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

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Overview

This document contains the code to reproduce the statistical analyses described in [Prasad and Morris (2024)]

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.

```
theme_set(theme_classic() +  theme(legend.position = "bottom"))
```

Load the data

```
prost_2024_singular <- read_csv("prost_2022_singular_n400_nref.csv")
prost_2024_plural <- read_csv("prost_2022_plural_n400_nref.csv")
```

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

```
prost_2024_singular$Anteriority <- factor(prost_2024_singular$Anteriority,
                                          levels=c('Frontal',
                                                   'FrontoCentral',
                                                   'Central',
                                                   'CentroParietal',
                                                   'Parietal'))

prost_2024_singular$Referentiality <- factor(prost_2024_singular$Referentiality,
                                          levels=c('Referential',
                                                   'NonReferential'))
levels(prost_2024_singular$Anteriority)
```

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

```
levels(prost_2024_singular$Referentiality)
```

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

```r
prost_2024_plural$Anteriority <- factor(prost_2024_plural$Anteriority,
                                        levels=c('Frontal',
                                                 'FrontoCentral',
                                                 'Central',
                                                 'CentroParietal',
                                                 'Parietal'))

prost_2024_plural$Referentiality <- factor(prost_2024_plural$Referentiality,
                                        levels=c('Referential',
                                                 'NonReferential'))
levels(prost_2024_plural$Anteriority)
```

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

```r
levels(prost_2024_plural$Referentiality)
```

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

Check ANOVA assumptions

- *No significant outliers in any cell of the design.* This can be checked by visualizing the data using box plot methods and by using the function `identify_outliers()` in the `rstatix` package.

```r
library(rstatix)
kable(identify_outliers(prost_2024_singular, diff_score))
```

SubjID	Referentiality	Gender_Status	Group	Anteriority	Baseline	Critical	diff_score	is.outlier	is.extreme
221	Referential	NonGendered	Binary	Frontal	-1.23075	5.06575	6.2965	TRUE	FALSE

- *Normality*: the outcome (or dependent) variable should be approximately normally distributed in each cell of the design. This can be checked using the Shapiro-Wilk normality test `shapiro_test()`in the `rstatix` package.

```r
kable(shapiro_test(prost_2024_singular, diff_score))
```

variable	statistic	p
diff_score	0.9958463	0.0403519

- *Assumption of sphericity*: the variance of the differences between groups should be equal. This can be checked using the Mauchly's test of sphericity, which is automatically reported when using the R function `anova_test()` in the `rstatix` package.

Analysis using `rstatix()`" The N400 effect when antecedents are co-indexed with *himself* or *herself*

```r
library(kableExtra)
fitted.model.0 <- anova_test(data = prost_2024_singular,
                      dv = diff_score,
                      wid = SubjID,
                      within = c(Referentiality, Gender_Status, Anteriority),
                      between = Group)
kable(fitted.model.0$ANOVA)
```

Effect	DFn	DFd	F	p	p<.05	ges
Group	1	36	0.937	0.339000		0.006000
Referentiality	1	36	12.225	0.001000	*	0.073000
Gender_Status	1	36	1.273	0.267000		0.006000
Anteriority	4	144	2.061	0.089000		0.003000
Group:Referentiality	1	36	0.676	0.416000		0.004000

Effect	DFn	DFd	F	p	p<.05	ges
Group:Gender__Status	1	36	0.461	0.501000		0.002000
Group:Anteriority	4	144	5.150	0.000661	*	0.007000
Referentiality:Gender__Status	1	36	0.248	0.622000		0.001000
Referentiality:Anteriority	4	144	1.385	0.242000		0.002000
Gender__Status:Anteriority	4	144	2.353	0.057000		0.003000
Group:Referentiality:Gender__Status	1	36	5.735	0.022000	*	0.029000
Group:Referentiality:Anteriority	4	144	0.758	0.554000		0.000901
Group:Gender__Status:Anteriority	4	144	0.971	0.425000		0.001000
Referentiality:Gender__Status:Anteriority	4	144	0.210	0.933000		0.000170
Group:Referentiality:Gender__Status:Anteriority	4	144	1.491	0.208000		0.001000

```
kable(fitted.model.0$`Mauchly's Test for Sphericity`)
```

Effect	W	p	p<.05
Anteriority	0.007	0	*
Group:Anteriority	0.007	0	*
Referentiality:Anteriority	0.003	0	*
Group:Referentiality:Anteriority	0.003	0	*
Gender__Status:Anteriority	0.005	0	*
Group:Gender__Status:Anteriority	0.005	0	*
Referentiality:Gender__Status:Anteriority	0.021	0	*
Group:Referentiality:Gender__Status:Anteriority	0.021	0	*

```
kable(fitted.model.0$`Sphericity Corrections`)
```

Effect	GGe	DF[GG]	p[GG]	p[GG]<.05	HFe	DF[HF]	p[HF]	p[HF]<.05
Anteriority	0.312	1.25, 44.89	0.155		0.318	1.27, 45.72	0.154	
Group:Anteriority	0.312	1.25, 44.89	0.021	*	0.318	1.27, 45.72	0.021	*
Referentiality:Anteriority	0.301	1.21, 43.41	0.252		0.306	1.22, 44.09	0.252	
Group:Referentiality:Anteriority	0.301	1.21, 43.41	0.412		0.306	1.22, 44.09	0.414	
Gender__Status:Anteriority	0.307	1.23, 44.23	0.127		0.312	1.25, 44.99	0.126	
Group:Gender__Status:Anteriority	0.307	1.23, 44.23	0.348		0.312	1.25, 44.99	0.349	
Referentiality:Gender__Status:Anteriority	0.364	1.45, 52.35	0.740		0.375	1.5, 53.99	0.747	
Group:Referentiality:Gender__Status:Anteriority	0.364	1.45, 52.35	0.234		0.375	1.5, 53.99	0.234	

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

```
fitted.model.1 <- ezANOVA(data = prost_2024_singular
                , dv = diff_score
                , wid = SubjID
                , within = .(Referentiality, Gender_Status, Anteriority)
                , between = Group
                , type = 3
                , return_aov = F)
kable(fitted.model.1$ANOVA)
```

	Effect	DFn	DFd	F	p	p<.05	ges
2	Group	1	36	0.9374869	0.3393853		0.0061154
3	Referentiality	1	36	12.2247770	0.0012717	*	0.0725640
5	Gender__Status	1	36	1.2733561	0.2666022		0.0060392
7	Anteriority	4	144	2.0606903	0.0890227		0.0029742
4	Group:Referentiality	1	36	0.6762734	0.4162868		0.0043097
6	Group:Gender__Status	1	36	0.4610781	0.5014631		0.0021952
8	Group:Anteriority	4	144	5.1495811	0.0006606	*	0.0073995
9	Referentiality:Gender__Status	1	36	0.2476607	0.6217534		0.0012879
11	Referentiality:Anteriority	4	144	1.3854470	0.2419070		0.0016448
13	Gender__Status:Anteriority	4	144	2.3525738	0.0567932		0.0032557
10	Group:Referentiality:Gender__Status	1	36	5.7351452	0.0219568	*	0.0289967
12	Group:Referentiality:Anteriority	4	144	0.7584705	0.5539662		0.0009011
14	Group:Gender__Status:Anteriority	4	144	0.9712661	0.4252771		0.0013467
15	Referentiality:Gender__Status:Anteriority	4	144	0.2095779	0.9327769		0.0001698
16	Group:Referentiality:Gender__Status:Anteriority	4	144	1.4910541	0.2079557		0.0012071

```r
kable(fitted.model.1$`Mauchly's Test for Sphericity`)
```

	Effect	W	p	p<.05
7	Anteriority	0.0065489	0	*
8	Group:Anteriority	0.0065489	0	*
11	Referentiality:Anteriority	0.0032815	0	*
12	Group:Referentiality:Anteriority	0.0032815	0	*
13	Gender__Status:Anteriority	0.0046353	0	*
14	Group:Gender__Status:Anteriority	0.0046353	0	*
15	Referentiality:Gender__Status:Anteriority	0.0214673	0	*
16	Group:Referentiality:Gender__Status:Anteriority	0.0214673	0	*

```r
kable(fitted.model.1$`Sphericity Corrections`)
```

	Effect	GGe	p[GG]	p[GG]<.05	HFe	p[HF]	p[HF]<.05
7	Anteriority	0.3117498	0.1546225		0.3175191	0.1540735	
8	Group:Anteriority	0.3117498	0.0213677	*	0.3175191	0.0207421	*
11	Referentiality:Anteriority	0.3014694	0.2518826		0.3062118	0.2522243	
12	Group:Referentiality:Anteriority	0.3014694	0.4120582		0.3062118	0.4139260	
13	Gender__Status:Anteriority	0.3071411	0.1268326		0.3124468	0.1261545	
14	Group:Gender__Status:Anteriority	0.3071411	0.3476944		0.3124468	0.3490464	
15	Referentiality:Gender__Status:Anteriority	0.3635434	0.7398651		0.3748964	0.7470389	
16	Group:Referentiality:Gender__Status:Anteriority	0.3635434	0.2342388		0.3748964	0.2342634	

Analysis using lmer

From Introduction to Regression Methods for Public Health Using R by Ramzi W. Nahhas Use `car::Anova(, type = 3)` to test whether all the adjusted regression coefficients associated with a single term in the model (e.g., a single predictor, a single interaction) are simultaneously zero. For binary categorical predictors, continuous predictors, and interactions between them, the `car::Anova()` output is redundant with the regression coefficient table output from summary() since each such term only has one corresponding regression coefficient. However, you must use `car::Anova()` to test the significance of a categorical predictor with more than two levels or of an interaction that involves a categorical predictor with more than two levels. `car::Anova()` carries out comparisons for each of a set of specific pairs of nested models – each comparison is between the full model and a reduced model with one predictor (or interaction) removed.

```r
library(lme4)
library(car)
fitted.model.2 <- lmer(diff_score ~ Referentiality * Gender_Status * Anteriority * Group + (1|SubjID), data=prost_2024_singular)
kable(Anova(fitted.model.2, type = 3))
```

	Chisq	Df	Pr(>Chisq)
(Intercept)	13.9568993	1	0.0001870
Referentiality	18.4878884	1	0.0000171
Gender__Status	5.3711839	1	0.0204721
Anteriority	0.4515462	4	0.9780433
Group	1.0148563	1	0.3137422
Referentiality:Gender__Status	2.7870613	1	0.0950284
Referentiality:Anteriority	0.7239185	4	0.9483469
Gender__Status:Anteriority	0.0278034	4	0.9999043
Referentiality:Group	4.7252892	1	0.0297222
Gender__Status:Group	1.0660344	1	0.3018429
Anteriority:Group	3.5827404	4	0.4654095
Referentiality:Gender__Status:Anteriority	0.2301309	4	0.9938665
Referentiality:Gender__Status:Group	2.5108295	1	0.1130664
Referentiality:Anteriority:Group	0.2413978	4	0.9932763
Gender__Status:Anteriority:Group	2.1311230	4	0.7116569
Referentiality:Gender__Status:Anteriority:Group	1.0823851	4	0.8970568

Post-hoc tests : Group x Gender Status x Referentiality

If there is a significant three-way interaction effect, you can decompose it into:

- *Simple two-way interaction*: run two-way interaction at each level of third variable,
- *Simple simple main effect*: run one-way model at each level of second variable, and
- *Simple simple pairwise comparisons*: run pairwise or other post-hoc comparisons if necessary.

Compute simple two-way interaction

You are free to decide which two variables will form the simple two-way interactions and which variable will act as the third (moderator) variable. In the following R code, we have considered the simple two-way interaction of Referentiality*Gender Status at each level of Anaphor Type

It is recommended to adjust the p-value for multiple testing (Bonferroni correction) by dividing the current α-level you declare statistical significance at (i.e., p < 0.05) by the number of simple two-way interaction you are computing (i.e., 2). Thus two-way interaction as statistically significant when $p < 0.025$ (i.e., $p < 0.05/2$).

```
binary <- filter(prost_2024_singular, Group == "Binary")
nonbinary <- filter(prost_2024_singular, Group == "NonBinary")


two.way.binary <- binary |>
  ezANOVA(dv = diff_score,
          wid = SubjID,
          within = c(Referentiality, Gender_Status),
          within_full = c(Referentiality, Gender_Status, Anteriority),
          type = 3,
          return_aov = F)
kable(two.way.binary$ANOVA)
```

	Effect	DFn	DFd	F	p	p<.05	ges
2	Referentiality	1	19	7.512031	0.0129912	*	0.1247497
3	Gender__Status	1	19	1.800293	0.1954940		0.0182718
4	Referentiality:Gender__Status	1	19	4.466196	0.0480272	*	0.0494418

```
two.way.nonbinary <- nonbinary |>
  ezANOVA(dv = diff_score,
          wid = SubjID,
          within = c(Referentiality, Gender_Status),
          within_full = c(Referentiality, Gender_Status, Anteriority),
          type = 3,
          return_aov = F)
kable(two.way.nonbinary$ANOVA)
```

	Effect	DFn	DFd	F	p	p<.05	ges
2	Referentiality	1	17	5.2008595	0.0357473	*	0.0535930
3	Gender__Status	1	17	0.0916053	0.7658183		0.0011910
4	Referentiality:Gender__Status	1	17	1.6882520	0.2111772		0.0226639

Compute simple simple main effects

A statistically significant simple two-way interaction can be followed up with simple simple main effects.

Group the data by Group and Gender__Status, and analyze the simple main effect of Referentiality.

```
ref.effect.G <- binary |>
  filter(Gender_Status == "Gendered") |>
  ezANOVA(dv = diff_score,
          wid = SubjID,
          within = c(Referentiality),
          within_full = c(Referentiality, Gender_Status, Anteriority),
          type = 3,
          return_aov = F)

ref.effect.NG <- binary |>
  filter(Gender_Status == "NonGendered") |>
  ezANOVA(dv = diff_score,
          wid = SubjID,
          within = c(Referentiality),
          within_full = c(Referentiality, Gender_Status, Anteriority),
          type = 3,
          return_aov = F)

kable(ref.effect.G$ANOVA)
```

Effect of Referentiality at each Gender_Status cell for Binary Participants

	Effect	DFn	DFd	F	p	p<.05	ges
2	Referentiality	1	19	13.44203	0.0016409	*	0.2853275

```
kable(ref.effect.NG$ANOVA)
```

	Effect	DFn	DFd	F	p	p<.05	ges
2	Referentiality	1	19	0.6579303	0.4273362		0.0202408

```
ref.effect.G.NB <- nonbinary |>
  filter(Gender_Status == "Gendered") |>
  ezANOVA(dv = diff_score,
          wid = SubjID,
          within = c(Referentiality),
          within_full = c(Referentiality, Gender_Status, Anteriority),
          type = 3,
          return_aov = F)

ref.effect.NG.NB <- nonbinary |>
  filter(Gender_Status == "NonGendered") |>
  ezANOVA(dv = diff_score,
          wid = SubjID,
          within = c(Referentiality),
          within_full = c(Referentiality, Gender_Status, Anteriority),
          type = 3,
          return_aov = F)

kable(ref.effect.G.NB$ANOVA)
```

Effect of Referentiality at each Gender_Status cell for Non-Binary Participants

	Effect	DFn	DFd	F	p	p<.05	ges
2	Referentiality	1	17	0.2887792	0.5979685		0.0068336

```
kable(ref.effect.NG.NB$ANOVA)
```

	Effect	DFn	DFd	F	p	p<.05	ges
2	Referentiality	1	17	6.39245	0.0216531	*	0.1403301

Condition Means

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

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

```
kable(singular_means1 <- prost_2024_singular |>
  group_by(Group, Referentiality) |>
  summarise(Mean = mean(diff_score),
            SE = sem(diff_score),
            SD = sd(diff_score),
            Max = max(diff_score),
            Min = min(diff_score)), digits = 2)
```

Group	Referentiality	Mean	SE	SD	Max	Min
Binary	Referential	-0.91	0.15	2.09	6.30	-5.12
Binary	NonReferential	0.34	0.12	1.69	4.79	-5.06
NonBinary	Referential	-0.39	0.14	1.85	4.44	-5.21

Group	Referentiality	Mean	SE	SD	Max	Min
NonBinary	NonReferential	0.39	0.13	1.80	3.88	-4.12

```
kable(singular_means2 <- prost_2024_singular |>
  filter(Group == "Binary") |>
  group_by(Group, Gender_Status, Referentiality) |>
  summarise(Mean = mean(diff_score),
            SE = sem(diff_score),
            SD = sd(diff_score),
            Max = max(diff_score),
            Min = min(diff_score)), digits = 2)
```

Group	Gender_Status	Referentiality	Mean	SE	SD	Max	Min
Binary	Gendered	Referential	-1.51	0.19	1.90	4.41	-5.12
Binary	Gendered	NonReferential	0.49	0.16	1.64	3.90	-4.58
Binary	NonGendered	Referential	-0.31	0.21	2.11	6.30	-5.05
Binary	NonGendered	NonReferential	0.19	0.17	1.73	4.79	-5.06

```
kable(singular_means2 <- prost_2024_singular |>
  group_by(Group, Anteriority) |>
  summarise(Mean = mean(diff_score),
            SE = sem(diff_score),
            SD = sd(diff_score),
            Max = max(diff_score),
            Min = min(diff_score)), digits = 2)
```

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

Compute simple simple main effects with Bonferroni adjustment using `pwc()` function in the `rstatix`

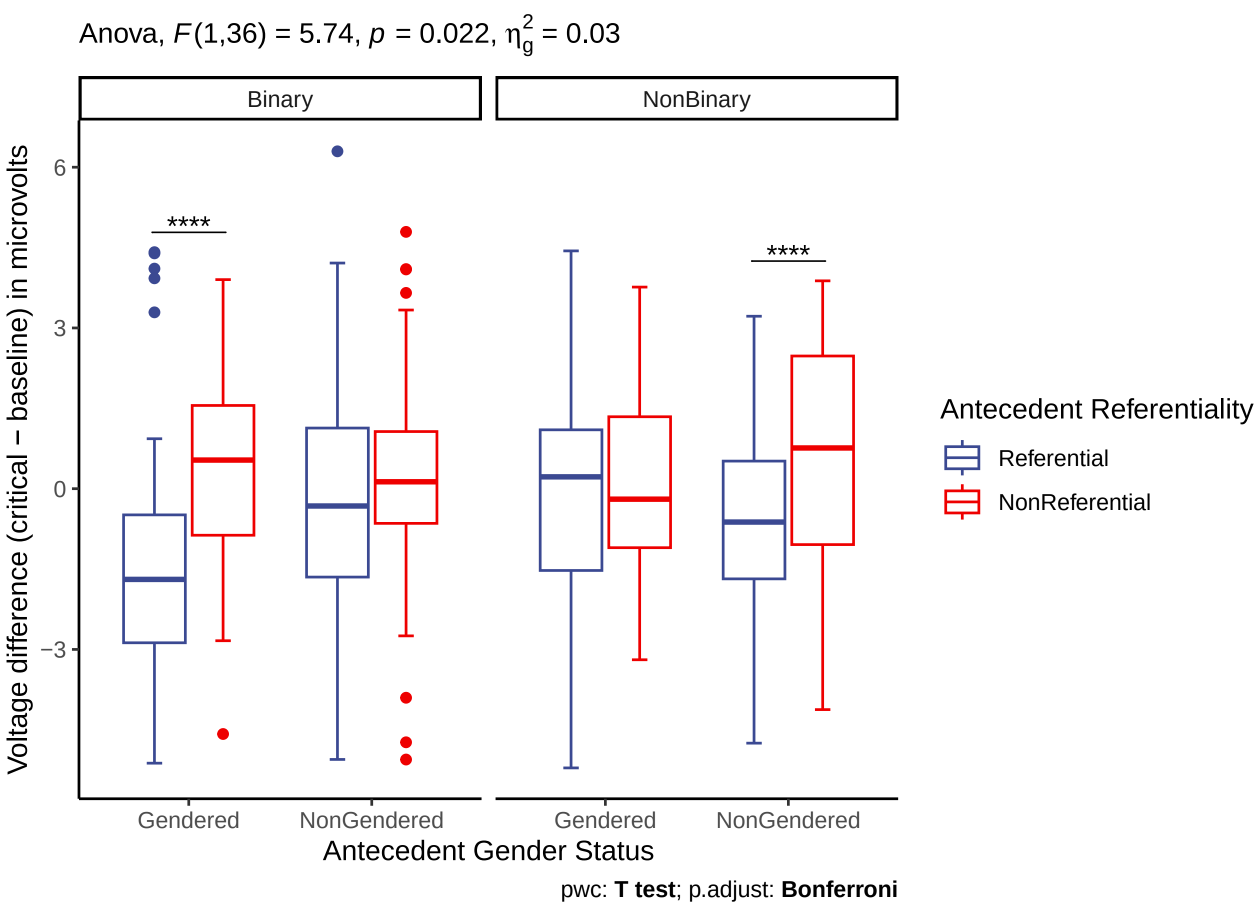
```
# Pairwise comparisons
pwc <- prost_2024_singular |>
  group_by(Group, Gender_Status) |>
  pairwise_t_test(diff_score ~ Referentiality, paired = TRUE, p.adjust.method = "bonferroni") |>
  select(-p, -.y., -n2 ) # Remove details
kable(pwc)
```

Gender_Status	Group	group1	group2	n1	statistic	df	p.adj	p.adj.signif
Gendered	Binary	Referential	NonReferential	100	-7.659899	99	0.00e+00	****
NonGendered	Binary	Referential	NonReferential	100	-1.721702	99	8.80e-02	ns
Gendered	NonBinary	Referential	NonReferential	90	-1.142697	89	2.56e-01	ns
NonGendered	NonBinary	Referential	NonReferential	90	-5.201870	89	1.30e-06	****

Visualization: Box plots with p-values

```
library(ggplot2)
library(ggsci)
library(ggpubr)
```

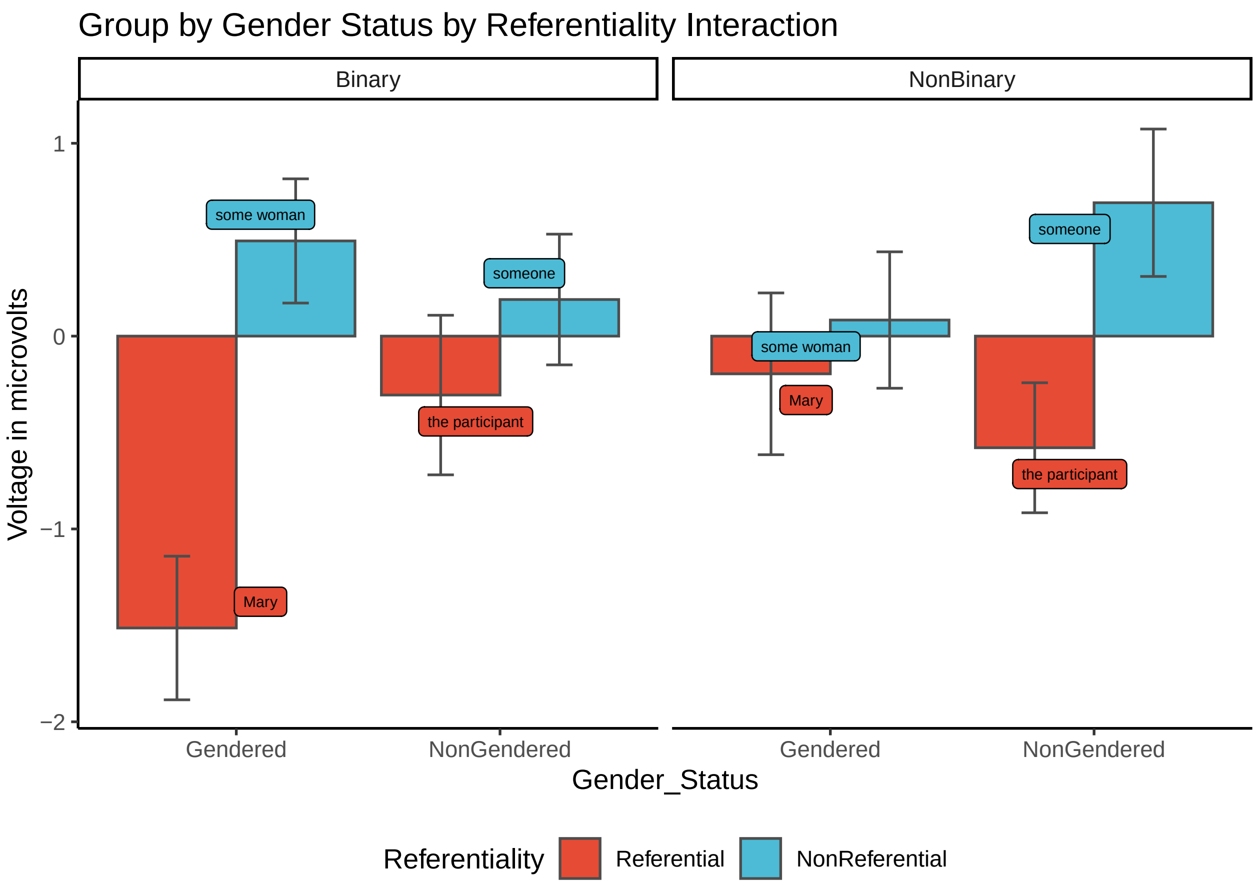
```r
bxp <- prost_2024_singular |>
  ggplot(mapping = aes(x = Gender_Status, y = diff_score, colour = Referentiality)) +
  geom_boxplot(staplewidth = .25) +
  facet_wrap(~ Group, ncol = 2) +
  labs(y = "Voltage difference (critical - baseline) in microvolts", x = "Gender Status") +
  theme_classic() +
  scale_color_aaas() +
  scale_fill_aaas(alpha = 0.3)


pwc <- pwc |> add_xy_position(x = "Gender_Status")
bxp +
  stat_pvalue_manual(pwc, tip.length = 0, hide.ns = TRUE) +
  labs(subtitle = get_test_label(fitted.model.0, detailed = TRUE, correction = "none", row = 11), caption = get_pwc_label(pwc)) +
  xlab("Antecedent Gender Status") +
  labs(colour="Antecedent Referentiality" )
```



Interaction Plots: Group x Gender Status x Referentiality Interaction

```r
summary_data <- prost_2024_singular |>
  group_by(Group, Gender_Status, Referentiality) |>
  summarise(mean = mean(diff_score), se = sem(diff_score))|>
  mutate(lwr = mean - (1.96*se), upr = mean + (1.96*se))
summary_data$label = c("Mary","some woman", "the participant", "someone","Mary","some woman", "the participant", "someone")


ggplot(summary_data, aes(x = Gender_Status,
                         y = mean,
                         ymin = lwr,
                         ymax = upr,
                         fill = Referentiality,
```

```
                              group = Referentiality,
                              label = label)) +
  geom_bar(position=position_dodge(), stat="identity", colour = "grey30") +
  facet_wrap(~ Group, ncol = 2) +
  geom_errorbar(width = .2, colour = "grey30", position = position_dodge(.9))  +
  geom_label_repel(show.legend = FALSE, cex = 2, colour = "black", force = 1) +
  scale_fill_npg() + ylab("Voltage in microvolts") +
  ggtitle("Group by Gender Status by Referentiality Interaction")
```



Post-hoc tests for Analysis 1: GROUP x ANTERIORITY interaction

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_2024_singular, (Anteriority == "Frontal"))))
```

Table 20: 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

```r
# Binary vs Non-Binary Fronto-Central

pander(t.test(diff_score ~ Group
       ,dplyr::filter(prost_2024_singular, (Anteriority == "FrontoCentral"))))
```

Table 22: 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

```r
# Binary vs Non-Binary Central

pander(t.test(diff_score ~ Group
       ,dplyr::filter(prost_2024_singular, (Anteriority == "Central"))))
```

Table 24: 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

```r
# Binary vs Non-Binary Centro-Parietal

pander(t.test(diff_score ~ Group
       ,dplyr::filter(prost_2024_singular, (Anteriority == "CentroParietal"))))
```

Table 26: 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

```r
# Binary vs Non-Binary Parietal

pander(t.test(diff_score ~ Group
       ,dplyr::filter(prost_2024_singular, (Anteriority == "Parietal"))))
```

Table 28: 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

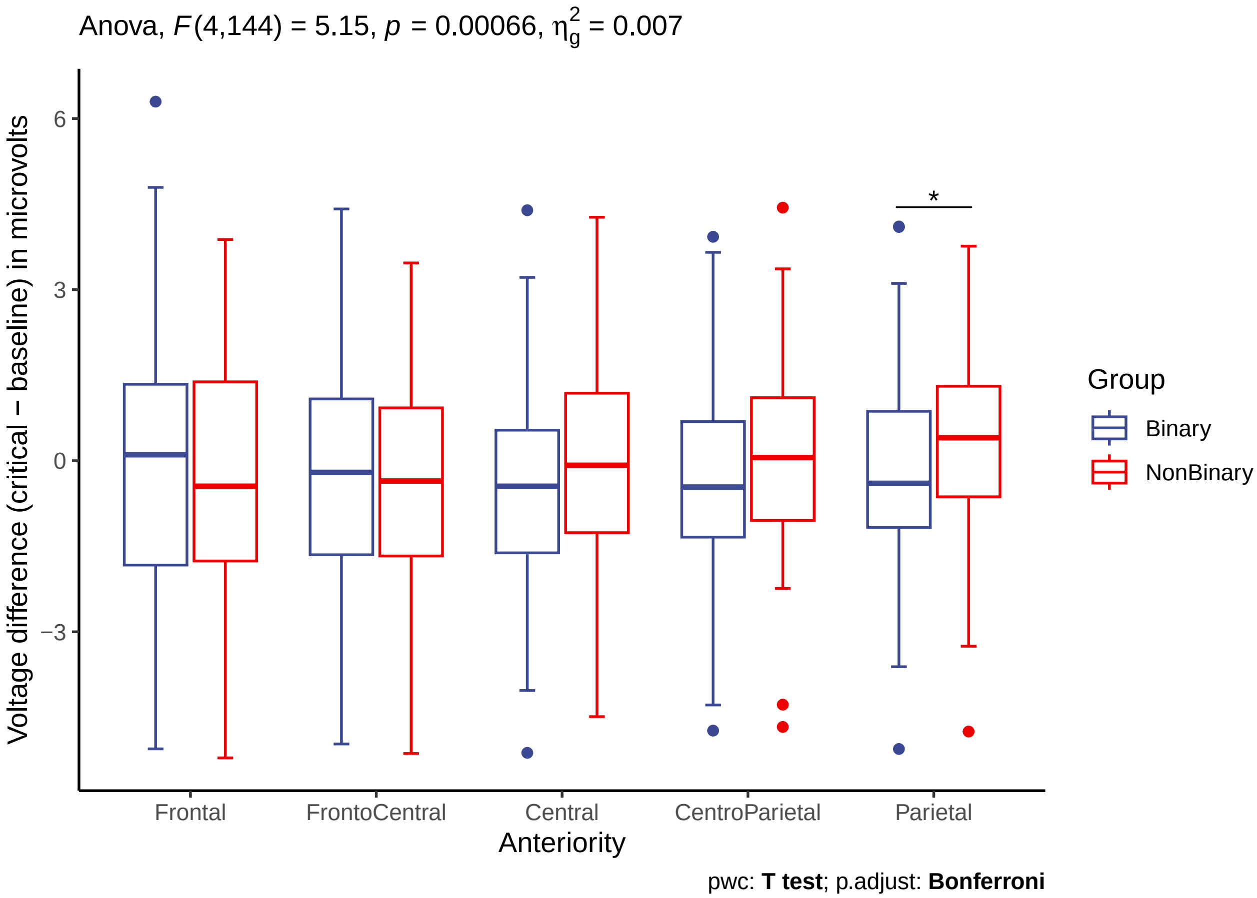
Visualization: Box plots with p-values

Compute simple simple main effects with Bonferroni adjustment using `pwc()` function in the `rstatix`

```
# Pairwise comparisons
pwc3 <- prost_2024_singular |>
  group_by(Anteriority) |>
  pairwise_t_test(diff_score ~ Group, p.adjust.method = "bonferroni") |>
  select(-p, -.y. ) # Remove details
kable(pwc3)
```

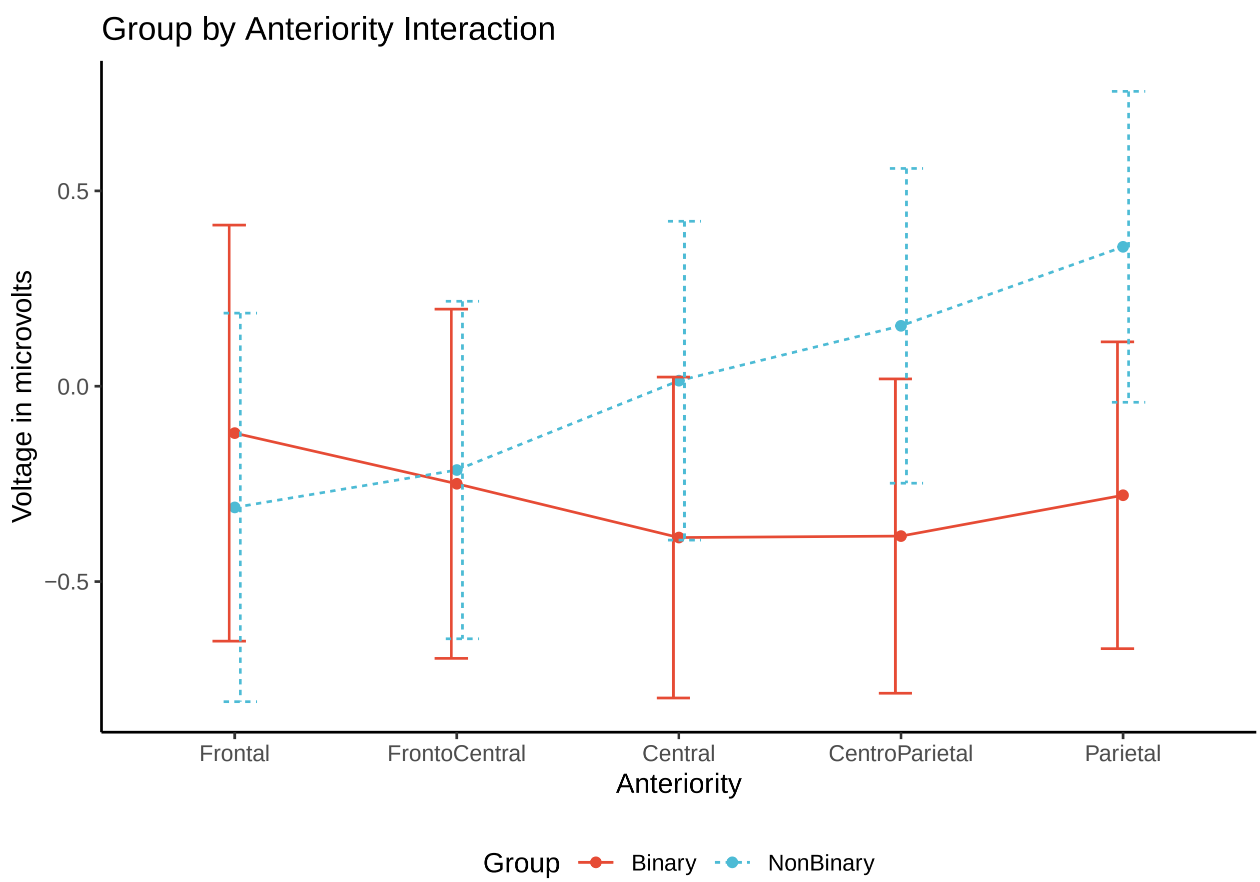
Anteriority	group1	group2	n1	n2	p.signif	p.adj	p.adj.signif
Frontal	Binary	NonBinary	80	72	ns	0.6120	ns
FrontoCentral	Binary	NonBinary	80	72	ns	0.9120	ns
Central	Binary	NonBinary	80	72	ns	0.1770	ns
CentroParietal	Binary	NonBinary	80	72	ns	0.0666	ns
Parietal	Binary	NonBinary	80	72	*	0.0276	*

```
library(ggplot2)
library(ggsci)
library(ggpubr)

bxp3 <- prost_2024_singular |>
  ggplot(mapping = aes(x = Anteriority, y = diff_score, colour = Group)) +
  geom_boxplot(staplewidth = .25) +
  labs(y = "Voltage difference (critical - baseline) in microvolts", x = "Anteriority") +
  theme_classic() +
  scale_color_aaas() +
  scale_fill_aaas(alpha = 0.3)


pwc3 <- pwc3 |> add_xy_position(x = "Anteriority")
bxp3 +
  stat_pvalue_manual(pwc3, tip.length = 0, hide.ns = TRUE) +
  labs(subtitle = get_test_label(fitted.model.0, detailed = TRUE, correction = "none", row = 7), caption = get_pwc_label(pwc3)) +
  xlab("Anteriority") +
  labs(colour="Group" )
```



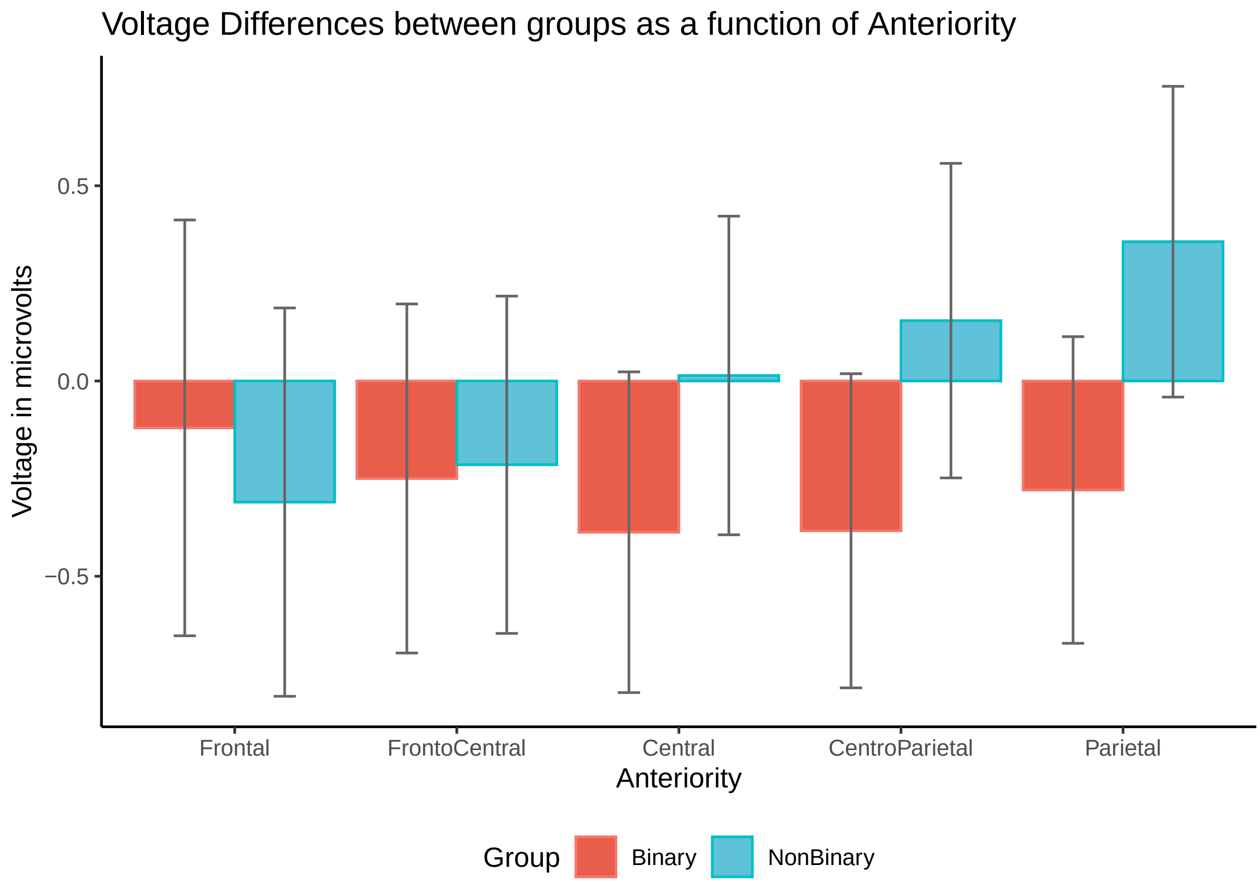
Interaction Plot: Group x Anteriority

```
summary_data_3 <- prost_2024_singular |>
  group_by(Group, Anteriority) |>
  summarise(mean = mean(diff_score), se = sem(diff_score))|>
  mutate(lwr = mean - (1.96*se), upr = mean + (1.96*se))

ggplot(summary_data_3, aes(x = Anteriority,
                           y = mean,
                           ymin = lwr,
                           ymax = upr,
                           colour = Group,
                           linetype= Group,
                           group = Group)) +
  geom_point() +
  geom_line() +
  geom_errorbar(width = .3, position = position_dodge(.1)) +
  scale_colour_npg() + ylab("Voltage in microvolts") +
  ggtitle("Group by Anteriority Interaction")
```




```
# scale_fill_manual(values=c("cadetblue", "lightpink1"))
```

```
summary_data_3 <- prost_2024_singular |>
  group_by(Group, Anteriority) |>
  summarise(mean = mean(diff_score), se = sem(diff_score))|>
  mutate(lwr = mean - (1.96*se), upr = mean + (1.96*se))

ggplot(summary_data_3, aes(x = Anteriority,
                          y = mean,
                          ymin = lwr,
                          ymax = upr,
                          fill = Group,
                          colour = Group,
                          group = Group)) +
  geom_bar(position=position_dodge(), stat="identity") +
  geom_errorbar(width = .2, colour = "grey40", position = position_dodge(.9))  +
  scale_fill_npg(alpha = .9) + ylab("Voltage in microvolts") +
  ggtitle("Voltage Differences between groups as a function of Anteriority")
```




```
#scale_fill_manual(values=c("cadetblue", "lightpink1"))
```