MQP - Methods for Learning What Works in Educational Technology

2023-02-15

This document contains all the code used during the analysis of our data.

Libraries

The tidyverse and meta libraries were used during the analysis.

```
library(tidyverse)

## ── Attaching packages ───────────────────────────────────────────────────
tidyverse 1.3.2 ──
## ✔ ggplot2 3.3.6      ✔ purrr   0.3.5
## ✔ tibble  3.1.8      ✔ dplyr   1.0.10
## ✔ tidyr   1.2.1      ✔ stringr 1.4.1
## ✔ readr   2.1.3      ✔ forcats 0.5.2
## ── Conflicts ─────────────────────────────────────────────────────
tidyverse_conflicts() ──
## ✖ dplyr::filter() masks stats::filter()
## ✖ dplyr::lag()    masks stats::lag()

library(meta)

## Loading 'meta' package (version 6.0-0).
## Type 'help(meta)' for a brief overview.
## Readers of 'Meta-Analysis with R (Use R!)' should install
## older version of 'meta' package: https://tinyurl.com/dt4y5drs
```

Loading in the Data

The table of data must be loaded in before it can be worked with.

```
load("hintVSexplbig.RData")
```

Getting Student Totals

If you want to output the total number of students who were given the hint vs the explanation for all experiments, use the code below.

```
sampleSizes <- hintVSexplbig%>%group_by(rand)%>%summarize(n=n())
sampleSizes

## # A tibble: 101 × 2
##    rand                n
##    <chr>           <int>
##  1 1208901;1183943  3078
```

```
##   2 1208908;1183944  1888
##   3 1208924;1183945  1419
##   4 1210635;1182830  2090
##   5 1216467;1206699  4918
##   6 1216469;1206700  4895
##   7 1216499;1208558  3613
##   8 1216503;1208560  2893
##   9 1216548;1209448  1412
##  10 1216565;1208624  1540
## # … with 91 more rows
```

Getting Treatment Effects, Standard Errors, and P-values

To get all the treatment effects, standard errors, and p-values for all experiments, use the code below.

```
betaSE <- NULL
for(rr in unique(hintVSexplbig$rand)){
  dat1 <- filter(hintVSexplbig, rand==rr)
  mod <- glm(formula = npc ~ selectedHint, family = binomial, data = dat1)
  betaSE <- rbind(betaSE,
                  summary(mod)$coef['selectedHintTRUE',]
                 )
}
betaSE
```

```
##            Estimate Std. Error     z value     Pr(>|z|)
##   [1,]  0.064187007 0.08889446  0.72205853 0.4702584930
##   [2,]  0.033074202 0.09514648  0.34761352 0.7281304489
##   [3,]  0.021365919 0.10942003  0.19526515 0.8451853805
##   [4,]  0.095668568 0.09163631  1.04400285 0.2964840691
##   [5,]  0.167766082 0.21617448  0.77606794 0.4377088719
##   [6,]  0.101812067 0.12644576  0.80518369 0.4207136843
##   [7,]  0.038069446 0.11477205  0.33169614 0.7401187154
##   [8,]  0.017808159 0.09191856  0.19373845 0.8463806825
##   [9,] -0.045998942 0.08394883 -0.54794023 0.5837329468
##  [10,]  0.062905412 0.06506764  0.96676949 0.3336592775
##  [11,] -0.056417253 0.07829680 -0.72055634 0.4711825261
##  [12,] -0.001214540 0.07970316 -0.01523829 0.9878420743
##  [13,]  0.038069652 0.08585159  0.44343560 0.6574506916
##  [14,]  0.078130177 0.08167131  0.95664163 0.3387481708
##  [15,] -0.043146470 0.09778480 -0.44123904 0.6590399546
##  [16,] -0.389985595 0.10694114 -3.64673118 0.0002655975
##  [17,]  0.200903939 0.13173676  1.52504079 0.1272489231
##  [18,] -0.009211178 0.10849140 -0.08490238 0.9323390036
##  [19,]  0.240690898 0.17740748  1.35671224 0.1748726631
##  [20,] -0.099183435 0.12368021 -0.80193457 0.4225908088
##  [21,]  0.040945819 0.17130736  0.23901961 0.8110903754
##  [22,]  0.127078173 0.17321111  0.73366062 0.4631556024
##  [23,] -0.048151582 0.22124398 -0.21764019 0.8277094686
```

```
## [24,]  0.107513369 0.26872542  0.40008633 0.6890929319
## [25,] -0.104569505 0.28041757 -0.37290639 0.7092181167
## [26,] -0.051399581 0.07812432 -0.65792035 0.5105893118
## [27,]  0.064586943 0.10996997  0.58731436 0.5569925995
## [28,] -0.114148098 0.09514136 -1.19977365 0.2302272603
## [29,]  0.018810343 0.07460180  0.25214329 0.8009303118
## [30,]  0.067642888 0.10345923  0.65381199 0.5132329401
## [31,] -0.070718951 0.09908046 -0.71375272 0.4753801026
## [32,]  0.073934499 0.10751531  0.68766482 0.4916638781
## [33,] -0.036221263 0.10832434 -0.33437788 0.7380944316
## [34,] -0.110762014 0.10925547 -1.01378921 0.3106833450
## [35,]  0.075216000 0.08198864  0.91739536 0.3589355008
## [36,]  0.002227145 0.09048239  0.02461412 0.9803627556
## [37,]  0.210403358 0.09876033  2.13044414 0.0331349629
## [38,] -0.051261032 0.13435079 -0.38154619 0.7027980010
## [39,]  0.222262611 0.14484381  1.53449852 0.1249070578
## [40,]  0.015254914 0.10107288  0.15092984 0.8800310621
## [41,]  0.045685038 0.14910237  0.30640049 0.7592997361
## [42,]  0.068267971 0.10084793  0.67693971 0.4984442066
## [43,] -0.072076620 0.06697231 -1.07621522 0.2818310134
## [44,]  0.002852741 0.07018850  0.04064400 0.9675797063
## [45,] -0.124002333 0.08947244 -1.38592768 0.1657689866
## [46,]  0.035353985 0.12719201  0.27795759 0.7810449159
## [47,] -0.144510535 0.11109895 -1.30073718 0.1933484311
## [48,] -0.058354208 0.10152544 -0.57477426 0.5654439749
## [49,]  0.142457614 0.10091669  1.41163583 0.1580572167
## [50,]  0.211057030 0.15960628  1.32236042 0.1860481627
## [51,] -0.231956672 0.15151684 -1.53089698 0.1257948552
## [52,]  0.109063202 0.10930047  0.99782923 0.3183621760
## [53,]  0.131041553 0.10080951  1.29989281 0.1936377105
## [54,]  0.098543857 0.10860739  0.90734023 0.3642269044
## [55,] -0.101417567 0.10424193 -0.97290569 0.3306001779
## [56,] -0.068014876 0.11515495 -0.59063790 0.5547630656
## [57,] -0.034126048 0.10434207 -0.32705935 0.7436229999
## [58,]  0.023739314 0.07099041  0.33440168 0.7380764747
## [59,]  0.052017635 0.08999980  0.57797497 0.5632810156
## [60,]  0.027014595 0.06465941  0.41779832 0.6760945816
## [61,]  0.073286673 0.06903798  1.06154139 0.2884439336
## [62,]  0.024415491 0.06745474  0.36195366 0.7173866586
## [63,]  0.210433287 0.10983811  1.91584949 0.0553842557
## [64,]  0.174268451 0.19728674  0.88332572 0.3770603090
## [65,] -0.082727974 0.09619527 -0.86000047 0.3897887861
## [66,]  0.188253263 0.08997258  2.09234044 0.0364080724
## [67,] -0.054251933 0.08192158 -0.66224230 0.5078159509
## [68,]  0.111818491 0.08832825  1.26594261 0.2055336302
## [69,] -0.025632241 0.08577663 -0.29882546 0.7650732265
## [70,] -0.273321673 0.09882738 -2.76564727 0.0056809948
## [71,]  0.148907460 0.09441562  1.57714850 0.1147613602
## [72,] -0.122670276 0.12471268 -0.98362316 0.3253008352
## [73,] -0.057717796 0.09765109 -0.59106145 0.5544792467
```

```
##  [74,]  0.111450039 0.10235503  1.08885750 0.2762167286
##  [75,]  0.108565642 0.10366142  1.04730998 0.2949566369
##  [76,] -0.054529602 0.10639622 -0.51251445 0.6082910074
##  [77,]  0.197766671 0.11946077  1.65549467 0.0978241967
##  [78,]  0.072361831 0.11657901  0.62071065 0.5347900227
##  [79,]  0.074243143 0.13818919  0.53725724 0.5910899345
##  [80,]  0.012137624 0.13382997  0.09069436 0.9277354501
##  [81,] -0.070006860 0.10636175 -0.65819581 0.5104123194
##  [82,] -0.053919241 0.08463684 -0.63706584 0.5240819564
##  [83,]  0.049351675 0.08649745  0.57055643 0.5683003596
##  [84,] -0.107544674 0.12821801 -0.83876421 0.4016016383
##  [85,] -0.022530554 0.09384495 -0.24008276 0.8102661007
##  [86,] -0.170090409 0.10421722 -1.63207579 0.1026635214
##  [87,]  0.171854493 0.11970194  1.43568684 0.1510914724
##  [88,]  0.119858327 0.10277998  1.16616419 0.2435480684
##  [89,]  0.048105928 0.09175881  0.52426494 0.6000942790
##  [90,] -0.051843602 0.10411145 -0.49796255 0.6185104398
##  [91,] -0.134328844 0.08424591 -1.59448499 0.1108274508
##  [92,] -0.047891443 0.08507214 -0.56295098 0.5734682639
##  [93,] -0.081247280 0.07448330 -1.09081203 0.2753556020
##  [94,]  0.084599872 0.10188173  0.83037336 0.4063277217
##  [95,] -0.086945211 0.11226355 -0.77447408 0.4386504932
##  [96,]  0.124832619 0.11020540  1.13272692 0.2573289473
##  [97,] -0.045012541 0.05748237 -0.78306686 0.4335878486
##  [98,]  0.022204281 0.05720919  0.38812440 0.6979239766
##  [99,]  0.037538149 0.10992827  0.34147857 0.7327433340
## [100,]  0.027076489 0.13146484  0.20595994 0.8368222071
## [101,] -0.007190423 0.11676839 -0.06157851 0.9508984931
```

Pooling Effect Sizes

Say you want to find out what the effectiveness is of using a hint versus an explanation on a student's learning. You can pool together the treatment effects found earlier into one. But first we need to get all the variables necessary to do this and filter out and data that is unnecessary.

```
sampleSizes <-
hintVSexplbig%>%group_by(rand)%>%summarize(n=n(),n.e=sum(selectedHint),
event.e=sum(npc[selectedHint]), n.c=n-n.e, event.c=sum(npc[selectedExpl]))
sampleSizes

## # A tibble: 101 × 6
##    rand                 n   n.e event.e   n.c event.c
##    <chr>            <int> <int>   <dbl> <int>   <dbl>
##  1 1208901;1183943  3078  1549    1064  1529    1067
##  2 1208908;1183944  1888   963     348   925     359
##  3 1208924;1183945  1419   687     260   732     266
##  4 1210635;1182830  2090  1006     424  1084     440
##  5 1216467;1206699  4918  2461    1369  2457    1394
##  6 1216469;1206700  4895  2480    1206  2415    1161
```

```
##   7 1216499;1208558  3613  1835     1482  1778     1449
##   8 1216503;1208560  2893  1402      658  1491      730
##   9 1216548;1209448  1412   689      433   723      448
##  10 1216565;1208624  1540   783      719   757      680
## # … with 91 more rows
```

Now we can pool our effect sizes, and we will get an odds ratio out as a result. The odds ratio helps us determine whether the treatment or control has more effect. If the ratio is above 1, then the treatment has more of an effect than the control. If it's less than 1 then the control has more effect than the treatment. In our example here the hints are the treatment and the explanations are the control. We also get a p-value for the pooled effect as well.

```
m.bin <- metabin(event.e,
                 n.e,
                 event.c,
                 n.c,
                 data = sampleSizes,
                 sm = "OR",
                 method = "SSW",
                 fixed = FALSE,
                 random = TRUE,
                 title = "Hint vs Explanation Analysis")

summary(m.bin)

## Review:     Hint vs Explanation Analysis
##
##          OR           95%-CI %W(random)
## 1   0.9499 [0.8150; 1.1071]        1.4
## 2   0.8921 [0.7404; 1.0750]        0.9
## 3   1.0667 [0.8599; 1.3233]        0.7
## 4   1.0663 [0.8958; 1.2692]        1.0
## 5   0.9560 [0.8541; 1.0700]        2.3
## 6   1.0225 [0.9140; 1.1438]        2.3
## 7   0.9532 [0.8068; 1.1262]        1.7
## 8   0.9220 [0.7967; 1.0669]        1.4
## 9   1.0383 [0.8370; 1.2879]        0.7
## 10  1.2721 [0.8985; 1.8011]        0.7
## 11  0.9433 [0.7731; 1.1510]        0.8
## 12  1.1531 [0.9462; 1.4053]        0.7
## 13  1.0360 [0.8074; 1.3293]        0.8
## 14  1.2350 [0.9032; 1.6886]        0.7
## 15  0.7930 [0.5892; 1.0672]        0.7
## 16  1.0649 [0.9374; 1.2098]        1.8
## 17  1.0883 [0.8913; 1.3288]        0.8
## 18  1.1400 [0.9356; 1.3891]        0.8
## 19  1.1036 [0.8920; 1.3653]        0.7
## 20  0.9342 [0.7455; 1.1708]        0.7
## 21  0.9036 [0.7366; 1.1084]        0.7
## 22  1.1330 [0.9129; 1.4061]        0.7
```

```
## 23  0.9167 [0.7357; 1.1423]        0.7
## 24  0.9451 [0.8107; 1.1019]        1.2
## 25  1.0154 [0.8329; 1.2378]        0.8
## 26  1.0781 [0.9181; 1.2661]        1.1
## 27  1.0029 [0.8740; 1.1508]        1.6
## 28  1.0022 [0.8394; 1.1967]        0.9
## 29  1.0700 [0.8736; 1.3105]        0.8
## 30  1.2342 [1.0170; 1.4978]        1.1
## 31  0.9500 [0.7301; 1.2362]        1.1
## 32  1.2489 [0.9402; 1.6589]        1.1
## 33  0.9317 [0.7673; 1.1314]        0.8
## 34  0.9305 [0.8160; 1.0610]        1.7
## 35  1.0467 [0.7815; 1.4020]        1.1
## 36  1.0493 [0.8766; 1.2560]        1.3
## 37  0.9495 [0.7742; 1.1644]        1.3
## 38  0.8743 [0.7412; 1.0313]        1.1
## 39  1.0240 [0.8910; 1.1769]        1.9
## 40  1.0274 [0.9051; 1.1662]        1.8
## 41  1.0760 [0.9399; 1.2320]        1.8
## 42  1.0247 [0.8978; 1.1696]        1.7
## 43  1.0534 [0.8830; 1.2566]        1.5
## 44  1.1183 [0.9405; 1.3297]        1.1
## 45  0.9472 [0.8067; 1.1122]        1.1
## 46  0.9747 [0.8239; 1.1531]        1.0
## 47  0.8654 [0.6961; 1.0760]        0.8
## 48  1.0707 [0.8786; 1.3046]        0.8
## 49  1.2187 [0.9643; 1.5402]        0.7
## 50  1.0771 [0.8215; 1.4121]        0.7
## 51  1.0750 [0.8554; 1.3510]        0.7
## 52  1.0122 [0.7787; 1.3158]        0.7
## 53  0.9324 [0.7569; 1.1485]        0.8
## 54  0.8980 [0.6985; 1.1546]        0.7
## 55  0.9475 [0.8027; 1.1185]        1.0
## 56  0.8436 [0.6877; 1.0348]        0.7
## 57  1.1875 [0.9392; 1.5015]        0.7
## 58  1.1273 [0.9217; 1.3789]        0.7
## 59  1.1004 [0.9195; 1.3169]        1.1
## 60  1.1827 [0.7742; 1.8066]        1.1
## 61  1.0388 [0.8295; 1.3009]        1.1
## 62  1.0180 [0.8501; 1.2189]        0.9
## 63  1.1072 [0.8641; 1.4186]        0.7
## 64  1.2342 [0.9952; 1.5307]        0.8
## 65  1.1904 [0.8086; 1.7524]        1.0
## 66  0.9206 [0.7624; 1.1116]        0.9
## 67  1.2071 [1.0120; 1.4399]        0.9
## 68  0.9664 [0.7877; 1.1858]        0.7
## 69  1.1152 [0.9002; 1.3817]        1.5
## 70  0.9550 [0.8102; 1.1258]        1.1
## 71  0.9988 [0.8543; 1.1677]        1.2
## 72  1.0388 [0.8779; 1.2292]        1.0
```

```
## 73  1.0813 [0.9213; 1.2690]        1.1
## 74  0.9578 [0.7907; 1.1601]        1.0
## 75  0.9908 [0.8010; 1.2256]        0.7
## 76  0.6771 [0.5490; 0.8349]        0.7
## 77  1.2225 [0.9443; 1.5827]        0.7
## 78  1.0190 [0.8804; 1.1794]        1.4
## 79  1.0767 [0.8722; 1.3293]        0.8
## 80  0.9644 [0.7799; 1.1925]        0.7
## 81  0.8952 [0.7226; 1.1089]        0.7
## 82  1.1147 [0.9097; 1.3658]        1.2
## 83  0.9469 [0.7687; 1.1665]        1.1
## 84  0.8834 [0.7413; 1.0527]        0.9
## 85  0.9928 [0.7897; 1.2482]        0.7
## 86  1.0336 [0.8578; 1.2455]        0.9
## 87  1.0216 [0.8244; 1.2660]        0.8
## 88  0.9056 [0.7106; 1.1540]        0.8
## 89  1.0418 [0.7447; 1.4575]        0.7
## 90  0.9530 [0.6177; 1.4703]        0.7
## 91  1.1135 [0.6576; 1.8855]        0.7
## 92  1.1355 [0.8086; 1.5946]        0.7
## 93  0.9007 [0.5199; 1.5606]        0.7
## 94  0.7608 [0.6269; 0.9235]        0.8
## 95  0.8846 [0.6927; 1.1295]        0.7
## 96  1.1606 [0.9645; 1.3965]        1.0
## 97  0.9439 [0.7795; 1.1430]        0.8
## 98  1.1179 [0.9147; 1.3662]        0.7
## 99  1.0506 [0.8868; 1.2447]        1.0
## 100 0.9777 [0.8135; 1.1752]        0.9
## 101 1.0274 [0.7940; 1.3294]        0.8
##
## Number of studies combined: k = 101
## Number of observations: o = 214107
## Number of events: e = 133819
##
##                             OR            95%-CI    z p-value
## Random effects model 1.0177 [0.9967; 1.0392] 1.65  0.0995
##
## Quantifying heterogeneity:
##  tau^2 = 0 [0.0000; 0.0038]; tau = 0 [0.0000; 0.0617]
##  I^2 = 0.9% [0.0%; 25.0%]; H = 1.00 [1.00; 1.15]
##
## Test of heterogeneity:
##       Q d.f. p-value
##  100.94  100  0.4549
##
## Details on meta-analytical method:
## - Sample size method
## - Restricted maximum-likelihood estimator for tau^2
## - Q-Profile method for confidence interval of tau^2 and tau
```

Subsetting the Students

We may want to find more results than just the one above. For example what if we want to subset by students who clicked the button and evaluate the same thing (hint vs explanation on next problem correctness). Then we could use the code below to do that.

```
sampleSizes <-
hintVSexplbig%>%group_by(rand)%>%summarize(n=n(),n.e=sum(selectedHint &
tutoring_observed == 1), event.e=sum(npc[selectedHint & tutoring_observed ==
1]), n.c=sum(selectedExpl & tutoring_observed == 1),
event.c=sum(npc[selectedExpl & tutoring_observed == 1]))

m.bin <- metabin(event.e,
                 n.e,
                 event.c,
                 n.c,
                 data = sampleSizes,
                 sm = "OR",
                 method = "SSW",
                 fixed = FALSE,
                 random = TRUE,
                 title = "Hint vs Explanation Analysis")

summary(m.bin)

## Review:     Hint vs Explanation Analysis
##
##          OR             95%-CI %W(random)
## 1   0.8765 [0.6678;   1.1505]        2.3
## 2   0.7972 [0.4394;   1.4464]        1.0
## 3   1.1804 [0.6899;   2.0197]        1.6
## 4   0.3573 [0.1778;   0.7178]        0.4
## 5   1.2231 [0.4092;   3.6554]        0.3
## 6   1.5557 [1.1792;   2.0524]        3.7
## 7   0.7800 [0.1495;   4.0687]        0.1
## 8   0.4630 [0.0922;   2.3244]        0.1
## 9   0.5983 [0.1653;   2.1660]        0.1
## 10  1.4972 [0.8165;   2.7453]        0.6
## 11  0.9488 [0.7007;   1.2847]        2.7
## 12  0.9925 [0.7249;   1.3590]        1.9
## 13  1.0121 [0.6670;   1.5356]        1.1
## 14  0.8594 [0.3268;   2.2601]        0.2
## 15  0.2273 [0.0255;   2.0253]        0.1
## 16  0.5686 [0.2093;   1.5447]        0.2
## 17  1.2303 [0.8732;   1.7333]        1.7
## 18  1.0952 [0.5143;   2.3322]        0.4
## 19  1.1918 [0.5337;   2.6615]        0.5
## 20  0.5899 [0.1569;   2.2171]        0.2
## 21  1.0909 [0.5616;   2.1192]        0.5
## 22  1.2024 [0.7812;   1.8508]        1.7
```

```
## 23  1.0543 [0.7675;   1.4483]         1.6
## 24  1.1250 [0.3429;   3.6907]         0.2
## 25  0.1681 [0.0291;   0.9719]         0.1
## 26  1.2222 [0.1967;   7.5945]         0.1
## 27  1.0439 [0.7770;   1.4026]         2.7
## 28  0.8667 [0.2747;   2.7340]         0.1
## 29  1.3477 [0.8327;   2.1810]         2.0
## 30  1.1064 [0.8091;   1.5130]         1.8
## 31  0.4622 [0.1442;   1.4812]         0.1
## 32  1.3333 [0.1490;  11.9292]         0.0
## 33  0.9403 [0.6361;   1.3900]         2.1
## 34  0.9711 [0.7496;   1.2580]         2.8
## 35  0.2500 [0.0166;   3.7703]         0.0
## 36  0.9797 [0.6003;   1.5990]         0.7
## 37  0.3021 [0.0734;   1.2425]         0.2
## 38  0.9853 [0.5667;   1.7130]         0.6
## 39  1.1137 [0.8092;   1.5328]         1.6
## 40  1.8802 [1.0076;   3.5084]         1.1
## 41  1.2247 [0.9849;   1.5231]         3.4
## 42  1.0372 [0.7969;   1.3499]         2.6
## 43  1.1064 [0.8455;   1.4478]         2.8
## 44  1.0135 [0.7395;   1.3890]         1.7
## 45  1.2231 [0.8309;   1.8005]         1.8
## 46  0.9525 [0.7165;   1.2662]         2.2
## 47  1.6000 [0.6929;   3.6945]         0.6
## 48  1.2159 [0.8020;   1.8435]         1.6
## 49  1.8804 [1.1538;   3.0645]         0.8
## 50  1.0303 [0.5830;   1.8208]         0.6
## 51  0.1636 [0.0061;   4.3575]         0.0
## 52  1.5728 [0.8297;   2.9813]         0.4
## 53  1.7563 [0.5552;   5.5556]         0.1
## 54  3.2500 [0.4252;  24.8437]         0.1
## 55  3.6207 [0.1569;  83.5279]         0.1
## 56  0.7402 [0.4806;   1.1401]         1.0
## 57  1.4014 [0.8658;   2.2686]         0.9
## 58  1.6970 [1.0489;   2.7454]         0.7
## 59  1.1810 [0.7359;   1.8953]         0.7
## 60  3.2609 [0.1366;  77.8394]         0.0
## 61  0.1429 [0.0034;   5.9458]         0.0
## 62  1.2500 [0.0683;  22.8795]         0.0
## 63  9.8000 [0.3341; 287.4174]         0.0
## 64  4.3636 [0.9672;  19.6867]         0.1
## 65  5.6667 [0.1894; 169.5341]         0.0
## 66      NA                            0.0
## 67  4.2000 [0.1161; 151.9699]         0.0
## 68  0.6554 [0.3723;   1.1535]         0.5
## 69  1.3242 [0.8226;   2.1318]         1.0
## 70  0.7433 [0.4123;   1.3398]         0.6
## 71  0.9362 [0.6495;   1.3494]         1.9
## 72  1.4119 [0.9548;   2.0878]         1.7
```

```
## 73  0.9707 [0.5913;   1.5936]        1.2
## 74  0.9701 [0.7196;   1.3076]        1.8
## 75  0.7900 [0.4679;   1.3339]        0.7
## 76  0.3738 [0.2501;   0.5587]        1.3
## 77  1.5556 [0.3485;   6.9432]        0.1
## 78  1.1527 [0.9452;   1.4057]        4.1
## 79  1.1398 [0.5544;   2.3431]        1.8
## 80  0.9007 [0.5086;   1.5952]        2.3
## 81  1.1051 [0.5932;   2.0590]        2.3
## 82  2.3276 [1.2048;   4.4967]        0.6
## 83  0.8846 [0.4996;   1.5665]        0.7
## 84  0.9967 [0.7732;   1.2847]        2.6
## 85  1.0660 [0.5016;   2.2654]        0.3
## 86  1.0234 [0.4906;   2.1348]        0.4
## 87  0.9561 [0.2755;   3.3177]        0.2
## 88  1.0283 [0.6606;   1.6007]        0.8
## 89  0.4863 [0.2039;   1.1597]        0.3
## 90  1.6000 [0.6026;   4.2481]        0.2
## 91  0.4476 [0.1151;   1.7409]        0.1
## 92  1.2139 [0.5004;   2.9448]        0.2
## 93  0.8889 [0.1381;   5.7229]        0.1
## 94  0.7692 [0.6006;   0.9852]        2.7
## 95  0.6807 [0.3471;   1.3347]        0.4
## 96  0.9551 [0.6476;   1.4084]        1.3
## 97  0.8057 [0.4804;   1.3515]        0.9
## 98  1.0423 [0.6306;   1.7229]        1.0
## 99  1.4760 [0.9343;   2.3316]        1.5
## 100 0.9798 [0.7357;   1.3051]        2.0
## 101 0.8302 [0.5187;   1.3286]        0.8
##
## Number of studies combined: k = 100
## Number of observations: o = 38453
## Number of events: e = 12332
##
##                           OR            95%-CI    z p-value
## Random effects model 1.0567 [0.9910; 1.1267] 1.68  0.0923
##
## Quantifying heterogeneity:
##  tau^2 = 0.0195 [0.0031; 0.0701]; tau = 0.1395 [0.0553; 0.2648]
##  I^2 = 27.0% [6.0%; 43.4%]; H = 1.17 [1.03; 1.33]
##
## Test of heterogeneity:
##       Q d.f. p-value
##  135.70   99  0.0085
##
## Details on meta-analytical method:
## - Sample size method
## - Restricted maximum-likelihood estimator for tau^2
## - Q-Profile method for confidence interval of tau^2 and tau
## - Continuity correction of 0.5 in studies with zero cell frequencies
```

Filtering Data using “user_” Variables

Say we want to exclude any students from our data who did not even click the button for tutoring, we can do this and then evaluate the same thing again using the code below.

```
dat1 <- filter(hintVSexplbig, user_avg_support_requested != 0)
sampleSizes <- dat1%>%group_by(rand)%>%summarize(n=n(),n.e=sum(selectedHint),
event.e=sum(npc[selectedHint]), n.c=n-n.e, event.c=sum(npc[selectedExpl]))

m.bin <- metabin(event.e,
                 n.e,
                 event.c,
                 n.c,
                 data = sampleSizes,
                 sm = "OR",
                 method = "SSW",
                 fixed = FALSE,
                 random = TRUE,
                 title = "Hint vs Explanation Analysis")

summary(m.bin)

## Review:     Hint vs Explanation Analysis
##
##          OR            95%-CI %W(random)
## 1    0.9423 [0.8027; 1.1062]        1.4
## 2    0.8904 [0.7331; 1.0813]        0.9
## 3    1.0463 [0.8353; 1.3106]        0.7
## 4    1.0501 [0.8738; 1.2619]        1.0
## 5    0.9650 [0.8574; 1.0860]        2.3
## 6    1.0466 [0.9305; 1.1772]        2.3
## 7    0.9380 [0.7885; 1.1159]        1.7
## 8    0.8812 [0.7564; 1.0267]        1.4
## 9    0.9905 [0.7893; 1.2428]        0.7
## 10   1.2293 [0.8539; 1.7697]        0.7
## 11   0.9649 [0.7828; 1.1894]        0.8
## 12   1.1842 [0.9632; 1.4559]        0.7
## 13   1.0050 [0.7751; 1.3030]        0.8
## 14   1.2050 [0.8688; 1.6713]        0.7
## 15   0.8448 [0.6220; 1.1475]        0.7
## 16   1.0773 [0.9425; 1.2314]        1.8
## 17   1.0269 [0.8317; 1.2679]        0.8
## 18   1.1772 [0.9569; 1.4482]        0.8
## 19   1.1311 [0.9049; 1.4140]        0.8
## 20   0.9750 [0.7694; 1.2354]        0.7
## 21   0.9260 [0.7478; 1.1467]        0.7
## 22   1.1462 [0.9115; 1.4415]        0.7
## 23   0.9453 [0.7523; 1.1878]        0.7
## 24   0.9471 [0.8069; 1.1118]        1.3
## 25   1.0518 [0.8534; 1.2962]        0.8
```

```
## 26  1.0637 [0.8982; 1.2598]        1.1
## 27  1.0076 [0.8716; 1.1648]        1.5
## 28  0.9779 [0.8118; 1.1780]        0.9
## 29  1.0750 [0.8681; 1.3312]        0.8
## 30  1.2398 [1.0108; 1.5206]        1.1
## 31  0.9661 [0.7346; 1.2705]        1.1
## 32  1.1738 [0.8706; 1.5827]        1.1
## 33  0.9396 [0.7659; 1.1526]        0.8
## 34  0.9106 [0.7925; 1.0462]        1.7
## 35  1.1332 [0.8370; 1.5343]        1.1
## 36  1.0982 [0.9085; 1.3276]        1.3
## 37  0.9149 [0.7385; 1.1336]        1.3
## 38  0.8483 [0.7132; 1.0090]        1.1
## 39  1.0424 [0.9005; 1.2068]        1.9
## 40  1.0473 [0.9166; 1.1967]        1.8
## 41  1.0711 [0.9293; 1.2345]        1.7
## 42  1.0322 [0.8982; 1.1862]        1.7
## 43  1.0759 [0.8948; 1.2936]        1.4
## 44  1.1432 [0.9541; 1.3697]        1.1
## 45  0.9553 [0.8075; 1.1302]        1.1
## 46  0.9334 [0.7828; 1.1130]        1.0
## 47  0.8300 [0.6602; 1.0436]        0.8
## 48  1.1123 [0.9033; 1.3697]        0.8
## 49  1.1973 [0.9367; 1.5304]        0.7
## 50  1.0883 [0.8189; 1.4464]        0.7
## 51  1.0571 [0.8312; 1.3444]        0.7
## 52  1.0548 [0.8018; 1.3875]        0.7
## 53  0.9930 [0.7968; 1.2375]        0.8
## 54  0.9465 [0.7259; 1.2342]        0.7
## 55  0.9386 [0.7881; 1.1179]        1.0
## 56  0.8181 [0.6596; 1.0145]        0.7
## 57  1.1740 [0.9185; 1.5006]        0.7
## 58  1.0990 [0.8893; 1.3581]        0.7
## 59  1.0918 [0.9043; 1.3182]        1.1
## 60  1.3233 [0.8457; 2.0706]        1.1
## 61  0.9788 [0.7717; 1.2413]        1.1
## 62  1.0021 [0.8283; 1.2125]        0.9
## 63  1.1280 [0.8675; 1.4668]        0.7
## 64  1.1895 [0.9503; 1.4890]        0.8
## 65  1.2152 [0.8111; 1.8209]        0.9
## 66  0.9223 [0.7571; 1.1234]        0.9
## 67  1.2034 [0.9997; 1.4485]        0.9
## 68  0.9947 [0.8021; 1.2335]        0.7
## 69  1.0614 [0.8491; 1.3268]        1.5
## 70  0.9504 [0.8010; 1.1277]        1.1
## 71  1.0237 [0.8698; 1.2049]        1.2
## 72  1.0151 [0.8515; 1.2102]        1.0
## 73  1.0936 [0.9256; 1.2921]        1.1
## 74  0.9431 [0.7732; 1.1503]        1.1
## 75  0.9814 [0.7859; 1.2254]        0.7
```

```
## 76  0.6762 [0.5425; 0.8429]        0.7
## 77  1.2457 [0.9493; 1.6346]        0.7
## 78  1.0230 [0.8775; 1.1926]        1.4
## 79  1.1389 [0.9117; 1.4226]        0.8
## 80  0.9380 [0.7499; 1.1733]        0.7
## 81  0.9417 [0.7522; 1.1789]        0.7
## 82  1.1343 [0.9143; 1.4074]        1.1
## 83  0.9922 [0.7958; 1.2369]        1.1
## 84  0.8796 [0.7330; 1.0555]        1.0
## 85  1.0501 [0.8243; 1.3378]        0.7
## 86  1.0456 [0.8593; 1.2723]        0.9
## 87  1.0511 [0.8389; 1.3170]        0.8
## 88  0.8723 [0.6778; 1.1225]        0.8
## 89  1.1098 [0.7782; 1.5827]        0.7
## 90  0.9029 [0.5758; 1.4159]        0.7
## 91  1.2660 [0.7193; 2.2279]        0.7
## 92  1.0321 [0.7219; 1.4755]        0.7
## 93  0.9832 [0.5423; 1.7826]        0.7
## 94  0.7144 [0.5827; 0.8760]        0.8
## 95  0.9192 [0.7119; 1.1869]        0.7
## 96  1.1714 [0.9657; 1.4208]        1.0
## 97  0.9533 [0.7800; 1.1651]        0.8
## 98  1.1526 [0.9336; 1.4231]        0.7
## 99  1.0625 [0.8888; 1.2703]        1.0
## 100 0.9962 [0.8208; 1.2091]        0.9
## 101 1.1095 [0.8492; 1.4494]        0.8
##
## Number of studies combined: k = 101
## Number of observations: o = 194220
## Number of events: e = 121148
##
##                             OR            95%-CI    z p-value
## Random effects model 1.0228 [1.0004; 1.0457] 1.99  0.0462
##
## Quantifying heterogeneity:
##  tau^2 = 0.0003 [0.0000; 0.0044]; tau = 0.0162 [0.0000; 0.0663]
##  I^2 = 3.4% [0.0%; 24.1%]; H = 1.02 [1.00; 1.15]
##
## Test of heterogeneity:
##       Q d.f. p-value
##  103.57  100  0.3835
##
## Details on meta-analytical method:
## - Sample size method
## - Restricted maximum-likelihood estimator for tau^2
## - Q-Profile method for confidence interval of tau^2 and tau
```

What About Non-NPC Questions?

What if you wanted to know whether students are more likely to click a hint versus an explanation? Well we can repeat the same code used under **Pooling Effect Sizes** and replace all instances of npc with tutoring_oberserved. This would produce an odds ratio that should answer our question.

```
sampleSizes <-
hintVSexplbig%>%group_by(rand)%>%summarize(n=n(),n.e=sum(selectedHint),
event.e=sum(tutoring_observed[selectedHint]), n.c=n-n.e,
event.c=sum(tutoring_observed[selectedExpl]))

m.bin <- metabin(event.e,
                 n.e,
                 event.c,
                 n.c,
                 data = sampleSizes,
                 sm = "OR",
                 method = "SSW",
                 fixed = FALSE,
                 random = TRUE,
                 title = "Hint vs Explanation Analysis")

summary(m.bin)

## Review:     Hint vs Explanation Analysis
##
##          OR             95%-CI %W(random)
## 1    1.0370 [0.8864;  1.2131]        1.4
## 2    1.1000 [0.8777;  1.3786]        0.9
## 3    1.0273 [0.8328;  1.2671]        0.7
## 4    1.3177 [0.9370;  1.8531]        1.0
## 5    1.2600 [0.8908;  1.7822]        2.3
## 6    1.2171 [1.0755;  1.3772]        2.3
## 7    1.3450 [0.6571;  2.7532]        1.7
## 8    1.3571 [0.6140;  2.9994]        1.4
## 9    1.1077 [0.5860;  2.0939]        0.7
## 10   0.9422 [0.7173;  1.2375]        0.7
## 11   0.9715 [0.7996;  1.1803]        0.8
## 12   0.9600 [0.7877;  1.1701]        0.7
## 13   1.2896 [1.0363;  1.6049]        0.8
## 14   0.7315 [0.4537;  1.1795]        0.7
## 15   0.6233 [0.3657;  1.0623]        0.7
## 16   0.4697 [0.2907;  0.7589]        1.8
## 17   1.1460 [0.9425;  1.3935]        0.8
## 18   1.6724 [1.1926;  2.3453]        0.8
## 19   1.5416 [1.1396;  2.0853]        0.7
## 20   0.9421 [0.5901;  1.5042]        0.7
## 21   0.9976 [0.7318;  1.3599]        0.7
## 22   0.9556 [0.7823;  1.1673]        0.7
```

```
## 23  1.1211 [0.9110;  1.3798]        0.7
## 24  0.6951 [0.4273;  1.1309]        1.2
## 25  1.2085 [0.6239;  2.3409]        0.8
## 26  0.8888 [0.4094;  1.9296]        1.1
## 27  1.0966 [0.9476;  1.2690]        1.6
## 28  0.7661 [0.4286;  1.3693]        0.9
## 29  1.0119 [0.8370;  1.2233]        0.8
## 30  1.0395 [0.8705;  1.2413]        1.1
## 31  0.6319 [0.3661;  1.0906]        1.1
## 32  0.8864 [0.2970;  2.6457]        1.1
## 33  1.1466 [0.9454;  1.3906]        0.8
## 34  1.2417 [1.0756;  1.4335]        1.7
## 35  0.5410 [0.1579;  1.8531]        1.1
## 36  1.0242 [0.7932;  1.3225]        1.3
## 37  1.0784 [0.6833;  1.7019]        1.3
## 38  0.9968 [0.7527;  1.3200]        1.1
## 39  1.1440 [0.9641;  1.3575]        1.9
## 40  1.0853 [0.8897;  1.3238]        1.8
## 41  1.0380 [0.9077;  1.1870]        1.8
## 42  1.0647 [0.9192;  1.2334]        1.7
## 43  1.0498 [0.9050;  1.2176]        1.5
## 44  0.9352 [0.7801;  1.1211]        1.1
## 45  1.1240 [0.9407;  1.3431]        1.1
## 46  1.0809 [0.9100;  1.2840]        1.0
## 47  1.2077 [0.9134;  1.5970]        0.8
## 48  1.0505 [0.8633;  1.2784]        0.8
## 49  0.9737 [0.7564;  1.2534]        0.7
## 50  0.9129 [0.6897;  1.2083]        0.7
## 51  0.8098 [0.2460;  2.6658]        0.7
## 52  1.0854 [0.7815;  1.5075]        0.7
## 53  0.9164 [0.5327;  1.5762]        0.8
## 54  1.6581 [0.7213;  3.8115]        0.7
## 55  1.6919 [0.7645;  3.7447]        1.0
## 56  1.0409 [0.8282;  1.3082]        0.7
## 57  0.9382 [0.7385;  1.1919]        0.7
## 58  0.9983 [0.7683;  1.2972]        0.7
## 59  1.2108 [0.9432;  1.5544]        1.1
## 60  0.5701 [0.2267;  1.4339]        1.1
## 61  0.2428 [0.0271;  2.1752]        1.1
## 62  2.3475 [0.6053;  9.1043]        0.9
## 63  1.7057 [0.4061;  7.1633]        0.7
## 64  0.6463 [0.3350;  1.2469]        0.8
## 65  1.5471 [0.5044;  4.7453]        1.0
## 66  0.9715 [0.0607; 15.5535]        0.9
## 67  1.0213 [0.2056;  5.0720]        0.9
## 68  1.1283 [0.8390;  1.5174]        0.7
## 69  1.2565 [1.0178;  1.5511]        1.5
## 70  1.1260 [0.8583;  1.4771]        1.1
## 71  1.1863 [0.9984;  1.4097]        1.2
## 72  1.1173 [0.9310;  1.3410]        1.0
```

```
## 73  0.9556 [0.7821;  1.1675]        1.1
## 74  1.1731 [0.9800;  1.4042]        1.0
## 75  1.0951 [0.8367;  1.4334]        0.7
## 76  1.2156 [0.9771;  1.5125]        0.7
## 77  1.3154 [0.6548;  2.6424]        0.7
## 78  1.1790 [1.0183;  1.3649]        1.4
## 79  1.0471 [0.8598;  1.2753]        0.8
## 80  1.0681 [0.8763;  1.3020]        0.7
## 81  1.2354 [1.0100;  1.5110]        0.7
## 82  1.2288 [0.9355;  1.6140]        1.2
## 83  1.0679 [0.8248;  1.3826]        1.1
## 84  1.4596 [1.2239;  1.7405]        0.9
## 85  1.4223 [0.9842;  2.0555]        0.7
## 86  1.1573 [0.8253;  1.6227]        0.9
## 87  1.3589 [0.8635;  2.1386]        0.8
## 88  1.2182 [0.9527;  1.5578]        0.8
## 89  1.1566 [0.7766;  1.7226]        0.7
## 90  0.8873 [0.5404;  1.4570]        0.7
## 91  0.6434 [0.3475;  1.1912]        0.7
## 92  1.1482 [0.7328;  1.7989]        0.7
## 93  1.0785 [0.4727;  2.4606]        0.7
## 94  1.0192 [0.8344;  1.2450]        0.8
## 95  0.9142 [0.6445;  1.2966]        0.7
## 96  0.9333 [0.7631;  1.1415]        1.0
## 97  1.1299 [0.8891;  1.4359]        0.8
## 98  0.8527 [0.6785;  1.0717]        0.7
## 99  1.0624 [0.8784;  1.2850]        1.0
## 100 0.9119 [0.7586;  1.0962]        0.9
## 101 0.9283 [0.7250;  1.1885]        0.8
##
## Number of studies combined: k = 101
## Number of observations: o = 214107
## Number of events: e = 38453
##
##                           OR            95%-CI    z p-value
## Random effects model 1.0411 [0.9795; 1.1066] 1.30  0.1952
##
## Quantifying heterogeneity:
##  tau^2 = 0.0023 [0.0000; 0.0143]; tau = 0.0476 [0.0000; 0.1197]
##  I^2 = 18.2% [0.0%; 36.8%]; H = 1.11 [1.00; 1.26]
##
## Test of heterogeneity:
##       Q d.f. p-value
##  122.25  100  0.0647
##
## Details on meta-analytical method:
## - Sample size method
## - Restricted maximum-likelihood estimator for tau^2
## - Q-Profile method for confidence interval of tau^2 and tau
```

Here are all the other code bits we used to answer our Non-NPC questions.

```
sampleSizes <-
hintVSexplbig%>%group_by(rand)%>%summarize(n=n(),n.e=sum(selectedHint),
event.e=sum(problem_completed[selectedHint]), n.c=n-n.e,
event.c=sum(problem_completed[selectedExpl]))

m.bin <- metabin(event.e,
                 n.e,
                 event.c,
                 n.c,
                 data = sampleSizes,
                 sm = "OR",
                 method = "SSW",
                 fixed = FALSE,
                 random = TRUE,
                 title = "Hint vs Explanation Analysis")

summary(m.bin)

sampleSizes <-
hintVSexplbig%>%group_by(rand)%>%summarize(n=n(),n.e=sum(selectedHint),
event.e=sum(tryNext[selectedHint]), n.c=n-n.e,
event.c=sum(tryNext[selectedExpl]))

m.bin <- metabin(event.e,
                 n.e,
                 event.c,
                 n.c,
                 data = sampleSizes,
                 sm = "OR",
                 method = "SSW",
                 fixed = FALSE,
                 random = TRUE,
                 title = "Hint vs Explanation Analysis")

summary(m.bin)

sampleSizes <-
hintVSexplbig%>%group_by(rand)%>%summarize(n=n(),n.e=sum(selectedHint),
event.e=sum(assignment_completed[selectedHint]), n.c=n-n.e,
event.c=sum(assignment_completed[selectedExpl]))

m.bin <- metabin(event.e,
                 n.e,
                 event.c,
                 n.c,
                 data = sampleSizes,
                 sm = "OR",
                 method = "SSW",
```

```
                 fixed = FALSE,
                 random = TRUE,
                 title = "Hint vs Explanation Analysis")

summary(m.bin)

sampleSizes <-
hintVSexplbig%>%group_by(rand)%>%summarize(n=n(),n.e=sum(selectedHint),
event.e=sum(answer_given[selectedHint]), n.c=n-n.e,
event.c=sum(answer_given[selectedExpl]))

m.bin <- metabin(event.e,
                 n.e,
                 event.c,
                 n.c,
                 data = sampleSizes,
                 sm = "OR",
                 method = "SSW",
                 fixed = FALSE,
                 random = TRUE,
                 title = "Hint vs Explanation Analysis")

summary(m.bin)
```