Truncating Bar Graphs Persistently Misleads Viewers

Department of Psychology and Neuroscience + Center for Cognitive Neuroscience
Duke University

Reading group - January 18, 2022
Sanne Willems
Y-axis truncation

Common technique that can distort the message of the graph

e.g. currently the default in Microsoft Excel
Research questions

• How large is the truncation effect? (Study 1)
• Can we inoculate viewers against the truncation effect? (Study 2-3)
• Does the inoculation effect last for 1 day? (Study 4)
• Who is more susceptible to the truncation effect? (Study 5)
Graphs + questions

Compare the ... of X and Y. How different are they?

- 1 not at all different
- 2
- 3
- 4 moderately different
- 5
- 6
- 7 extremely different
How large is the truncation effect? – Study 1

Randomized:
• 20 correct graphs
• 20 misleading graphs

Outcome per person:
• mean score for correct graphs
• mean score of misleading graphs

N = 24
How large is the truncation effect? – Study 1

Results:

• Significant difference
t(23) = 14.25, p < .0001
• 95% CI of difference = [0.92, 1.24]

Conclusion:
There is a truncation effect.
Can we inoculate viewers against the truncation effect? – Study 2

What if we warn people?

Same set-up as study 1, but with warning, example and feedback

$n = 109$

Some the graphs were created to be misleading. For example, you might see a graph where the y-axis does not start at 0, as in the graph on the left. We call this technique axis truncation. As you can see, this gives the impression that there is a larger difference in interest rates between 2008 and 2012 than might be warranted.
Can we inoculate viewers against the truncation effect? – Study 2

Results:

• Significant difference  
  \( t(108) = 10.64, p < .0001 \)
• 95% CI of difference = [0.52, 0.78]
• 85% showed truncation in the expected direction

Conclusion:
There is still a truncation effect.
Can we inoculate viewers against the truncation effect? – Study 2
Can we inoculate viewers against the truncation effect? – Study 3

Combination of study 1 and 2:
• 2 groups: warning / no warning
• N = 119
Can we inoculate viewers against the truncation effect? – Study 3

Results main effect (control vs misleading)

• Significant main effect (control vs misleading)  
  \( t(118) = 10.70, p < .0001 \)
• 95% CI of difference = [0.57, 0.83]
• 84% showed truncation in the expected direction
Can we inoculate viewers against the truncation effect? – Study 3

Results: Linear mixed effects model

<table>
<thead>
<tr>
<th></th>
<th>Estimate (b)</th>
<th>95% CI of the Estimate</th>
<th>SE</th>
<th></th>
<th></th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>4.04</td>
<td>[3.67, 4.44]</td>
<td>0.20</td>
<td>20.07</td>
<td>&lt; .0001</td>
<td></td>
</tr>
<tr>
<td>Graph Type (Control or Truncated)</td>
<td>0.79</td>
<td>[0.68, 0.89]</td>
<td>0.05</td>
<td>15.50</td>
<td>&lt; .0001</td>
<td></td>
</tr>
<tr>
<td>Warning Condition (No Warning or Warning)</td>
<td>−0.32</td>
<td>[−0.61, −0.04]</td>
<td>0.14</td>
<td>2.21</td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td>Graph Type × Warning Condition Interaction</td>
<td>−0.16</td>
<td>[−0.29, −0.03]</td>
<td>0.07</td>
<td>2.31</td>
<td>.02</td>
<td></td>
</tr>
</tbody>
</table>

Note. Both experimental conditions (graph type and warning or no warning) were dummy-coded. No Warning served as the reference group for the between-subjects manipulation. Control graphs served as the reference group for the within-subject manipulation.
Can we inoculate viewers against the truncation effect? – Study 3

Results: Linear mixed effects model

- Warning message reduced graph ratings for truncated graphs more than for the control graphs (estimate = 0.16)
- Warning let to an overall decrease in graph ratings for both types
Does the inoculation effect last for 1 day? - Study 4

• Same set-up as Study 3, but with extension:

• Participants were given 40 new graphs 1 day later (warning not repeated)
  • 20 correct
  • 20 misleading

• n = 157
Does the inoculation effect last for 1 day? - Study 4

Results main effect (control vs misleading)

• Significant main effect (control vs misleading)
  \[ t(156) = 15.97, p < .0001 \]
• 95% CI of difference = [0.72, 0.92]
• 88.5%/85.4% showed truncation in the expected direction
Does the inoculation effect last for 1 day? - Study 4

Results: Linear mixed effects model
- time point not significant; protective effect not significantly reduced

<table>
<thead>
<tr>
<th>Estimate (b)</th>
<th>95% CI of the Estimate</th>
<th>SE</th>
<th>t(r)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.76</td>
<td>[3.46, 4.08]</td>
<td>0.16</td>
<td>22.79</td>
</tr>
<tr>
<td>Graph Type (Control or Truncated)</td>
<td>1.15</td>
<td>[1.06, 1.24]</td>
<td>0.05</td>
<td>24.96</td>
</tr>
<tr>
<td>Warning Condition (No Warning or Warning)</td>
<td>0.19</td>
<td>[−0.07, 0.49]</td>
<td>0.14</td>
<td>1.37</td>
</tr>
<tr>
<td>Timepoint (Session 1 or Session 2)</td>
<td>−0.08</td>
<td>[−0.17, 0.01]</td>
<td>0.05</td>
<td>1.79</td>
</tr>
<tr>
<td>Graph Type × Warning Condition</td>
<td>−0.59</td>
<td>[−0.72, −0.46]</td>
<td>0.07</td>
<td>9.03</td>
</tr>
<tr>
<td>Timepoint × Graph Type</td>
<td>−0.15</td>
<td>[−0.27, −0.02]</td>
<td>0.07</td>
<td>2.24</td>
</tr>
<tr>
<td>Timepoint × Warning Condition</td>
<td>−0.15</td>
<td>[−0.28, −0.02]</td>
<td>0.07</td>
<td>2.35</td>
</tr>
<tr>
<td>Timepoint × Graph Type × Warning Condition</td>
<td>0.13</td>
<td>[−0.06, 0.30]</td>
<td>0.09</td>
<td>1.35</td>
</tr>
</tbody>
</table>

Note. Experimental conditions (graph type, warning or no warning, session 1 or session 2) were dummy-coded. No Warning and Session 1 served as the reference groups for the between-subject manipulations. Control graphs served as the reference group for the within-subject manipulation.
Does the inoculation effect last for 1 day? - Study 4

Results: Linear mixed effects model

Conclusions:
• A warning reduced the truncation effect, by lowering ratings for truncated graphs specifically
• Ratings were lower in the first session compared to the second session

Overall: warning influences, but does not eliminate truncation effect. Effect lasts for at least a day
Who is more susceptible to the truncation effect? – Study 1 - 5

Graph Literacy:
• 10-item measure
• Self-reported
• 6-point scale

Final score = sum of all items
Higher score -> greater graph literacy

Example questions:
• How good are you at working with bar charts?
• Are graphs easier to understand than numbers?
• How often do you find graphical information to be useful?
Who is more susceptible to the truncation effect? – Study 1 - 5

Result:
In all studies, graph literacy did not predict the size of the truncation effect.
Who is more susceptible to the truncation effect? - Study 5

Experts vs non-experts

Postdoctoral students:
• Quantitative field (n = 165)
• Humanities (n = 165)
-> comparable demographically, but different expertise

Same set-up as Study 3
• Warning/no warning group
Who is more susceptible to the truncation effect? - Study 5

Results main effects

• Significant effect control vs misleading
  \( t(329) = 13.9, p < .0001 \)
• 95% CI of difference = [0.37, 0.50]

• Smaller truncation effect in quantitative field if no warning was given
Who is more susceptible to the truncation effect? - Study 5

Results: Linear mixed effects model

Table 3
Results for Study 5 from a Linear Mixed Effects Model Predicting Graph Ratings

<table>
<thead>
<tr>
<th></th>
<th>Estimate (b)</th>
<th>95% CI of the Estimate</th>
<th>SE</th>
<th>t(1f)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.90</td>
<td>[3.56, 4.35]</td>
<td>0.21</td>
<td>18.22</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Graph Type (Control or Truncated)</td>
<td>0.69</td>
<td>[0.63, 0.75]</td>
<td>0.03</td>
<td>20.30</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Warning Condition (No Warning or Warning)</td>
<td>−0.30</td>
<td>[−0.47, −0.11]</td>
<td>0.09</td>
<td>3.31</td>
<td>.001</td>
</tr>
<tr>
<td>Field (Humanities or Quantitative)</td>
<td>−0.20</td>
<td>[−0.37, −0.04]</td>
<td>0.09</td>
<td>2.19</td>
<td>.03</td>
</tr>
<tr>
<td>Graph Type × Warning Condition</td>
<td>0.42</td>
<td>[−0.51, −0.32]</td>
<td>0.05</td>
<td>8.59</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Field × Graph Type</td>
<td>−0.14</td>
<td>[−0.23, −0.03]</td>
<td>0.05</td>
<td>2.97</td>
<td>.003</td>
</tr>
<tr>
<td>Field × Warning Condition</td>
<td>0.32</td>
<td>[0.06, 0.57]</td>
<td>0.13</td>
<td>2.47</td>
<td>.01</td>
</tr>
<tr>
<td>Field × Graph Type × Warning Condition</td>
<td>0.10</td>
<td>[−0.04, 0.24]</td>
<td>0.07</td>
<td>1.50</td>
<td>.13</td>
</tr>
</tbody>
</table>

Note. Experimental conditions (graph type, warning or no warning, humanities or quantitative) were dummy-coded. No Warning and Humanities served as the reference groups for the between-subjects manipulations. Control graphs served as the reference group for the within-subject manipulation.
Who is more susceptible to the truncation effect? - Study 5

Results: Linear mixed effects model

- Warning reduced size of truncation effect, but made participants more cautious for both types of graphs
- Truncation effect was smaller in the quantitative field
- When no warning is given, humanities group rate graphs higher
Overall conclusion

A warning can reduce the truncation effect somewhat, both immediately and after 1 day, but it does not eliminate the effect completely.
Discussion

• Set-up: Not a realistic scenario of how bar charts are encountered

• Graph literacy: maybe these bar charts were too standard; a difference may be seen for more complex data visualisations (experience needed)

• Truncation effect not eliminated: initially observed difference anchors judgments

Recommendation: always start at zero for bar charts. But not needed for line/dot plots.