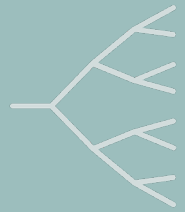
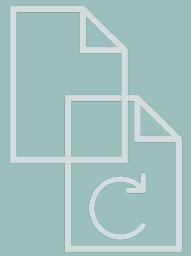
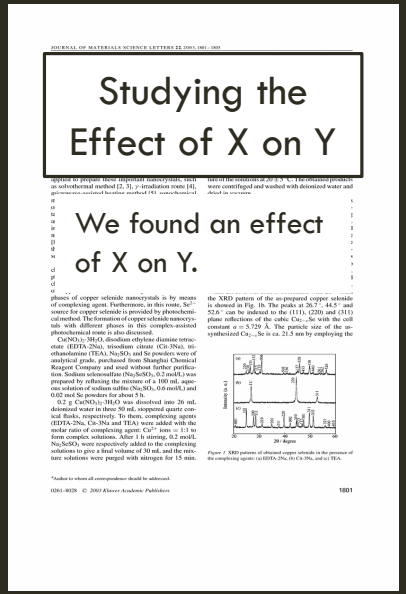


A 4-STEP ROBUSTNESS CHECK

Dr. Michèle B. Nuijten
Tilburg University

ROBUSTNESS



JOURNAL OF MATERIALS SCIENCE LETTERS 22 2003, 1801 – 1803

Studying the Effect of X on Y

We found an effect of X on Y.

phases of copper selenide nanocrystals is by means of complexing agent. Furthermore, in this route, Se^{2-} source for copper selenide is provided by photochemical method. The formation of copper selenide nanocrystals with different phases in this complex-assisted photochemical route is also discussed.

$Cu(NO_3)_2 \cdot 3H_2O$, disodium ethylene diamine tetraacetate (EDTA-2Na), trisodium citrate (Cit-3Na), triethanolamine (TEA), Na_2SO_3 and Se powders were of analytical grade, purchased from Shanghai Chemical Reagent Company and used without further purification. Sodium selenosulfate (Na_2SeSO_3, 0.2 mol/L) was prepared by refluxing the mixture of a 100 mL aqueous solution of sodium sulfite (Na_2SO_3, 0.6 mol/L) and 0.02 mol Se powders for about 5 h.

0.2 g $Cu(NO_3)_2 \cdot 3H_2O$ was dissolved into 26 mL deionized water in three 50 mL stoppered quartz conical flasks, respectively. To them, complexing agents (EDTA-2Na, Cit-3Na and TEA) were added with the molar ratio of complexing agent: Cu^{2+} ions = 1:1 to form complex solutions. After 1 h stirring, 0.2 mol/L Na_2SeSO_3 were respectively added to the complexing solutions to give a final volume of 30 mL and the mixture solutions were purged with nitrogen for 15 min.

the XRD pattern of the as-prepared copper selenide is showed in Fig. 1b. The peaks at 26.7°, 44.5° and 52.6° can be indexed to the (111), (220) and (311) plane reflections of the cubic $Cu_{2-x}Se$ with the cell constant $a = 5.729$ Å. The particle size of the as-synthesized $Cu_{2-x}Se$ is ca. 21.3 nm by employing the

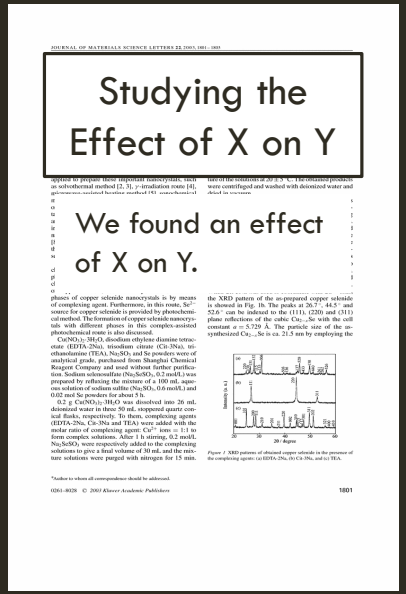
Figure 1 XRD patterns of obtained copper selenide in the presence of the complexing agents: (a) EDTA-2Na, (b) Cit-3Na, and (c) TEA.

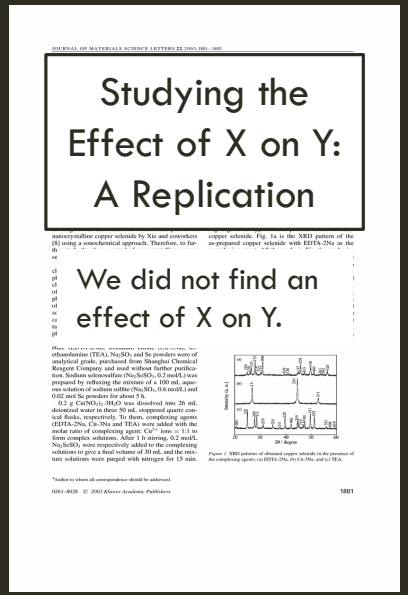
*Author to whom all correspondence should be addressed.

0261–8028 © 2003 *Kluwer Academic Publishers* 1801

Robustness ≈
“Can I trust this result?”

ASSESSING ROBUSTNESS THROUGH REPLICATION





Cons of replication: time & money

FOCUS ON REPRODUCIBILITY FIRST

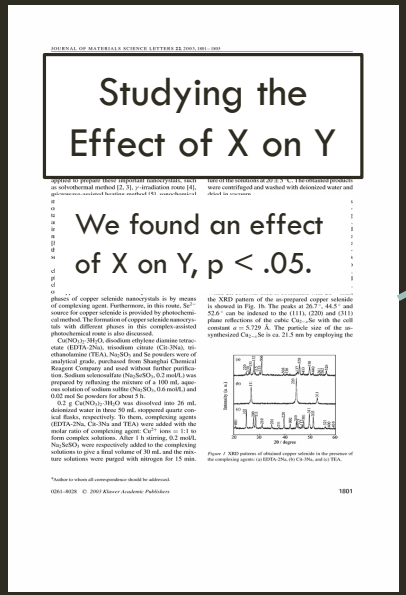
Replicability

A study is successfully **replicated** if the same/a similar result is found in a new sample.

Reproducibility

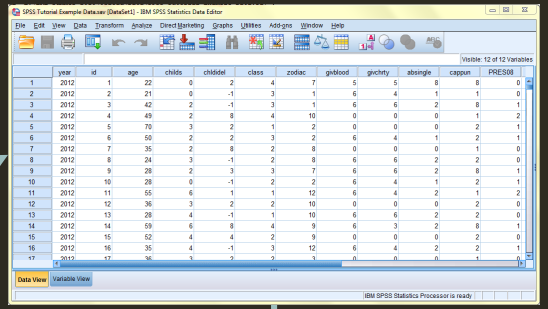
A study is successfully **reproduced** if independent reanalysis of the original data, using the same analytic approach, leads to the same results.

REPRODUCIBILITY IS A PREREQUISITE FOR REPLICABILITY



Studying the Effect of X on Y

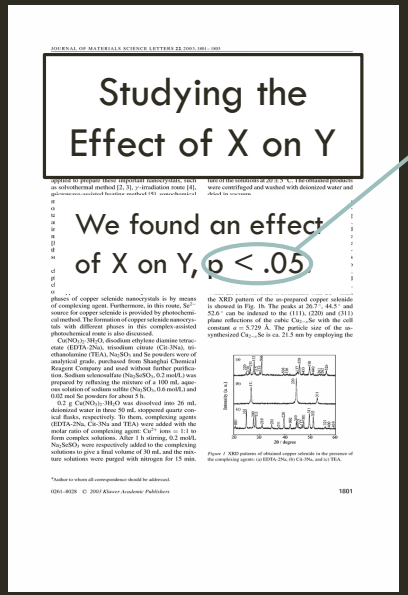
We found an effect of X on Y, $p < .05$.



Reanalyze following reported procedures

$p > .05$??

REPRODUCIBILITY IS A PREREQUISITE FOR REPLICABILITY



- If a result is not **reproducible,** it has no clear bearing on theory or practice
- An irreproducible number is effectively **meaningless**

You don't need replication to find out whether this finding is robust. It's not.

VERIFY REPORTED NUMBERS BEFORE INVESTING IN A REPLICATION

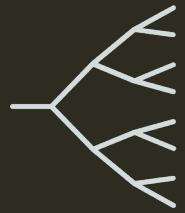
4 STEP ROBUSTNESS CHECK

1.

Are there visible errors in reported numbers?

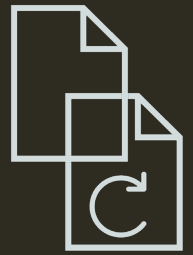
2.

Does reanalysis of the original data give the same outcomes?



3.

How sensitive is the result to alternative analytical choices?



4.

Does a replication study in a new sample find the same results?

1. ARE THERE VISIBLE ERRORS IN REPORTED NUMBERS?

"70% of the patients recovered within a week (60/100)."

Recalculated: 60%

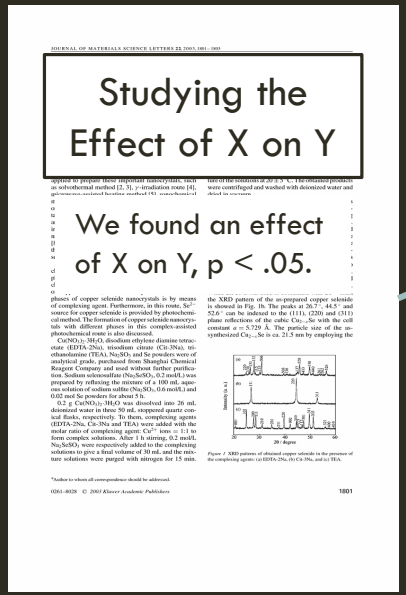
"In total, we interviewed 20 residents: 11 men and 12 women."

Recalculated: 23 residents

"The effect was significant, $t(28) = 1.02$, $p < .05$."

Recalculated: $p = .32$

2. DOES REANALYSIS OF THE ORIGINAL DATA GIVE THE SAME OUTCOMES?



JOURNAL OF MATERIALS SCIENCE LETTERS 22 2003, 1801 – 1803

Studying the Effect of X on Y

We found an effect of X on Y, $p < .05$.

phases of copper selenide nanocrystals is by means of complexing agent. Furthermore, in this route, Se^{2-} source for copper selenide is provided by photochemical method. The formation of copper selenide nanocrystals with different phases in this complex-assisted photochemical route is also discussed.

$Cu(NO_3)_2 \cdot 3H_2O$, disodium ethylene diamine tetraacetate (EDTA-2Na), trisodium citrate (Cit-3Na), triethanolamine (TEA), Na_2SO_3, and Se powders were of analytical grade, purchased from Shanghai Chemical Reagent Company and used without further purification. Sodium selenosulfate (Na_2SeSO_3, 0.2 mol/L) was prepared by refluxing the mixture of a 100 mL aqueous solution of sodium sulfite (Na_2SO_3, 0.6 mol/L) and 0.02 mol Se powders for about 5 h.

0.2 g $Cu(NO_3)_2 \cdot 3H_2O$ was dissolved into 26 mL deionized water in three 50 mL stoppered quartz conical flasks, respectively. To them, complexing agents (EDTA-2Na, Cit-3Na and TEA) were added with the molar ratio of complexing agent: Cu^{2+} ions = 1:1 to form complex solutions. After 1 h stirring, 0.2 mol/L Na_2SeSO_3 were respectively added to the complexing solutions to give a final volume of 30 mL and the mixture solutions were purged with nitrogen for 15 min.

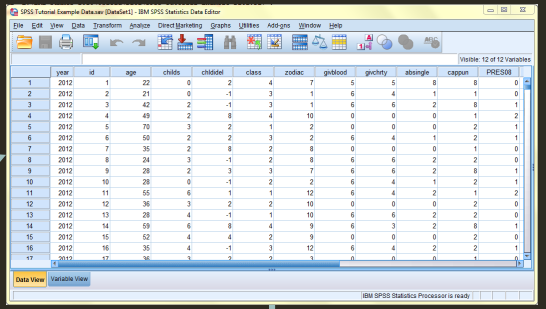
the XRD pattern of the as-prepared copper selenide is showed in Fig. 1b. The peaks at 26.7°, 44.5° and 52.6° can be indexed to the (111), (220) and (311) plane reflections of the cubic $Cu_{2-x}Se$ with the cell constant $a = 5.729$ Å. The particle size of the as-synthesized $Cu_{2-x}Se$ is ca. 21.5 nm by employing the

Figure 1 XRD patterns of obtained copper selenide in the presence of the complexing agents: (a) EDTA-2Na, (b) Cit-3Na, and (c) TEA.

*Author to whom all correspondence should be addressed.

0261–8028 © 2003 Kluwer Academic Publishers

1801



SPSS Tutorial Example Data.sav [DataSet1] - IBM SPSS Statistics Data Editor

File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help

Visible: 12 of 12 Variables

	year	id	age	childs	childdel	class	zodiac	givblood	givchrty	absingle	cappun	PRES08
1	2012	1	22	0	2	4	7	5	5	8	8	0
2	2012	2	21	0	-1	3	1	6	4	1	1	0
3	2012	3	42	2	-1	3	1	6	6	2	8	1
4	2012	4	49	2	8	4	10	0	0	0	1	2
5	2012	5	70	3	2	1	2	0	0	0	2	1
6	2012	6	50	2	2	3	2	6	4	1	2	1
7	2012	7	35	2	8	2	8	0	0	0	1	0
8	2012	8	24	3	-1	2	8	6	6	2	2	0
9	2012	9	28	2	3	3	7	6	6	2	8	1
10	2012	10	28	0	-1	2	2	6	4	1	2	1
11	2012	11	55	6	1	1	12	6	4	2	1	2
12	2012	12	36	3	2	2	10	0	0	0	2	0
13	2012	13	28	4	-1	1	10	6	6	2	2	0
14	2012	14	59	6	8	4	9	6	3	2	8	1
15	2012	15	52	4	4	2	9	0	0	0	2	0
16	2012	16	35	4	-1	3	12	6	4	2	2	1
17	2012	17	36	3	2	3	3	0	0	0	1	0

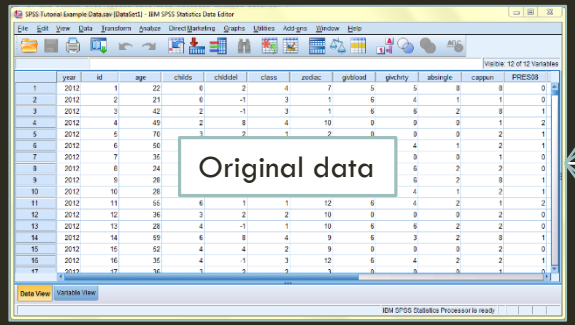
Data View Variable View

IBM SPSS Statistics Processor is ready

Reanalyze following reported procedures

$p > .05$??

3. HOW SENSITIVE IS THE RESULT TO ALTERNATIVE ANALYTICAL CHOICES?



Test two-tailed instead of one-tailed → p > .05

Remove one seemingly arbitrary covariate → p > .05

Reanalyze following reported procedures → **p < .05**

Include the outlier that was removed → p > .05

Exclude the last observation → p > .05

HOW COMMON ARE REPRODUCIBILITY PROBLEMS?

- 50% of psychology papers contain statistical reporting inconsistencies
  Nuijten et al., 2016
- 64% of psychology papers showed different results upon reanalysis
  Hardwicke et al., 2020
- up to 63% of psychology authors admit to opportunistic use of flexibility in analyses
  John et al., 2012

ASSESSING ROBUSTNESS

1.

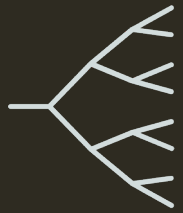
Are there visible errors in reported numbers?

< 1 hour

2.

Does reanalysis of the original data give the same outcomes?

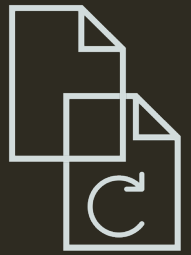
1 day



3.

How sensitive is the result to alternative analytical choices?

1 week



4.

Does a replication study in a new sample find the same results?

1 year

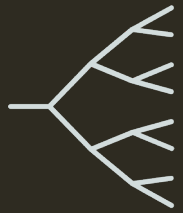
IMPROVING ROBUSTNESS

1.

Check the internal consistency of your reported results

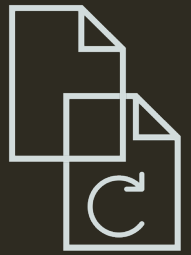
2.

Share your raw data and analysis scripts



3.

Conduct and report your own sensitivity analyses

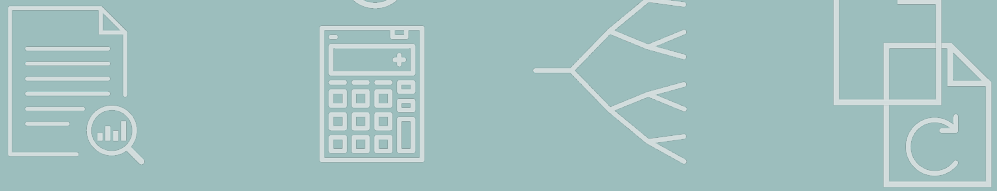


4.

Write detailed methods sections and share materials

4-STEP ROBUSTNESS CHECK

- Details matter
- Correct and robust numbers are basic requirements for scientific quality
- Assess and improve robustness in four efficient steps



THANK YOU!

@MicheleNuijten
m.b.nuijten@uvt.nl
https://mbnuijten.com