Human-Computer Interaction

Subjective Measures + Scale Construction

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Today's Agenda

- Topic overview
  - Overview of subjective measures
  - How to design good questions
  - Scale construction
- Hands-on activity: Project study design feedback

Recap: *What are different kinds of measurements we can take?*

1. **Objective**: Measurement from participants against an objective standard, e.g., performance in a test
2. **Behavioral**: Measurement of the actions and behaviors of participants, E.g., how much eye-contact participants maintain with a robot
3. **Subjective**: Measurement of self-report data on subjective evaluations, e.g., preferences, personality 👈 **our focus today**
4. **Physiological**: Measurements taken directly from participants' bodies, e.g., body temperature, GSR, EEG, EMG, fMRI

What are subjective measures?

Definition: Measurements of the subjective perceptions, e..g, thoughts, feelings, preferences, and individual traits using self-reported data collection instruments, often *questions*.

Types of subjective measurement instruments:

1. **Standardized responses:** Questionnaires
2. **Open-ended responses:** Interviews

These instruments can be administered by the researcher or by the respondent.

*What is a **survey** then?*

Definition: A survey is a quantitative empirical research method that uses questionnaires or interviews to collect, analyze, and interpret data from populations of interest.

What does a subjective measure look like?

Subjective measures follow the archetypal formats below:

Open-ended question

What barriers did you face, in attempting to use the Banjee software to complete your tasks?[1]

[Open-ended answer]

Closed-ended question

What is your impression of using the website for www.veggieworld.com?

Please circle one number:

Frustrating **1 2 3 4 5 6 7** *Satisfying*

[1] Lazar et al., 2017, Chapter 5 - Surveys

What are open-ended questions?

Definition: Questions designed to prompt rich, unstructured responses for participants that will generate data that can be qualitatively or quantitatively analyzed.

What barriers did you face, in attempting to use the Banjee software to complete your tasks?[1]

[Open-ended answer]

[1] Lazar et al., 2017, Chapter 5 - Surveys

What are closed-ended questions?

Definition: Questions where standardized response instruments are used to standardize responses so that statistical methods can be used.

What is your impression of using the website for www.veggieworld.com?

Please circle one number:

Frustrating **1 2 3 4 5 6 7** *Satisfying*

What are different standardized response instruments?

1. Likert scales
2. Rating scales
3. Semantic differential scales

What is a Likert scale?

Definition: A Likert scale includes a number of rank-ordered items that respondents use to express their level of agreement with a statement or a question.

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

What is a rating scale?

Definition: A rating scale is a numerical range with which participants can express their level of agreement with a statement or a question.

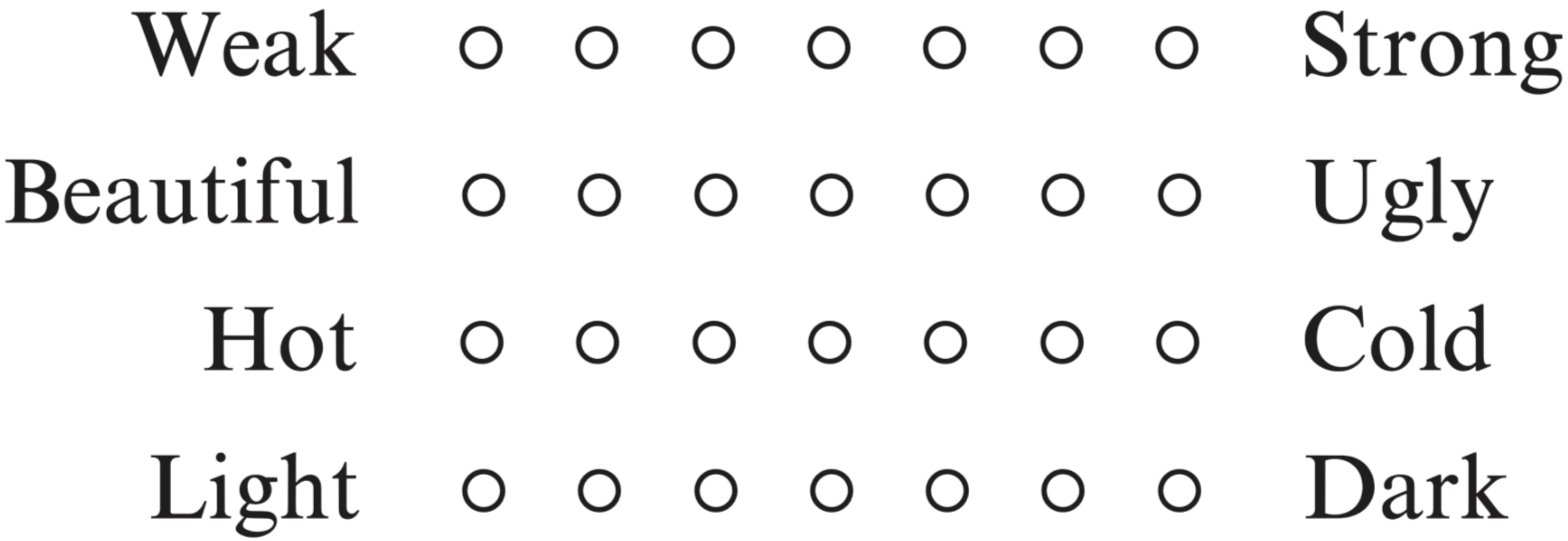
1 2 3 4 5 6 7

An anchored rating scale provides anchor terms that ground the ends of the scale in descriptive terms:

Frustrating **1 2 3 4 5 6 7** *Satisfying*

What is a semantic differential scale?

Definition: The semantic differential technique involves presenting pairs of bipolar, or opposite, adjectives at either end of a series of scales.[1]



Weak ○ ○ ○ ○ ○ ○ ○ Strong

Beautiful ○ ○ ○ ○ ○ ○ ○ Ugly

Hot ○ ○ ○ ○ ○ ○ ○ Cold

Light ○ ○ ○ ○ ○ ○ ○ Dark

[1] Lazar et al., 2017, Chapter 5 - Surveys

How to design good questions?

Principle 1: *Avoid “leading” or “loaded” questions*

Example

Don’t you agree that social workers should earn more money than they currently earn?

- Yes, they should earn more
- No, they should not earn more
- Don’t know/no opinion

Principle 2: *Avoid double negatives*

Example

Do you agree or disagree with the following statement?

Teachers should not be required to supervise their students during recess.

Principle 3: *Always aim at capturing firsthand experiences and beware of asking about information that is acquired only secondhand*

Tip

People are very good at describing criminal activity directed at them but terrible at describing how much crime happens in their neighborhood

Principle 4: *Beware of asking hypothetical questions*

Tip

People are not good at predicting what they will do as they have limited direct experience with future situations

Principle 5: *Beware of asking about causality*

Tip

Events mostly have more than one reason

People are not good at describing why they do the things they do

Example

Were you limited in your daily activities because of your back problem?

What is the main reason why you did not vote?

Were you homeless because of high cost of housing?

Principle 6: *Beware of asking about solutions to complex problems*

Tip

People in general do not have informed opinions about complex issues

Principle 7: *Avoid asking more than one question at a time*

Tip

The answers to two questions can be dramatically different

Example

Would you like to be rich and famous?

Are you physically able to do things like swim and run without difficulty?

Principle 8: *Avoid asking questions that impose unwarranted assumptions*

Tip

Double-barreled or one-and-a-half-barreled questions

Example

Should the organization reduce paperwork required of employees by hiring more administrators?

With the economy the way it is, do you think investing in the stock market is a good idea?

Principle 9: *Beware of questions that include hidden contingencies*

Tip

Questions must apply to the majority of your sample

Example

To measure social activity:

How often did you attend religious services or participate church-related activities during the past month?

Principle 10: *The words in questions should be chosen so that all respondents understand their meaning and have the same sense of what the meaning is*

~

Principle 11: *When words or terms that have meanings that are likely no to be shared, definitions should be provided to all respondents*

Example

"In the past 12 months, how many times have you seen or talked with a medical doctor about your health?

Include visits to psychiatrists, ophthalmologists, and any other professional with a medical degree."

Principle 12: *If definitions are provided, they should be given before the question itself is asked*

Example

How many days in the past week have you done any exercise? When you consider exercise be sure to include walking, work around the house, or work on a job, if you think they constituted exercise.

Better: The next question is going to ask you about how often you've engaged in exercise. We want to you to include walking, anything you may do around the house, or work around the house, or work on a job, if you think they constituted exercise. Using this definition, in the last week, on how many days did you do any exercise?

Principle 13: *The time period referred to by a question should be unambiguous and questions about feelings or behaviors must refer to a period of time*

Tip

Questions about feelings or behaviors must refer to a period of time.

Example

Are you able to run half a mile without stopping?

How many drinks do you usually have on days when you drink any alcoholic beverages at all?

Principle 14: *If what is to be covered is too complex to be included in a single question, ask multiple questions*

~

Principle 15: *Use multiple questions to measure the same thing*

~

Principle 16: *A question should end with the question itself. If there are response alternatives, they should constitute the final part of the question*

Example

Would you say that you are very likely, fairly likely, or not likely to move out of this house in the next year?

Better: In the coming year, how likely are you to move to another home? Would you say very likely, fairly likely, or not very likely?

Principle 17: *Clearly communicate to all respondents the kind of answer that constitutes an adequate answer to a question*

Example

“When did you move to this community?”

Possible answers:

- When I was sixteen.
- Right after I was married.
- In 1953.

Better: “In what year did you move to this community?”

Principle 18: *Specify the number of responses to be given to questions for which more than one answer is possible*

Example

What was it about the brand you bought that made you buy it rather than some other brand? List all that apply.

Principle 19: *Design survey instruments to make the tasks of reading questions, following instructions, and recording answers as easy as possible for interviewers and respondent*

~

Principle 20: *Measurements will be better to the extent that people answering questions are oriented to the task in a consistent way*

Tip

Train your respondents!

What are scales?

Definition: A scale is an instrument made up of individual *items* that measures self-reported data on a *construct*.

What is a construct?

Definition: A concept or attribute of interest that we wish to measure and that has been conceptualized to aid in the measurement.

What is an item?

Definition: A question or a survey prompt that participants respond to.

Recap: *What are different types of variables?*

Nominal: names of groups or categories, e.g., males vs. females, American vs. Japanese

Ordinal: rank-ordering of measurements, e.g., very satisfied, satisfied, neutral, unsatisfied, very unsatisfied

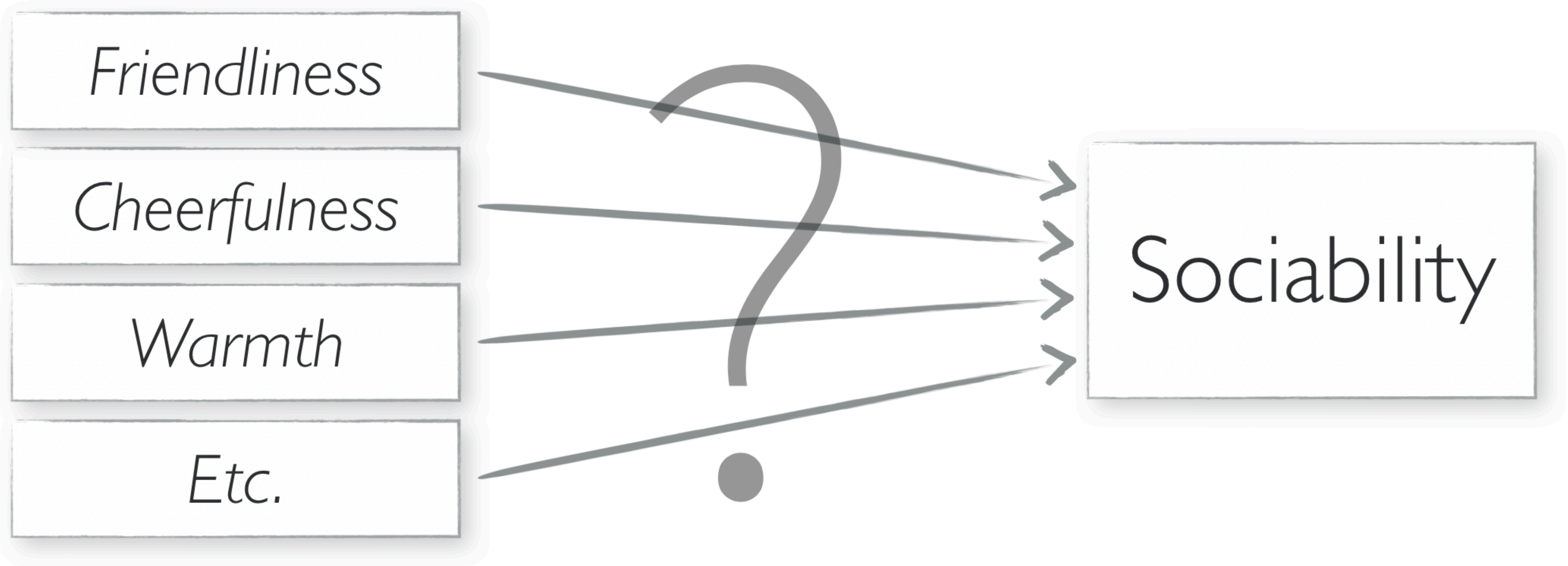
Interval: measurements along a scale with no real zero, e.g., happiness in a scale of 1 to 7 👈 **variable type used for scales**

Ratio: absolute measurements along a scale with a real zero, e.g., a person's weight

Why are scales important?

An example: how can we measure *sociability*?

Too vague and multifaceted to be measured directly. Might be made up of sub-constructs, e.g., *friendliness*, *cheerfulness*, *warmth*, etc.



How do we make up scales?

A proposed algorithm:

1. Consider the construct you wish to measure, e.g., sociability, trust, usability
2. Using mind-mapping or lists, write down potential components of the construct, e.g., sociability ↠ friendliness; trust ↠ credibility; usability ↠ ease of use (e.g., use a thesaurus or WordNet)
3. The connections will serve as hypotheses that will be tested statistically through a process called *factor analysis*
4. Prune connections that may not be substantiated in data later

What is factor analysis?

Definition: A statistical test to explore relationships among items that make up a provisional scale used for scale construction and data reduction.

What does factor analysis do?

- Removes redundancy/duplication from a set of correlated variables
- Represents correlated variables with a smaller set of derived variables, called **factors**, that are relatively independent of one another
- Represents the statistical relationships between items and factors as **loadings**; greater loading indicates stronger relationship

Are there different type of factor analyses?

Exploratory factor analysis aims to discover relationships among items and constructs. E.g., *what are components of sociability*?

Confirmatory factor analysis aims to confirm whether proposed relationships are substantiated in data. E.g., *how well do my questions measure sociability*?

Exploratory-confirmatory factor analysis aims to first discover and then confirm relationships in order to develop usable scales. E.g., *what is a good scale of sociability*?

How do we do exploratory factor analysis?

- Collect and explore data — choose relevant variables
- Extract initial factors via principal components analysis (PCA)
- Choose number of factors to retain
- Choose estimation method, estimate model
- Rotate and interpret
- Decide if changes need to be made and estimate, rotate, and implement again
- Construct scales and use in further analysis

How do we do confirmatory factor analysis?

- Define the factor model
- Collect measurements
- Obtain the correlation matrix
- Fit the model to the data
- Evaluate model adequacy
- Compare with other models

What is the exploratory-confirmatory factor analysis?

- Perform an exploratory factor analysis and decide on the number of factors, m.
- Fit an m-factor model, and rotate to simple structure using, e.g., *varimax*.
- For each column of the factor pattern, find the largest loading, then constrain all the other loadings in that row to be zero, and fit the resulting model as a confirmatory factor model.
- Examine the factor pattern and test all factor loadings. Delete non-significant loadings from the model.

Where do we get started?

Imagine that we are interested in measuring factors that might affect people's decisions about buying a car.

We design a questionnaire with a number of items that we think will be relevant: price, safety, exterior appearance, space/comfort, technology, after sales service, resale value, fuel type, fuel efficiency, color, maintenance, test drive, product reviews, testimonials.

How important is the following factors in your decision to purchase?

Price	Not important	1	2	3	4	5	Important
Safety	Not important	1	2	3	4	5	Important
Exterior appearance	Not important	1	2	3	4	5	Important
Space/comfort	Not important	1	2	3	4	5	Important
Technology	Not important	1	2	3	4	5	Important
After sales service	Not important	1	2	3	4	5	Important
Resale value	Not important	1	2	3	4	5	Important
Fuel type	Not important	1	2	3	4	5	Important
Fuel efficiency	Not important	1	2	3	4	5	Important
Color	Not important	1	2	3	4	5	Important
Maintenance	Not important	1	2	3	4	5	Important
Test drive	Not important	1	2	3	4	5	Important
Product reviews	Not important	1	2	3	4	5	Important
Testimonials	Not important	1	2	3	4	5	Important

Given m factors and n observed variables:

$$X_1 = \lambda_{11}F_1 + \lambda_{12}F_2 + \ldots + \lambda_{1m}F_m + e_1$$

$$X_2 = \lambda_{21}F_1 + \lambda22F_2 + \ldots + \lambda2mF_m + e_3$$

$$\ldots$$

$$Xn = \lambda n1F1 + \lambda n2F2 + \ldots + \lambda nmFm + en$$

In matrix notation:

$$\boldsymbol{X_{n\times1} = \Lambda_{n\times m} F_{m\ times1} + e_{n\times1}}$$

$$\boxed{\begin{matrix} X_1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ X_n \end{matrix}} = \boxed{\begin{matrix} \lambda_{11} & \cdots\cdots & \lambda_{1m} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \lambda_{n1} & \cdots\cdots & \lambda_{nm} \end{matrix}} \boxed{\begin{matrix} F_1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ F_m \end{matrix}} + \boxed{\begin{matrix} e_1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ e_m \end{matrix}}$$

How do we interpret the factor matrix?

What is factor rotation?

Definition: Factor rotation is a statistical technique that allows us to make more clear-cut decisions by spreading variability more evenly among factors by redefining factors to force loadings to be very high (-1 or 1) or very low (0).

There are different methods of factor rotation. We will use *varimax*, which maximizes squared loading variance across variables (sum over factors).

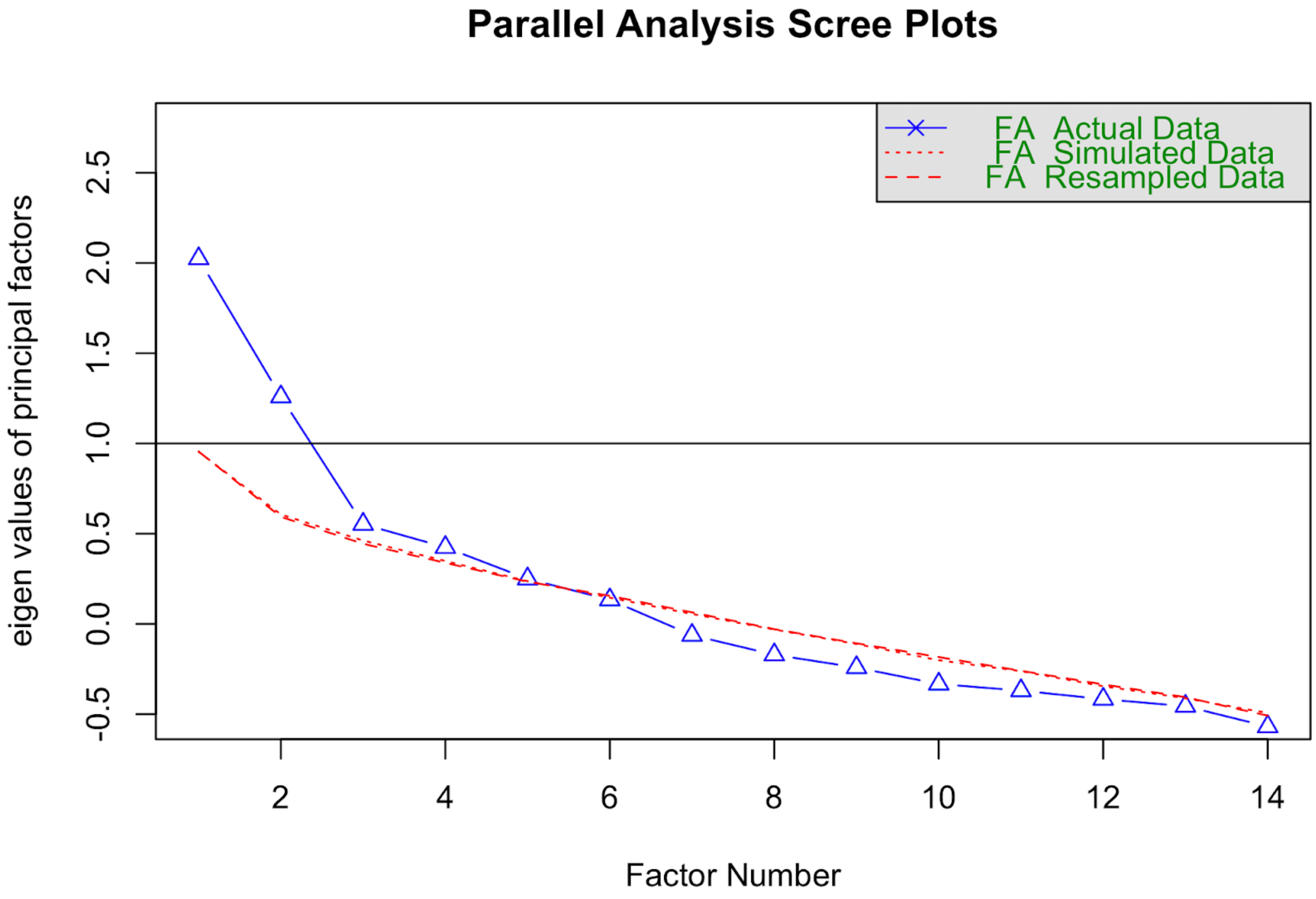
Let's try it out! [2] *[^3]*

[2] We'll use R.
[^3]: We will use same data from PromptCloud.

Step 1. Determine the number of factors using PCA

```
install.packages("psych")
library(psych)
pa = fa.parallel(data, fm = 'minres', fa = 'fa')
```

This will produce what is called a Scree plot that will plot eigenvalues on the Y axis and number of factors on the X axis.


Parallel Analysis Scree Plots
FA Actual Data
FA Simulated Data
FA Resampled Data
eigen values of principal factors
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
2
4
6
8
10
12
14
Factor Number

How do we determine the number of factors?

There are two methods:

1. **Kaiser Criterion**:[4] take eigenvalues that are larger than 1.
2. **Scree test**:[^5] find point of inflection and consider the factors up to the leveling off.

[4] Kaiser, 1960, The application of electronic computers to factor analysis
[^5]: Cattell, 1966, The Scree test for the number of factors

Step 2: Factor rotation

Calculate loadings for each variable on each factor:

$$corr(F_i, X_j) = \lambda_{ji}$$

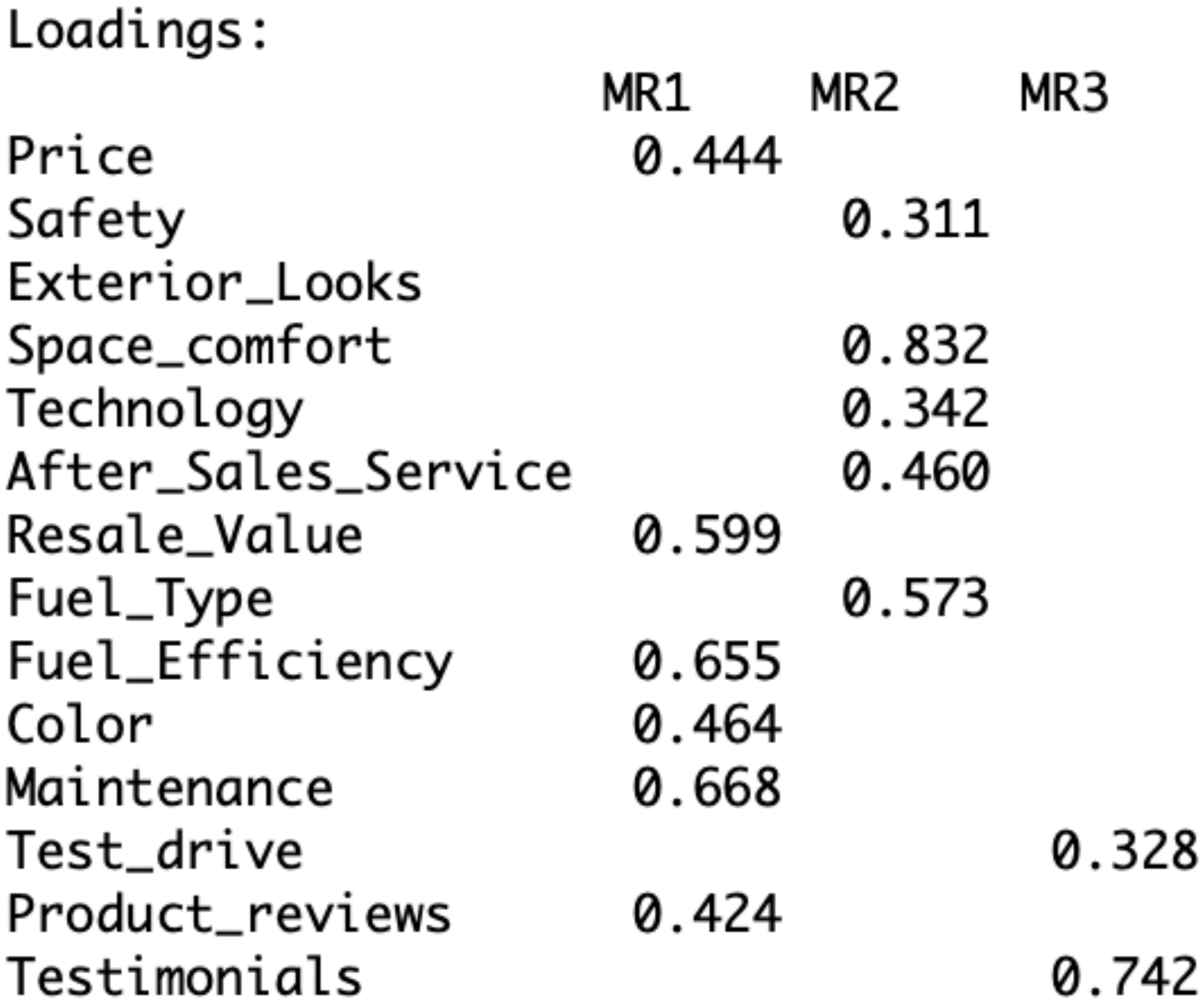
Apply factor rotation to spread the variability evenly among variables:

```
fit = fa(data,nfactors = 3,rotate = "varimax",fm="minres")
```

Visualize the factor matrix:

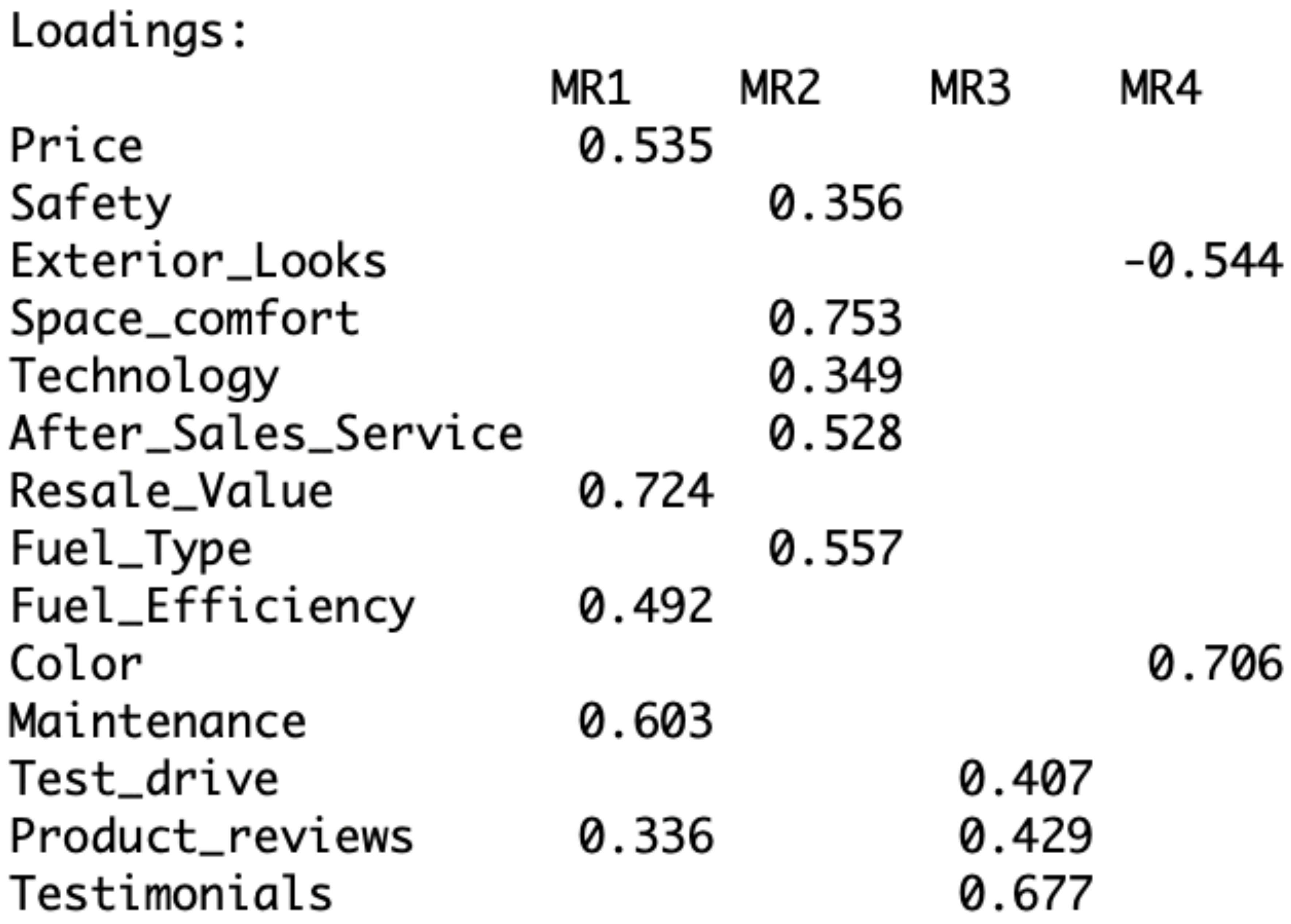
```
print(fit$loadings,cutoff = 0.3)
```

This will print out the following factor matrix:



```
Loadings:
                    MR1    MR2    MR3
Price                0.444
Safety                      0.311
Exterior_Looks
Space_comfort               0.832
Technology                  0.342
After_Sales_Service         0.460
Resale_Value         0.599
Fuel_Type                   0.573
Fuel_Efficiency      0.655
Color                0.464
Maintenance          0.668
Test_drive                         0.328
Product_reviews      0.424
Testimonials                       0.742
```

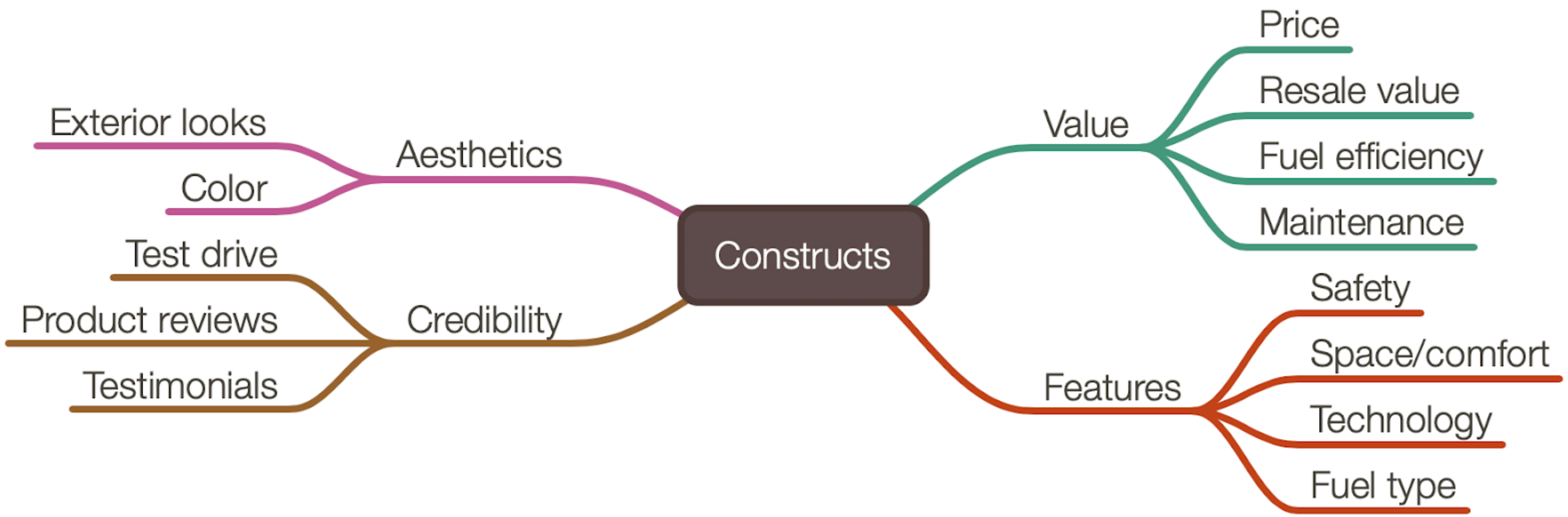
We can iteratively interpret and recalculate:



```
Loadings:
                    MR1    MR2    MR3    MR4
Price                0.535
Safety                      0.356
Exterior_Looks                           -0.544
Space_comfort               0.753
Technology                  0.349
After_Sales_Service         0.528
Resale_Value         0.724
Fuel_Type                   0.557
Fuel_Efficiency      0.492
Color                                     0.706
Maintenance          0.603
Test_drive                         0.407
Product_reviews      0.336         0.429
Testimonials                       0.677
```

Step 3: Scale construction

We inspect all factors and items that load to them:



To create a scale, we combine the items that load to that scale:

```
scale_value = cbind("Price","Resale_Value","Fuel_Efficiency","Maintenance")
```

Step 4: Test scale reliability

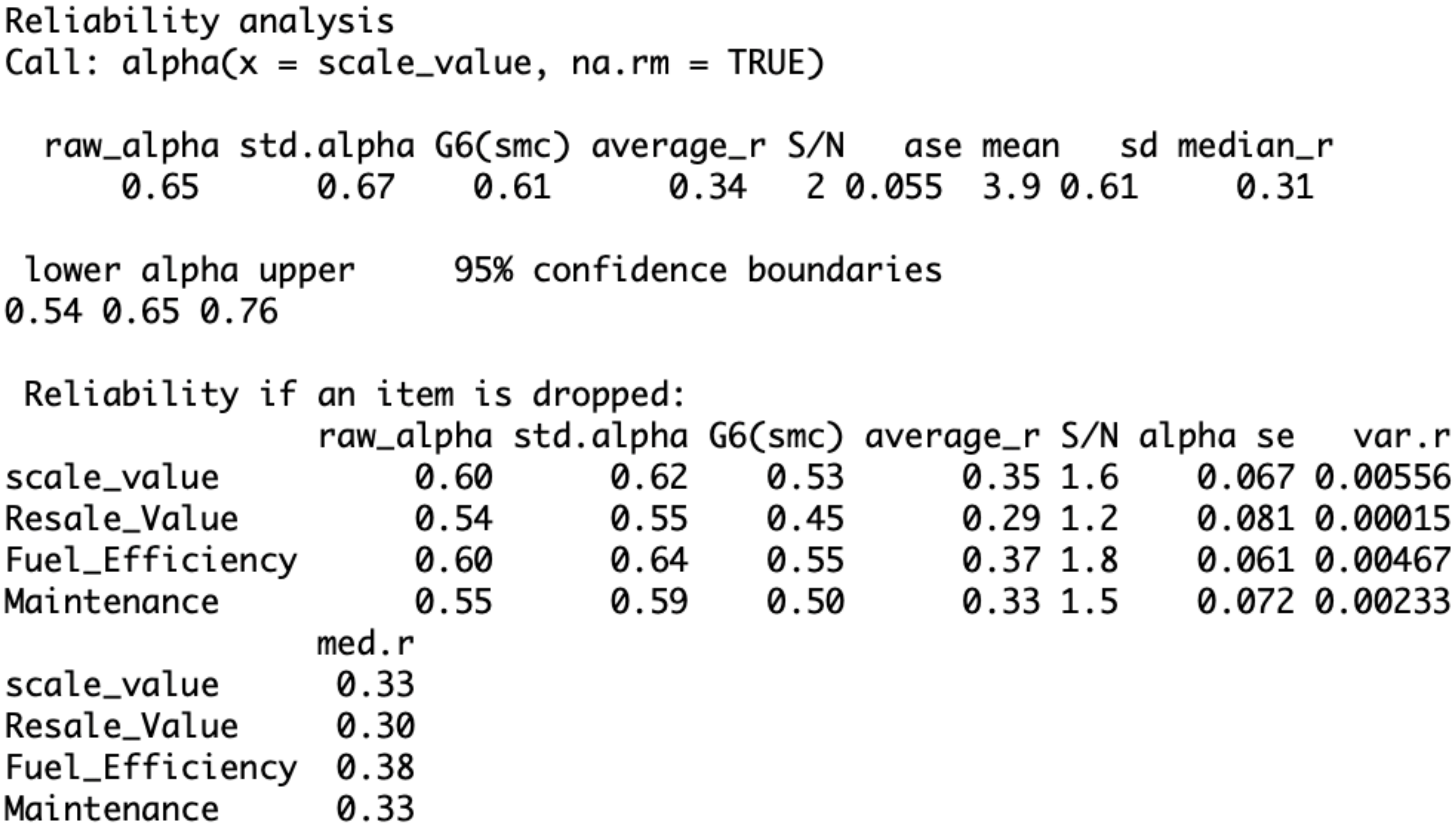
Recap: Most commonly used measure of scale reliability is Cronbach's α.

Cronbach's alpha	**Internal consistency**
$\alpha \geq .9$	Excellent
$.9 > \alpha \geq .8$	Good
$.8 > \alpha \geq .7$	Acceptable
$.7 > \alpha \geq .6$	Questionable
$.6 > \alpha \geq .5$	Poor
$.5 > \alpha$	Unacceptable

To calculate Cronbach's α:

```
alpha(scale_value, na.rm = TRUE)
```

This will produce:



```
Reliability analysis
Call: alpha(x = scale_value, na.rm = TRUE)

  raw_alpha std.alpha G6(smc) average_r S/N   ase mean   sd median_r
      0.65      0.67    0.61      0.34   2 0.055  3.9 0.61     0.31

 lower alpha upper     95% confidence boundaries
0.54 0.65 0.76

 Reliability if an item is dropped:
                raw_alpha std.alpha G6(smc) average_r S/N alpha se   var.r
scale_value          0.60      0.62    0.53      0.35 1.6    0.067 0.00556
Resale_Value         0.54      0.55    0.45      0.29 1.2    0.081 0.00015
Fuel_Efficiency      0.60      0.64    0.55      0.37 1.8    0.061 0.00467
Maintenance          0.55      0.59    0.50      0.33 1.5    0.072 0.00233
                med.r
scale_value      0.33
Resale_Value     0.30
Fuel_Efficiency  0.38
Maintenance      0.33
```

Hands-on activity:
We will (randomly) pair up to give each other feedback on study designs.