STATISTICAL HORIZONS

Interactions in Regression Analysis

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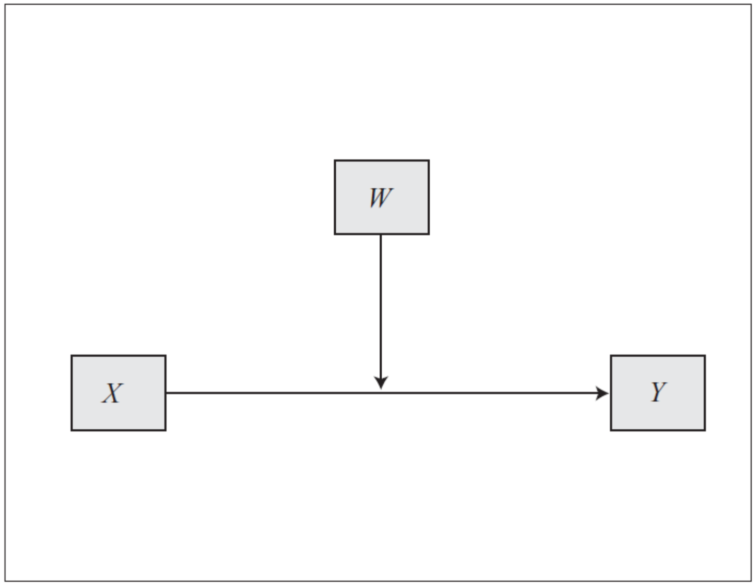
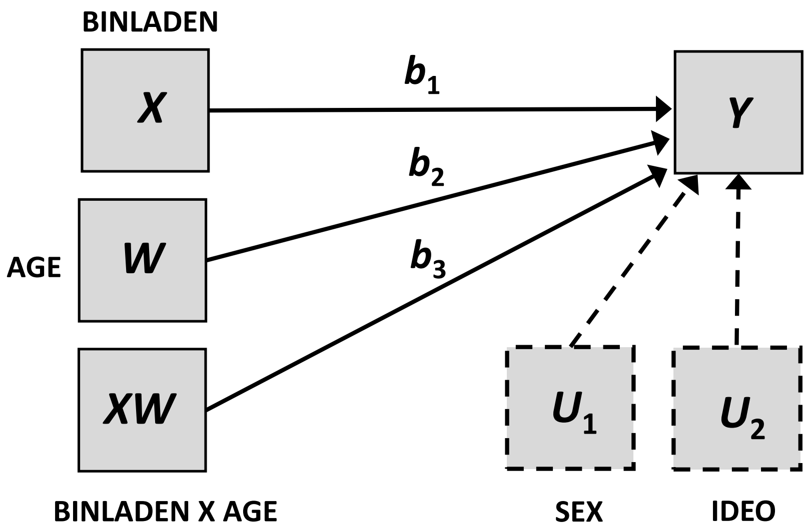
Estimation using PROCESS

PROCESS Model 1

Model 1



Statistical model




```
process y=stereo/x=binladen/w=age/cov=sex ideo/jn=1/plot=1/model=1.
```

```
%process (data=obl,y=stereo,x=binladen,w=age,cov=sex ideo,jn=1,plot=1,
   model=1)
```

```
process(data=obl,y="stereo",x="binladen",w="age",cov=c("sex","ideo"),jn=1,
   plot=1,model=1);
```

PROCESS output

OUTPUT A

```
Model   : 1
    Y   : stereo
    X   : binladen
    W   : age

Covariates:
 sex      ideo

Sample
Size:  661

*************************************************************************
OUTCOME VARIABLE:
 stereo

Model Summary
          R       R-sq        MSE          F        df1        df2          p
      .3643      .1327      .6459    20.0448     5.0000   655.0000      .0000

Model
              coeff         se          t          p       LLCI       ULCI
constant     1.7422      .1518    11.4775      .0000     1.4441     2.0402
binladen      .5402      .1980     2.7279      .0065      .1513      .9290
age           .0831      .0245     3.4001      .0007      .0351      .1312
Int_1        -.0834      .0387    -2.1567      .0314     -.1594     -.0075
sex           .0386      .0633      .6095      .5424     -.0857      .1629
ideo          .1300      .0143     9.1235      .0000      .1021      .1580

Product terms key:
 Int_1    :        binladen x        age

Test(s) of highest order unconditional interaction(s):
       R2-chng          F        df1        df2          p
X*W      .0062     4.6514     1.0000   655.0000      .0314
```

$$\hat{Y} = 1.742 + 0.540X + 0.083W - 0.083XW + \cdots$$

PROCESS generates the product for you

PROCESS output

PROCESS sees that the moderator is quantitative (because it has more than 2 values) so it implements the pick-a-point procedure with moderator values equal to the 16th, 50th, and 84th percentiles of the distribution of the moderator.

```
*****************************************************************************

Focal predict: binladen (X)
      Mod var: age      (W)

Conditional effects of the focal predictor at values of the moderator(s):

W →     age     Effect       se          t          p       LLCI       ULCI
     3.0000      .2899    .0957     3.0284      .0026      .1019      .4778
     4.8000      .1397    .0637     2.1918      .0287      .0145      .2648
     6.7000     -.0188    .0959     -.1963      .8444     -.2072      .1695

******************************************************************************
```

$$\theta_{X\to Y} = 0.540 - 0.083W$$

OUTPUT A

Media coverage of OBL's death affected stereotype endorsement among the "relatively young" ($\theta_{X\to Y|W=3.0}$ = 0.290, $p < .01$) and "middle-aged" ($\theta_{X\to Y|W=4.8}$ = 0.140, $p < .05$) but not among the "relatively older" ($\theta_{X\to Y|W=6.502}$ = -0.019, $p = .844$).

Additional "pick-a-point" probing options

Adding **moments = 1** to the PROCESS command produces estimates of the conditional effect of *X* at the mean, a standard deviation below the mean, and a standard deviation above the mean of the moderator.

```
process ... /moments=1.
```

```
process (data = ... ,moments=1)
```

```
process (data = ... ,moments=1)
```

age	Effect	se	t	p	LLCI	ULCI
3.1905	.2740	.0904	3.0324	.0025	.0966	.4514
4.8460	.1359	.0637	2.1324	.0333	.0108	.2610
6.5015	-.0023	.0903	-.0252	.9799	-.1796	.1751

Or use the **wmodval** option to request one or more specific values of the moderator at which to condition *X*'s effect on *Y*.

```
process ... /wmodval=3,5,7.
```

```
%process (data = ... , wmodval=3 5 7)
```

```
process (data = ... , wmodval=c(3,5,7))
```

age	Effect	se	t	p	LLCI	ULCI
3.0000	.2899	.0957	3.0284	.0026	.1019	.4778
5.0000	.1230	.0640	1.9224	.0550	-.0026	.2487
7.0000	-.0439	.1049	-.4182	.6759	-.2498	.1621

Generating a graph from PROCESS "PLOT" option output

Use the plot option in the PROCESS command, toggling it on with **plot=1** in the command To produce estimates of the outcome at values of focal predictor and moderator. Use **plot=2** to get standard errors and confidence intervals as well.

```
DATA LIST FREE/
   binladen    age         stereo      .
BEGIN DATA.
       .0000      3.0000      2.7092
      1.0000      3.0000      2.9991
       .0000      4.8000      2.8588
      1.0000      4.8000      2.9985
       .0000      6.7000      3.0168
      1.0000      6.7000      2.9980
END DATA.
GRAPH/SCATTERPLOT=
 age        WITH      stereo    BY        binladen .
```

PROCESS for SPSS writes the code for you. Cut and paste as syntax into SPSS and execute.

```
data;
input binladen age stereo;
datalines;
       .0000     3.0000      2.7092
      1.0000     3.0000      2.9991
       .0000     4.8000      2.8588
      1.0000     4.8000      2.9985
       .0000     6.7000      3.0168
      1.0000     6.7000      2.9980
run;
proc sgplot;reg x=age y=stereo/group=binladen;run;
```

PROCESS for SAS and R only gives you this. Plug these values into the SAS and R code from earlier.

OUTPUT A

The Johnson-Neyman technique

The Johnson-Neyman technique seeks to find the value or values of the moderator *(W)* within the data, if they exist, such that the *p*-value for the ratio of the conditional effect of the focal predictor at that value or values of *W* is exactly equal to some chosen level of significance α

To do so, we ask what value of *W* produces a ratio exactly equal to the critical *t* value (t_{crit}) required to reject the null hypothesis that the conditional effect of *X* is equal to zero?

$$t_{crit} = \frac{b_1 + b_3 W}{\sqrt{s_{b_1}^2 + 2W s_{b_1 b_3} + W^2 s_{b_3}^2}}$$

Isolate *W* and solve the polynomial that results. The quadratic formula finds the solutions:

$$W = \frac{-2(t_{crit}^2 s_{b_1 b_3}^{-} - b_1 b_3) \pm \sqrt{(2t_{crit}^2 s_{b_1 b_3}^{-} - 2b_1 b_3)^2 - 4(t_{crit}^2 s_{b_3}^2 - b_3^2)(t_{crit}^2 s_{b_1}^2 - b_1^2)}}{2(t_{crit}^2 s_{b_3}^2 - b_3^2)}$$

We would not attempt to do this by hand

Johnson-Neyman output from PROCESS

Use the JN option in the PROCESS command, toggling it on with **jn=1** in the command

$\theta_{X \rightarrow Y} | W$

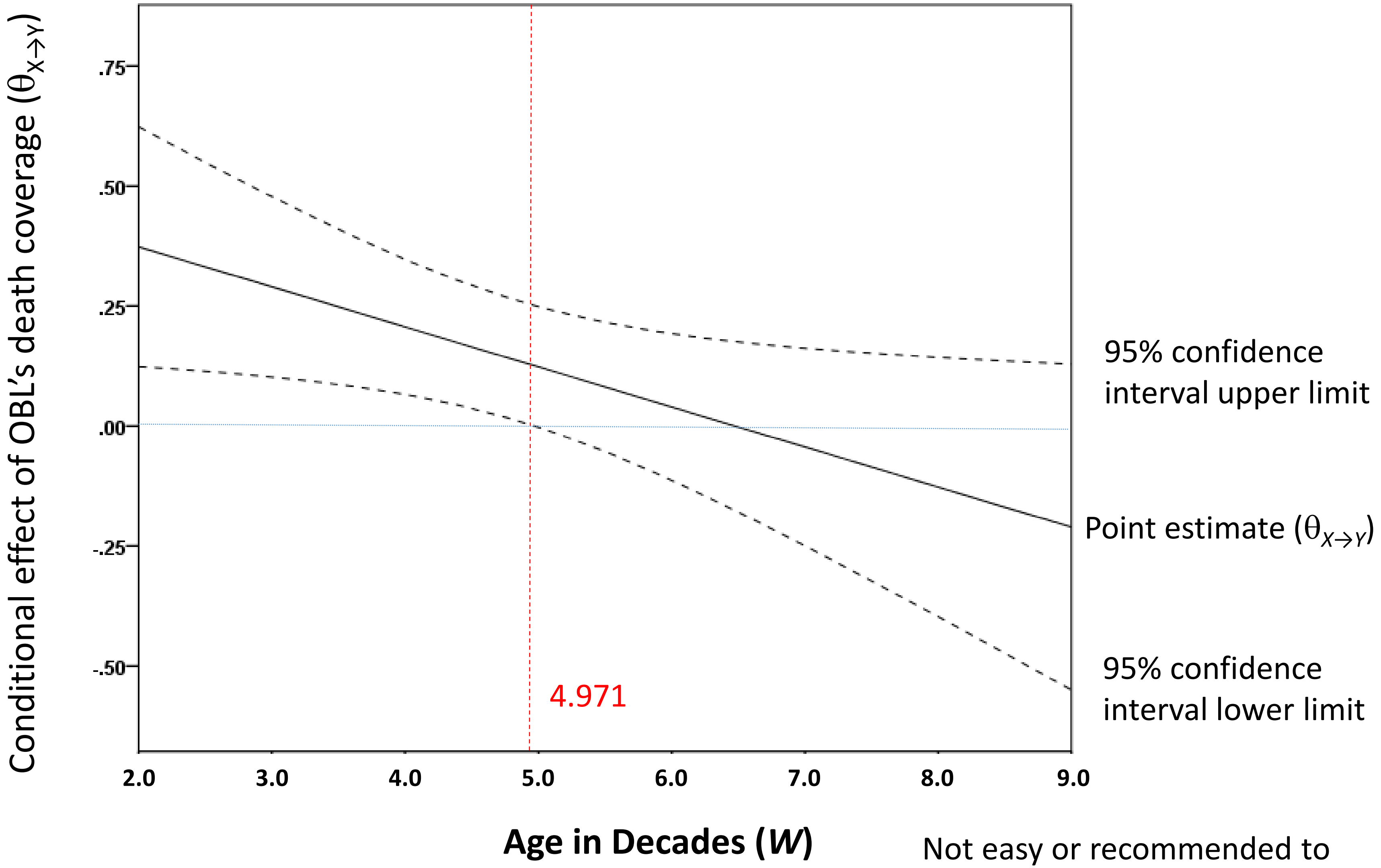
W

```
******************** JOHNSON-NEYMAN TECHNIQUE *************************

Moderator value(s) defining Johnson-Neyman significance region(s)
     Value    % below    % above
    4.9707    57.3374    42.6626

Conditional effect of X on Y at values of the moderator (M)
       age     Effect         se          t          p       LLCI       ULCI
    1.8000      .3900      .1340     2.9109      .0037      .1269      .6531
    2.1700      .3591      .1216     2.9540      .0032      .1204      .5979
    2.5400      .3283      .1096     2.9939      .0029      .1130      .5436
    2.9100      .2974      .0983     3.0239      .0026      .1043      .4905
    3.2800      .2665      .0879     3.0310      .0025      .0939      .4392
    3.6500      .2356      .0788     2.9923      .0029      .0810      .3903
    4.0200      .2048      .0713     2.8726      .0042      .0648      .3447
    4.3900      .1739      .0661     2.6304      .0087      .0441      .3037
    4.7600      .1430      .0638     2.2419      .0253      .0178      .2683
    4.9707      .1255      .0639     1.9636      .0500      .0000      .2509
    5.1300      .1122      .0646     1.7350      .0832     -.0148      .2391
    5.5000      .0813      .0685     1.1860      .2361     -.0533      .2159
    5.8700      .0504      .0750      .6721      .5017     -.0969      .1977
    6.2400      .0195      .0835      .2342      .8149     -.1443      .1834
    6.6100     -.0113      .0933     -.1213      .9035     -.1946      .1720
    6.9800     -.0422      .1043     -.4047      .6858     -.2469      .1625
    7.3500     -.0731      .1159     -.6303      .5287     -.3007      .1546
    7.7200     -.1039      .1281     -.8112      .4175     -.3555      .1477
    8.0900     -.1348      .1407     -.9579      .3384     -.4111      .1415
    8.4600     -.1657      .1536    -1.0785      .2812     -.4673      .1360
    8.8300     -.1966      .1668    -1.1787      .2390     -.5240      .1309
    9.2000     -.2274      .1801    -1.2630      .2070     -.5810      .1262
```

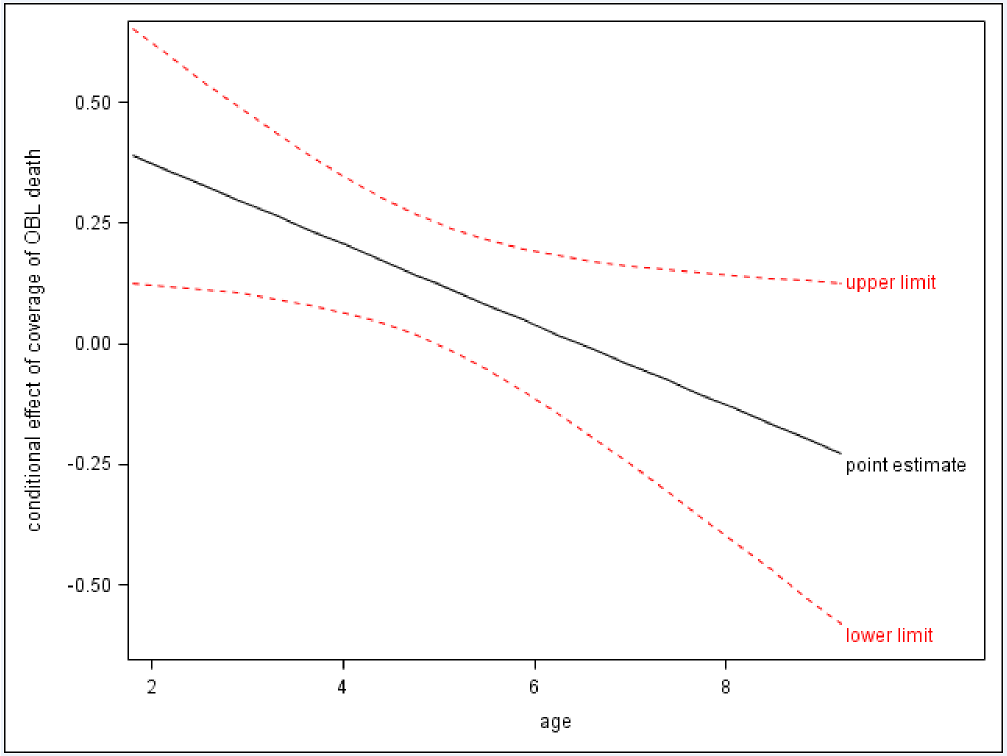
A Johnson-Neyman plot



Not easy or recommended to attempt to produce this in SPSS

A Johnson-Neyman plot (SAS)

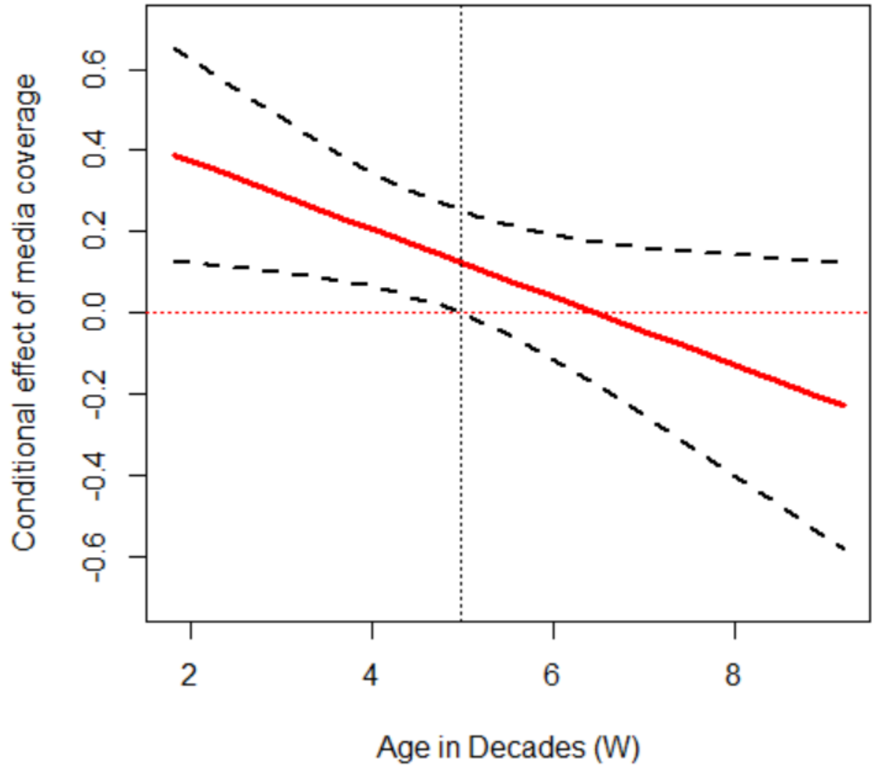
```
data;
input age effect llci ulci;
cards;
    1.8000      .3900      .1269      .6531
    2.1700      .3591      .1204      .5979
    2.5400      .3283      .1130      .5436
    2.9100      .2974      .1043      .4905
    3.2800      .2665      .0939      .4392
    3.6500      .2356      .0810      .3903
    4.0200      .2048      .0648      .3447
    4.3900      .1739      .0441      .3037
    4.7600      .1430      .0178      .2683
    4.9706      .1255      .0000      .2509
    5.1300      .1122     -.0148      .2391
    5.5000      .0813     -.0533      .2159
    5.8700      .0504     -.0969      .1977
    6.2400      .0195     -.1443      .1834
    6.6100     -.0113     -.1946      .1720
    6.9800     -.0422     -.2469      .1625
    7.3500     -.0731     -.3007      .1546
    7.7200     -.1039     -.3555      .1477
    8.0900     -.1348     -.4111      .1415
    8.4600     -.1657     -.4673      .1360
    8.8300     -.1966     -.5240      .1309
    9.2000     -.2274     -.5810      .1262
run;
proc sgplot;
  series x=age y=ulci/curvelabel = 'upper limit' lineattrs=(color=red pattern=ShortDash);
  series x=age y=effect/curvelabel = 'point estimate' lineattrs=(color=black pattern=Solid);
  series x=age y=llci/curvelabel = 'lower limit' lineattrs=(color=red pattern=ShortDash);
  yaxis label = 'conditional effect of coverage of OBL death';
run;
```



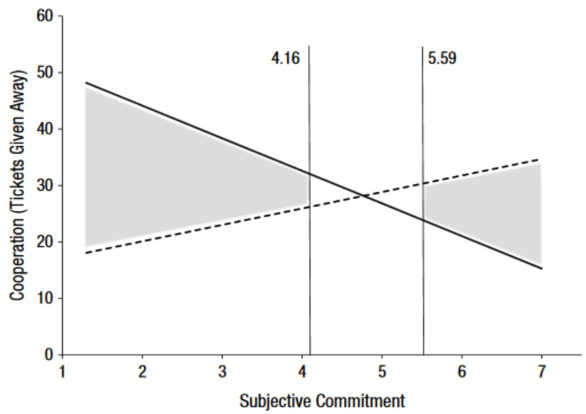
A Johnson-Neyman plot (R)

```
age<-c(1.8,2.17,2.54,2.91,3.28,3.65,4.02,4.39,4.76,4.97,5.13,5.5,5.87,
  6.24,6.61,6.98,7.35,7.72,8.09,8.46,8.83,9.20)
effect<-c(.390,.359,.328,.297,.266,.236,.205,.174,.143,.126,.112,.081,
  .050,.020,-.011,-.042,-.073,-.104,-.135,-.166,-.197,-.227)
llci<-c(.127,.120,.113,.104,.094,.081,.065,.044,.018,.000,-.015,
  -.053,-.097,-.144,-.195,-.247,-.301,-.356,-.411,-.467,-.524,-.581)
ulci<-c(.653,.598,.544,.491,.439,.390,.345,.304,.268,.251,.239,.216,
  .198,.183,.172,.163,.155,.148,.142,.136,.131,.126)
plot(x=age,y=effect,type="l",pch=19,ylim=c(-.7,.7),xlim=c(1.8,9.2),lwd=3,
ylab="Conditional effect of media coverage",
xlab="Age in Decades (W)",col="red")
points(age,llci,lwd=2,lty=2,type="l",col="black")
points(age,ulci,lwd=2,lty=2,type="l",col="black")
abline(h=0,untf = FALSE,lty=3,lwd=1,col="red")
abline(v=4.971,untf=FALSE,lty=3,lwd=1)
text(4.971,-2.1,"4.971",cex=0.8)
```

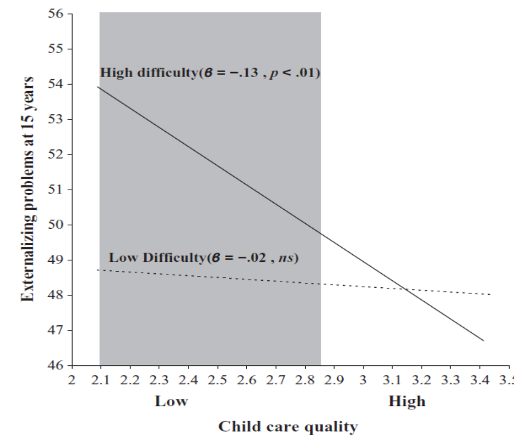
From the JN option in PROCESS.



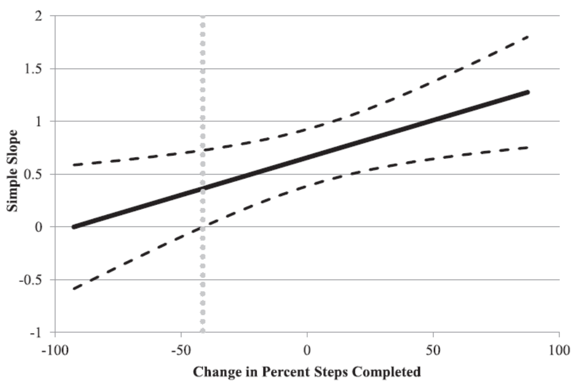
Some visual representations in the literature



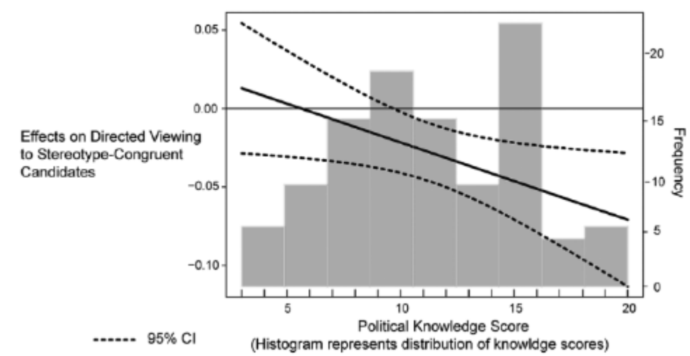
Romano, A., & Balliet, D. (2017). Reciprocity outperforms conformity to promote cooperation. *Psychological Science, 28*, 1490-1502.



Belsky, J., & Pluess, M. (2011). Differential susceptibility to long-term effects of quality of child care on externalizing behavior in adolescence? *International Journal of Behavioral Development, 36*, 2-10.



Allen, K. B., Allen, B., Austin, K. E. et al. (2015). Synchrony-desynchrony in the tripartite model of fear: Predicting treatment outcome in clinically phobic children. *Behaviour Research and Therapy, 71*, 54-64.



Coronel, J. C., & Federmeier, K. D. (2016). The effects of gender cues and political sophistication on candidate evaluation: A comparison of self-report and eye movement measurements of stereotyping. *Communication Research, 43*, 922-944.