Supplementary Analysis

Set-up

In [1]:
```
# loading library and setting up directory
suppressWarnings(suppressMessages(library(tidyverse)))
suppressWarnings(suppressMessages(library(lmerTest)))
suppressWarnings(suppressMessages(library(ggeffects)))
suppressWarnings(suppressMessages(library(emmeans)))
suppressWarnings(suppressMessages(library(sjPlot)))
suppressWarnings(suppressMessages(library(magrittr)))
suppressWarnings(suppressMessages(library(DescTools)))

# Set theme
apa_theme <- theme(
plot.margin = unit(c(1, 1, 1, 1), "cm"),
plot.background = element_rect(fill = "white", color = NA),
plot.title = element_text(size = 22, face = "bold",
                          hjust = 0.5,
                          margin = margin(b = 15)),
axis.line = element_line(color = "black", size = .5),
axis.title = element_text(size = 18, color = "black",
                          face = "bold"),
axis.text = element_text(size = 15, color = "black"),
axis.text.x = element_text(margin = margin(t = 10)),
axis.title.y = element_text(margin = margin(r = 10)),
axis.ticks = element_line(size = .5),
panel.grid = element_blank(),
legend.position = 'top',
legend.background = element_rect(color = "black"),
legend.text = element_text(size = 15),
legend.margin = margin(t = 5, l = 5, r = 5, b = 5),
legend.key = element_rect(color = NA, fill = NA)
)

theme_set(theme_minimal(base_size = 18) +
        apa_theme)
```

```
Warning message:
“The `size` argument of `element_line()` is deprecated as of ggplot2 3.4.
0.
ℹ Please use the `linewidth` argument instead.”
```

load file

In [2]:
```
metadf <- read.csv('wiki_name_hits_title_majority.csv')
# glimpse(metadf)
metadf %>% filter(confidence > .80) -> metadf
metadf %>% mutate(TF=substring(TIMEFRAME,1,4)) -> metadf

# number of portraits in each condition
metadf %>% group_by(Condition) %>% summarise(n=n())
# levels(factor(metadf$SCHOOL))
metadf %>% mutate(SCHOOL = factor(SCHOOL,levels=c('Italian',
```

```
    'American','Austrian','Belgian','Bohemian','Danish',
    'Dutch','English','Finnish','Flemish','French','German',
    'Hungarian','Irish','Netherlandish','Norwegian',
    'Polish','Russian','Scottish','Spanish','Swedish','Swiss','Other')))
```

A tibble: 3 × 2

Condition	n
<chr>	<int>
Post_Renaissance	1339
Religion	162
Renaissance	968

Coding of Direct vs. Averted Gaze

To classify each portrait into \textit{direct} versus \textit{averted gaze}, we implemented a continuous probabilistic rule that accounts for both \textbf{head orientation} (\texttt{headYaw}) and \textbf{eye orientation} (\texttt{gazeYaw}). \texttt{headYaw} was coded in degrees such that 0° corresponds to a frontal head orientation and positive values indicate rightward rotation. \texttt{gazeYaw} was coded such that 0° corresponds to direct frontal gaze and positive values indicate leftward deviation.

Because the perceptual `cone of direct gaze` narrows as the head rotates away from the frontal position, we defined a head-dependent tolerance parameter $\tau(h)$. Specifically, when the head was frontal (0°), gaze was considered `direct` within $\pm 7.5^{\circ}$; when the head was rotated 30°, the tolerance narrowed to $\pm 3^{\circ}$. For intermediate angles between 0° and 30°, we linearly interpolated the tolerance; values beyond 30° were fixed at $\pm 3^{\circ}$.

To model the transition smoothly rather than as a hard cutoff, we converted this rule into a cumulative normal distribution:

$$p_{\text{direct}} = \Phi\left(\frac{\tau(|h|) - |g|}{\sigma}\right),$$

where $|h|$ is the absolute headYaw, $|g|$ is the absolute gazeYaw, $\tau(|h|)$ is the tolerance at that head orientation, σ is a slope parameter (set to 2° in the main analyses), and Φ is the standard normal cumulative distribution function.

This formulation produces a probability of direct gaze that decreases gradually as gaze deviates from the head-dependent tolerance. For categorical analyses, we coded trials as `direct` when $p_{\text{direct}} \geq 0.5$, and as `averted` otherwise. In robustness checks, we also sampled classifications probabilistically from p_{direct}.

In [3]:

```
# ロジスティック関数で閾値を計算する関数
threshold_func <- function(yaw, max_th = 7.5, min_th = 0.5, k = 0.08, mid
  min_th + (max_th - min_th) / (1 + exp(k * (yaw - midpoint)))
}
```

```
metadf <- metadf %>%
  rowwise() %>%
  mutate(
    # 顔の向きに応じた閾値を計算
    threshold = threshold_func(abs(headYaw)),

    # 直視か逸らしを判定
    gaze_cat = ifelse(abs(gazeYaw) <= threshold, "direct", "avert")
  ) %>%
  ungroup()
```

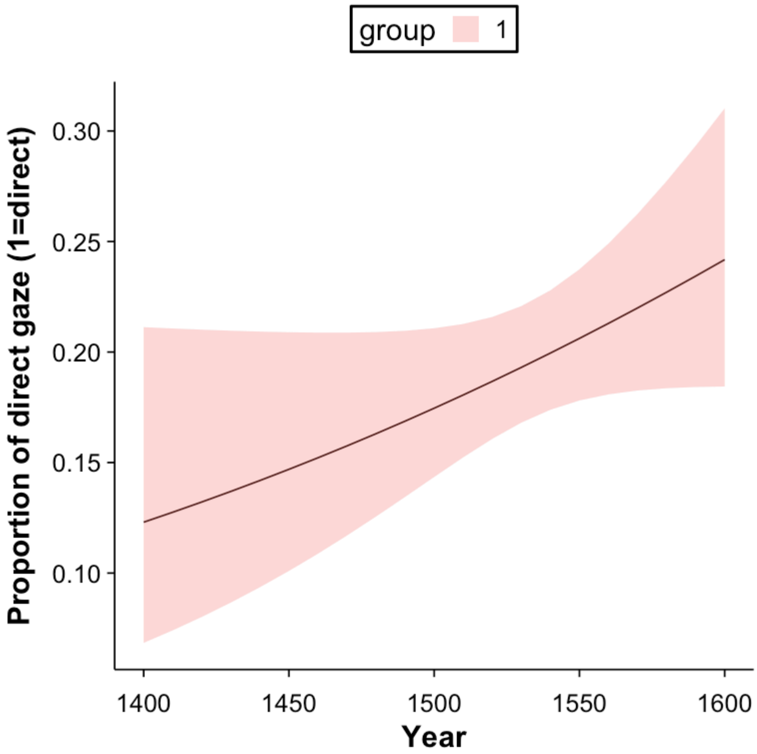
Direct gaze during the Renaissance

To examine diachronic changes in gaze orientation during the Renaissance, we estimated a logistic regression model predicting whether a portrait depicted a direct gaze (1) versus an averted gaze (0) from the date of production (restricted to 1400--1600). The model revealed a significant negative intercept ($\beta = -7.71$, $SE = 3.62$, $p = .033$), reflecting the overall rarity of direct gaze at the beginning of the period. The coefficient for date was positive ($\beta = 0.004$, $SE = 0.002$, $p = .082$), indicating that portraits produced later in the Renaissance were somewhat more likely to be depicted with direct gaze. Although this effect did not reach conventional levels of statistical significance, the trend suggests a gradual increase in direct gaze between 1400 and 1600.

In [4]:
```
fit2 <- metadf %>% mutate(gaze_cat2=ifelse(gaze_cat=='avert',0,1)) %>%
    filter(Condition=='Renaissance', SCHOOL != 'Other' & SCHOOL != 'Finni
    glm(gaze_cat2~date, family = binomial("logit"),data=.)

summary(fit2)

glm_p <- ggpredict(fit2, terms = c("date"))

(p <-ggplot() +
     geom_line(data = glm_p, aes(x = x, y = predicted), show.legend = F)
     geom_ribbon(data = glm_p, aes(x = x, ymin = conf.low, ymax = conf.hi
     ylab('Proportion of direct gaze (1=direct)') + xlab('Year') + scale_
```

```
Call:
glm(formula = gaze_cat2 ~ date, family = binomial("logit"), data = .)

Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept) -7.712833   3.622882  -2.129   0.0333 *
date         0.004106   0.002359   1.740   0.0818 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 864.93  on 875  degrees of freedom
Residual deviance: 861.84  on 874  degrees of freedom
AIC: 865.84

Number of Fisher Scoring iterations: 4
```

```
Data were 'prettified'. Consider using `terms="date [all]"` to get
  smooth plots.
```



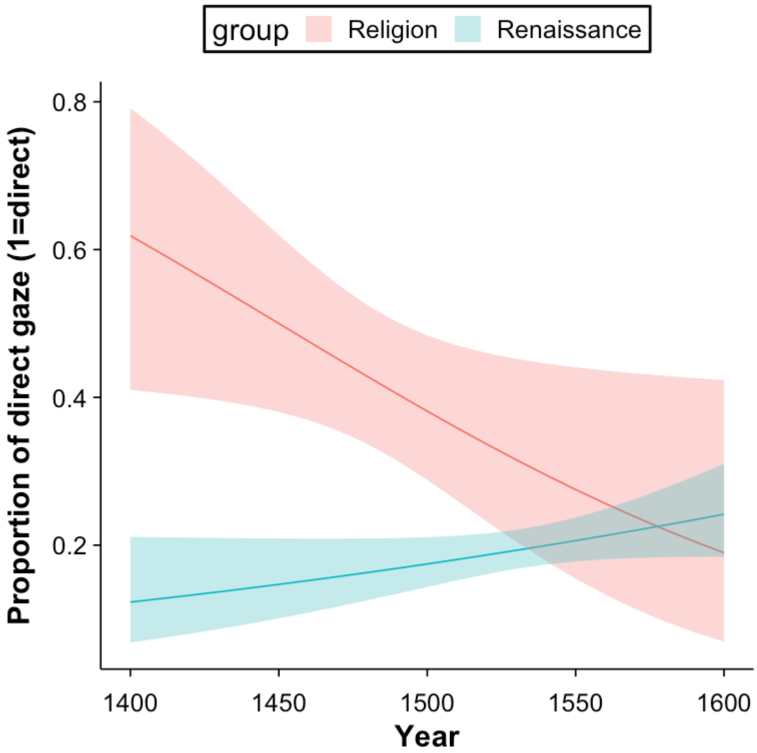
Secular vs Religous paintings

To assess whether diachronic changes in gaze orientation differed across stylistic contexts, we fitted a logistic regression model predicting the likelihood of direct gaze from date, Condition, and their interaction (1400--1600. The analysis revealed a significant negative effect of date in the religious paintings ($\beta = -0.0097$, $SE = 0.0047$, $p = .038$), indicating that direct gaze became less likely over time in religious paintings. By contrast, a significant positive interaction emerged between date and the secular paintings ($\beta = 0.0138$, $SE = 0.0052$, $p = .008$). This pattern suggests that while religious portraits showed a slight decline in direct gaze, secular portraits exhibited the opposite tendency, with a gradual increase in the likelihood of direct gaze as the period progressed. The main effect of the secular portraits was also significant ($\beta = -21.75$, $SE = 7.82$, $p = .005$), reflecting the lower baseline probability of direct gaze at the start of the Renaissance period.

In [5]:
```
fit2 <- metadf %>% mutate(gaze_cat2=ifelse(gaze_cat=='avert',0,1),Conditi
summary(fit2)
glm_p <- ggpredict(fit2, terms = c("date","Condition"))
# glm_p
(p <-ggplot() +
     geom_line(data = glm_p, aes(x = x, y = predicted, color = group), sh
     geom_ribbon(data = glm_p, aes(x = x, ymin = conf.low, ymax = conf.hi
     ylab('Proportion of direct gaze (1=direct)') + xlab('Year') + scale_
# ggsave('Gaze_Shift_Left_Renai_only.png',p)
```

```
Call:
glm(formula = gaze_cat2 ~ date * Condition, family = binomial("logit"),
    data = .)

Coefficients:
                            Estimate Std. Error z value Pr(>|z|)
(Intercept)                14.036663   6.925771   2.027  0.04269 *
date                       -0.009680   0.004670  -2.073  0.03818 *
ConditionRenaissance      -21.749496   7.816110  -2.783  0.00539 **
date:ConditionRenaissance   0.013787   0.005232   2.635  0.00841 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1039.3  on 985  degrees of freedom
Residual deviance: 1006.8  on 982  degrees of freedom
AIC: 1014.8

Number of Fisher Scoring iterations: 4
```

```
Data were 'prettified'. Consider using `terms="date [all]"` to get
  smooth plots.
```



Popularity

To test whether direct gaze predicted the cultural prominence of portraits, we fitted a linear mixed-effects model with the log-transformed number of web search hits as the dependent variable, gaze category (0 = averted, 1 = direct) and sitter fame (log-transformed number of Wikipedia language editions) as fixed effects, and author as a random intercept.

The model revealed a strong positive effect of sitter fame ($\beta = 0.27$, $SE = 0.04$, $t = 6.53$, $p < .001$), indicating that portraits of more famous sitters were consistently associated with greater cultural prominence. By contrast, gaze orientation had no reliable effect ($\beta = -0.02$, $SE = 0.11$, $t = -0.18$, $p = .858$). Thus, while sitter fame strongly predicted the visibility of a portrait in contemporary search metrics, there was no evidence that direct gaze independently contributed to cultural prominence.

In [6]:
```
metadf %<>% mutate(log_hits = scale(log1p(Hits)),log_fame=scale(log1p(1+a

metadf %>% filter(date>1400,date<1600,
    Condition=='Renaissance', SCHOOL != 'Other' & SCHOOL != 'Finnish' & S
    lmer(log_hits~gaze_cat+log_fame+(1|AUTHOR),data=.) -> fit1
summary(fit1)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: log_hits ~ gaze_cat + log_fame + (1 | AUTHOR)
   Data: .

REML criterion at convergence: 528.2

Scaled residuals:
     Min       1Q   Median       3Q      Max
-2.58189 -0.53482 -0.05321  0.59300  2.28798

Random effects:
 Groups   Name        Variance Std.Dev.
 AUTHOR   (Intercept) 0.2416   0.4915
 Residual             0.3023   0.5499
Number of obs: 270, groups:  AUTHOR, 65

Fixed effects:
                Estimate Std. Error        df t value Pr(>|t|)
(Intercept)      0.13422    0.07827  63.40465   1.715   0.0913 .
gaze_catdirect  -0.01940    0.10844 264.29330  -0.179   0.8581
log_fame         0.26868    0.04113 265.74087   6.532 3.28e-10 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
            (Intr) gz_ctd
gaze_ctdrct -0.240
log_fame     0.057 -0.085
```

Ukiyo-e

In [7]:
```
ukiyo <- read.csv('metafile.csv')
# glimpse(ukiyo)

# ロジスティック関数で閾値を計算する関数
threshold_func <- function(yaw, max_th = 7.5, min_th = 0.5, k = 0.08, mid
  min_th + (max_th - min_th) / (1 + exp(k * (yaw - midpoint)))
}

ukiyo <- ukiyo %>%
```

```
  rowwise() %>%
  mutate(
    # 顔の向きに応じた閾値を計算
    threshold = threshold_func(abs(headYaw)),

    # 直視か逸らしを判定
    gaze_cat = ifelse(abs(gazeYaw) <= threshold, "direct", "avert")
  ) %>%
  ungroup()
```

Eye gaze using cone of direct gaze

We next examined whether the prevalence of direct gaze changed over time in the ukiyo-e sample. A logistic regression was fitted with gaze category (0 = averted, 1 = direct) predicted by year of production. The model revealed no significant association between year and the likelihood of direct gaze ($\beta = -0.026$, $SE = 0.022$, $p = .243$). The intercept was also non-significant ($\beta = 46.02$, $SE = 41.60$, $p = .269$). In sum, the analysis provided no evidence for a diachronic increase (or decrease) in direct gaze in ukiyo-e portraits across the period examined.

In [9]:
```
fit2 <- ukiyo %>% mutate(gaze_cat2=ifelse(gaze_cat=='avert',0,1)) %>%
    glm(gaze_cat2~year, family = binomial("logit"),data=.)

summary(fit2)
```

```
Call:
glm(formula = gaze_cat2 ~ year, family = binomial("logit"), data = .)

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept) 46.02458   41.59760   1.106    0.269
year        -0.02624    0.02248  -1.167    0.243

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 43.949  on 88  degrees of freedom
Residual deviance: 42.573  on 87  degrees of freedom
  (65 個の観測値が欠損のため削除されました)
AIC: 46.573

Number of Fisher Scoring iterations: 5
```