. The β coefficient is an estimate of the general factor saturation of the component elements.

This same analysis can be repeated on other data sets reported by Rushton and Irwing (2008 (in press)).

The Comrey Personality Inventory

The hierarchical and the bi-factor solutions may be seen graphically in Figure 3. Once again, the low saturation of the general factor ($\omega_h = .22$) suggests that the lower order factors provide a better description of the data. The structure using ICLUST shows that lower order clusters are more internally consistent than combining them all into one cluster (Figure 4). At the highest level $\beta = .31$ while at the lower level the values are .47 and .50, or .47, .50, and .60 for the three subcluster solution. Once again, although it is possible to extract a general factor, the saturation of this general factor in the items is roughly half the magnitude of the group factor saturation at the lower levels.

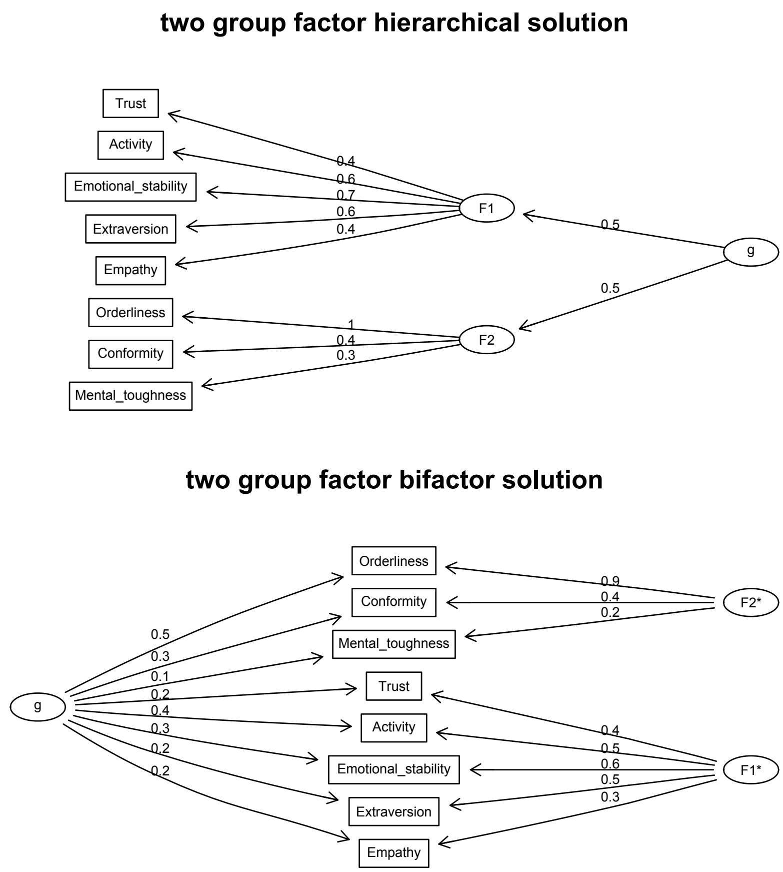

Figure 3. A two factor solution to the Comrey Personality Inventory can be shown hierarchically (top panel) or with a bi-factor solution (lower panel).

Table 2: Comrey correlation matrix and Schmid-Leiman bi-factor solution.

```
> comrey
                     Tru   Ord   Con  Act   ES  Ext    MT   Emp
Trust               1.00  0.01  0.14 0.11 0.34 0.12 -0.07  0.33
Orderliness         0.01  1.00  0.48 0.36 0.11 0.01 -0.26  0.05
Conformity          0.14  0.48  1.00 0.20 0.18 0.05 -0.27  0.08
Activity            0.11  0.36  0.20 1.00 0.39 0.35  0.10  0.25
Emotional_stability 0.34  0.11  0.18 0.39 1.00 0.36  0.14  0.15
Extraversion        0.12  0.01  0.05 0.35 0.36 1.00  0.01  0.24
Mental_toughness   -0.07 -0.26 -0.27 0.10 0.14 0.01  1.00 -0.26
Empathy             0.33  0.05  0.08 0.25 0.15 0.24 -0.26  1.00

> omega(comrey,2,labels=rownames(comrey))

Omega
Alpha:  0.63
Lambda.6:   0.68
Omega Hierarchical:   0.22
Omega Total   0.71

Schmid Leiman Factor loadings:
                       g  F1*  F2*   h2   u2
Trust               0.15 0.36 0.07 0.15 0.85
Orderliness         0.46 0.01 0.88 1.00 0.00
Conformity          0.27 0.12 0.40 0.25 0.75
Activity            0.37 0.49 0.22 0.42 0.58
Emotional_stability 0.30 0.60 0.03 0.45 0.55
Extraversion        0.21 0.50 0.10 0.30 0.70
Mental_toughness-   0.08 0.10 0.25 0.08 0.92
Empathy             0.16 0.33 0.02 0.13 0.87

With eigenvalues of:
   g  F1*  F2*
0.61 1.11 1.06
```

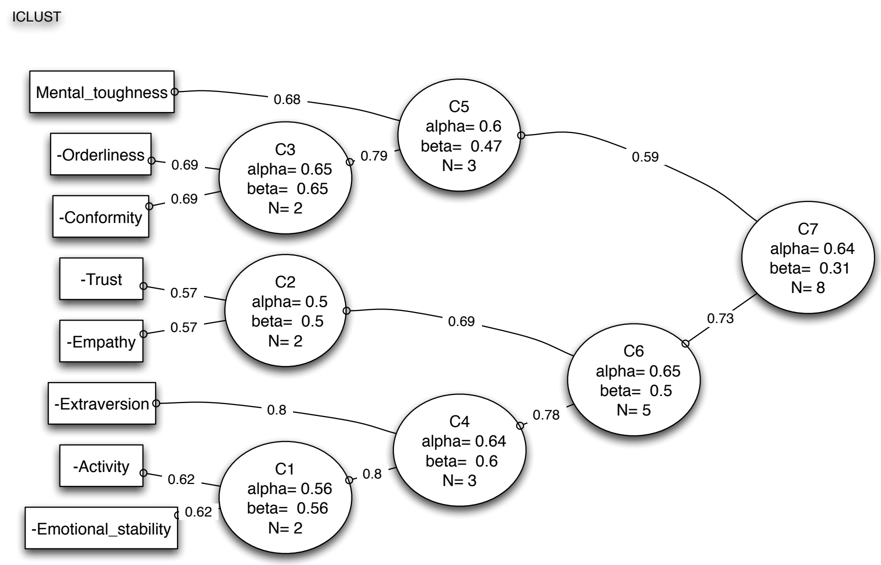

Figure 4. A hierarchical cluster solution to the Comrey Personality Inventory shows that a more optimal clustering is two or three lower level clusters. Note that all except mental toughness have been reversed.

The MMPI

Yet another data set reported by Rushton and Irwing (2008 (in press)) that shows a the general factor is the MMPI-2. However, applying a bifactor analysis, this general factor accounts for 36% of the variance is the MMPI-2 scales (Table 3). Using the correlation matrix from Rushton and Irwing (2008 (in press)) and the default values for the `omega` function, the exploratory simple structured hierarchical solution is very different from the non-simple structured solution of (Rushton & Irwing, 2008 (in press)) (Figure 5).

Comparison to mental ability tests

We can compare these solutions of personality tests to what is found when analyzing some classic data sets. Five sets are considered:

1. 9 mental tests from Thurstone. These are 9 tests taken by McDonald (1999) from 17 tests reported by Bechtoldt (1961) who in turn had reanalyzed these tests from an earlier study by (Thurstone & Thurstone, 1941). These 9 tests are a classic example of a

Table 3: Analysis of the correlations from the MMPI-2. The correlation matrix is from Rushton &Irwing, in press.

```
> mmpi
> omega(mmpi)


     Hs     D    Hy   Pd   Mf   Pa   Pt   Sc    Ma    Si
Hs 1.00  0.55  0.47 0.35 0.03 0.24 0.56 0.58  0.20  0.35
D  0.55  1.00  0.35 0.36 0.15 0.29 0.54 0.44 -0.14  0.55
Hy 0.47  0.35  1.00 0.26 0.16 0.27 0.02 0.08 -0.04 -0.17
Pd 0.35  0.36  0.26 1.00 0.12 0.41 0.49 0.60  0.39  0.13
Mf 0.03  0.15  0.16 0.12 1.00 0.21 0.16 0.11  0.01  0.10
Pa 0.24  0.29  0.27 0.41 0.21 1.00 0.39 0.43  0.18  0.10
Pt 0.56  0.54  0.02 0.49 0.16 0.39 1.00 0.84  0.35  0.56
Sc 0.58  0.44  0.08 0.60 0.11 0.43 0.84 1.00  0.49  0.44
Ma 0.20 -0.14 -0.04 0.39 0.01 0.18 0.35 0.49  1.00 -0.20
Si 0.35  0.55 -0.17 0.13 0.10 0.10 0.56 0.44 -0.20  1.00

Omega
Alpha:  0.8
Lambda.6:   0.87
Omega Hierarchical:   0.36
Omega Total   0.89

Schmid Leiman Factor loadings:
      g  F1*  F2*  F3*   h2   u2
Hs 0.46 0.36 0.25 0.42 0.59 0.41
D  0.44 0.14 0.57 0.32 0.64 0.36
Hy 0.17 0.02 0.06 0.98 1.00 0.00
Pd 0.38 0.51 0.04 0.21 0.45 0.55
Mf 0.11 0.06 0.08 0.15 0.05 0.95
Pa 0.29 0.33 0.02 0.23 0.25 0.75
Pt 0.58 0.62 0.34 0.04 0.83 0.17
Sc 0.58 0.73 0.16 0.01 0.90 0.10
Ma 0.19 0.63 0.48 0.09 0.68 0.32
Si 0.40 0.12 0.75 0.19 0.77 0.23

With eigenvalues of:
  g F1* F2* F3*
1.5 1.9 1.3 1.4
```

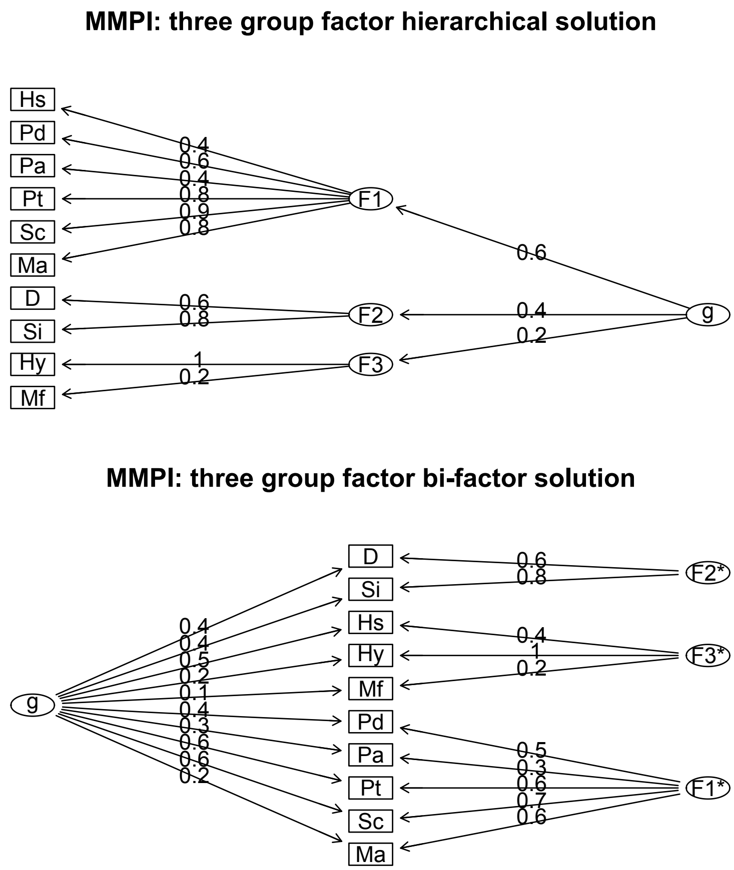

Figure 5. Hierarchical and bi-factor solutions to the MMPI-2 correlation matrix.

hierarchical factor solution and are discussed by McDonald (1999) as well as by Fox (2009).

2. 17 mental tests from Thurstone/Bechtoldt.
3. 14 tests from Holzinger and Swineford (1937). These are the data used by Holzinger to demonstrate a bi-factor solution.
4. 9 tests from Brigham. These are reported by Thurstone (1933)
5. 24 mental tests from Holzinger and Harman. Another classic data set.

The first four data sets are included in the `bifactor` data in the **psych** package data sets. The last is in core R. The following analysis just show the summary statistics from the omega function.

9 mental tests from Thurstone

A classic data set is the 9 variable Thurstone problem which is discussed in detail by R. P. McDonald (1985, 1999) and and is used as example in the sem package as well as in the PROC CALIS manual for SAS. These nine tests were grouped by Thurstone, 1941 (based on other data) into three factors: Verbal Comprehension, Word Fluency, and Reasoning. The original data came from Thurstone and Thurstone (1941) but were reanalyzed by Bechthold (1961) who broke the data set into two. McDonald, in turn, selected these nine variables from a larger set of 17. The sample size is 213. See Table 4 and Figures 6 for the bifactor and 7 for the hierarchical solution.

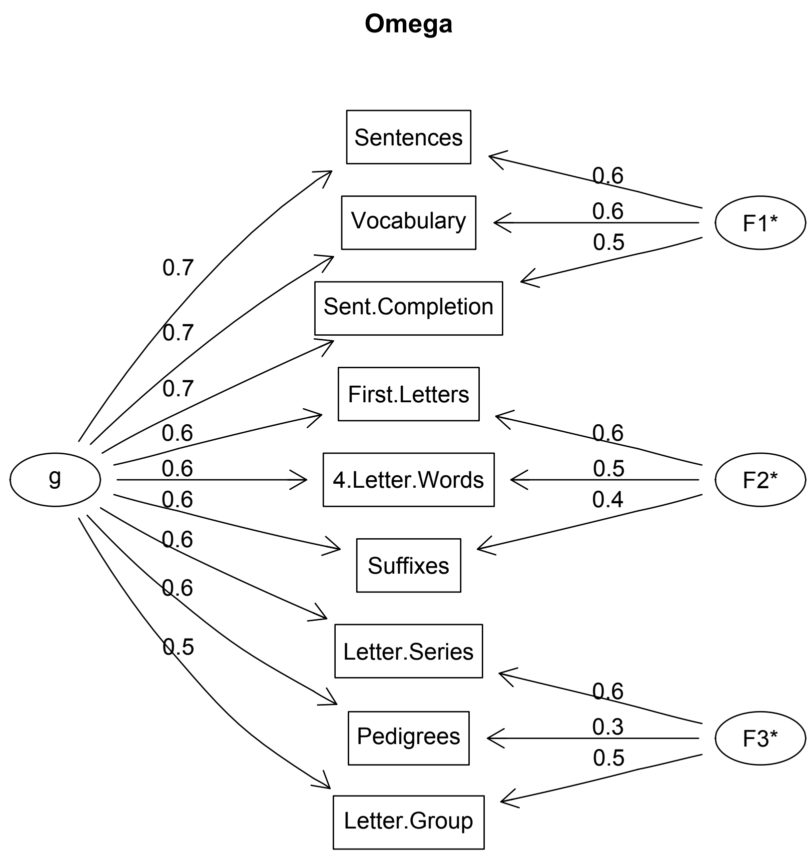

Figure 6. The Thurstone 9 variable problem has clear 3 lower order and one higher order factor structure. This shows the bifactor solution.

Table 4: 9 mental tests from Thurstone. These are used by McDonald and others to show a clear hierarchical structure.

```
> om.t <- omega(Thurstone,n.obs=213)
> om.t

Omega
Call: omega(m = Thurstone, n.obs = 213)
Alpha:  0.89
G.6:   0.91
Omega Hierarchical:   0.74
Omega Total   0.93

Schmid Leiman Factor loadings greater than  0.2
                g    F1*  F2*  F3*  h2   u2
Sentences       0.71 0.57           0.83
Vocabulary      0.73 0.55           0.84
Sent.Completion 0.68 0.52           0.73 0.27
First.Letters   0.65      0.56      0.73 0.27
4.Letter.Words  0.62      0.49      0.63 0.37
Suffixes        0.56      0.41      0.50 0.50
Letter.Series   0.59           0.61 0.72 0.28
Pedigrees       0.58 0.23      0.34 0.50 0.50
Letter.Group    0.54           0.46 0.53 0.47

With eigenvalues of:
   g  F1*  F2*  F3*
3.60 0.96 0.74 0.71

general/max  3.73   max/min =   1.36
The degrees of freedom for the model is 12  and the fit was  0.01
```

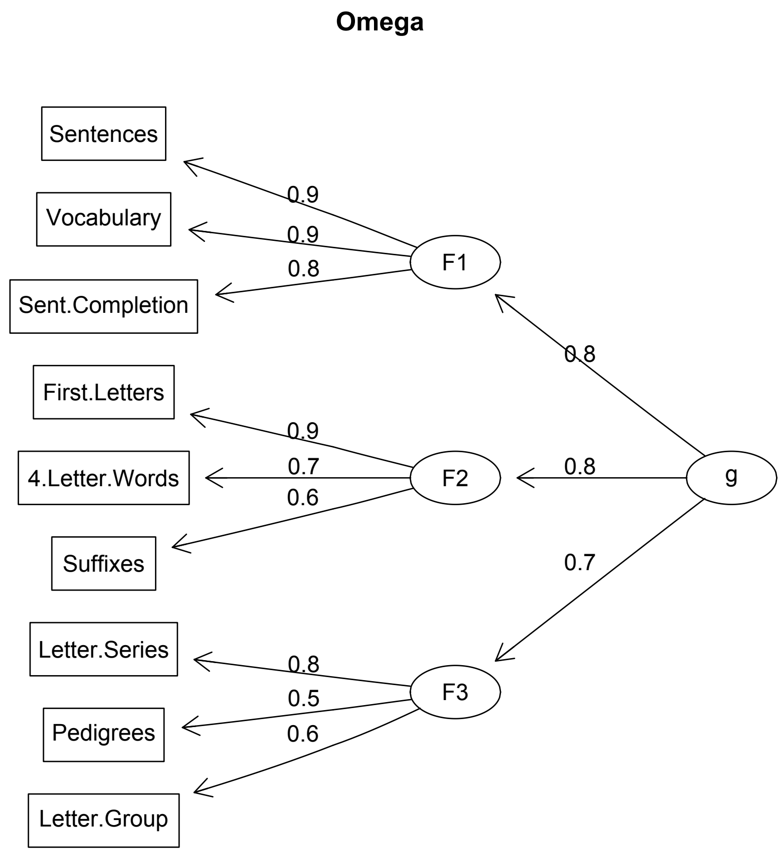

Figure 7. The Thurstone 9 variable problem has clear 3 lower order and one higher order factor structure. This shows the hierarchcal solution solution.

17 mental tests from Thurstone/Bechtoldt

This set is the 17 variables from which the clear 3 factor solution used by McDonald (1999) is abstracted. 6 lower order factors are extracted. See Table 5

The bi-factor solution of the Bechtoldt data show a clear general factor and lower level, orthogonalized residual factors (Figure 8)

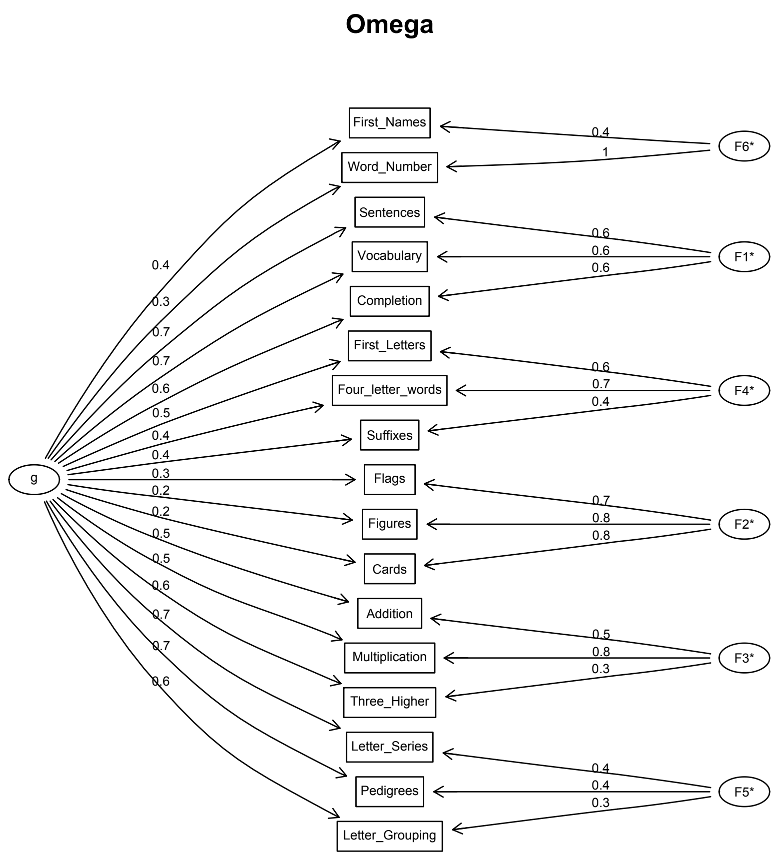

Figure 8. Bechtoldt reported 17 variables taken from Thurstone. They show a clear bifactor or hierarchical structure.

14 mental tests from Holzinger

These 14 variables are from Holzinger and Swineford (1937) who introduced the bifactor model (one general factor and several group factors) for mental abilities. This

Table 5: 17 mental tests from Thurstone and Bechtold

```
Omega
Call: omega(m = Bechtoldt.1, nfactors = 6, n.obs = 213)
Alpha:  0.89
G.6:   0.93
Omega Hierarchical:   0.72
Omega Total   0.95

Schmid Leiman Factor loadings greater than  0.2
                  g    F1*  F2*  F3*  F4*  F5*  F6*  h2   u2
First_Names       0.40                          0.37 0.33 0.67
Word_Number       0.29                          0.95 1.00
Sentences         0.68 0.58                          0.83
Vocabulary        0.67 0.63                          0.87
Completion        0.65 0.57 0.20                     0.77 0.23
First_Letters     0.53                0.56           0.60 0.40
Four_letter_words 0.45                0.69           0.68 0.32
Suffixes          0.45                0.42           0.43 0.57
Flags             0.33      0.71                     0.63 0.37
Figures           0.20      0.85                     0.76 0.24
Cards             0.24      0.79                     0.69 0.31
Addition          0.52           0.50                0.54 0.46
Multiplication    0.53           0.77                0.86
Three_Higher      0.57           0.33                0.52 0.48
Letter_Series     0.74                     0.42      0.73 0.27
Pedigrees         0.69                     0.39      0.64 0.36
Letter_Grouping   0.64                     0.31      0.53 0.47

With eigenvalues of:
   g  F1*  F2*  F3*  F4*  F5*  F6*
4.78 1.12 1.96 1.00 0.99 0.46 1.07

general/max  2.44   max/min =   4.24
The degrees of freedom for the model is 49  and the fit was  0.27
The number of observations was  213  with Chi Square =  54.37  with prob <  0.28
```

is a nice demonstration data set of a hierarchical factor structure that can be analyzed using the omega function or using sem. The bifactor model is typically used in measures of cognitive ability.

The 14 variables are ordered to reflect 3 spatial tests, 3 mental speed tests, 4 motor speed tests, and 4 verbal tests. The sample size is 355. See Table 6.

9 mental tests from Brigham/Thurstone

These 9 mental tests were reported by Thurstone (1933) are the data set of 4,175 students reported by Professor Brigham of Princeton to the College Entrance Examination Board. This set does not show a clear bifactor solution but is included as a demonstration of the differences between a maximimum likelihood factor analysis solution versus a principal axis factor solution. See Table 7.

24 mental tests from Holzinger/Harman

The 24 mental tests from Holzinger and Swineford have been analzyed by Harman and many others as an example of factor analysis. See Table 8 and Figure 9.

Discussion and conclusions

Yes, it is possible to find a general factor of personality. But is this the most useful level of analysis? I do not believe so. Based upon the psychometric principal that a measure should be interpreted in terms of its common variance, it is hard to justify thinking about measures with 205-36% common variance. Just as some have claimed that affect reflects one common dimension from happy to sad (Russell & Carroll, 1999), others have shown that it is better to consider happy and sad as separate dimensions (Rafaeli & Revelle, 2006). This debate between forming higher order constructs versus focusing on lower order, but correlated constructs is long running. In the field of intelligence, the introduction of the bifactor model (Holzinger & Swineford, 1937) clarified the use of hierarchical models and allowed for the estimation of the relative importance of each. When g has large saturations on each test, it is clearly useful to think in terms of g. But when the saturation is low, and when there is good biological evidence for separate, although correlated systems associated with the lower order constructs (e.g., the three brain systems model of reinforcement sensitivity theory (Corr, 2008; Gray & McNaughton, 2000; Revelle, 2008)), it will prove more useful to develop theories at the lower order level.

When we compare the general factor solutions of the personality tests to those of the ability tests, it is quite clear that what is a clear g in ability is much muddier in personality.

Table 6: 14 mental tests from Holzinger and Swineford. A four factor solution is used.

```
> om.h <- omega(Holzinger,4,n.obs=355)
> om.h

Omega
Call: omega(m = Holzinger, nfactors = 4, n.obs = 355)
Alpha:  0.85
G.6:   0.88
Omega Hierarchical:   0.65
Omega Total   0.9

Schmid Leiman Factor loadings greater than  0.2
     g    F1*  F2*  F3*  F4*  h2   u2
T1   0.52      0.28      0.26 0.41 0.59
T2   0.69                0.33 0.65 0.35
T3.4 0.66                0.59 0.79 0.21
T6   0.58      0.42           0.56 0.44
T28  0.45      0.44           0.40 0.60
T29  0.52      0.46           0.49 0.51
T32            0.24 0.38      0.22 0.78
T34  0.33           0.67      0.58 0.42
T35                 0.43      0.24 0.76
T36a 0.43 0.20      0.43      0.44 0.56
T13  0.59 0.55                0.67 0.33
T18  0.55 0.65                0.72 0.28
T25b 0.49 0.53                0.55 0.45
T77  0.47 0.55                0.54 0.46

With eigenvalues of:
   g  F1*  F2*  F3*  F4*
3.45 1.43 0.78 1.02 0.59

general/max  2.41   max/min =   2.44
The degrees of freedom for the model is 41  and the fit was  0.12
The number of observations was  355  with Chi Square =  41.46  with prob <  0.45
```

Table 7: 9 ability items from the College Entrance Exam reported by Brigham and Thurstone.

```
> om.bt <- omega(Thurstone.33,n.obs = 4175)
> om.bt


Omega
Call: omega(m = Thurstone.33, n.obs = 4175)
Alpha:  0.9
G.6:   0.91
Omega Hierarchical:   0.85
Omega Total   0.93

Schmid Leiman Factor loadings greater than  0.2
          g    F1*  F2*  F3*  h2   u2
Def       0.77                0.61 0.39
Arith     0.53           0.55 0.59 0.41
Class     0.76                0.58 0.42
A_Lang    0.67                0.49 0.51
Ant       0.80      0.28      0.72 0.28
Number    0.48           0.62 0.62 0.38
Analog    0.77                0.60 0.40
Logical   0.71                0.56 0.44
Paragraph 0.71      0.70      1.00

With eigenvalues of:
    g   F1*   F2*   F3*
4.372 0.014 0.627 0.752

general/max  5.82   max/min =   55.28
The degrees of freedom for the model is 12  and the fit was  0.06
The number of observations was  4175  with Chi Square =  260.05  with prob <  1.1e-48
>
```

Table 8: default title

```
> om.harm <- omega(test.data,4,n.obs=231)
> summary(om.harm)

Omega
Alpha:  0.91
Omega Hierarchical:   0.65
Omega Total:   0.93

With eigenvalues of:
  g F1* F2* F3* F4*
5.3 2.0 1.4 1.7 1.1

general/max  2.61   max/min =   1.85
The degrees of freedom for the model is 186  and the fit was  1.71
The number of observations was  231  with Chi Square =  373.81  with prob <  0
```

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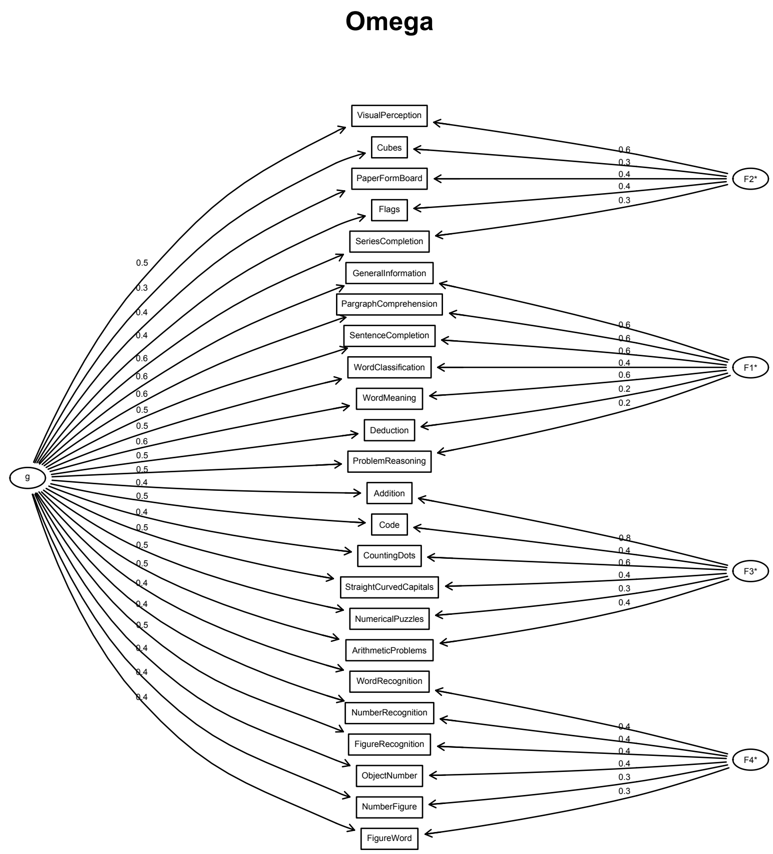

Figure 9. The bifactor solution to the Holzinger Harman problem shows a clear general factor.

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