Power Analysis: A Crucial Step in any Social Science Study

Kuba Glazek, Ph.D.
Methodology Expert
National Center for Academic and Dissertation Excellence
Los Angeles
Outline

• The four elements of a meaningful study
  – Alpha ($p$ value)
  – Power
  – Effect size
  – Adequate sample size

• Techniques for obtaining an adequate sample size

• Design implications
Qualitative Studies

• Power $\rightarrow$ Saturation
• Collect data until consistent/repetitive themes emerge
• Usually $N = 12$ is an upper limit (Baker & Edwards, 2012)
Alpha and Type I Error

• Corresponds to $p$ value ($p < .05$)
• $P(robability)$ of a type I error
  – Incorrectly rejecting a null hypothesis
  – AKA false alarm
  – “Observing” an effect that isn’t really there due to sampling error
Power and Type II Error

• Corresponds to 1-\(\beta\) value
• Probability of committing a *type II error*
  – Missing an effect that really is there (i.e., “observing” \(p > .05\))
  – AKA miss
  – Due to lack of *power* to detect the effect
• The less data collected, the less precise the estimate of any potential effect
Underpowered Study Consequences

• Cannot know whether
  – effect does not exist
OR
  – Effect exists, but study was *underpowered* (i.e., not enough data to detect it)

• If study is conducted, participants are put in harm’s way without hope of valid conclusion

• A potentially effective treatment may be overlooked
## Overview

<table>
<thead>
<tr>
<th>Study Finding</th>
<th>Effect present</th>
<th>Effect absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>State of the World</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effect present</td>
<td>Reject H₀</td>
<td>Type II error (miss)</td>
</tr>
<tr>
<td>Effect absent</td>
<td>Type I error (false alarm)</td>
<td>Retain H₀</td>
</tr>
</tbody>
</table>

- **Desired outcomes**
  - Probability of type I error less than 5% ($p < .05$)
  - Probability of type II error less than 20% ($1 - \beta < .8$)
Oversampling

• The more data collected, the more precise the estimate of effect, the more power to detect an effect
• Clinical significance may be non-existent
• My expose too many participants to potential danger
Effect Size

• Alpha only states *whether* an effect is significant

• Need to know the magnitude of effect, as well
  – With enough data, 1% improvement may be significant
  – With too little data, a 50% improvement may be non-significant

• If $p$ is greater than .05, effect size is still informative
Required Sample Size

- Determined by three inputs
  - Chosen alpha
  - Chosen power
  - Expected effect size

<table>
<thead>
<tr>
<th>State of the World</th>
<th>Effect present</th>
<th>Effect absent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Effect present</td>
<td>Reject $H_0$</td>
</tr>
<tr>
<td>Effect absent</td>
<td>Type I error</td>
<td>Retain $H_0$</td>
</tr>
</tbody>
</table>
“Expected” Effect Size?

- Review previous literature studying similar constructs
- Note the sample size used
- Note reported effect sizes
  - Cohen’s $d$ or Hedges’s $g$
  - Eta ($\eta$, $\eta^2$, $\eta_p^2$)
  - Omega ($\omega$, $\omega^2$)
  - Pearson’s $r$
- Statistical tests used in previous lit do not have to be identical to those appropriate to your study’s design
“Expected” Effect Size?

• If effect size not reported, can use other values to calculate

• Durlak, J. A. (2009). How to select, calculate, and interpret effect sizes. *Journal of Pediatric Psychology*
  – Cohen’s $d$ to Pearson’s $r$ and vice-versa
  – Cohen’s $d$ and Hedges’s $g$ from means and SDs
  – Pearson’s $r$ from Student’s $t$ and vice-versa
  – Article available at [http://jpepsy.oxfordjournals.org/content/early/2009/02/16/jpepsy.jsp004.full.pdf+html](http://jpepsy.oxfordjournals.org/content/early/2009/02/16/jpepsy.jsp004.full.pdf+html)
“Expected” Effect Size?

• If all else fails, obtain a range of sample sizes necessary for a range of effect sizes
• Only consider small to medium effects
  – Large effects are obvious and further scientific inquiry would be more redundant than useful
  – Available via EBSCO database
### Table I

*ES Indexes and Their Values for Small, Medium, and Large Effects*

<table>
<thead>
<tr>
<th>Test</th>
<th>ES index</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. $m_A$ vs. $m_B$ for independent means</td>
<td>$d = \frac{m_A - m_B}{\sigma}$</td>
<td>.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.80</td>
</tr>
<tr>
<td>2. Significance of product-moment $r$</td>
<td>$r$</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.50</td>
</tr>
<tr>
<td>3. $r_A$ vs. $r_B$ for independent $r$s</td>
<td>$q = z_A - z_B$ where $z = $ Fisher's $z$</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.50</td>
</tr>
<tr>
<td>4. $P = .5$ and the sign test</td>
<td>$g = P - .50$</td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.25</td>
</tr>
<tr>
<td>5. $P_A$ vs. $P_B$ for independent proportions</td>
<td>$h = \phi_A - \phi_B$ where $\phi = $ arcsine transformation</td>
<td>.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.80</td>
</tr>
<tr>
<td>6. Chi-square for goodness of fit and contingency</td>
<td>$w = \sqrt{\sum_{i=1}^{k} \frac{(P_{oi} - P_{oi})^2}{P_{oi}}}$</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.50</td>
</tr>
<tr>
<td>7. One-way analysis of variance</td>
<td>$f = \frac{\sigma_m}{\sigma}$</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.40</td>
</tr>
<tr>
<td>8. Multiple and multiple partial correlation</td>
<td>$f^2 = \frac{R^2}{1 - R^2}$</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.35</td>
</tr>
</tbody>
</table>

*Note:* ES = population effect size.

Cohen (1992)
Table 2
*N for Small, Medium, and Large ES at Power = .80 for α = .01, .05, and .10*

<table>
<thead>
<tr>
<th>Test</th>
<th>Sm</th>
<th>Med</th>
<th>Lg</th>
<th>Sm</th>
<th>Med</th>
<th>Lg</th>
<th>Sm</th>
<th>Med</th>
<th>Lg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean dif</td>
<td>586</td>
<td>95</td>
<td>38</td>
<td>393</td>
<td>64</td>
<td>26</td>
<td>310</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>Sig r</td>
<td>1,163</td>
<td>25</td>
<td>41</td>
<td>783</td>
<td>85</td>
<td>28</td>
<td>617</td>
<td>68</td>
<td>22</td>
</tr>
<tr>
<td>r dif</td>
<td>2,339</td>
<td>263</td>
<td>96</td>
<td>1,573</td>
<td>177</td>
<td>66</td>
<td>1,240</td>
<td>140</td>
<td>52</td>
</tr>
<tr>
<td>P = .5</td>
<td>1,165</td>
<td>127</td>
<td>44</td>
<td>783</td>
<td>85</td>
<td>30</td>
<td>616</td>
<td>67</td>
<td>23</td>
</tr>
<tr>
<td>P dif</td>
<td>584</td>
<td>93</td>
<td>36</td>
<td>392</td>
<td>63</td>
<td>25</td>
<td>309</td>
<td>49</td>
<td>19</td>
</tr>
<tr>
<td>χ²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 df</td>
<td>1,168</td>
<td>130</td>
<td>38</td>
<td>785</td>
<td>87</td>
<td>26</td>
<td>618</td>
<td>69</td>
<td>25</td>
</tr>
<tr>
<td>2 df</td>
<td>1,388</td>
<td>154</td>
<td>56</td>
<td>964</td>
<td>107</td>
<td>39</td>
<td>771</td>
<td>86</td>
<td>31</td>
</tr>
<tr>
<td>3 df</td>
<td>1,546</td>
<td>172</td>
<td>62</td>
<td>1,090</td>
<td>121</td>
<td>44</td>
<td>880</td>
<td>98</td>
<td>35</td>
</tr>
<tr>
<td>4 df</td>
<td>1,675</td>
<td>186</td>
<td>67</td>
<td>1,194</td>
<td>133</td>
<td>48</td>
<td>968</td>
<td>108</td>
<td>39</td>
</tr>
<tr>
<td>5 df</td>
<td>1,787</td>
<td>199</td>
<td>71</td>
<td>1,293</td>
<td>143</td>
<td>51</td>
<td>1,045</td>
<td>116</td>
<td>42</td>
</tr>
<tr>
<td>6 df</td>
<td>1,887</td>
<td>210</td>
<td>75</td>
<td>1,362</td>
<td>151</td>
<td>54</td>
<td>1,113</td>
<td>124</td>
<td>45</td>
</tr>
<tr>
<td>ANOVA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2gᵃ</td>
<td>586</td>
<td>95</td>
<td>38</td>
<td>393</td>
<td>64</td>
<td>26</td>
<td>310</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>3gᵃ</td>
<td>464</td>
<td>76</td>
<td>30</td>
<td>322</td>
<td>52</td>
<td>21</td>
<td>258</td>
<td>41</td>
<td>17</td>
</tr>
<tr>
<td>4gᵃ</td>
<td>388</td>
<td>63</td>
<td>25</td>
<td>274</td>
<td>45</td>
<td>18</td>
<td>221</td>
<td>36</td>
<td>15</td>
</tr>
<tr>
<td>5gᵃ</td>
<td>336</td>
<td>55</td>
<td>22</td>
<td>240</td>
<td>39</td>
<td>16</td>
<td>193</td>
<td>32</td>
<td>13</td>
</tr>
<tr>
<td>6gᵃ</td>
<td>299</td>
<td>49</td>
<td>20</td>
<td>215</td>
<td>35</td>
<td>14</td>
<td>174</td>
<td>28</td>
<td>12</td>
</tr>
<tr>
<td>7gᵃ</td>
<td>271</td>
<td>44</td>
<td>18</td>
<td>195</td>
<td>32</td>
<td>13</td>
<td>159</td>
<td>26</td>
<td>11</td>
</tr>
<tr>
<td>Mult R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2kᵇ</td>
<td>698</td>
<td>97</td>
<td>45</td>
<td>481</td>
<td>67</td>
<td>30</td>
<td>481</td>
<td>67</td>
<td>30</td>
</tr>
<tr>
<td>3kᵇ</td>
<td>780</td>
<td>108</td>
<td>50</td>
<td>547</td>
<td>76</td>
<td>34</td>
<td>547</td>
<td>76</td>
<td>34</td>
</tr>
<tr>
<td>4kᵇ</td>
<td>841</td>
<td>118</td>
<td>55</td>
<td>599</td>
<td>84</td>
<td>38</td>
<td>599</td>
<td>84</td>
<td>38</td>
</tr>
<tr>
<td>5kᵇ</td>
<td>901</td>
<td>126</td>
<td>59</td>
<td>645</td>
<td>91</td>
<td>42</td>
<td>645</td>
<td>91</td>
<td>42</td>
</tr>
<tr>
<td>6kᵇ</td>
<td>953</td>
<td>134</td>
<td>63</td>
<td>686</td>
<td>97</td>
<td>45</td>
<td>686</td>
<td>97</td>
<td>45</td>
</tr>
<tr>
<td>7kᵇ</td>
<td>998</td>
<td>141</td>
<td>66</td>
<td>726</td>
<td>102</td>
<td>48</td>
<td>726</td>
<td>102</td>
<td>48</td>
</tr>
<tr>
<td>8kᵇ</td>
<td>1,039</td>
<td>147</td>
<td>69</td>
<td>757</td>
<td>107</td>
<td>50</td>
<td>757</td>
<td>107</td>
<td>50</td>
</tr>
</tbody>
</table>

Cohen (1992)
G*Power

• Cohen (1992) gives generic examples
• Unique effect size estimates may require unique power analysis
• Allows for determining effect sizes from various inputs (e.g., correlations, means, SDs, etc.)
• Can get technical
  – Start with Cohen
Thank You! Questions?

Presentation available on YouTube
• https://www.youtube.com/channel/UCHCvwPnugSXf85vbQfSeLJQ
• http://bit.ly/1GE1XsD
• or just search for “NCADE”

Email: ncade.me@thechicagoschool.edu
Office: Los Angeles campus 825-B
Phone: (213) 615-7290