Psychometric Instrument Development

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Lecture 6

Survey Research & Design in Psychology

James Neill, 2016

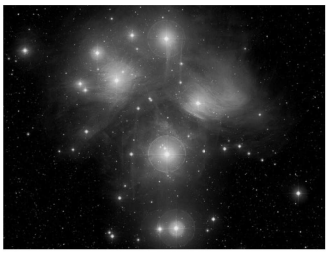
Overview

1. Recap: Exploratory factor analysis
2. Concepts & their measurement
3. Measurement error
4. Psychometrics
5. Reliability & validity
6. Composite scores
7. Writing up instrument development

Readings: Psychometrics

1. Bryman & Cramer (1997). Concepts and their measurement. [eReserve]
2. DeCoster, J. (2000). Scale construction notes. [Online]
3. Howitt & Cramer (2005). Reliability and validity: Evaluating the value of tests and measures. [eReserve]
4. Howitt & Cramer (2011/2014). Ch 36/37: Reliability in scales and measurement: Consistency and measurement. [Textbook/eReserve]
5. Wikiversity. Measurement error. [Online]
6. Wikiversity.
7. Reliability and validity. [Online]

Recap: Exploratory Factor Analysis



What is factor analysis?

- Factor analysis is:
  - a *family* of multivariate correlational methods used to identify clusters of covariance (called factors)
- Two main types (extraction methods):
  - Exploratory factor analysis (EFA)
  - Confirmatory factor analysis (CFA)

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EFA assumptions

- Sample size
  - 5+ cases per variables (min.)
  - 20+ cases per variable (ideal)
  - Another guideline: Or *N* > 200
- Check bivariate outliers & linearity
- Factorability: check any of:
  - Correlation matrix: Some > .3?
  - Anti-image correlation matrix diags > .5
  - Measures of Sampling Adequacy
    - KMO > ~ .5 to 6; Bartlett's sig?

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Summary of EFA steps

1. Test assumptions
   - Sample size
   - Outliers & linearity
   - Factorability
2. Select type of analysis
   - Extraction
     - Principal Components (PC)
     - Principal Axis Factoring (PAF)
   - Rotation
     - Orthorgonal (Varimax)
     - Oblique (Oblimin)

Summary of EFA steps

3. Determine no. of factors
   - Theory?
   - Kaiser's criterion?
   - Eigen Values and Scree plot?
   - % variance explained?
   - Interpretability of weakest factor?
4. Select items
   - Check factor loadings to identify which items belong in which factor
   - Drop items 1-by-1 if
     - primary loading low? (< .5 ?)
     - cross-loadings high? (> .3 ?)
     - item wording doesn't belong to meaning of factor

Summary of EFA steps

5. Name and define factors
6. Examine correlations amongst factors
7. Check factor structure for sub-groups
8. Analyse internal reliability
9. Compute composite scores

Covered in this lecture

EFA example 4: University student motivation

Example EFA: University student motivation

- 271 UC students responded to 24 university student motivation statements in 2008 using an 8-point Likert scale (False to True)
- For example:
  "I study at university … "
  - to enhance my job prospects.
  - because other people have told me I should.
- EFA PC Oblimin revealed 5 factors

Example EFA: Pattern matrix

	Component				
	1	2	3	4	5
motiv15	.964				
motiv20	.914				
motiv25	.779				
motiv10	.750				
motiv05	.713				
motiv09		.955			
motiv14		.922			
motiv24		.912			
motiv04		.885			
motiv19		.765			
motiv07			-.906		
motiv22			-.884		
motiv17			-.883		
motiv01			-.876		
motiv12			-.734		
motiv03			-.725		
motiv13				.925	
motiv23				.862	
motiv18				.847	
motiv11					.817
motiv21					.767
motiv02					.740
motiv16			-.248		.664
motiv06					.628

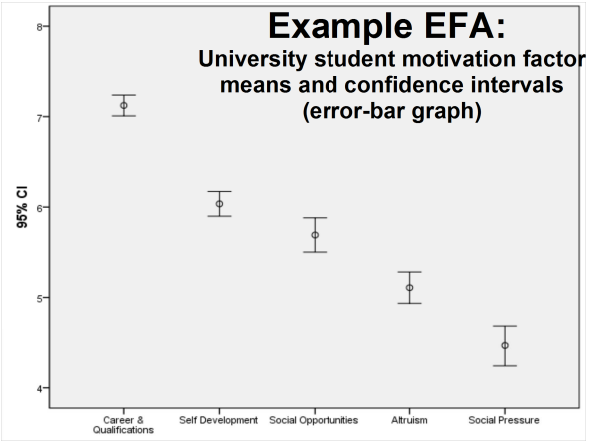
Example EFA:
University student motivation

1. Career & Qualifications
   (6 items; α = .92)
2. Self Development
   (5 items; α = .81)
3. Social Opportunities
   (3 items; α = .90)
4. Altruism
   (5 items; α = .90)
5. Social Pressure
   (5 items; α = .94)

Example EFA:
University student motivation factor correlations

Motivation	CQ	SD	SO	AL	SP
Career & Qualif.		.26	.25	.24	.06
Self Develop.			.33	**.55**	**-.18**
Social Enjoyment				.26	.33
Altruism					.11
Social Pressure					

Example EFA:
University student motivation factor means and confidence intervals (error-bar graph)



Exploratory factor analysis: Q & A

Questions?

Concepts & their measurement

Operationalising fuzzy concepts

Concepts & their measurement:
Bryman & Cramer (1997, p. 53)

Concepts

- express common elements in the world (to which we give a name)
- form a linchpin in the process of social research

Hypotheses

- express relations between **concepts**

Concepts & their measurement:
Bryman & Cramer (1997, p. 53)

"Once formulated, a concept … will need to be ***operationally defined***, in order for systematic research to be conducted in relation to it..."

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Concepts & their measurement:
Bryman & Cramer (1997, p. 53)

"...An ***operational definition*** specifies the procedures (operations) that will permit differences between individuals in respect of the concept(s) concerned to be precisely specified..."

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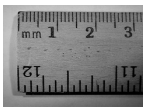
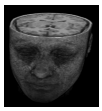
Concepts & their measurement:
Bryman & Cramer (1997, p. 53)

"...What we are in reality talking about here is ***measurement****,* that is, the assignment of numbers to the units of analysis - be they people, organizations, or nations - to which a concept refers."





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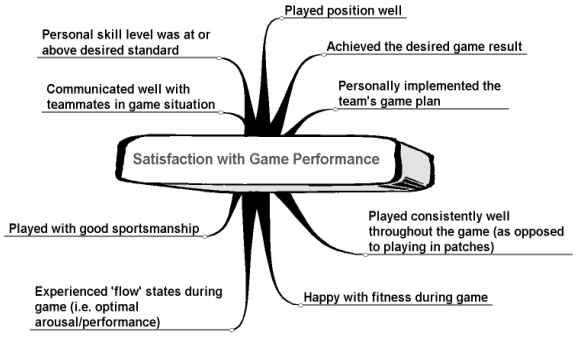
Operationalisation

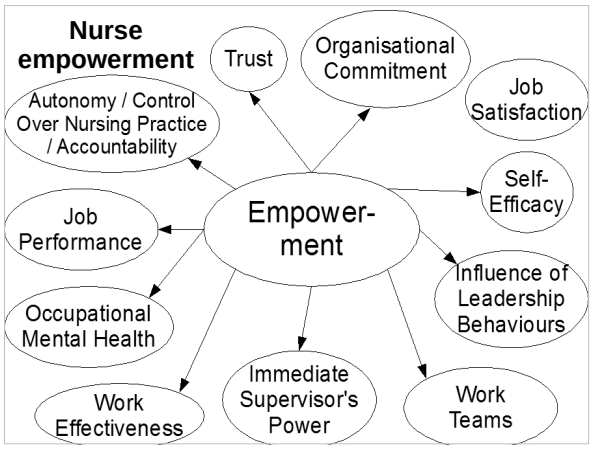
- ...is the act of making a ***fuzzy concept*** measurable.
- Social science often uses ***multi-item measures*** to assess related but distinct aspects of a fuzzy concept.

Operationalisation steps

1. Brainstorm indicators of a concept
2. Define the concept
3. Draft measurement items
4. Pre-test and pilot test
5. Examine psychometric properties – how precise are the measures?
6. Redraft/refine and re-test

Operationalisating a fuzzy concept: Example (Brainstorming indicators)





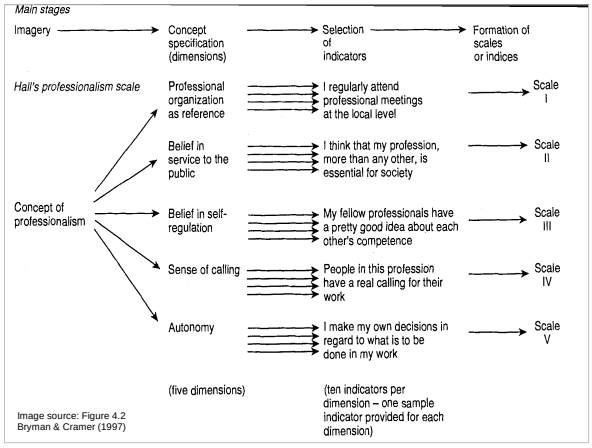


Image source: Figure 4.2 Bryman & Cramer (1997)

Measurement error

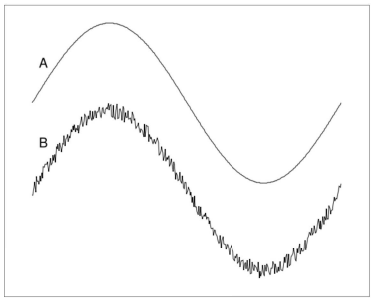


Image source: http://commons.wikimedia.org/wiki/File:Noise_effect.svg

Measurement error

Measurement error is any deviation from the **true value** caused by the measurement procedure.

- **Observed score** =
  true score +/- measurement error
- Measurement error =
  systematic error + random error

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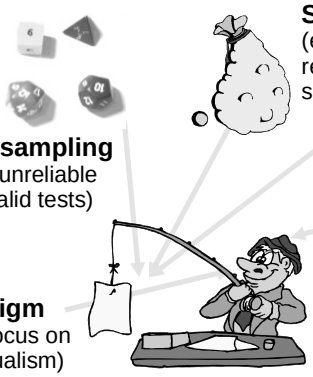
Sources of measurement error



Sampling (e.g., non-representative. sample)

Respondent bias (e.g., social desirability)

Researcher bias (e.g., researcher favours a hypothesis)

Non-sampling (e.g., unreliable or invalid tests)

Paradigm (e.g., focus on individualism)

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Measurement precision & noise

- The lower the precision, the more participants are needed to make up for the "noise" in the measurements.
- Even with a larger sample, noisy data can be hard to interpret.
- Especially when testing and assessing individual clients, special care is needed when interpreting results of noisy tests.

http://www.sportsci.org/resource/stats/precision.html

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Minimising measurement error

- Use well designed measures:
  - Multiple indicators for fuzzy constructs
  - Sensitive to target constructs
  - Clear instructions and questions
- Use standard administration procedures.
- Minimise potential demand characteristics (e.g., train interviewers)

Minimising measurement error

- Obtain a representative sample:
  - Use probability-sampling, if possible
  - For non-probability sampling, use strategies to minimise selection bias
- Maximise response rate:
  - Pre-survey contact
  - Minimise length / time / hassle
  - Rewards / incentives
  - Coloured paper
  - Call backs / reminders

Minimising measurement error

- Ensure administrative accuracy:
  - Set up efficient coding, with well-labelled variables
  - Check data (double-check at least a portion of the data)

Psychometrics

Psychometrics: Goal

To validly measure differences between individuals and groups in psychosocial qualities such as attitudes and personality.

Psychometric tasks

- Develop approaches and procedures (theory and practice) for measuring psychological phenomena
- Design and test psychological measurement instrumentation
  (e.g., examine and improve reliability and validity of psychological tests)

Psychometrics: As test-taking grows, test-makers grow rarer

> "Psychometrics, one of the most obscure, esoteric and cerebral professions in America, is now also one of the hottest."
> - As test-taking grows, test-makers grow rarer, David M. Herszenhor, May 5, 2006, New York Times

Psychometricians are in demand due to increased testing of educational and psychological capacity and performance.

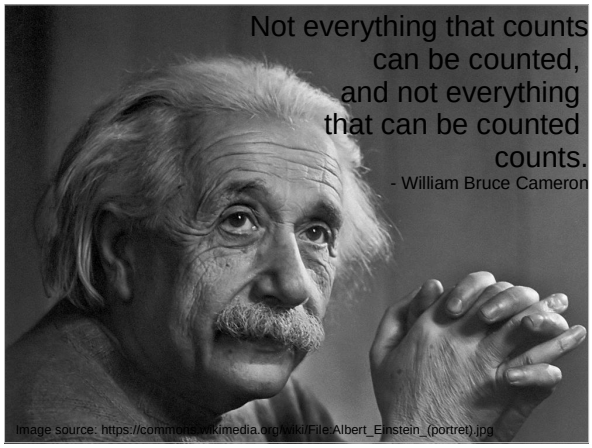

Image source: https://commons.wikimedia.org/wiki/File:Albert_Einstein_(portret).jpg

Psychometric methods

- Factor analysis
  - Exploratory
  - Confirmatory
- Classical test theory
  - Reliability
  - Validity

Reliability & Validity

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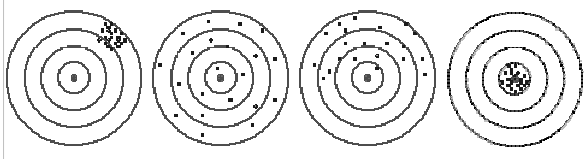
Reliability and validity
(Howitt & Cramer, 2005)

Reliability and validity ("classical test theory") are ways of evaluating psychological tests and measures.

- Reliability is about consistency of
  - the items within the measure
  - a measure over time
- Validity is about whether the measure actually measures what it is intended to measure.

Reliability vs. validity

In classical test theory, reliability is generally thought to be necessary for validity, but it does not guarantee validity.



In practice, a test of a relatively changeable psychological construct such as suicide ideation, may be valid (i.e., accurate), but not particularly reliable over time (because suicide ideation is likely to fluctuate).

Reliability and validity
(Howitt & Cramer, 2005)

- Reliability and validity are not inherent characteristics of measures. They are affected by the context and purpose of the measurement → a measure that is valid for one purpose may not be valid for another purpose.

Reliability

Reproducibility of a measurement

Types of reliability

- **Internal consistency**: Correlation among multiple items in a factor
- **Test-retest reliability**: Correlation between test at one time and another
  - Product-moment correlation (*r*)
- **Inter-rater reliability**: Correlation between one observer and another:
  - Kappa

Reliability rule of thumb

< .6 = Unreliable
.6 = OK
.7 = Good
.8 = Very good, strong
.9 = Excellent
> .95 = may be overly reliable or redundant – this is subjective and depends on the nature what is being measured

Reliability rule of thumb

Table 7 Fabrigar et al (1999).

Table 7 Fabrigar et al. (1999)

Variable	*Journal of Personality and Social Psychology* N	%	*Journal of Applied Psychology* N	%
Average reliability of variables				
Less than .60	3	1.9	2	3.4
.60–.69	6	3.8	5	8.6
.70–.79	33	20.8	9	15.5
.80–.89	33	20.8	11	19.0
.90–1.00	14	8.8	9	15.5
Unknown	70	44.0	22	37.9

Rule of thumb - reliability coefficients should be over .70, up to approx. .90

Internal consistency
(or internal reliability)

Internal consistency refers to:

- How well multiple items combine as a measure of a single concept
- The extent to which responses to multiple items are consistent with one another

Internal consistency can measured by:

- Split-half reliability
- Odd-even reliability
- Cronbach's Alpha (α)

Internal consistency
(Recoding)

If dealing with a mixture of positively and negatively worded items, remember to ensure that negatively-worded items are recoded.

Types of internal consistency: Split-half reliability

- Sum the scores for the first half (e.g., 1, 2, 3) of the items.
- Sum the scores for the second half (e.g., 4, 5, 6) of the items.
- Compute a correlation between the sums of the two halves.

Types of internal consistency: Odd-even reliability

- Sum the scores for items 1, 3, 5, etc.
- Sum the scores for items 2, 4, 6, etc.
- Compute a correlation between the sums of the two halves.

Types of internal reliability: Alpha (Cronbach's α)

- Averages all possible split-half reliability coefficients.
- Akin to a single score which represents the degree of intercorrelation amongst the items.

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How many items per factor?

- More items → greater reliability
  (The more items, the more 'rounded' the measure)
- Law of diminishing returns
- Min. = 2?
- Max. = unlimited?
- Typically ~ 4 to 12 items per factor
- Final decision is subjective and depends on research context

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Internal reliability example: Student-rated quality of maths teaching

- 10-item scale measuring students' assessment of the educational quality of their maths classes
- 4-point Likert scale ranging from: strongly disagree to strongly agree

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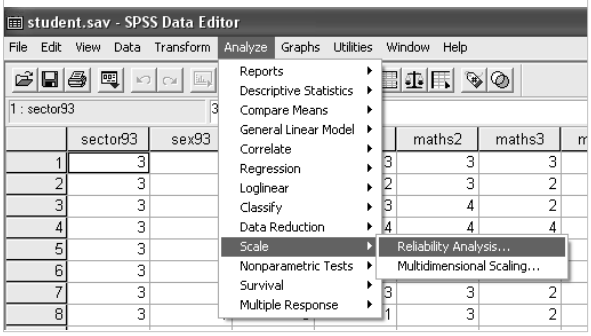
Quality of mathematics teaching

1. My maths teacher is friendly and cares about me.
2. The work we do in our maths class is well organised.
3. My maths teacher expects high standards of work from everyone.
4. My maths teacher helps me to learn.
5. I enjoy the work I do in maths classes.

+ 5 more

Internal reliability example: Quality of maths teaching



SPSS: Corrected Item-total correlation

Item-total correlations should be > ~.5

Reliability Statistics

Cronbach's Alpha	N of Items
.885	10

A measure for examining the relationship between individual items and the total scale, this is the correlation between the given item and the item sum if the given item is not included in the scale. Smaller values indicate the given item is not well correlated with the others.

Item-To

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
school1	41.15	98.608	.438	.888
school2	40.04	91.500	.648	.872

SPSS: Cronbach's α

If Cronbach's α if item deleted is higher than the α, consider removing item.

Reliability Statistics

Cronbach's Alpha	N of Items
.885	10

A measure for examining the relationship between individual items and the total scale, this is the value of Cronbach's Alpha for the remaining items if the given item is not included in the scale.

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
school1	41.15	98.608	.438	.888
school2	40.04	91.500	.648	.872

SPSS: Reliability output

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Alpha if Item Deleted
MATHS1	25.2749	25.5752	.6614	.8629
MATHS2	25.0333	26.5322	.6235	.8661
MATHS3	**25.0192**	**30.5174**	**.0996**	**.9021**
MATHS4	24.9786	25.8671	.7255	.8589
MATHS5	25.4664	25.6455	.6707	.8622
MATHS6	25.0813	24.9830	.7114	.8587
MATHS7	25.0909	26.4215	.6208	.8662
MATHS8	25.8699	25.7345	.6513	.8637
MATHS9	25.0340	26.1201	.6762	.8623
MATHS10	25.4642	25.7578	.6495	.8638

Remove this item.

Reliability Coefficients

N of Cases = 1353.0 N of Items = 10

Alpha = .8790

SPSS: Reliability output

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Alpha if Item Deleted
MATHS1	22.2694	24.0699	.6821	.8907
MATHS2	22.0280	25.2710	.6078	.8961
MATHS4	21.9727	24.4372	.7365	.8871
MATHS5	22.4605	24.2235	.6801	.8909
MATHS6	22.0753	23.5423	.7255	.8873
MATHS7	22.0849	25.0777	.6166	.8955
MATHS8	22.8642	24.3449	.6562	.8927
MATHS9	22.0280	24.5812	.7015	.8895
MATHS10	22.4590	24.3859	.6524	.8930

Reliability Coefficients

N of Cases = 1355.0 N of Items = 9

Alpha = .9024 ← Alpha improves.

Table * . Definitions of the Life Effectiveness Questionnaire dimensions, with Internal Consistency and Test-Retest Correlations

LEQ 8-factor model	Description	3 items per scale	
		Test-Retest *r*	Alpha
Achievement Motivation	Motivation to achieve excellence and put the required effort into action to attain it.	.68	.87
Active Initiative *	Initiating action in new situations.	.73	.81
Emotional Control	Maintaining emotional control when faced with potentially stressful situations.	.75	.87
Intellectual Flexibility	Adapting thinking and accommodating new information from changing conditions and different perspectives.	.60	.78
Self Confidence *	Confidence in abilities and the success of actions.	.73	.84
Social Competence	Ability in and success of social interactions.	.75	.86
Task Leadership	Ability to lead other people effectively when a task needs to be done and productivity is the primary requirement.	.81	.82
Time Management	Makes optimum use of time.	.75	.84
Total	Effective in generic life skills.	.72	.84
N		.67	.93

Validity

Validity is the extent to which an instrument actually measures what it purports to measure.

Validity = does the test measure what its meant to measure?

Validity

- Validity is multifaceted and includes:
  - Comparing wording of the items with theory and expert opinion
  - Correlations with similar and dissimilar measures
  - How well the measure predicts the future

Types of validity

- Face validity
- Content validity
- Criterion validity
  - Concurrent validity
  - Predictive validity
- Construct validity
  - Convergent validity
  - Discriminant validity

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Face validity
(low-level of importance overall)

- **Asks**:
  "Do the questions appear to measure what the test purports to measure?"
- **Important for**:
  Respondent buy-in
- **How assessed**:
  Read the test items

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Content validity
(next level of importance)

- **Asks**:
  "Are questions measuring the complete construct?"
- **Important for**:
  Ensuring holistic assessment
- **How assessed**:
  Diverse means of item generation (lit. review, theory, interviews, expert review)

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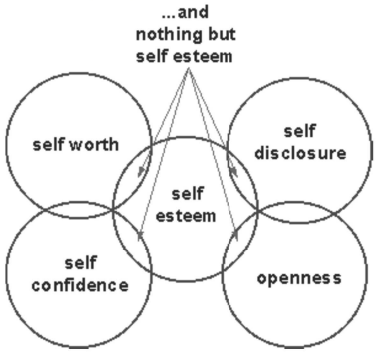
Criterion validity
(high importance)

- **Asks**:
  "Can a test score predict real world outcomes?"
- **Important for**:
  Test relevance and usefulness
- **How assessed**:
  Concurrent validity: Correlate test scores with recognised external criteria such as performance appraisal scores
  Predictive validity: Correlate test scores with future outcome e.g., offender risk rating with recidivism

Construct validity
(high importance)

- **Asks**:
  Does the test assess the construct it purports to?
  ("the truth, the whole truth and nothing but the truth.")
- **Important for**:
  Making inferences from operationalisations to theoretical constructs
- **How assessed**:
  - **Theoretical** (is the theory about the construct valid?)
  - **Statistical**
    Convergent – correlation with similar measures
    Discriminant – not correlated with other constructs

Construct validity
(high importance)



Composite Scores

Composite scores

Combine item-scores into overall factor scores which represent individual differences in each of the target constructs.

These new 'continuous' variables can then be used for:

- Descriptive statistics and histograms
- Correlations
- As IVs and/or DVs in inferential analyses such as MLR and ANOVA

Composite scores

There are two ways of creating composite scores:

- Unit weighting
- Regression weighting

Unit weighting

Average (or total) of item scores within a factor.
(each variable is equally weighted)

$X = \text{mean}(y_1 \ldots y_p)$

.25 .25 .25 .25

Creating composite scores: Dealing with missing data

It can be helpful to maximise the sample size by allowing for some missing data.

Composite scores: Missing data

SPSS syntax:

Compute X = mean (v1, v2, v3, v4, v5, v6)
Compute X = mean**.4** (v1, v2, v3, v4, v5, v6)

Specify a min. # of items. If the min. isn't available, the composite score will be missing

How many items can be missed? Depends on overall reliability. A rule of thumb:

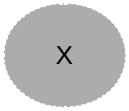
- Allow 1 missing per 4 to 5 items
- Allow 2 missing per 6 to 8 items
- Allow 3+ missing per 9+ items

A researcher may decide to be more or less conservative depending on the factors' reliability, sample size, and the nature of the study.

Regression weighting

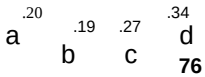
Factor score regression weighting

The contribution of each item to the composite score is weighted to reflect some items more than other items.



X = 20*a + .19*b + .27*c + .34*d

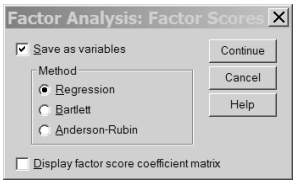
This is arguably more valid, but the advantage may be marginal, and it makes factor scores difficult to compare.



Regression weighting

Two calculation methods:

- Manual (use Compute)
- Automatic (use Factor Analysis – Factor Scores)



Regression weighting – SPSS data

Variable view: Variables auto-calculated through SPSS factor analysis

64	FAC1_1	Numeric	11	5	REGR factor score 1 for analysis 1	N
65	FAC2_1	Numeric	11	5	REGR factor score 2 for analysis 1	N
66	FAC3_1	Numeric	11	5	REGR factor score 3 for analysis 1	N
67	FAC4_1	Numeric	11	5	REGR factor score 4 for analysis 1	N
68	FAC5_1	Numeric	11	5	REGR factor score 5 for analysis 1	N
69	FAC6_1	Numeric	11	5	REGR factor score 6 for analysis 1	N
70	FAC7_1	Numeric	11	5	REGR factor score 7 for analysis 1	N
71	FAC8_1	Numeric	11	5	REGR factor score 8 for analysis 1	N
72	FAC9_1	Numeric	11	5	REGR factor score 9 for analysis 1	N

Data view: Data are standardised, centred around 0

	FAC1_1	FAC2_1	FAC3_1	FAC4_1	FAC5_1	FAC6_1	FAC7_1	FAC8_1	FAC9_1
5	.46	.41	-4.41	-1.29	.93	.26	-2.63	.99	-1.21
3	-1.34	-1.90	3.17	-1.06	-.10	1.95	-1.39	.66	-.08
1	-.36	-.02	1.61	-1.27	-2.05	-1.77	-.74	.72	1.00
2	.51	-.09	.11	.56	1.05	-.72	-.93	1.06	-.17
3	.30	-.54	-.14	2.65	-.54	.11	1.82	.53	1.23
1	-.01	1.18	.56	-.26	1.35	-1.36	-.58	-1.06	-.63
2	-1.91	-1.74	1.73	-.36	-2.47	1.34	.37	.86	-.38

Writing up instrument development

Writing up instrument development

- Introduction
  - Literature review about underlying factors – theory and research
- Method
  - Materials/Instrumentation – summarise the design and development of the measures and the expected factor structure
    e.g., present a table of the expected factors and their operational definitions.

Writing up instrument development

- Results
  - Factor analysis
    - Assumption testing
    - Extraction method & rotation
    - # of factors, with names and definitions
    - # of items removed and rationale
    - Item factor loadings & communalities
    - Factor correlations
  - Reliability for each factor
  - Composite scores for each factor
  - Correlations between factors

Writing up instrument development

- Discussion
  - Theoretical underpinning – Was it supported by the data? What adaptations should be made to the theory?
  - Quality / usefulness of measure – Provide an objective, critical assessment, reflecting the measures' strengths and weaknesses
  - Recommendations for further improvement
- Writing up a factor analysis
  - Download examples: http://goo.gl/fD2qby

Summary

Summary: What is psychometrics?

1. Science of psychological measurement
2. Goal: Validly measure individual psychosocial differences
3. Design and test psychological measures e.g., using
   1. Factor analysis
   2. Reliability and validity

Summary: Concepts & their measurement

1. Concepts name common elements
2. Hypotheses identify relations between concepts
3. Brainstorm indicators of a concept
4. Define the concept
5. Draft measurement items
6. Pre-test and pilot test
7. Examine psychometric properties
8. Redraft/refine and re-test

Summary: Measurement error

1. Deviation of measure from true score
2. Sources:
    1. Non-sampling (e.g., paradigm, respondent bias, researcher bias)
    2. Sampling (e.g., non-representativeness)
3. How to minimise:
    1. Well-designed measures
    2. Reduce demand effects
    3. Representative sampling
    4. Maximise response rate
    5. Ensure administrative accuracy

Summary: Reliability

1. Consistency or reproducibility
2. Types
    1. Internal consistency
    2. Test-retest reliability
3. Rule of thumb
    1. > .6 OK
    2. > .8 Very good
4. Internal consistency
    1. Split-half
    2. Odd-even
    3. Cronbach's Alpha

Summary: Validity

1. Extent to which a measure measures what it is intended to measure
2. Multifaceted
   1. Compare with theory and expert opinion
   2. Correlations with similar and dissimilar measures
   3. Predicts future

Summary: Composite scores

Ways of creating composite (factor) scores:

1. **Unit weighting**
   1. Total of items or
   2. Average of items (recommended for lab report)
2. **Regression weighting**
   1. Each item is weighted by its importance to measuring the underlying factor (based on regression weights)

Summary: Writing up instrument development

1. **Introduction**
   1. Review constructs & previous structures
   2. Generate research question
2. **Method**
   1. Explain measures and their development
3. **Results**
   1. Factor analysis
   2. Reliability of factors
   3. Descriptive statistics for composite scores
   4. Correlations between factors
4. **Discussion**
   1. Theory? / Measure? / Recommendations?

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