Tutorial on the R package ReplicationSuccess

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Installation

- Linux / Windows

```
install.packages(pkgs = "ReplicationSuccess",
                 repos ="http://R-Forge.R-project.org")
```

- Mac

```
install.packages(pkgs = "ReplicationSuccess",
                 repos = "http://R-Forge.R-project.org",
                 type = "source")
```

Replication studies

Direct replication

– Repeating original study using the same methodology

→ Tool to assess credibility of scientific discoveries

→ Regulatory requirement

Replication studies

Direct replication

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→ Regulatory requirement

Replication crisis

- Low replicability of many scientific discoveries

→ Increased interest in meta-science

→ Large-scale replication projects

Large-scale replication projects

– 2015: Reproducibility project psychology

Large-scale replication projects

- 2015: Reproducibility project psychology
- 2016: Experimental economics replication project

Large-scale replication projects

- 2015: Reproducibility project psychology
- 2016: Experimental economics replication project
- 2018: Experimental philosophy replicability project

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Large-scale replication projects

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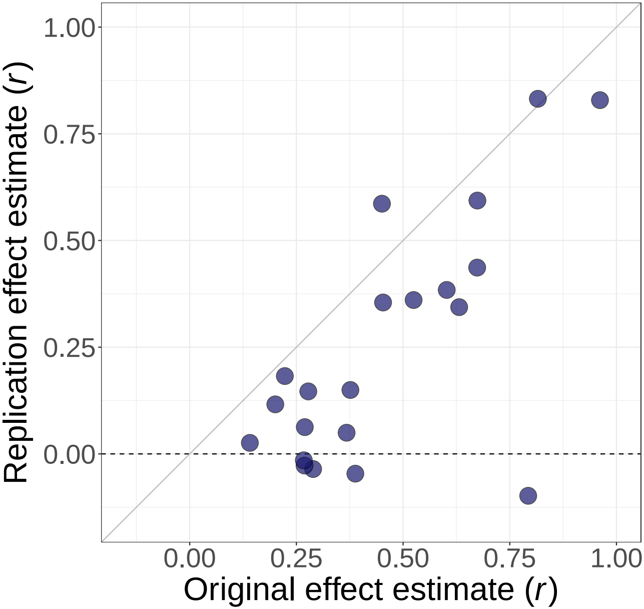
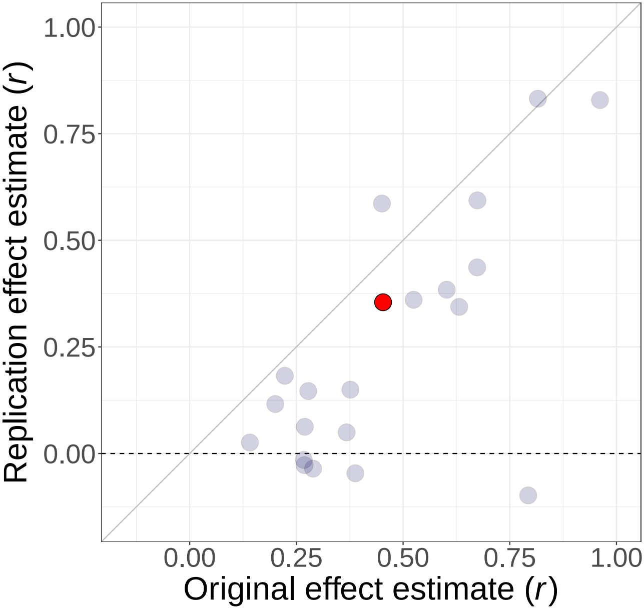
Social sciences replication project



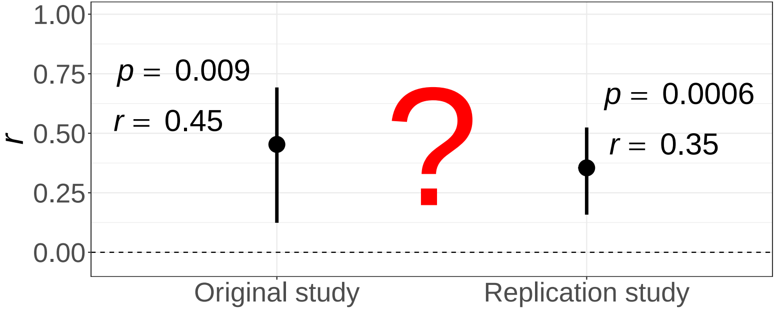
Social sciences replication project



Morewedge et al. (2010). Science

Original discovery

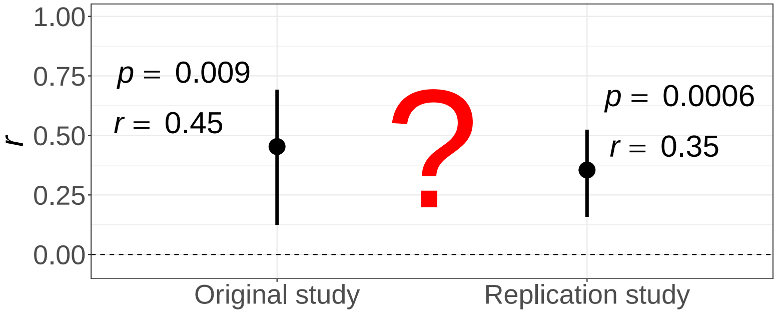
“Repeatedly imagining eating a food subsequently reduces the actual consumption of that food”



When is a replication successful?

Some proposed criteria

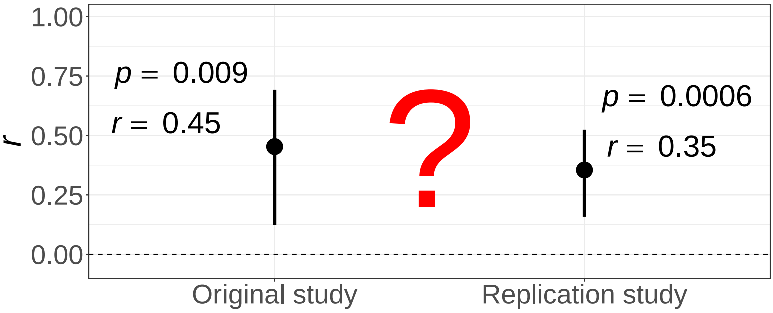
1. Statistical significance



When is a replication successful?

Some proposed criteria

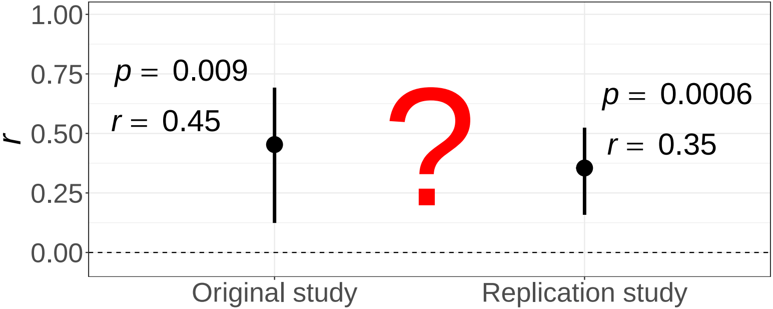
1. Statistical significance
2. Compatibility of effect estimates



When is a replication successful?

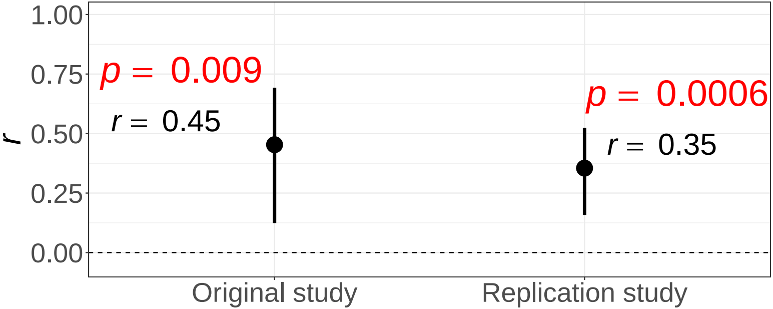
Some proposed criteria

1. Statistical significance
2. Compatibility of effect estimates
3. Sceptical *p*-value



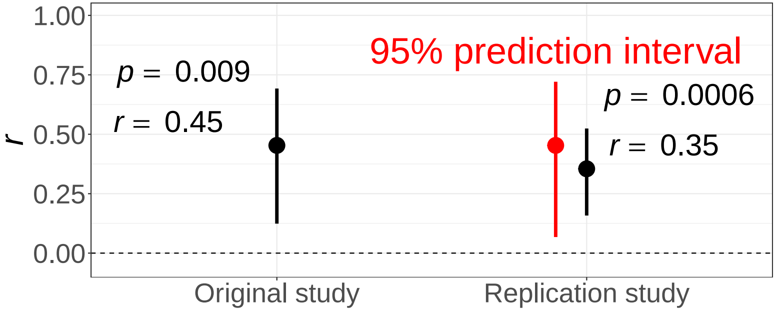
1. Statistical significance

Are original and replication estimates statistically significant?



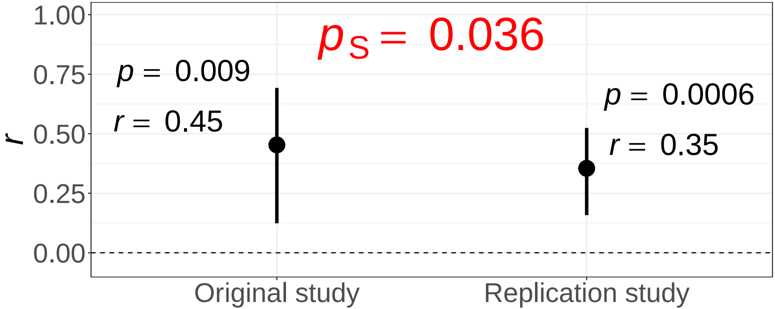
2. Compatibility of effect estimates

Is the replication estimate contained in its prediction interval?



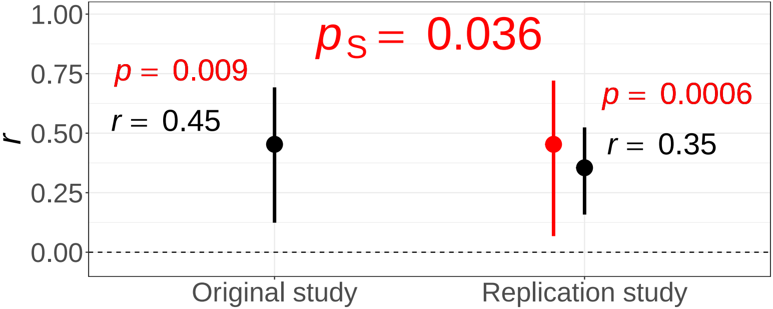
3. Sceptical p-value

?At which level can we convince a sceptic who argues that the original study is no longer signficant at that level?



Drawbacks of classical approaches

- Signficiance can always be achieved by increasing sample size
- Estimates can be compatible but provide no information about true effect



Design of replication studies

Replication sample size

- Direct replication $\rightarrow$ procedures of replication study as closely matched as possible to original study
- But proper sample size calculation is essential and depends on analysis strategy

Design of replication studies

What is used in practice

- Standard power calculation
- Depending on the projects, goal is to have between 80% and 95% power in the replication study to detect the effect estimate from the original study
- Shrinkage of the original effect estimate is sometimes used (e.g. in Camerer et al. (2018))

Design of replication studies

Issues with this method

- Uncertainty of original effect estimate is ignored
- Heterogeneity between original and replication study is not taken into account
- Arbitrary shrinkage methods

Package

To add: small intro to package (goal, structure etc)

Statistical framework of package

- Effect estimates are assumed to be normally distributed

  → usually fulfilled after suitable transformation
- Relative quantities (as opposed to absolute quantities)

  → *p*-value or test statistic of original study

  → Relative sample size n_r/n_o
- Design prior

  → Conditional: ignores uncertainty of original study

  → Predictive: reflects that there is still uncertainty about the true effect after the original experiment

Statistical framework of package

Suggestion: Use the example from Morewedge to illustrate relative quantities?

Approaches (title not optimal)

1. Statistical significance

Two functions:

- `powerSignificance()` and `sampleSizeSignificance()`

Main arguments

- `po` or `to`: *p*-value or test statistic of the original study
- `c`: relative sample size n_r/n_o (only for `powerSignificance`)
- `power`: desired level of replication power (only for `sampleSizeSignificance()`)
- `designPrior`: conditional or predictive
- `shrinkage`

– powerSignficance + arguments – sampleSizeSignificance + arguments – exercises

Comparison of effect size

– predictionInterval – sampleSizePI – sampleSizePIwidth

Reverse Bayes

– pSceptical – powerReplicationSuccess – sampleSizeReplicationSuccess

Outlook

– Interim – Heterogeneity – EB shrinkage

References

Camerer, C. F., Dreber, A., Forsell, E., Ho, T., Huber, J., Johannesson, M., Kirchler, M., Almenberg, J., Altmejd, A., Chan, T., Heikensten, E., Holzmeister, F., Imai, T., Isaksson, S., Nave, G., Pfeiffer, T., Razen, M., and Wu, H. (2016). Evaluating replicability of laboratory experiments in economics. *Science*, 351:1433 – 1436.

Camerer, C. F., Dreber, A., Holzmeister, F., Ho, T., Huber, J., Johannesson, M., Kirchler, M., Nave, G., Nosek, B., Pfeiffer, T., Altmejd, A., Buttrick, N., Chan, T., Chen, Y., Forsell, E., Gampa, A., Heikenstein, E., Hummer, L., Imai, T., Isaksson, S., Manfredi, D., Rose, J., Wagenmakers, E., and Wu, H. (2018). Evaluating the replicability of social science experiments in Nature and Science between 2010 and 2015. *Nature Human Behavior*, 2:637 – 644.

Cova, F., Strickland, B., Abatista, A., Allard, A., Andow, J., Attie, M., Beebe, J., Berniūnas, R., Boudesseul, J., Colombo, M., Cushman, F., Diaz, R., N'Djaye Nikolai van Dongen, N., Dranseika, V., Earp, B. D., Torres, A. G., Hannikainen, I., Hernández-Conde, J. V., Hu, W., Jaquet, F., Khalifa, K., Kim, H., Kneer, M., Knobe, J., Kurthy, M., Lantian, A., Liao, S.-y., Machery, E., Moerenhout, T., Mott, C., Phelan, M., Phillips, J., Rambharose, N., Reuter, K., Romero, F., Sousa, P., Sprenger, J., Thalabard, E., Tobia, K., Viciana, H., Wilkenfeld, D., and Zhou, X. (2018). Estimating the reproducibility of experimental philosophy. *Review of Philosophy and Psychology*.

Held, L. (2019). A new standard for the analysis and design of replication studies (with discussion). *Journal of the Royal Statistical Society: Series A (Statistics in Society)*.

Open Science Collaboration (2015). Estimating the reproducibility of psychological science. *Science*, 349(6251):aac4716.

Pawel, S. and Held, L. (2019). Probabilistic forecasting of replication studies. Preprint.