# Synthesis of single-case research: Meta-analytic methods & challenges

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# Outline

1. Research synthesis & meta-analysis

2. Effect sizes for single-case research
   - Desiderata
   - Examples using direct observation of behavior

3. Challenges & data quality issues

# Research synthesis & meta-analysis

- **Systematic review:** A literature review that uses systematic search techniques and inclusion criteria to identify a body of relevant literature.

- **Research synthesis**: the systematic integration of empirical research for purposes of drawing generalizations (Cooper & Hedges, 2009).

- **Meta-analysis**: statistical methods that support research synthesis, especially methods for combining results from a collection of studies.

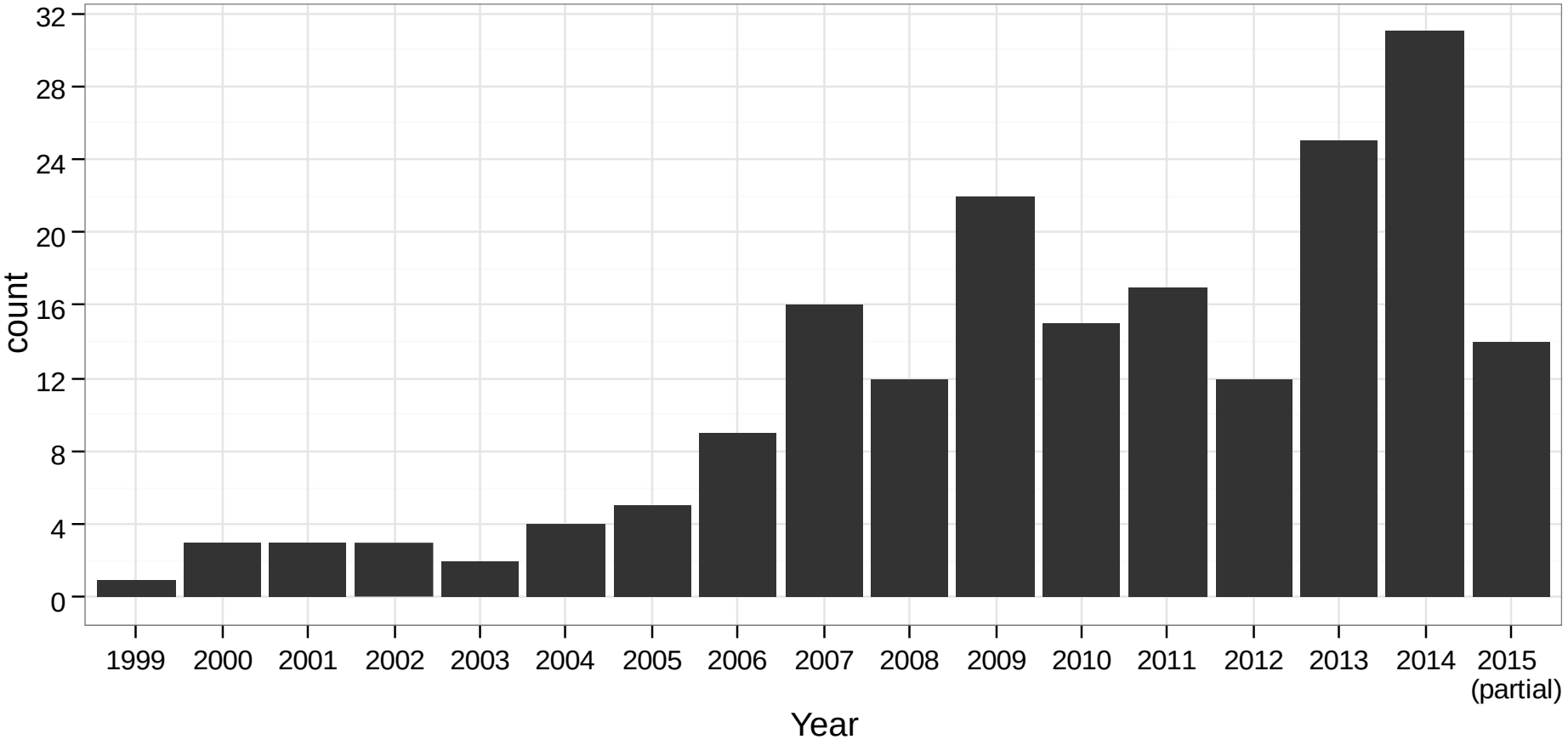
# Disciplines that rely on research synthesis

- Medicine (cf. the Cochrane Collaboration)
- Education
- Psychology
- Social policy (justice, welfare, etc.)
- Physical sciences
- Economics, international development

# Why synthesize single-case studies?

1. Describe and clarify the state of research on a topic.
2. Establish evidence-based practices.
3. Understanding ***variation*** in treatment effectiveness.
4. Monitor and provide feedback about methodological quality, potential problems.

# Quantitative Syntheses of SCR for students with disabilities: 1999-2014



# Effect size measures

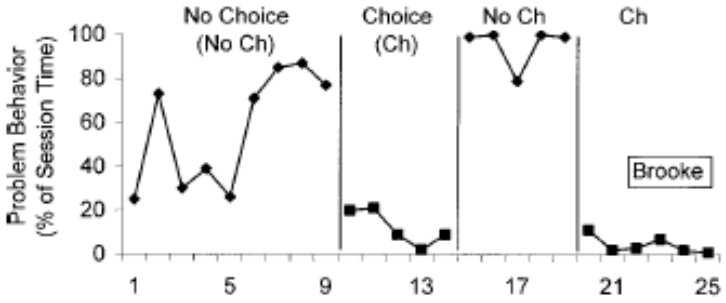
Characteristics of a good effect size measure (Lipsey & Wilson, 2001):

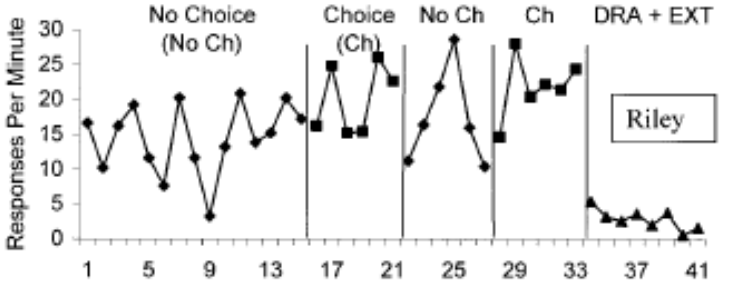
1. Interpretable measure of *magnitude* & *direction* of treatment effect
2. Comparable across cases & studies
3. Not influenced by arbitrary procedural characteristics:
   - sample size/phase length
   - outcome measurement procedures
   - other study design features
4. Computable from available data
5. Accompanied by a measure of uncertainty (i.e., a standard error)

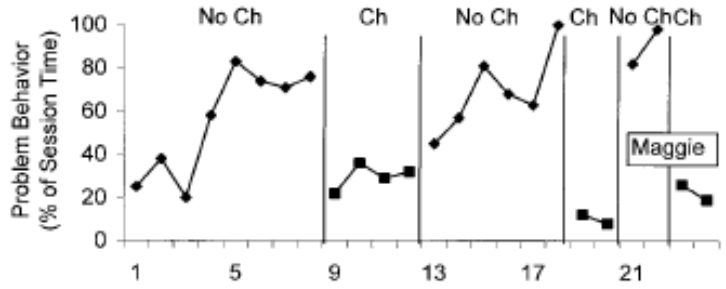
# Effect sizes for single-case research

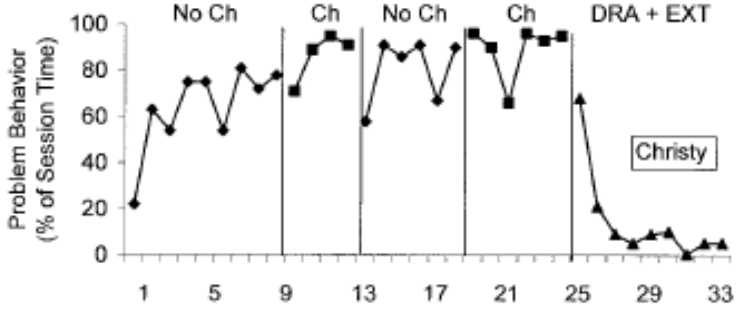
- Non-overlap measures
  - Percentage of non-overlapping data (PND; Scruggs et al., 1987)
  - Percentage exceeding the median (PEM; Ma, 2006)
  - Non-overlap of all pairs (Parker & Vannest, 2009)
  - Others: PAND, RIRD, Tau-U,…
- Within-case standardized mean differences (Busk & Serlin, 1992)
- Ratio/log-ratio measures (Pustejovsky, 2014)
- Design-comparable standardized mean differences (Pustejovsky, Hedges, & Shadish, 2014)

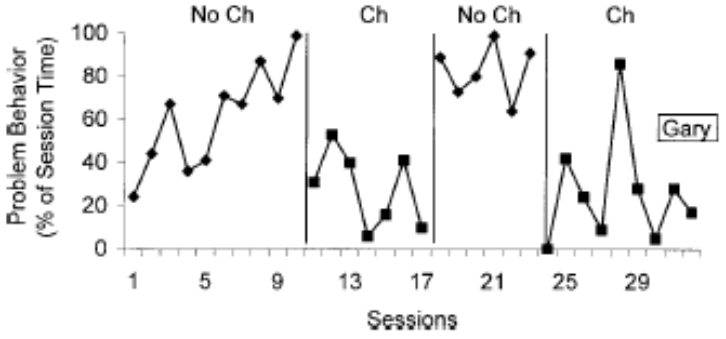
# Romaniuk et al. (2002). The influence of activity choice on problem behaviors maintained by escape versus attention.

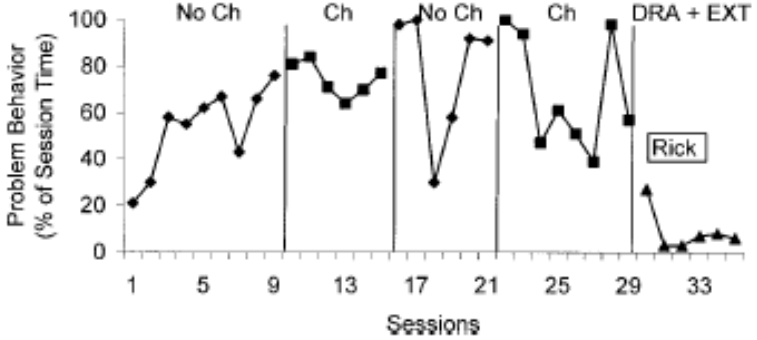


# Percentage of Non-overlapping Data

- Most commonly applied effect size measure in synthesis of SCR for students with disabilities (Maggin et al., 2011)

- For "positive" behaviors:
  PND = % of observations in treatment condition that are larger than the maximum observation in baseline

- For "negative" behaviors:
  PND = % of observations in treatment condition that are smaller than the minimum observation in baseline

# Romaniuk example

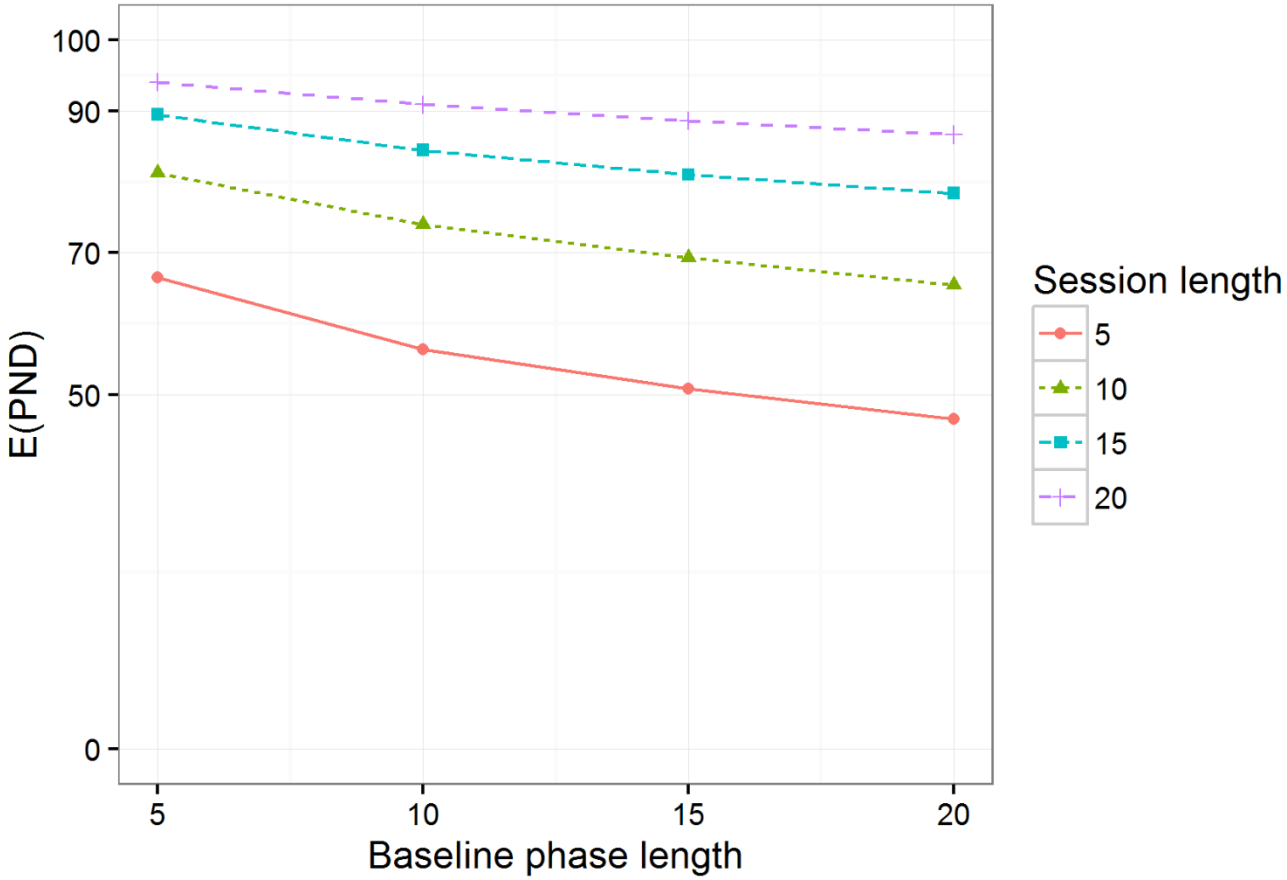
| Case | Function | PND |
|---|---|---|
| Brooke | Escape | 100% |
| Gary | Escape | 50% |
| Maggie | Escape | 38% |
| Christy | Attention | 0% |
| Rick | Attention | 0% |
| Riley | Attention | 0% |

Problems with PND

1. Does not capture direction of effect
2. No measure of uncertainty
3. Magnitude depends on length of baseline

# A simulated example (Pustejovsky, 2015)

- Baseline behavior duration = 50%, frequency = 1/min
- Treatment reduces behavior to duration = 25%, frequency = 0.5/min
- Continuous recording



# Within-case standardized mean difference

SMD measures differences in standard-deviation units:

$$d = \frac{\bar{y}_T - \bar{y}_B}{s_p}$$

where $s_p$ is the pooled standard deviation, i.e., the square-root of the pooled variance

$$s_p^2 = \frac{(n_T - 1)s_T^2 + (n_B - 1)s_B^2}{n_T + n_B - 2}$$

# Romaniuk example

| Case | Function | PND | SMD (s.e.) |
|---|---|---|---|
| Brooke | Escape | 100% | -2.95 (0.59) |
| Gary | Escape | 50% | -1.95 (0.43) |
| Maggie | Escape | 38% | -2.16 (0.54) |
| Christy | Attention | 0% | 1.12 (0.44) |
| Rick | Attention | 0% | 0.36 (0.37) |
| Riley | Attention | 0% | 1.03 (0.38) |
| Meta-analysis | Escape | | -2.26 (0.29) |
| | Attention | | 0.81 (0.23) |

Problems with SMD

- What if duration during baseline has mean = 0.5, SD = 0.3?

# Response ratio

- Ratio measures are closely connected to % changes:

$$\text{Response Ratio} = \frac{\bar{y}_T}{\bar{y}_B}$$

- Log-transformation is used to make sampling distribution closer to normal:

$$lRR = \log\left(\text{Response Ratio}\right) = \log\left(\bar{y}_T\right) - \log\left(\bar{y}_B\right)$$

$$s.e. \approx \sqrt{\frac{s_T^2}{n_T \bar{y}_T^2} + \frac{s_B^2}{n_B \bar{y}_B^2}}$$

# Response ratio

- A 95% confidence interval for the log-response ratio:

$$\left[lRR - 1.96 \times s.e., \quad lRR + 1.96 \times s.e.\right]$$

- A 95% confidence interval for % change:

$$100\% \times \left[\exp\left(lRR - 1.96 \times s.e.\right) - 1, \quad \exp\left(lRR + 1.96 \times s.e.\right) - 1\right]$$

# Romaniuk example

| Case | Function | PND | SMD (s.e.) | IRR (s.e.) |
|---|---|---|---|---|
| Brooke | Escape | 100% | -2.95 (0.59) | -2.39 (0.37) |
| Gary | Escape | 50% | -1.95 (0.43) | -0.96 (0.23) |
| Maggie | Escape | 38% | -2.16 (0.54) | -1.09 (0.19) |
| Christy | Attention | 0% | 1.12 (0.44) | 0.22 (0.08) |
| Rick | Attention | 0% | 0.36 (0.37) | 0.12 (0.13) |
| Riley | Attention | 0% | 1.03 (0.38) | 0.31 (0.10) |
| Meta-analysis | Escape | | -2.26 (0.29) | -1.22 (0.13) |
| | Attention | | 0.81 (0.23) | 0.23 (0.06) |

- Escape: 66-77% ***reduction*** in problem behavior
- Attention: 13-40% ***increase*** in problem behavior

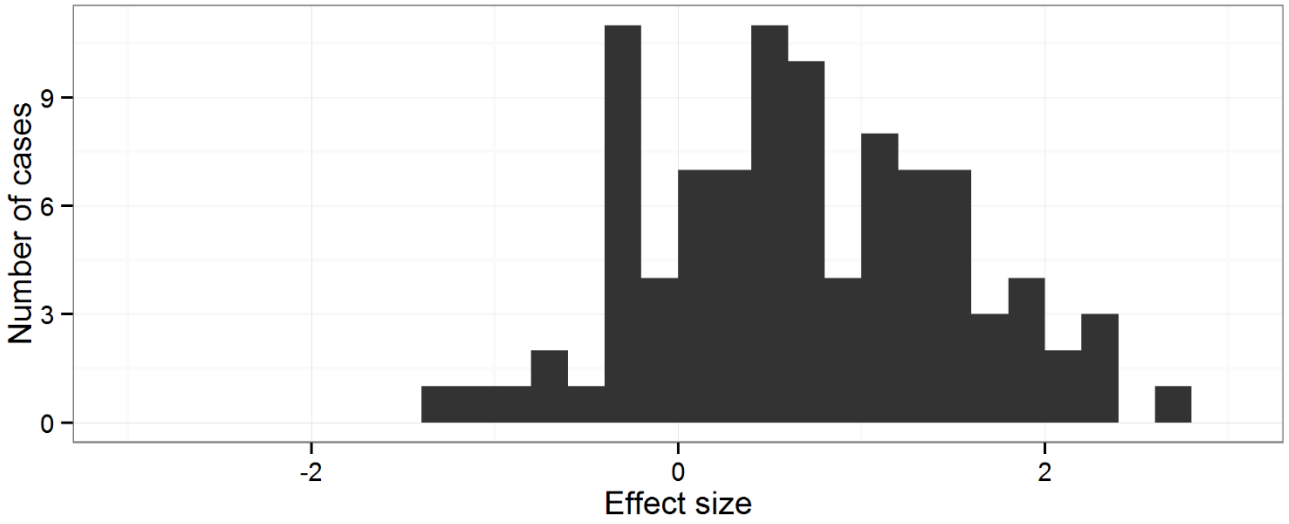
# Response Ratio

- Can sometimes be used to make comparisons across recording procedures (Pustejovsky, 2014)
- Current methods don't handle
  - Serial dependence
  - Time trends
  - Floors/ceilings in the measurements
- …but PND and SMD have problems with these too.
- Interval recording procedures need special treatment (Pustejovsky & Swan, 2014)

# Challenges & data-quality issues

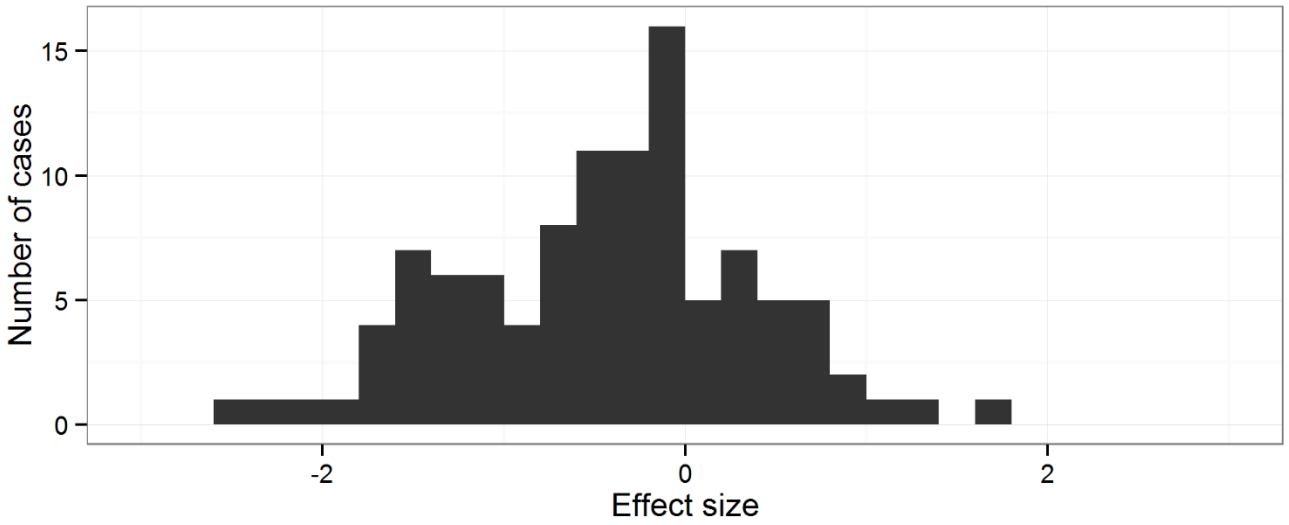
- Selective reporting
- Construct validity of interval recording data

# Selective reporting




Published studies
Mean ES: 0.68
78% of effects are > 0

All studies
Mean ES: 0.08
51% of effects are > 0




Unpublished studies
Mean ES: -0.46
25% of effects are > 0

# Interval recording

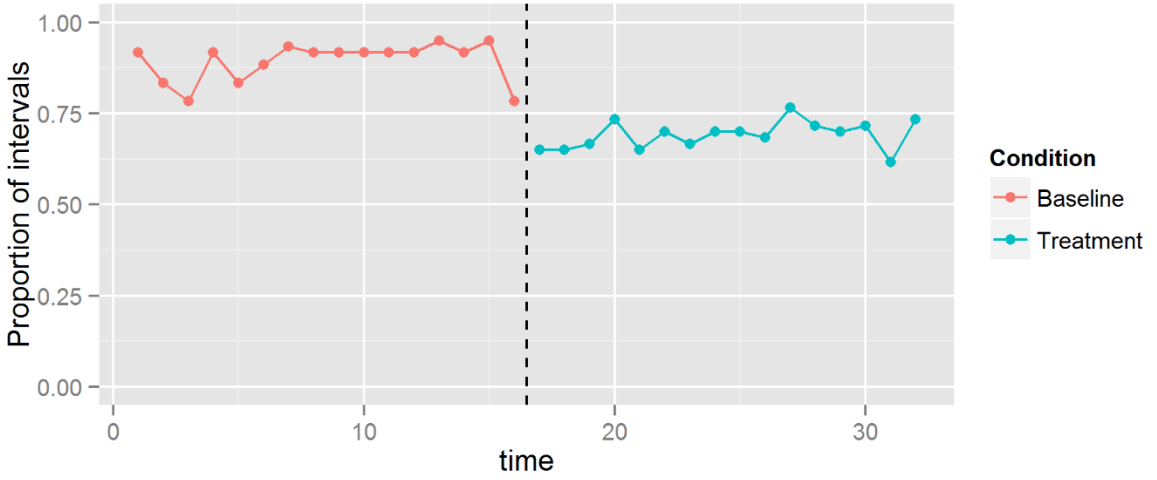
- Partial interval recording over-estimates % duration.
- Whole interval recording under-estimates % duration.

- Extent of systematic bias depends on
  - % duration
  - Frequency of the behavior
  - Length of intervals
  - Distribution of inter-event times

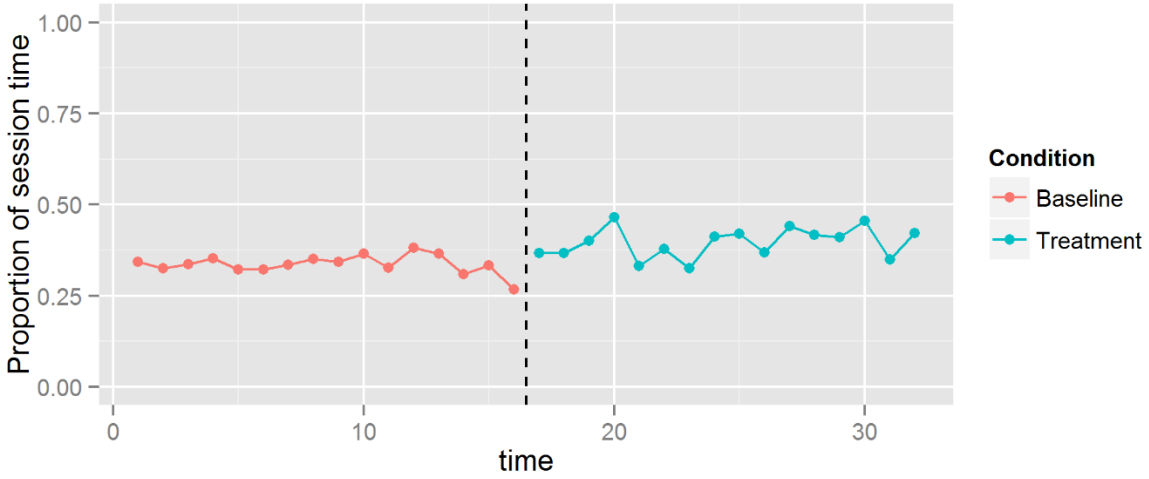
- Systematic bias can lead to systematically wrong inferences.

# A simulated example of partial interval recording

Using PIR, it appears that prevalence decreases…




…when sample prevalence has instead increased slightly.



# Interval recording

- If you are conducting a study…
  - DON'T USE INTERVAL RECORDING TO MEASURE BEHAVIOR.
  - Unless you already know a lot about the behavior.

- If studies to be synthesized use interval recording…
  - Need specialized methods for estimating valid effect sizes
  - These require prior knowledge about the behavior.
  - More details: Pustejovsky & Swan (2014).

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