Figures for 'A Primer on Visualizations for Comparing Populations...'

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This vignette shows how to reproduce the main figures in "A Primer on Visualizations for Comparing Populations, Including the Issue of Overlapping Confidence Intervals" (Wright, Klein, and Wieczorek, 2017, *The American Statistician*, in press).

Note: For this vignette itself, we automatically save the figures below using the `knitr` package with option `dev="tikz"` instead of saving them individually. In the final section of the vignette, we show an example of how to save individual plots using the `tikz()` function in the `tikzDevice` package.

Workflow to reproduce figures from the article

First, we load the package and the `TravelTime2011` dataset used in the paper. We also create string versions of our estimates and their standard errors that will print with a consistent number of digits.

```
library(RankingProject)
data(TravelTime2011)
USdata <- TravelTime2011
head(USdata)
```

```
##   Rank        State Estimate.2dec SE.2dec Abbreviation  Region FIPS
## 1    1 South Dakota         16.86    0.28           SD MIDWEST   46
## 2    2 North Dakota         16.91    0.36           ND MIDWEST   38
## 3    3     Nebraska         18.06    0.19           NE MIDWEST   31
## 4    4      Wyoming         18.10    0.50           WY    WEST   56
## 5    5      Montana         18.18    0.32           MT    WEST   30
## 6    6       Alaska         18.39    0.33           AK PACIFIC    2
```

```
# Format estimates and SEs into strings with 2 digits past the decimal
USdata$Estimate.Print = formatC(USdata$Estimate.2dec,
                                format = 'f', digits = 2)
# For SEs, also drop the leading 0
USdata$SE.Print = substring(formatC(USdata$SE.2dec,
                                    format = 'f', digits = 2),
                            first = 2)
```

Next, we set up several list-type objects to contain parameters needed for the tables and plots. As in the article, we use Colorado (CO) as the reference state. The option `tikzText=TRUE` lets us use LaTeX-style text and symbols in the figures, instead of basic R-style text.

```
# Set Colorado as the reference state
refAbbr <- "CO"
refRow  <- which(USdata$Abbreviation==refAbbr)

# Set up parameter lists for table function and figure function
```

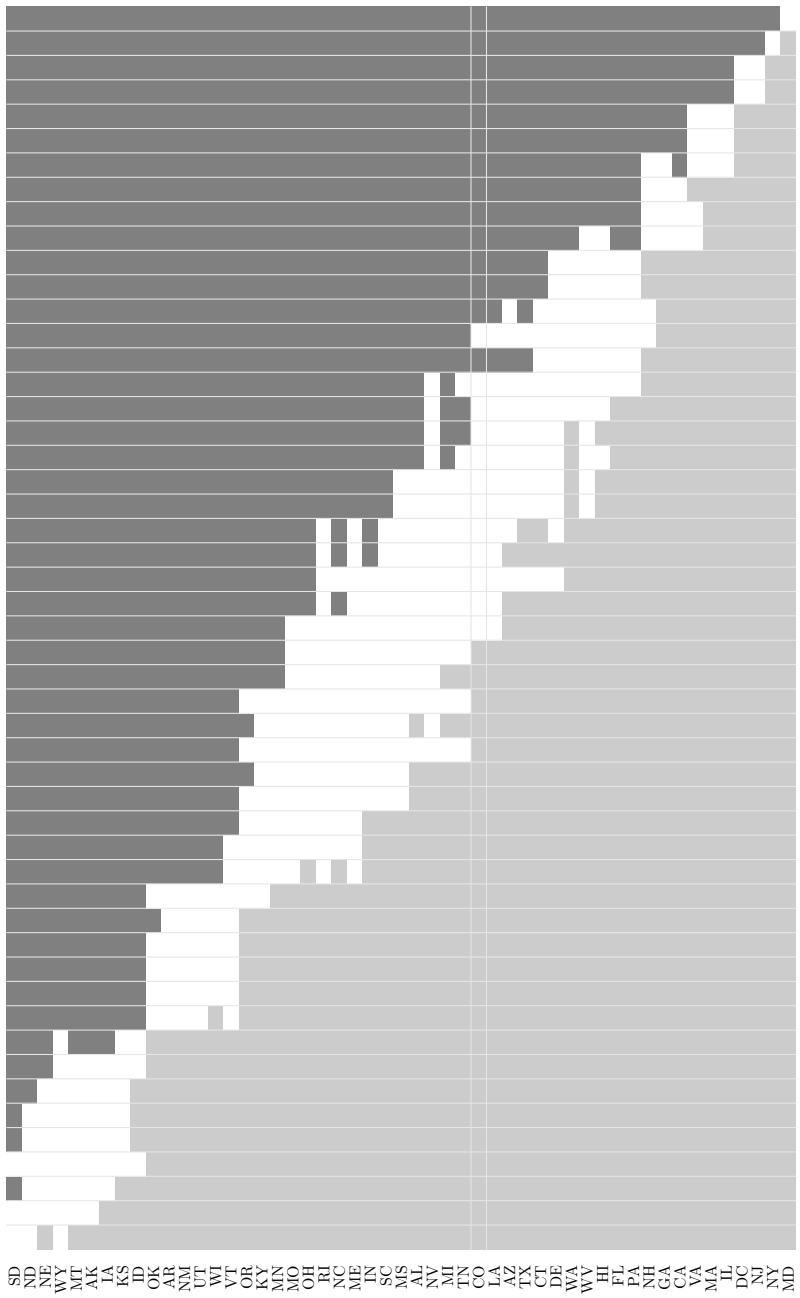
```
tableParList <- with(USdata,
                     list(ranks = Rank, names = Abbreviation,
                          est = Estimate.Print, se = SE.Print,
                          placeType = "State", tikzText = TRUE))
plotParList <- with(USdata,
                      list(est = Estimate.2dec, se = SE.2dec,
                           names = Abbreviation, refName = refAbbr,
                           confLevel = .90, tikzText = TRUE))
```

Reproduce Figure 3, the "shaded columns plot":

```
# Shaded Columns plot
plotParList$plotType <- "columns"
# Specify where to position the "Reference State:" text,
# and adjust column widths from their defaults
tableParList = c(tableParList,
                 list(columnsPlotRefLine = .7, col2 = .55, col3 = .8))
RankPlotWithTable(tableParList = tableParList, plotParList = plotParList,
                  tableWidthProp = 2/7, tikzText = TRUE)
```

$\hat{r}_k$	State (k)	$\hat{\theta}_k$	SE_k
51	MD	32.21	.15
50	NY	31.50	.09
49	NJ	30.53	.12
48	DC	30.10	.32
47	IL	28.17	.11
46	MA	27.99	.13
45	VA	27.74	.13
44	CA	27.14	.07
43	GA	27.11	.17
42	NH	26.90	.30
41	PA	25.92	.09
40	FL	25.76	.11
39	HI	25.69	.27
38	WV	25.58	.31
37	WA	25.51	.14
36	DE	25.30	.37
35	CT	24.98	.19
34	TX	24.82	.07
33	AZ	24.76	.15
32	LA	24.54	.15
31	CO	24.51	.19
30	TN	24.23	.14
29	MI	24.11	.10
28	NV	24.10	.27
27	AL	23.94	.14
26	MS	23.86	.24
25	SC	23.61	.16
24	IN	23.45	.11
23	ME	23.41	.25
22	NC	23.37	.12
21	RI	23.36	.29
20	OH	23.12	.09
19	MO	23.07	.13
18	MN	22.99	.10
17	KY	22.86	.15
16	OR	22.54	.16
15	VT	21.94	.31
14	WI	21.92	.11
13	UT	21.61	.20
12	NM	21.43	.27
11	AR	21.31	.23
10	OK	21.13	.15
9	ID	19.66	.24
8	KS	18.90	.16
7	IA	18.77	.13
6	AK	18.39	.33
5	MT	18.18	.32
4	WY	18.10	.50
3	NE	18.06	.19
2	ND	16.91	.36
1	SD	16.86	.28

Reference State:



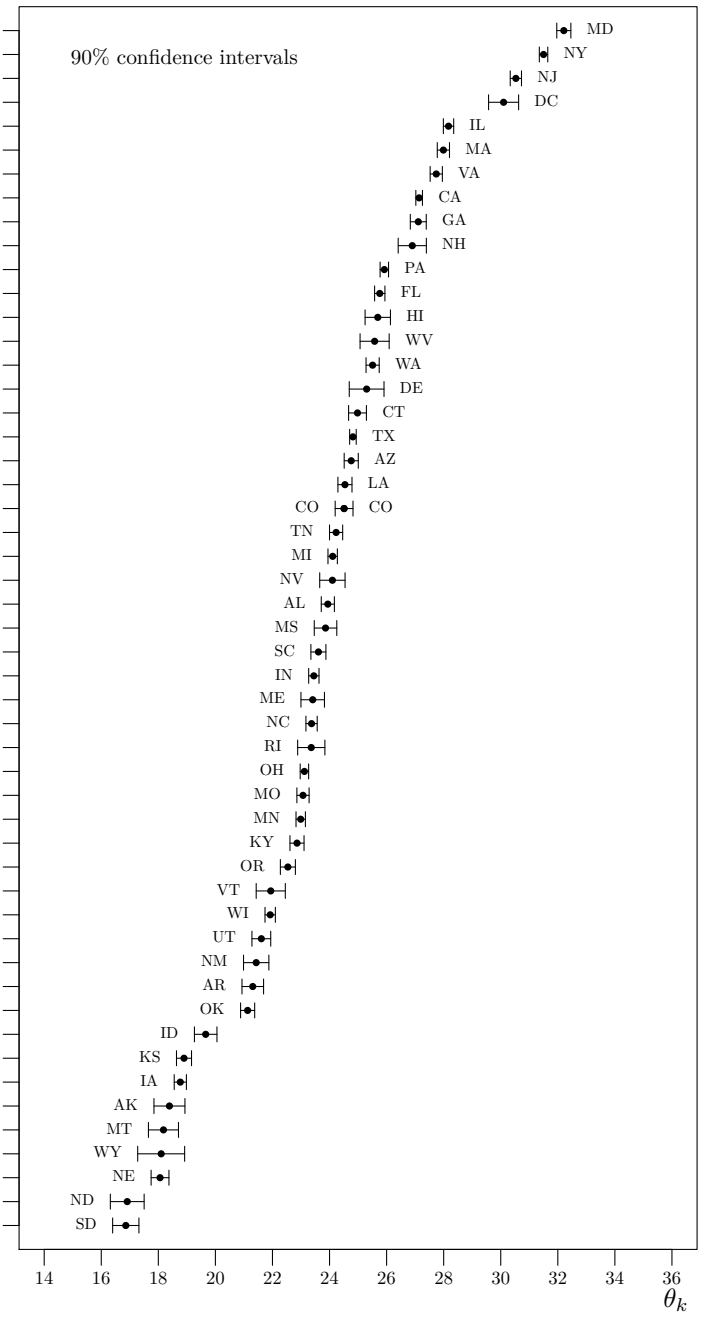

```
# Reset defaults for future plots
tableParList[c("columnsPlotRefLine", "col2", "col3")] <- NULL
```

Reproduce Figure 1, the plot of individual 90% confidence intervals (CIs):

```r
# For all remaining figures,
# table will show full state names instead of abbreviations
tableParList$names <- USdata$State

# Individual CIs
plotParList$plotType <- "individual"
plotParList$cex <- 0.6
RankPlotWithTable(tableParList = tableParList, plotParList = plotParList,
                  tikzText = TRUE)
```

$\hat{r}_k$	*State* (k)	$\hat{\theta}_k$	SE_k
51	Maryland	32.21	.15
50	New York	31.50	.09
49	New Jersey	30.53	.12
48	District of Columbia	30.10	.32
47	Illinois	28.17	.11
46	Massachusetts	27.99	.13
45	Virginia	27.74	.13
44	California	27.14	.07
43	Georgia	27.11	.17
42	New Hampshire	26.90	.30
41	Pennsylvania	25.92	.09
40	Florida	25.76	.11
39	Hawaii	25.69	.27
38	West Virginia	25.58	.31
37	Washington	25.51	.14
36	Delaware	25.30	.37
35	Connecticut	24.98	.19
34	Texas	24.82	.07
33	Arizona	24.76	.15
32	Louisiana	24.54	.15
31	Colorado	24.51	.19
30	Tennessee	24.23	.14
29	Michigan	24.11	.10
28	Nevada	24.10	.27
27	Alabama	23.94	.14
26	Mississippi	23.86	.24
25	South Carolina	23.61	.16
24	Indiana	23.45	.11
23	Maine	23.41	.25
22	North Carolina	23.37	.12
21	Rhode Island	23.36	.29
20	Ohio	23.12	.09
19	Missouri	23.07	.13
18	Minnesota	22.99	.10
17	Kentucky	22.86	.15
16	Oregon	22.54	.16
15	Vermont	21.94	.31
14	Wisconsin	21.92	.11
13	Utah	21.61	.20
12	New Mexico	21.43	.27
11	Arkansas	21.31	.23
10	Oklahoma	21.13	.15
9	Idaho	19.66	.24
8	Kansas	18.90	.16
7	Iowa	18.77	.13
6	Alaska	18.39	.33
5	Montana	18.18	.32
4	Wyoming	18.10	.50
3	Nebraska	18.06	.19
2	North Dakota	16.91	.36
1	South Dakota	16.86	.28

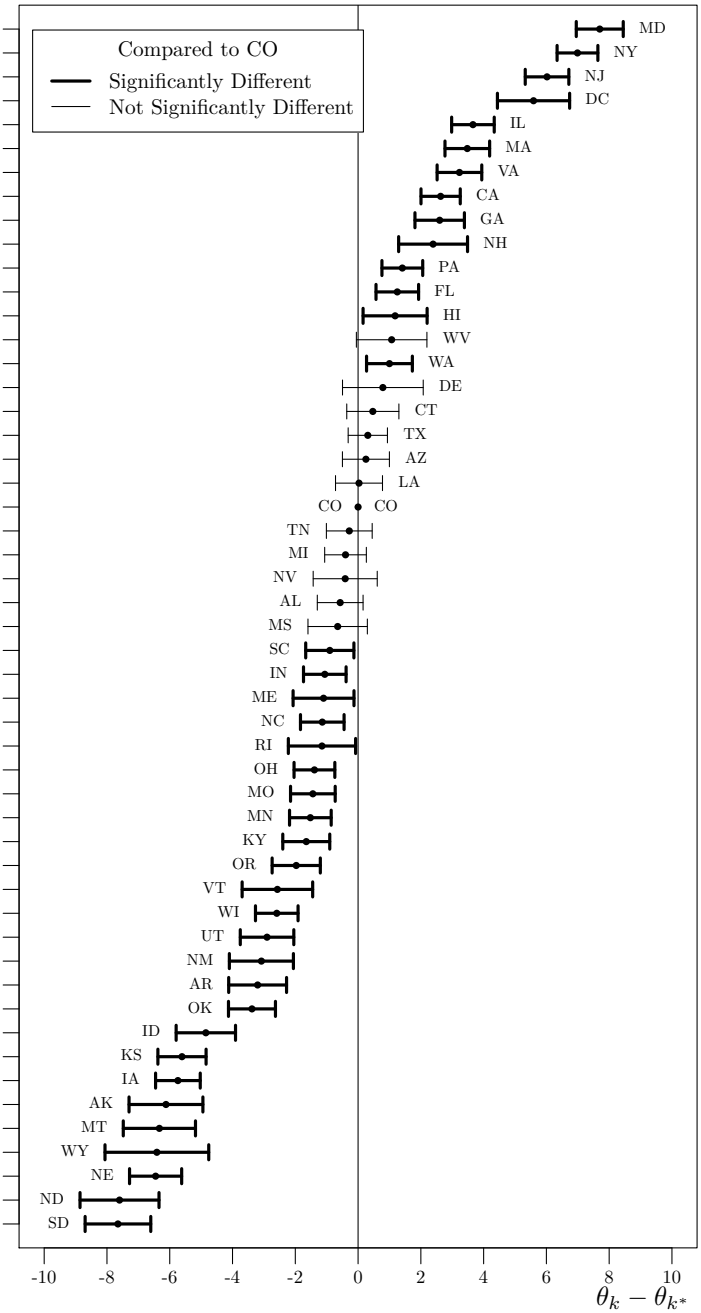


Reproduce Figure 4, the plot of demi-Bonferroni-corrected 90% CIs for the difference between the reference state Colorado and all other states:

```
# CIs for differences from ref
plotParList$plotType <- "difference"
```

```
RankPlotWithTable(tableParList = tableParList, plotParList = plotParList,
                  annotRefName = USdata$State[refRow],
                  annotRefRank = USdata$Rank[refRow],
                  tikzText = TRUE)
```

$\hat{r}_k$	*State* (k)	$\hat{\theta}_k$	SE_k
51	Maryland	32.21	.15
50	New York	31.50	.09
49	New Jersey	30.53	.12
48	District of Columbia	30.10	.32
47	Illinois	28.17	.11
46	Massachusetts	27.99	.13
45	Virginia	27.74	.13
44	California	27.14	.07
43	Georgia	27.11	.17
42	New Hampshire	26.90	.30
41	Pennsylvania	25.92	.09
40	Florida	25.76	.11
39	Hawaii	25.69	.27
38	West Virginia	25.58	.31
37	Washington	25.51	.14
36	Delaware	25.30	.37
35	Connecticut	24.98	.19
34	Texas	24.82	.07
33	Arizona	24.76	.15
32	Louisiana	24.54	.15
31	Colorado	24.51	.19
30	Tennessee	24.23	.14
29	Michigan	24.11	.10
28	Nevada	24.10	.27
27	Alabama	23.94	.14
26	Mississippi	23.86	.24
25	South Carolina	23.61	.16
24	Indiana	23.45	.11
23	Maine	23.41	.25
22	North Carolina	23.37	.12
21	Rhode Island	23.36	.29
20	Ohio	23.12	.09
19	Missouri	23.07	.13
18	Minnesota	22.99	.10
17	Kentucky	22.86	.15
16	Oregon	22.54	.16
15	Vermont	21.94	.31
14	Wisconsin	21.92	.11
13	Utah	21.61	.20
12	New Mexico	21.43	.27
11	Arkansas	21.31	.23
10	Oklahoma	21.13	.15
9	Idaho	19.66	.24
8	Kansas	18.90	.16
7	Iowa	18.77	.13
6	Alaska	18.39	.33
5	Montana	18.18	.32
4	Wyoming	18.10	.50
3	Nebraska	18.06	.19
2	North Dakota	16.91	.36
1	South Dakota	16.86	.28

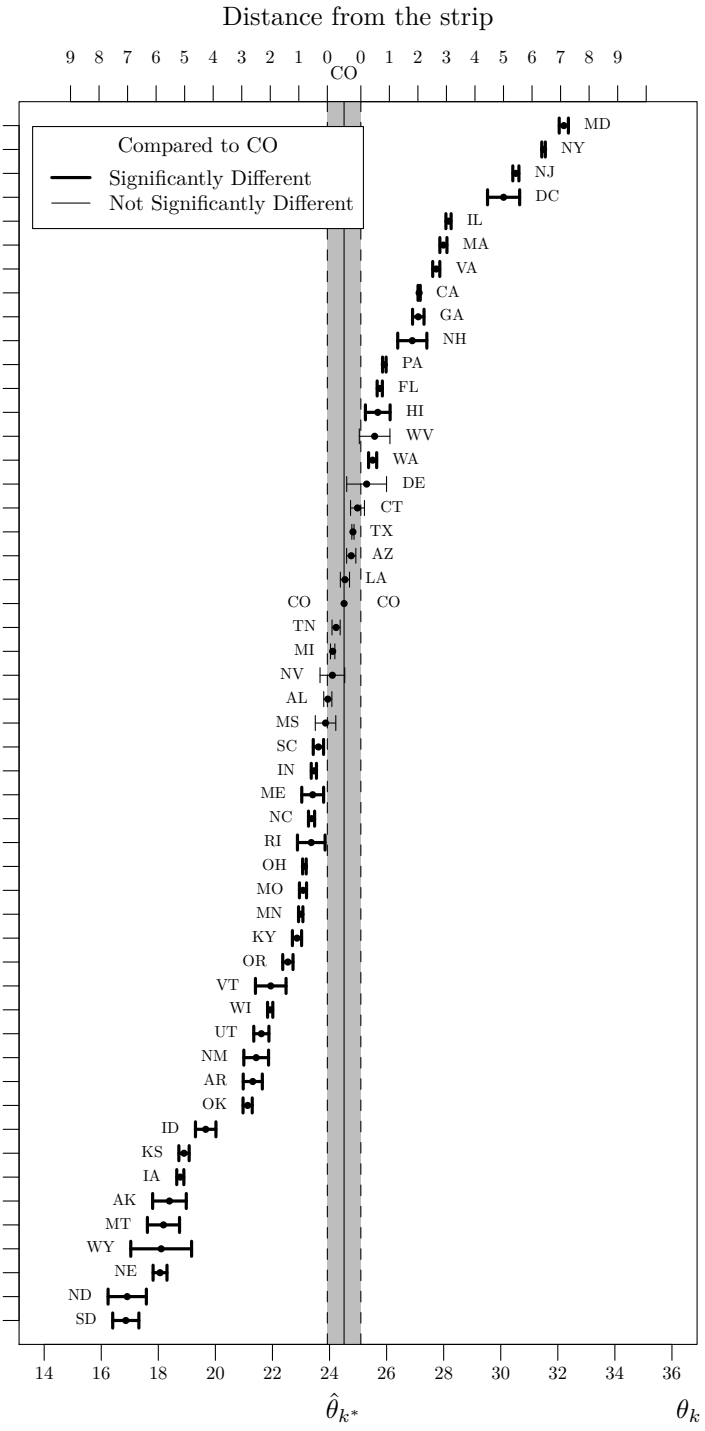


Reference State (k^*): Colorado
Rank: 31

Reproduce Figure 7, the plot of demi-Bonferroni-corrected 90% "comparison intervals" (based on Almond et al., 2000) for comparing the reference state Colorado to all other states:

```
# Comparison intervals
plotParList$plotType <- "comparison"
plotParList$thetaLine <- 1.5
RankPlotWithTable(tableParList = tableParList, plotParList = plotParList,
                  tikzText = TRUE)
```

$\hat{r}_k$	*State* (k)	$\hat{\theta}_k$	SE_k
51	Maryland	32.21	.15
50	New York	31.50	.09
49	New Jersey	30.53	.12
48	District of Columbia	30.10	.32
47	Illinois	28.17	.11
46	Massachusetts	27.99	.13
45	Virginia	27.74	.13
44	California	27.14	.07
43	Georgia	27.11	.17
42	New Hampshire	26.90	.30
41	Pennsylvania	25.92	.09
40	Florida	25.76	.11
39	Hawaii	25.69	.27
38	West Virginia	25.58	.31
37	Washington	25.51	.14
36	Delaware	25.30	.37
35	Connecticut	24.98	.19
34	Texas	24.82	.07
33	Arizona	24.76	.15
32	Louisiana	24.54	.15
31	Colorado	24.51	.19
30	Tennessee	24.23	.14
29	Michigan	24.11	.10
28	Nevada	24.10	.27
27	Alabama	23.94	.14
26	Mississippi	23.86	.24
25	South Carolina	23.61	.16
24	Indiana	23.45	.11
23	Maine	23.41	.25
22	North Carolina	23.37	.12
21	Rhode Island	23.36	.29
20	Ohio	23.12	.09
19	Missouri	23.07	.13
18	Minnesota	22.99	.10
17	Kentucky	22.86	.15
16	Oregon	22.54	.16
15	Vermont	21.94	.31
14	Wisconsin	21.92	.11
13	Utah	21.61	.20
12	New Mexico	21.43	.27
11	Arkansas	21.31	.23
10	Oklahoma	21.13	.15
9	Idaho	19.66	.24
8	Kansas	18.90	.16
7	Iowa	18.77	.13
6	Alaska	18.39	.33
5	Montana	18.18	.32
4	Wyoming	18.10	.50
3	Nebraska	18.06	.19
2	North Dakota	16.91	.36
1	South Dakota	16.86	.28

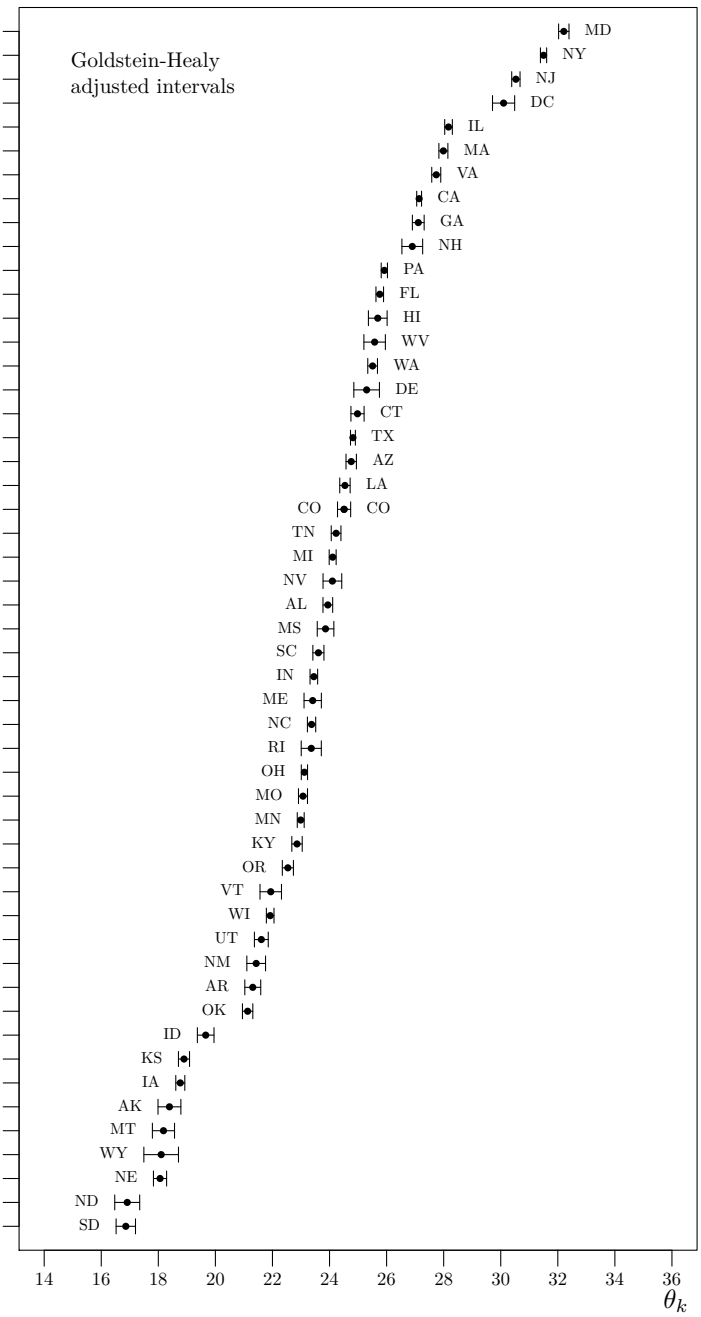



```
plotParList$thetaLine <- NULL
```

Reproduce Figure 10, the plot of Goldstein-Healy-adjusted "90%" CIs (based on Goldstein and Healy, 1995), which are in fact 77.49% CIs as chosen to achieve an "average significance level" of $\alpha = 0.10$:

```r
# Goldstein-Healy adjusted CIs
plotParList$plotType <- "individual"
plotParList$GH <- TRUE
RankPlotWithTable(tableParList = tableParList, plotParList = plotParList,
                  tikzText = TRUE)
```

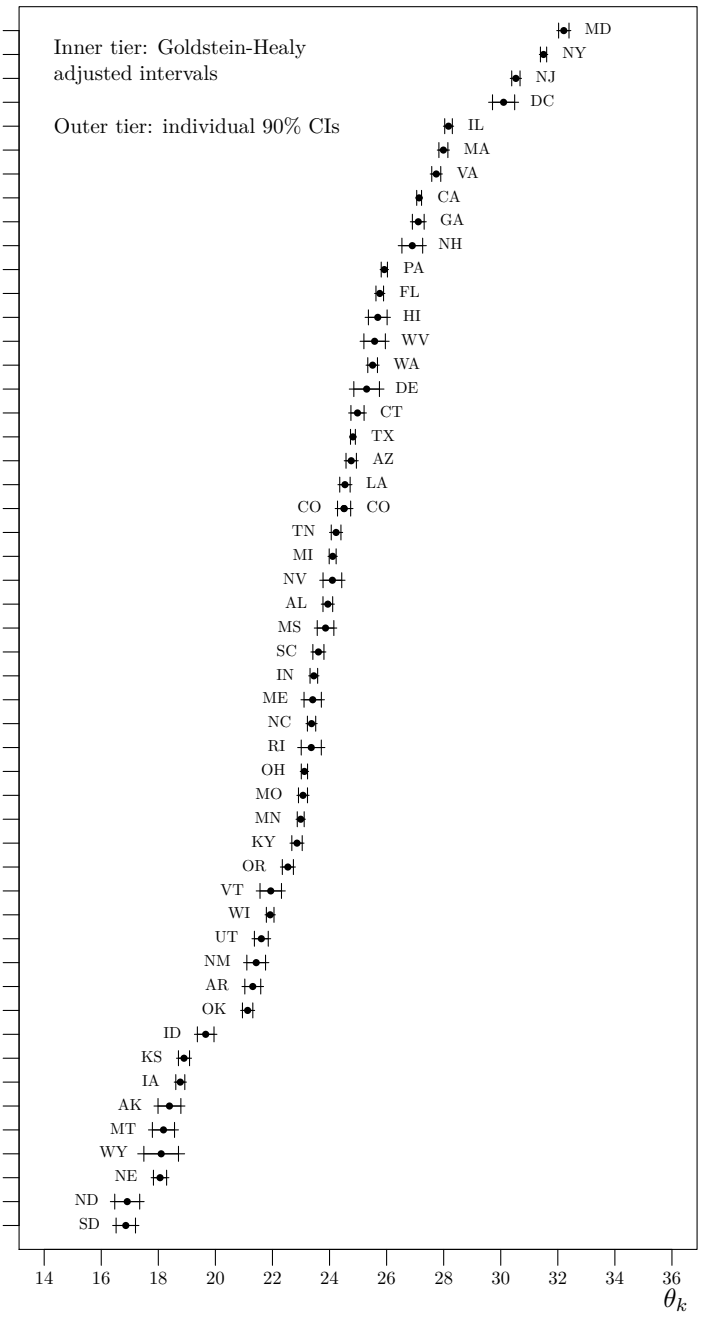
$\hat{r}_k$	*State* (k)	$\hat{\theta}_k$	SE_k
51	Maryland	32.21	.15
50	New York	31.50	.09
49	New Jersey	30.53	.12
48	District of Columbia	30.10	.32
47	Illinois	28.17	.11
46	Massachusetts	27.99	.13
45	Virginia	27.74	.13
44	California	27.14	.07
43	Georgia	27.11	.17
42	New Hampshire	26.90	.30
41	Pennsylvania	25.92	.09
40	Florida	25.76	.11
39	Hawaii	25.69	.27
38	West Virginia	25.58	.31
37	Washington	25.51	.14
36	Delaware	25.30	.37
35	Connecticut	24.98	.19
34	Texas	24.82	.07
33	Arizona	24.76	.15
32	Louisiana	24.54	.15
31	Colorado	24.51	.19
30	Tennessee	24.23	.14
29	Michigan	24.11	.10
28	Nevada	24.10	.27
27	Alabama	23.94	.14
26	Mississippi	23.86	.24
25	South Carolina	23.61	.16
24	Indiana	23.45	.11
23	Maine	23.41	.25
22	North Carolina	23.37	.12
21	Rhode Island	23.36	.29
20	Ohio	23.12	.09
19	Missouri	23.07	.13
18	Minnesota	22.99	.10
17	Kentucky	22.86	.15
16	Oregon	22.54	.16
15	Vermont	21.94	.31
14	Wisconsin	21.92	.11
13	Utah	21.61	.20
12	New Mexico	21.43	.27
11	Arkansas	21.31	.23
10	Oklahoma	21.13	.15
9	Idaho	19.66	.24
8	Kansas	18.90	.16
7	Iowa	18.77	.13
6	Alaska	18.39	.33
5	Montana	18.18	.32
4	Wyoming	18.10	.50
3	Nebraska	18.06	.19
2	North Dakota	16.91	.36
1	South Dakota	16.86	.28



Reproduce Figure 11, the plot of two-tiered error bars, where the inner tier are the same Goldstein-Healy-adjusted "90%" CIs from Figure 10, and the outer tier are the same individual 90% CIs from Figure 1:

```
# Double-tiered GH plot:
# inner tiers are GH CIs,
# outer tiers are usual 90% CIs
plotParList$tiers <- 2
# Legend auto-positioning is poor with line breaks in legend text;
# we can improve it by controlling (X,Y) manually
plotParList$legendX <- 13
plotParList$legendY <- 52
RankPlotWithTable(tableParList = tableParList, plotParList = plotParList,
                  tikzText = TRUE)
```

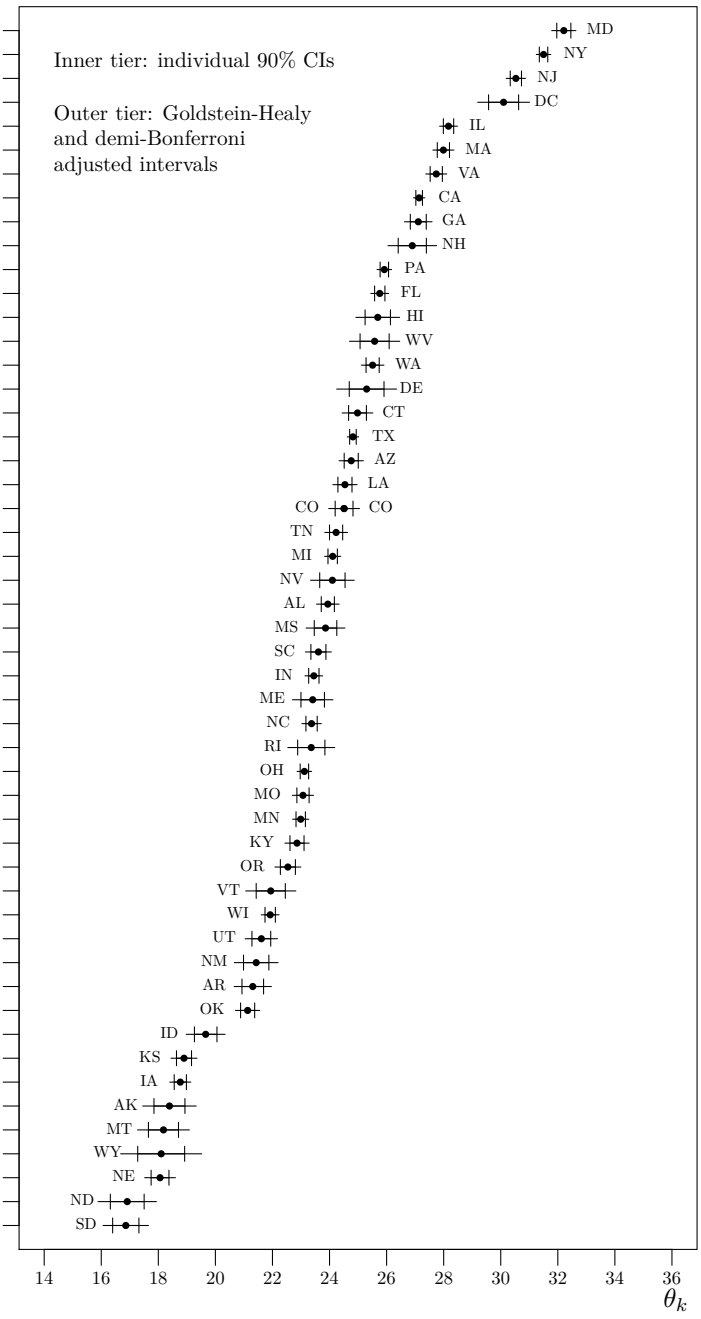
$\hat{r}_k$	*State* (k)	$\hat{\theta}_k$	SE_k
51	Maryland	32.21	.15
50	New York	31.50	.09
49	New Jersey	30.53	.12
48	District of Columbia	30.10	.32
47	Illinois	28.17	.11
46	Massachusetts	27.99	.13
45	Virginia	27.74	.13
44	California	27.14	.07
43	Georgia	27.11	.17
42	New Hampshire	26.90	.30
41	Pennsylvania	25.92	.09
40	Florida	25.76	.11
39	Hawaii	25.69	.27
38	West Virginia	25.58	.31
37	Washington	25.51	.14
36	Delaware	25.30	.37
35	Connecticut	24.98	.19
34	Texas	24.82	.07
33	Arizona	24.76	.15
32	Louisiana	24.54	.15
31	Colorado	24.51	.19
30	Tennessee	24.23	.14
29	Michigan	24.11	.10
28	Nevada	24.10	.27
27	Alabama	23.94	.14
26	Mississippi	23.86	.24
25	South Carolina	23.61	.16
24	Indiana	23.45	.11
23	Maine	23.41	.25
22	North Carolina	23.37	.12
21	Rhode Island	23.36	.29
20	Ohio	23.12	.09
19	Missouri	23.07	.13
18	Minnesota	22.99	.10
17	Kentucky	22.86	.15
16	Oregon	22.54	.16
15	Vermont	21.94	.31
14	Wisconsin	21.92	.11
13	Utah	21.61	.20
12	New Mexico	21.43	.27
11	Arkansas	21.31	.23
10	Oklahoma	21.13	.15
9	Idaho	19.66	.24
8	Kansas	18.90	.16
7	Iowa	18.77	.13
6	Alaska	18.39	.33
5	Montana	18.18	.32
4	Wyoming	18.10	.50
3	Nebraska	18.06	.19
2	North Dakota	16.91	.36
1	South Dakota	16.86	.28



Reproduce Figure 12, another plot of two-tiered error bars, where now the inner tier are the same individual 90% CIs from Figure 1, and the outer tier are demi-Bonferroni-corrected Goldstein-Healy-adjusted "90%" CIs (in fact 99.55% CIs):

```
# Double-tiered GH + Bonferroni plot:
# inner tiers are usual 90% CIs,
# outer tiers are 50-way demi-Bonferroni-corrected GH CIs
plotParList$Bonferroni <- "demi"
RankPlotWithTable(tableParList = tableParList, plotParList = plotParList,
                  tikzText = TRUE)
```

$\hat{r}_k$	*State* (k)	$\hat{\theta}_k$	SE_k
51	Maryland	32.21	.15
50	New York	31.50	.09
49	New Jersey	30.53	.12
48	District of Columbia	30.10	.32
47	Illinois	28.17	.11
46	Massachusetts	27.99	.13
45	Virginia	27.74	.13
44	California	27.14	.07
43	Georgia	27.11	.17
42	New Hampshire	26.90	.30
41	Pennsylvania	25.92	.09
40	Florida	25.76	.11
39	Hawaii	25.69	.27
38	West Virginia	25.58	.31
37	Washington	25.51	.14
36	Delaware	25.30	.37
35	Connecticut	24.98	.19
34	Texas	24.82	.07
33	Arizona	24.76	.15
32	Louisiana	24.54	.15
31	Colorado	24.51	.19
30	Tennessee	24.23	.14
29	Michigan	24.11	.10
28	Nevada	24.10	.27
27	Alabama	23.94	.14
26	Mississippi	23.86	.24
25	South Carolina	23.61	.16
24	Indiana	23.45	.11
23	Maine	23.41	.25
22	North Carolina	23.37	.12
21	Rhode Island	23.36	.29
20	Ohio	23.12	.09
19	Missouri	23.07	.13
18	Minnesota	22.99	.10
17	Kentucky	22.86	.15
16	Oregon	22.54	.16
15	Vermont	21.94	.31
14	Wisconsin	21.92	.11
13	Utah	21.61	.20
12	New Mexico	21.43	.27
11	Arkansas	21.31	.23
10	Oklahoma	21.13	.15
9	Idaho	19.66	.24
8	Kansas	18.90	.16
7	Iowa	18.77	.13
6	Alaska	18.39	.33
5	Montana	18.18	.32
4	Wyoming	18.10	.50
3	Nebraska	18.06	.19
2	North Dakota	16.91	.36
1	South Dakota	16.86	.28



Using `tikzDevice::tikz()` to save individual figures

For this vignette, the figures above were automatically converted to PDF format using `knitr` with chunk option `dev="tikz"`. When not using `knitr`, we may prefer to save plots one at a time "manually." To do this,

we can explicitly call the `tikz()` function from the `tikzDevice` package, as in the following example code.

The `tikz()` function works much like `pdf()` or `png()` and other standard functions for saving plots from R scripts. We must remember to call `dev.off()` after the plotting function runs, to let R know the plot is ready to be saved.

Using `tikz()` will create and save a `.tex` file. To convert this to a figure, we can:

- compile it into a standalone PDF separately; or
- use R's `tools::texi2pdf()` which compiles the PDF and saves it in the current working directory; or
- set `standAlone=FALSE` below, then copy-paste the contents of the saved `.tex` file directly into a larger `.tex` document.

```
# Not run:
library(tikzDevice)
tikz("/path/to/my/file.tex", standAlone = TRUE, width = 6.5, height = 8)
RankPlotWithTable(tableParList = tableParList, plotParList = plotParList,
                  tikzText = TRUE)
dev.off()
tools::texi2pdf("/path/to/my/file.tex")
```