The N400 effect when singular gendered antecedents are co-indexed with (a) *himself* or *herself* (b) *themselves*

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Overview

This document contains the code to reproduce the statistical analyses described in Prasad and Morris (2019). You can download the data and the original .Rmd file here.

This document has two sections:

2. Analysis 1: The N400 effect when antecedents are co-indexed with *himself* or *herself*
3. Analysis 2: The N400 effect when antecedents are co-indexed with *themselves*

Define functions, set parameters and load

Define standard error of mean function

```
sem <- function(x) sd(x)/sqrt(length(x))
```

Before we begin, let's set some general parameters for `ggplot2`. We will set a general theme using the `theme_set()` function. We will use the 'classic' theme which gives us clean white background rather than the default grey with white grid lines. And we will position the legend at the top of the graph rather than at the right side which is the default.

Then we re-order factor levels for *Anteriority* & *Referentiality*

```
## [1] "Frontal"        "FrontoCentral"  "Central"        "CentroParietal"
## [5] "Parietal"
```

```
## [1] "Referential"    "NonReferential"
```

```
## [1] "Frontal"        "FrontoCentral"  "Central"        "CentroParietal"
## [5] "Parietal"
```

```
## [1] "Referential"    "NonReferential"
```

Analysis 1: The N400 effect when antecedents are co-indexed with *himself* or *herself*

```r
ezANOVA(data = prost_2022_singular
              , dv = diff_score
              , wid = SubjID
              , within = .(Referentiality, Gender_Status, Anteriority)
              , between = Group
              , type = 3
              , return_aov = F
              )
```

```
## $ANOVA
##                                          Effect DFn DFd          F
## 2                                         Group   1  36  0.9374869
## 3                                Referentiality   1  36 12.2247770
## 5                                 Gender_Status   1  36  1.2733561
## 7                                   Anteriority   4 144  2.0606903
## 4                          Group:Referentiality   1  36  0.6762734
## 6                           Group:Gender_Status   1  36  0.4610781
## 8                             Group:Anteriority   4 144  5.1495811
## 9                  Referentiality:Gender_Status   1  36  0.2476607
## 11                   Referentiality:Anteriority   4 144  1.3854470
## 13                    Gender_Status:Anteriority   4 144  2.3525738
## 10           Group:Referentiality:Gender_Status   1  36  5.7351452
## 12             Group:Referentiality:Anteriority   4 144  0.7584705
## 14              Group:Gender_Status:Anteriority   4 144  0.9712661
## 15     Referentiality:Gender_Status:Anteriority   4 144  0.2095779
## 16 Group:Referentiality:Gender_Status:Anteriority   4 144  1.4910541
##                p p<.05          ges
## 2  0.3393852751       0.0061153894
## 3  0.0012717043     * 0.0725639615
## 5  0.2666022045       0.0060391927
## 7  0.0890226513       0.0029742361
## 4  0.4162867596       0.0043096566
## 6  0.5014630657       0.0021952289
## 8  0.0006605669     * 0.0073995058
## 9  0.6217533918       0.0012878955
## 11 0.2419070474       0.0016448157
## 13 0.0567931874       0.0032557088
## 10 0.0219567998     * 0.0289966816
## 12 0.5539661827       0.0009011341
## 14 0.4252771122       0.0013467020
## 15 0.9327769406       0.0001698395
## 16 0.2079557263       0.0012070793
##
## $`Mauchly's Test for Sphericity`
##                                          Effect           W            p
## 7                                   Anteriority 0.006548926 2.246469e-32
## 8                             Group:Anteriority 0.006548926 2.246469e-32
## 11                   Referentiality:Anteriority 0.003281484 2.660831e-37
## 12             Group:Referentiality:Anteriority 0.003281484 2.660831e-37
## 13                    Gender_Status:Anteriority 0.004635292 7.771205e-35
## 14              Group:Gender_Status:Anteriority 0.004635292 7.771205e-35
## 15     Referentiality:Gender_Status:Anteriority 0.021467327 5.607135e-24
## 16 Group:Referentiality:Gender_Status:Anteriority 0.021467327 5.607135e-24
```

```
##    p<.05
## 7      *
## 8      *
## 11     *
## 12     *
## 13     *
## 14     *
## 15     *
## 16     *
##
## $`Sphericity Corrections`
##                                                Effect       GGe      p[GG]
## 7                                        Anteriority 0.3117498 0.15462251
## 8                                  Group:Anteriority 0.3117498 0.02136772
## 11                       Referentiality:Anteriority 0.3014694 0.25188259
## 12                 Group:Referentiality:Anteriority 0.3014694 0.41205819
## 13                        Gender_Status:Anteriority 0.3071411 0.12683261
## 14                  Group:Gender_Status:Anteriority 0.3071411 0.34769438
## 15         Referentiality:Gender_Status:Anteriority 0.3635434 0.73986510
## 16 Group:Referentiality:Gender_Status:Anteriority 0.3635434 0.23423883
##    p[GG]<.05       HFe      p[HF] p[HF]<.05
## 7            0.3175191 0.15407353
## 8          * 0.3175191 0.02074207         *
## 11           0.3062118 0.25222426
## 12           0.3062118 0.41392595
## 13           0.3124468 0.12615449
## 14           0.3124468 0.34904640
## 15           0.3748964 0.74703892
## 16           0.3748964 0.23426338
```

Condition Means for Analysis 1

The N400 effect when antecedents are co-indexed with *himself* or *herself*.

Significant Effects: **Referentiality; Group X Anteriority; Group x Referentiality x Gender Status**

Referentiality	Mean	SE	SD	Max	Min
Referential	-0.66	0.10	1.99	6.30	-5.21
NonReferential	0.36	0.09	1.74	4.79	-5.06

Anteriority	Group	Mean	SE	SD	Max	Min
Frontal	Binary	-0.12	0.27	2.43	6.30	-5.05
Frontal	NonBinary	-0.31	0.25	2.15	3.88	-5.21
FrontoCentral	Binary	-0.25	0.23	2.04	4.41	-4.97
FrontoCentral	NonBinary	-0.21	0.22	1.87	3.47	-5.13
Central	Binary	-0.39	0.21	1.87	4.39	-5.12
Central	NonBinary	0.01	0.21	1.77	4.27	-4.49
CentroParietal	Binary	-0.38	0.21	1.84	3.93	-4.73
CentroParietal	NonBinary	0.15	0.21	1.74	4.44	-4.67
Parietal	Binary	-0.28	0.20	1.79	4.11	-5.06
Parietal	NonBinary	0.36	0.20	1.72	3.76	-4.75

Referentiality	Gender_Status	Group	Mean	SE	SD	Max	Min
Referential	Gendered	Binary	-1.51	0.19	1.90	4.41	-5.12
Referential	Gendered	NonBinary	-0.20	0.21	2.03	4.44	-5.21
Referential	NonGendered	Binary	-0.31	0.21	2.11	6.30	-5.05
Referential	NonGendered	NonBinary	-0.58	0.17	1.63	3.22	-4.75
NonReferential	Gendered	Binary	0.49	0.16	1.64	3.90	-4.58
NonReferential	Gendered	NonBinary	0.08	0.18	1.71	3.76	-3.19
NonReferential	NonGendered	Binary	0.19	0.17	1.73	4.79	-5.06
NonReferential	NonGendered	NonBinary	0.69	0.20	1.85	3.88	-4.12

Post-hoc tests for Analysis 1: Group x Gender Status x Referentiality

The following chunk runs post-hoc tests for the 3-way ***"Group x Gender Status x Referentiality"*** Interaction

Binary Group. These are the post-hoc tests for the *binary* group.

"*Some woman... himself*" vs. "*Mary... himself*" Binary

```
pander(t.test(diff_score ~ Referentiality
       , filter(binary, (Gender_Status == "Gendered"))
       , paired=TRUE))
```

Table 4: Paired t-test: `diff_score` by `Referentiality`

Test statistic	df	P value	Alternative hypothesis	mean difference
-7.66	99	1.275e-11 * * *	two.sided	-2.007

"*Someone... himself*" vs. "*The participant... himself*" Binary

```
pander(t.test(diff_score ~ Referentiality
       , filter(binary, (Gender_Status == "NonGendered"))
       , paired=TRUE))
```

Table 5: Paired t-test: `diff_score` by `Referentiality`

Test statistic	df	P value	Alternative hypothesis	mean difference
-1.722	99	0.08825	two.sided	-0.4954

"*The participant... himself*" vs. "*Mary... himself*" Binary

```
pander(t.test(diff_score ~ Gender_Status
       , filter(binary, (Referentiality == "Referential"))
       , paired=TRUE))
```

Table 6: Paired t-test: `diff_score` by `Gender_Status`

Test statistic	df	P value	Alternative hypothesis	mean difference
-4.909	99	3.612e-06 * * *	two.sided	-1.208

"*Someone... himself*" vs. "*Some woman... himself*" Binary

```
pander(t.test(diff_score ~ Gender_Status
       , filter(binary, (Referentiality == "NonReferential"))
       , paired=TRUE))
```

Table 7: Paired t-test: `diff_score` by `Gender_Status`

Test statistic	df	P value	Alternative hypothesis	mean difference
1.248	99	0.2148	two.sided	0.3037

"*Someone... himself*" vs. "*Mary... himself*" Binary

```
mary_someone <- filter(binary, (Referentiality == "Referential" & Gender_Status == "Gendered") | (Refer

pander(t.test(diff_score ~ Gender_Status, mary_someone, paired=TRUE))
```

Table 8: Paired t-test: `diff_score` by `Gender_Status`

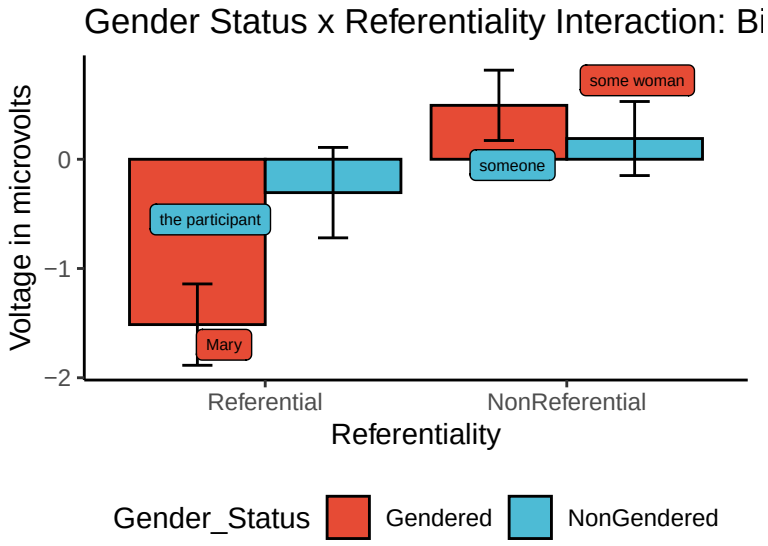
Test statistic	df	P value	Alternative hypothesis	mean difference
-6.88	99	5.47e-10 * * *	two.sided	-1.704

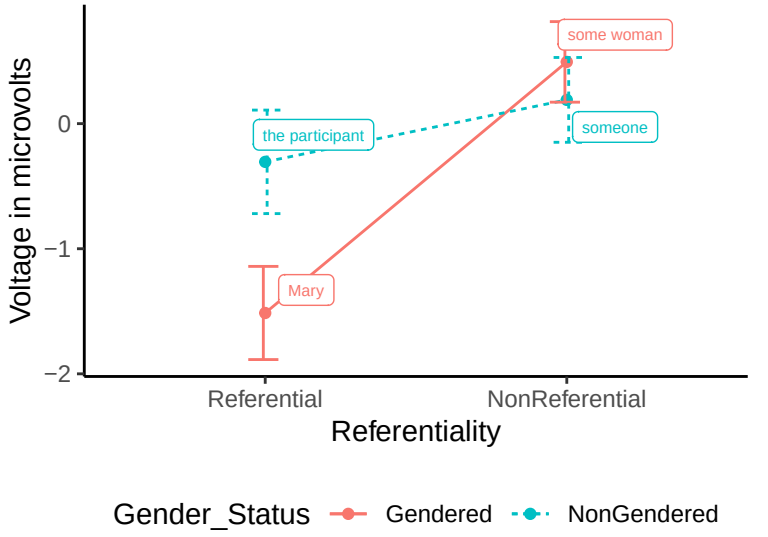
"*Some woman... himself*" vs. "*the participant... himself*" Binary

Table 9: Paired t-test: `diff_score` by `Gender_Status`

Test statistic	df	P value	Alternative hypothesis	mean difference
2.594	99	0.01094 *	two.sided	0.7992

Interaction Plots: Group x Gender Status x Referentiality Interaction: Binary





NonBinary Group. These are the post-hoc tests for the *NonBinary* group.

"*Some woman. . . himself*" vs. "*Mary. . . himself*" NonBinary

```
pander(t.test(diff_score ~ Referentiality
       ,filter(prost_2022_singular, (Gender_Status == "Gendered" & Group == "NonBinary"))
       ,paired=TRUE))
```

Table 10: Paired t-test: `diff_score` by `Referentiality`

Test statistic	df	P value	Alternative hypothesis	mean difference
-1.143	89	0.2562	two.sided	-0.279

"*Someone. . . himself*" vs. "*The participant. . . himself*" NonBinary

```
pander(t.test(diff_score ~ Referentiality
       , filter(prost_2022_singular, (Gender_Status == "NonGendered" & Group == "NonBinary"))
       , paired=TRUE))
```

Table 11: Paired t-test: `diff_score` by `Referentiality`

Test statistic	df	P value	Alternative hypothesis	mean difference
-5.202	89	1.251e-06 * * *	two.sided	-1.271

"*The participant... himself*" vs. "*Mary... himself*" NonBinary

```
pander(t.test(diff_score ~ Gender_Status
       , filter(prost_2022_singular, (Referentiality == "Referential" & Group == "NonBinary"))
       , paired=TRUE))
```

Table 12: Paired t-test: `diff_score` by `Gender_Status`

Test statistic	df	P value	Alternative hypothesis	mean difference
1.354	89	0.1791	two.sided	0.3834

"*Someone... himself*" vs. "*Some woman... himself*" NonBinary

```
pander(t.test(diff_score ~ Gender_Status
       , filter(prost_2022_singular, (Referentiality == "NonReferential" & Group == "NonBinary"))
       , paired=TRUE))
```

Table 13: Paired t-test: `diff_score` by `Gender_Status`

Test statistic	df	P value	Alternative hypothesis	mean difference
-2.792	89	0.006407 * *	two.sided	-0.6082

"*Someone... himself*" vs. "*Mary... himself*" NonBinary

```
mary_someone <- filter(nonbinary, (Referentiality == "Referential" & Gender_Status == "Gendered") | (Re

pander(t.test(diff_score ~ Gender_Status, mary_someone, paired=TRUE))
```

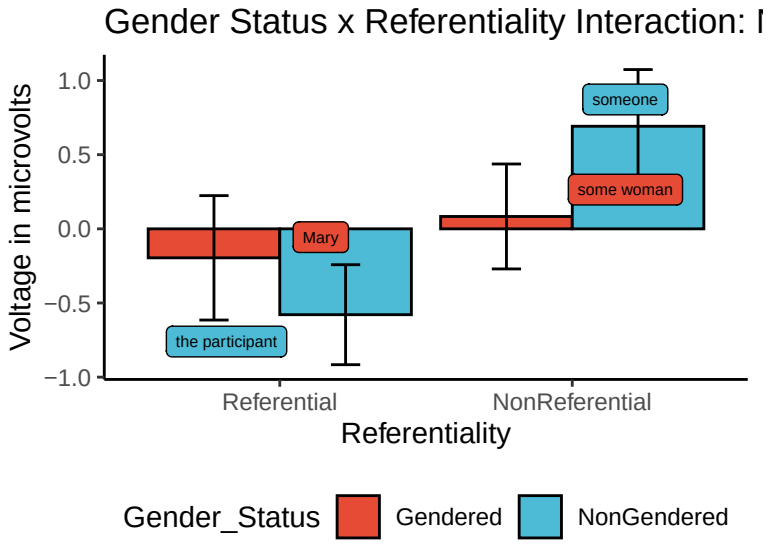
Table 14: Paired t-test: `diff_score` by `Gender_Status`

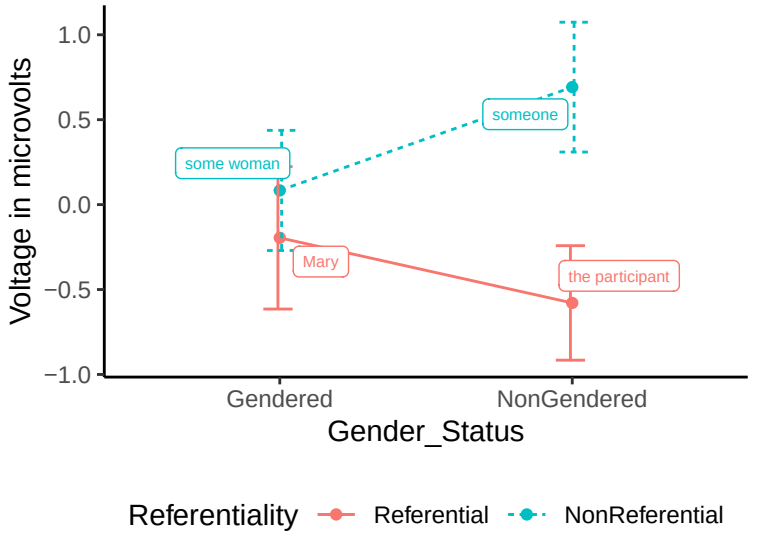
Test statistic	df	P value	Alternative hypothesis	mean difference
-3.549	89	0.0006201 * * *	two.sided	-0.8872

"*Some woman... himself*" vs. "*the participant... himself*" NonBinary

Table 15: Paired t-test: `diff_score` by `Gender_Status` ##### Interaction Plots: Group x Gender Status x Referentiality NonBinary

Test statistic	df	P value	Alternative hypothesis	mean difference
2.8	89	0.006269 * *	two.sided	0.6624





Post-hoc tests for Analysis 1: Group x Anteriority

The following chunk runs post-hoc tests for the 2-way ***"Group x Anteriority"*** Interaction

```
# Binary vs Non-Binary Frontal

pander(t.test(diff_score ~ Group
```

```
       ,dplyr::filter(prost_2022_singular, (Anteriority == "Frontal"))
       ,paired=FALSE))
```

Table 16: Welch Two Sample t-test: `diff_score` by `Group` (continued below)

Test statistic	df	P value	Alternative hypothesis	mean in group Binary
0.5115	150	0.6097	two.sided	-0.12

mean in group NonBinary
-0.3102

```
# Binary vs Non-Binary FrontoCentral

pander(t.test(diff_score ~ Group
       ,dplyr::filter(prost_2022_singular, (Anteriority == "FrontoCentral"))
       ,paired=FALSE))
```

Table 18: Welch Two Sample t-test: `diff_score` by `Group` (continued below)

Test statistic	df	P value	Alternative hypothesis
-0.1109	149.9	0.9119	two.sided

mean in group Binary	mean in group NonBinary
-0.2496	-0.2145

```
# Binary vs Non-Binary Central

pander(t.test(diff_score ~ Group
       ,dplyr::filter(prost_2022_singular, (Anteriority == "Central"))
       ,paired=FALSE))
```

Table 20: Welch Two Sample t-test: `diff_score` by `Group` (continued below)

Test statistic	df	P value	Alternative hypothesis
-1.359	149.7	0.1761	two.sided

mean in group Binary	mean in group NonBinary
-0.3873	0.01419

```
# Binary vs Non-Binary CentroParietal

pander(t.test(diff_score ~ Group
       ,dplyr::filter(prost_2022_singular, (Anteriority == "CentroParietal"))
       ,paired=FALSE))
```

Table 22: Welch Two Sample t-test: `diff_score` by `Group` (continued below)

Test statistic	df	P value	Alternative hypothesis
-1.853	149.6	0.06587	two.sided

mean in group Binary	mean in group NonBinary
-0.3836	0.1546

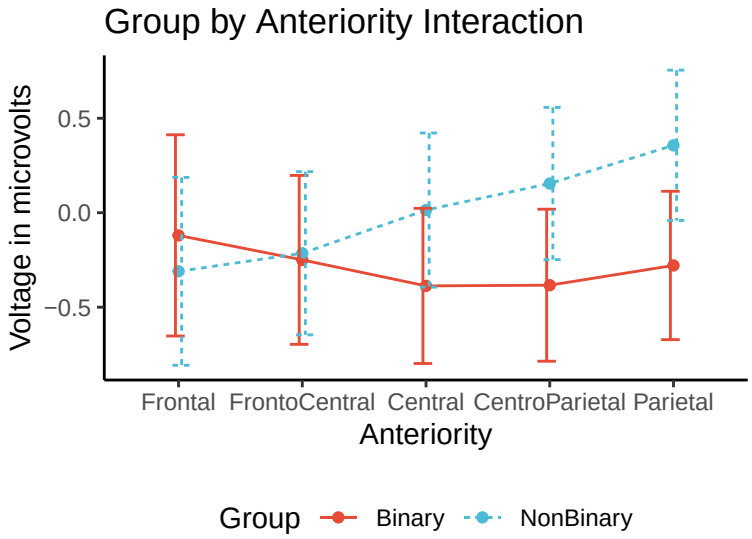
```
# Binary vs Non-Binary Parietal

pander(t.test(diff_score ~ Group
       ,dplyr::filter(prost_2022_singular, (Anteriority == "Parietal"))
       ,paired=FALSE))
```

Table 24: Welch Two Sample t-test: `diff_score` by `Group` (continued below)

Test statistic	df	P value	Alternative hypothesis
-2.229	149.3	0.02728 *	two.sided

mean in group Binary	mean in group NonBinary
-0.279	0.3568

Interaction Plot: Group x Anteriority



Analysis 2: The N400 effect when antecedents are co-indexed with *themselves*

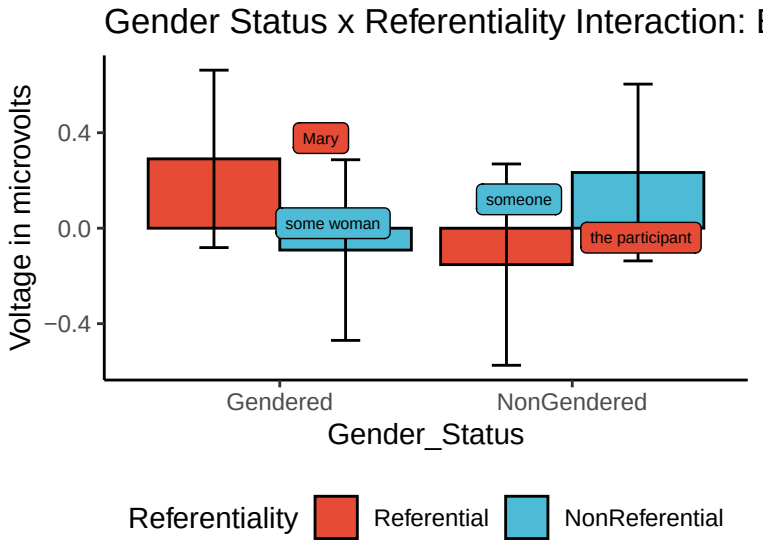
```
ezANOVA(data = prost_2022_plural
              , dv = diff_score
              , wid = SubjID
              , within = .(Referentiality, Gender_Status, Anteriority)
              , between = Group
              , type = 3
              , return_aov = F
              )
```

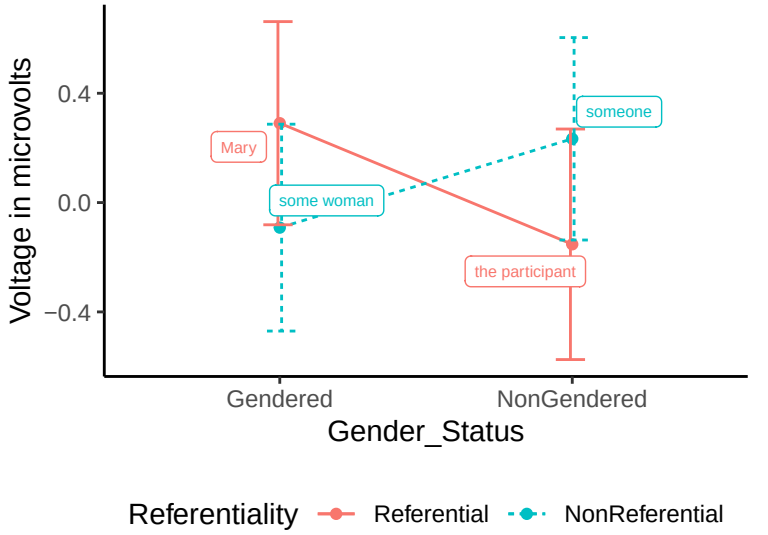
```
## $ANOVA
##                                          Effect DFn DFd           F         p
## 2                                         Group   1  36 0.238003158 0.6286102
## 3                                Referentiality   1  36 0.006154688 0.9379031
## 5                                 Gender_Status   1  36 0.097418428 0.7567506
## 7                                   Anteriority   4 144 1.400145919 0.2369032
## 4                          Group:Referentiality   1  36 0.007236331 0.9326798
## 6                           Group:Gender_Status   1  36 0.007002636 0.9337731
## 8                             Group:Anteriority   4 144 0.052760330 0.9947472
## 9                  Referentiality:Gender_Status   1  36 2.379600770 0.1316746
## 11                   Referentiality:Anteriority   4 144 1.192347966 0.3167516
## 13                    Gender_Status:Anteriority   4 144 0.867672469 0.4850282
## 10            Group:Referentiality:Gender_Status   1  36 0.046873525 0.8298179
## 12              Group:Referentiality:Anteriority   4 144 0.043204326 0.9964316
## 14               Group:Gender_Status:Anteriority   4 144 1.904147481 0.1128999
## 15      Referentiality:Gender_Status:Anteriority   4 144 0.632964163 0.6397719
## 16 Group:Referentiality:Gender_Status:Anteriority   4 144 0.102769696 0.9813708
##    p<.05          ges
## 2        1.997832e-03
## 3        3.485373e-05
## 5        4.305791e-04
## 7        9.550056e-04
## 4        4.097878e-05
## 6        3.096328e-05
## 8        3.601964e-05
## 9        1.303825e-02
## 11       1.299619e-03
## 13       8.881270e-04
## 10       2.601535e-04
## 12       4.715031e-05
## 14       1.946970e-03
## 15       5.894000e-04
## 16       9.574378e-05
##
## $`Mauchly's Test for Sphericity`
##                                          Effect           W           p
```

```
## 7                                    Anteriority 0.016789812 1.045004e-25
## 8                              Group:Anteriority 0.016789812 1.045004e-25
## 11                     Referentiality:Anteriority 0.003911051 4.769720e-36
## 12               Group:Referentiality:Anteriority 0.003911051 4.769720e-36
## 13                      Gender_Status:Anteriority 0.003122257 1.173632e-37
## 14                Group:Gender_Status:Anteriority 0.003122257 1.173632e-37
## 15       Referentiality:Gender_Status:Anteriority 0.019213046 9.302422e-25
## 16 Group:Referentiality:Gender_Status:Anteriority 0.019213046 9.302422e-25
##    p<.05
## 7      *
## 8      *
## 11     *
## 12     *
## 13     *
## 14     *
## 15     *
## 16     *
##
## $`Sphericity Corrections`
##                                           Effect       GGe     p[GG] p[GG]<.05
## 7                                    Anteriority 0.3526937 0.2517930
## 8                              Group:Anteriority 0.3526937 0.8942407
## 11                     Referentiality:Anteriority 0.3044471 0.2917829
## 12               Group:Referentiality:Anteriority 0.3044471 0.8798835
## 13                      Gender_Status:Anteriority 0.3064638 0.3780187
## 14                Group:Gender_Status:Anteriority 0.3064638 0.1731027
## 15       Referentiality:Gender_Status:Anteriority 0.3644889 0.4868838
## 16 Group:Referentiality:Gender_Status:Anteriority 0.3644889 0.8404737
##          HFe     p[HF] p[HF]<.05
## 7  0.3628201 0.2521395
## 8  0.3628201 0.8995014
## 11 0.3094842 0.2925234
## 12 0.3094842 0.8832019
## 13 0.3117017 0.3796759
## 14 0.3117017 0.1727463
## 15 0.3759502 0.4914678
## 16 0.3759502 0.8471746
```

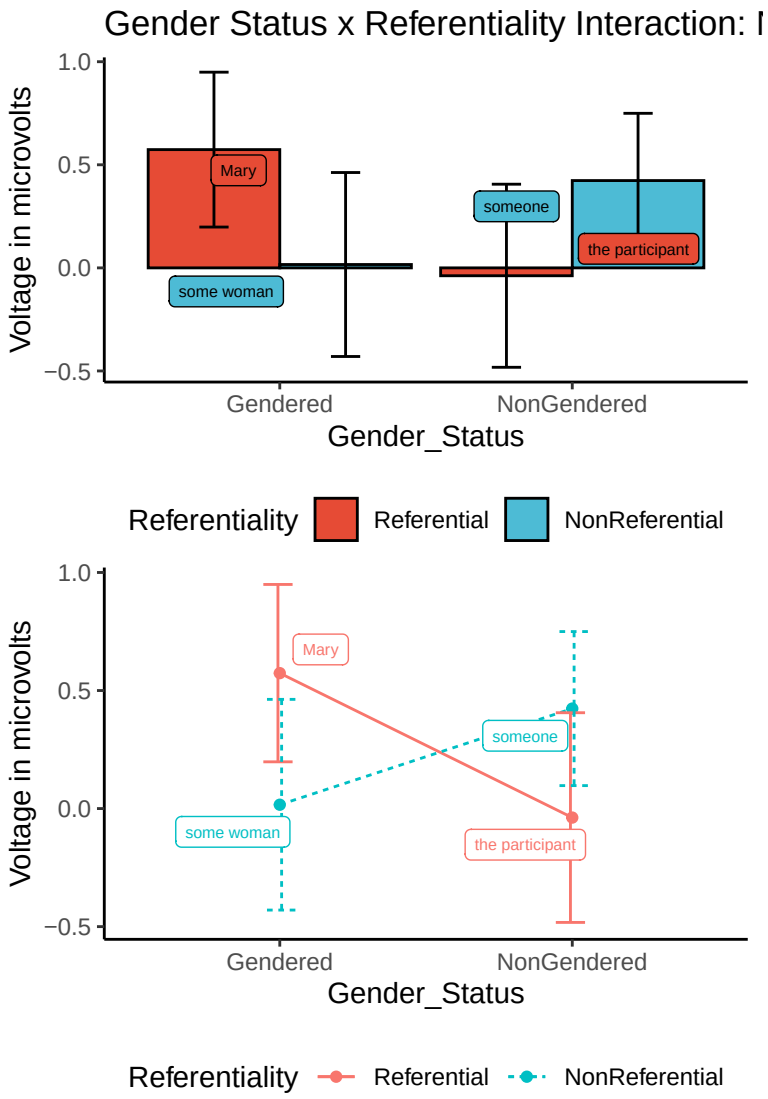
Interaction Plots for Analysis 2 Gender Status by Referentiality Interaction

Binary Group





NonBinary Group.


Gender Status x Referentiality Interaction: I
Voltage in microvolts
1.0
0.5
0.0
−0.5
Mary
some woman
someone
the participant
Gendered
NonGendered
Gender_Status
Referentiality
Referential
NonReferential
Voltage in microvolts
1.0
0.5
0.0
−0.5
Mary
some woman
someone
the participant
Gendered
NonGendered
Gender_Status
Referentiality
Referential
NonReferential