

# Power Analysis for Trust Experiment

```
suppressMessages({
  library(tidyverse)
  library(fixest)
  library(pwr)
})

DVERSION_TRUST <- "2024-04-29"

set.seed(42)

trounds <- read_csv(
  sprintf("../data/generated/trust_%s_rounds.csv", DVERSION_TRUST),
  show_col_types = FALSE
) %>%
  mutate(
    experiment = factor(ifelse(
      experiment == "ftrust",
      "Business Framing", "Neutral Framing"
    ), c("Neutral Framing", "Business Framing")),
    pct_returned = sent_back_amount/(3*sent_amount)
  )

tparticipants <- read_csv(
  sprintf("../data/generated/trust_%s_participants.csv", DVERSION_TRUST),
  show_col_types = FALSE
) %>%
  mutate(
    experiment = factor(ifelse(
      experiment == "ftrust",
      "Business Framing", "Neutral Framing"
    ), c("Neutral Framing", "Business Framing"))
  )
```

## Descriptive statistics of pretest data to standardize the power tests

```
mn_sent_start <- mean(trounds$sent_amount[trounds$round == 1])
sd_sent <- sd(trounds$sent_amount)
mn_pct_returned_start <- mean(trounds$pct_returned[trounds$round == 1])
sd_pct_returned <- sd(trounds$pct_returned)

message(sprintf(
  "Mean start (SD all) sent: %.2f (%.2f)", mn_sent_start, sd_sent
))
```

Mean start (SD all) sent: 50.00 (21.46)

```
message(sprintf(
  "Mean start (SD all) pct_returned: %.2f (%.2f)",
  mn_pct_returned_start, sd_pct_returned
))
```

Mean start (SD all) pct\_returned: 0.47 (0.07)

```
# Some pretest regressions to see how rounds affect our DVs:

ols_sent_amount <- lm(sent_amount ~ round, data = trounds)
summary(ols_sent_amount)
```

Call:

```
lm(formula = sent_amount ~ round, data = trounds)
```

Residuals:

Min	1Q	Median	3Q	Max
-71.191	-5.782	6.349	12.743	24.546

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	51.8478	1.6098	32.21	<2e-16 ***
round	3.9343	0.2594	15.16	<2e-16 ***

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 18.25 on 598 degrees of freedom

Multiple R-squared: 0.2777, Adjusted R-squared: 0.2765

F-statistic: 230 on 1 and 598 DF, p-value: < 2.2e-16

```
summary(lm(sent_amount ~ round*experiment, data = trounds))
```

Call:

```
lm(formula = sent_amount ~ round * experiment, data = trounds)
```

Residuals:

Min	1Q	Median	3Q	Max
-62.385	-7.516	3.044	11.645	30.209

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	50.9000	2.1647	23.514	< 2e-16 ***
round	3.1485	0.3489	9.025	< 2e-16 ***
experimentBusiness Framing	1.8956	3.0613	0.619	0.53603
round:experimentBusiness Framing	1.5717	0.4934	3.186	0.00152 **

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 17.36 on 596 degrees of freedom

Multiple R-squared: 0.3492, Adjusted R-squared: 0.3459

F-statistic: 106.6 on 3 and 596 DF, p-value: < 2.2e-16

```
summary(lm(log(sent_amount) ~ round, data = trounds))
```

Call:

```
lm(formula = log(sent_amount) ~ round, data = trounds)
```

Residuals:

Min	1Q	Median	3Q	Max
-1.5648	-0.1087	0.1269	0.2100	0.3323

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	3.970360	0.026209	151.49	<2e-16 ***
round	0.050413	0.004224	11.94	<2e-16 ***

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2972 on 598 degrees of freedom

Multiple R-squared: 0.1924, Adjusted R-squared: 0.191

F-statistic: 142.4 on 1 and 598 DF, p-value: < 2.2e-16

```
summary(lm(log(sent_amount) ~ round*experiment, data = trounds))
```

Call:

```
lm(formula = log(sent_amount) ~ round * experiment, data = trounds)
```

Residuals:

Min	1Q	Median	3Q	Max
-1.47441	-0.13989	0.06614	0.18173	0.42271

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	3.951069	0.035335	111.816	< 2e-16 ***
round	0.038565	0.005695	6.772	3.05e-11 ***
experimentBusiness Framing	0.038580	0.049972	0.772	0.44039
round:experimentBusiness Framing	0.023695	0.008054	2.942	0.00339 **

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2833 on 596 degrees of freedom

Multiple R-squared: 0.2684, Adjusted R-squared: 0.2648

F-statistic: 72.9 on 3 and 596 DF, p-value: < 2.2e-16

```
fe_sent_amount <- feols(
  sent_amount ~ experiment | round, cluster = c("round", "group_id"),
  data = trounds
)
summary(fe_sent_amount)
```

OLS estimation, Dep. Var.: sent\_amount

```

Observations: 600
Fixed-effects: round: 10
Standard-errors: Clustered (round & group_id)
                  Estimate Std. Error t value Pr(>|t|)
experimentBusiness Framing    10.54    3.77481  2.7922 0.049202 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
RMSE: 17.1      Adj. R2: 0.356154
                Within R2: 0.087098

```

```
fixef(fe_sent_amount)$round
```

```

      1      2      3      4      5      6      7      8
44.73000 52.14667 59.14667 65.48000 70.48000 74.39667 77.01333 78.93000
      9     10
79.63000 80.21333

```

```

# Clearly not exponential but decreasing positive trend for rounds.
# Sticking to a linear trend for the estimation.

```

```
summary(lm(pct_returned ~ round, data = trounds))
```

```

Call:
lm(formula = pct_returned ~ round, data = trounds)

```

```

Residuals:
      Min       1Q   Median       3Q      Max
-0.13615  0.03051  0.03217  0.03341  0.13176

```

```

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.4653435   0.0060013   77.540  <2e-16 ***
round        0.0004145   0.0009672    0.429   0.668
---

```

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```

Residual standard error: 0.06805 on 598 degrees of freedom
Multiple R-squared:  0.000307, Adjusted R-squared:  -0.001365
F-statistic: 0.1836 on 1 and 598 DF, p-value: 0.6684

```

```
summary(lm(pct_returned ~ round*experiment, data = trounds))
```

Call:

```
lm(formula = pct_returned ~ round * experiment, data = trounds)
```

Residuals:

	Min	1Q	Median	3Q	Max
	-0.157231	0.009436	0.011962	0.052513	0.152976

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
(Intercept)	4.438e-01	8.073e-03	54.972	< 2e-16 ***
round	4.626e-04	1.301e-03	0.356	0.722315
experimentBusiness Framing	4.311e-02	1.142e-02	3.776	0.000175 ***
round:experimentBusiness Framing	-9.624e-05	1.840e-03	-0.052	0.958306

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.06473 on 596 degrees of freedom

Multiple R-squared: 0.09852, Adjusted R-squared: 0.09398

F-statistic: 21.71 on 3 and 596 DF, p-value: 2.349e-13

```
fe_pct_returned <- feols(
  pct_returned ~ experiment | round, cluster = c("round", "group_id"),
  data = trounds
)
summary(fe_pct_returned)
```

OLS estimation, Dep. Var.: pct\_returned

Observations: 600

Fixed-effects: round: 10

Standard-errors: Clustered (round & group\_id)

	Estimate	Std. Error	t value	Pr(> t )
experimentBusiness Framing	0.042585	0.00571	7.45849	0.0017267 **

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

RMSE: 0.06451 Adj. R2: 0.083271

Within R2: 0.098241

```
fixef(fe_pct_returned)$round
```

```
      1      2      3      4      5      6      7      8  
0.4453742 0.4436570 0.4454169 0.4462034 0.4456308 0.4465914 0.4470964 0.4471571  
      9     10  
0.4477981 0.4483806
```

```
# No round trend in pct_returned based on pretest data
```

## Equation-based Power Analysis based on Pretest Data

### Round Based Analysis

```
pwr.t.test(500, 5/sd_sent)
```

Two-sample t test power calculation

```
      n = 500  
      d = 0.2329834  
sig.level = 0.05  
  power = 0.9573092  
alternative = two.sided
```

NOTE: n is number in \*each\* group

```
pwr.t.test(d = 5/sd_sent, power = 0.8)
```

Two-sample t test power calculation

```
      n = 290.1558  
      d = 0.2329834  
sig.level = 0.05  
  power = 0.8  
alternative = two.sided
```

NOTE: n is number in \*each\* group

```
pr <- pwr.t.test(n = 500, power = 0.8)
sprintf("MDE Trust sent: %.2f", pr$d * sd_sent)
```

```
[1] "MDE Trust sent: 3.81"
```

```
sprintf("MDE Trust pct_returned: %.4f", pr$d * sd_pct_returned)
```

```
[1] "MDE Trust pct_returned: 0.0121"
```

## Participant and Dyad Based Analysis

```
mn_payoff_part <- mean(tparticipants$payoff)
sd_payoff_part <- sd(tparticipants$payoff)
sprintf("Mean (SD) of part payoff: %.2f (%.2f)", mn_payoff_part, sd_payoff_part)
```

```
[1] "Mean (SD) of part payoff: 1234.87 (212.49)"
```

```
pwr.t.test(100, (0.1*mn_payoff_part)/sd_payoff_part)
```

Two-sample t test power calculation

```
      n = 100
      d = 0.5811406
sig.level = 0.05
  power = 0.9833857
alternative = two.sided
```

NOTE: n is number in *each* group

```
pr <- pwr.t.test(n = 100, power = 0.8)
sprintf(
  "MDE Payoff part: %.2f (%.1f %% of mean)", pr$d * sd_payoff_part,
  100*(pr$d * sd_payoff_part)/mn_payoff_part
)
```

```
[1] "MDE Payoff part: 84.60 (6.9 % of mean)"
```



```

dyads <- tparticipants %>%
  group_by(experiment, session_code, group_id) %>%
  summarise(sum_payoff = sum(payload), .groups = "drop")

mn_payoff_dyads <- mean(dyads$sum_payoff)
sd_payoff_dyads <- sd(dyads$sum_payoff)
sprintf("Mean (SD) of dyad payoff: %.2f (%.2f)", mn_payoff_dyads, sd_payoff_dyads)

```

```
[1] "Mean (SD) of dyad payoff: 2469.73 (317.12)"
```

```
pwr.t.test(50, (0.1*mn_payoff_dyads)/sd_payoff_dyads)
```

Two-sample t test power calculation

```

      n = 50
      d = 0.7788104
sig.level = 0.05
  power = 0.970997
alternative = two.sided

```

NOTE: n is number in *each* group

```

pr <- pwr.t.test(n = 50, power = 0.8)
sprintf(
  "MDE Payoff dyads: %.2f (%.1f %% of mean)", pr$d * sd_payoff_dyads,
  100*(pr$d * sd_payoff_dyads)/mn_payoff_dyads
)

```

```
[1] "MDE Payoff dyads: 179.44 (7.3 % of mean)"
```

## Simulation for regression based tests

```

if (file.exists("../data/generated/trust_sim_results.csv")) {
  trust_sim_results <- read_csv("../data/generated/trust_sim_results.csv", show_col_types
} else {

```

```

sim_data <- function(parms, runs = 50, rounds = 10) {
  cl <- function(val, vmin = 0, vmax = 100) {
    if (val > vmax) return(as.integer(vmax))
    if (val < vmin) return(as.integer(vmin))
    as.integer(round(val))
  }
  tr <- function(rd, exp, g, parms) {
    tsent_start = ifelse(
      exp == "ftrust",
      parms$tsent_start + parms$tsent_start_teffect,
      parms$tsent_start
    )
    tsent_grate = ifelse(
      exp == "ftrust",
      parms$tsent_grate + parms$tsent_grate_teffect,
      parms$tsent_grate
    )
    tpct_returned_start = ifelse(
      exp == "ftrust",
      parms$tpct_returned_start + parms$tpct_returned_start_teffect,
      parms$tpct_returned_start
    )
    tpct_returned_grate = ifelse(
      exp == "ftrust",
      parms$tpct_returned_grate + parms$tpct_returned_grate_teffect,
      parms$tpct_returned_grate
    )

    tibble(
      experiment = factor(ifelse(
        exp == "ftrust",
        "Business Framing", "Neutral Framing"
      ), c("Neutral Framing", "Business Framing")),
      group_id = g,
      round = rd,
      sent_amount = cl(
        tsent_start + (rd-1)*tsent_grate + rnorm(1, 0, parms$tsent_evar),
        0, 100
      ),
      sent_back_amount = cl(
        3*(tpct_returned_start + (rd-1)*tpct_returned_grate +

```

```

        rnorm(1, 0, parms$tpct_returned_evar))*sent_amount ,
        0, 3*sent_amount
    ),
    pct_returned = sent_back_amount/(3*sent_amount)
  )
}
bind_rows(
  lapply(
    c("trust", "ftrust"),
    function(e) bind_rows(
      lapply(
        1:runs,
        function(g) bind_rows(lapply(1:rounds, tr, e, g, parms))
      )
    )
  )
)
}

run_trust_sim <- function(te) {
  parms <- tibble(
    tsent_start = mn_sent_start,
    tsent_start_teffect = te$teffect_sent,
    tsent_grate = coef(ols_sent_amount)[2],
    tsent_grate_teffect = te$teffect_sent_grate,
    tsent_evar = sd_sent,
    tpct_returned_start = mn_pct_returned_start,
    tpct_returned_start_teffect = te$teffect_pct_returned,
    tpct_returned_grate = 0,
    tpct_returned_grate_teffect = te$teffect_pct_returned_grate,
    tpct_returned_evar = sd_pct_returned
  )
  smp <- sim_data(parms)
  ci_trust_sent_fe <- confint(
    feols(sent_amount ~ experiment | round, cluster = c("round", "group_id"), data = smp)
  )
  ci_trust_sent_round_fe <- confint(
    feols(sent_amount ~ experiment*round, cluster = c("round", "group_id"), data = smp)
  )
  ci_trust_pct_returned_fe <- confint(feols(
    pct_returned ~ experiment | round, cluster = c("round", "group_id"),

```

```

    data = smp %>% filter(sent_amount > 0)
  ))
  ci_trust_pct_returned_round_fe <- confint(feols(
    pct_returned ~ experiment*round, cluster = c("round", "group_id"),
    data = smp %>% filter(sent_amount > 0)
  ))
  tibble(
    sent_teffect_lb = pull(ci_trust_sent_fe[1]),
    sent_teffect_ub = pull(ci_trust_sent_fe[2]),
    sent_round_teffect_lb = ci_trust_sent_round_fe[4, 1],
    sent_round_teffect_ub = ci_trust_sent_round_fe[4, 2],
    pct_returned_teffect_lb = pull(ci_trust_pct_returned_fe[1]),
    pct_returned_teffect_ub = pull(ci_trust_pct_returned_fe[2]),
    pct_returned_round_teffect_lb = ci_trust_pct_returned_round_fe[4, 1],
    pct_returned_round_teffect_ub = ci_trust_pct_returned_round_fe[4, 2],
  )
}

sim_power_trust <- function(plan) {
  sim_results <- bind_rows(
    lapply(
      1:nrow(plan),
      function(x) {
        message(
          sprintf("Running trust sim, plan row %d of %d...", x, nrow(plan)),
          appendLF = F
        )
        rv <- bind_cols(plan[x,], run_trust_sim(plan[x,]))
        message("")
        rv
      }
    )
  )
}

plan <- bind_rows(
  expand_grid(
    n = 1:100,
    teffect_sent = 1:5,
    teffect_sent_grate = 0,
    teffect_pct_returned = c(0.005, 0.01, 0.015, 0.02, 0.025),

```

```

      teffect_pct_returned_grate = 0,
    ),
    expand_grid(
      n = 1:100,
      teffect_sent = 0,
      teffect_sent_grate = c(0.5, 1, 1.5, 2, 2.5),
      teffect_pct_returned = 0,
      teffect_pct_returned_grate = c(0.01, 0.02, 0.03, 0.04, 0.05)/5,
    )
  )
}

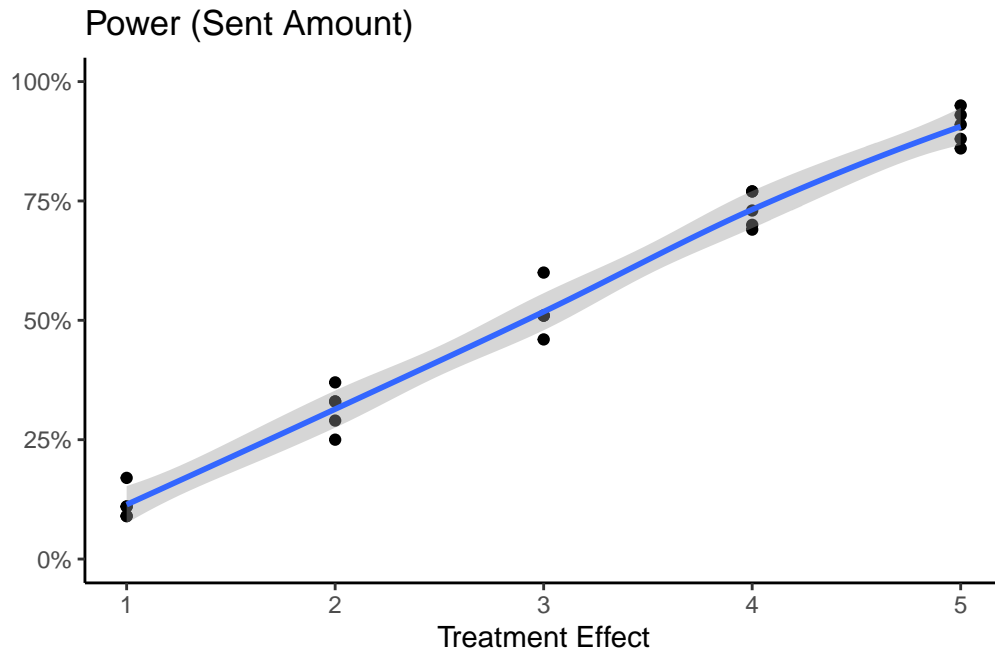
message(sprintf("Starting trust power simulations (%d runs): %s", nrow(plan), Sys.time()))
trust_sim_results <- sim_power_trust(plan)
write_csv(trust_sim_results, "../data/generated/trust_sim_results.csv")
message(sprintf("Done: %s", Sys.time()))
}

trust_power <- trust_sim_results %>%
  group_by(
    teffect_sent, teffect_sent_grate,
    teffect_pct_returned, teffect_pct_returned_grate
  ) %>%
  summarise(
    power_sent = mean(sent_teffect_lb > 0),
    power_sent_round = mean(sent_round_teffect_lb > 0),
    power_pct_returned = mean(pct_returned_teffect_lb > 0),
    power_pct_returned_round = mean(pct_returned_round_teffect_lb > 0),
    .groups = "drop"
  )

ggplot(
  trust_power %>% filter(teffect_sent_grate == 0),
  aes(x = teffect_sent, y = power_sent)
) + geom_point() + geom_smooth() +
  scale_y_continuous(limits = c(0, 1), labels = scales::percent) +
  labs(title = "Power (Sent Amount)", x = "Treatment Effect", y = "") +
  theme_classic()

```

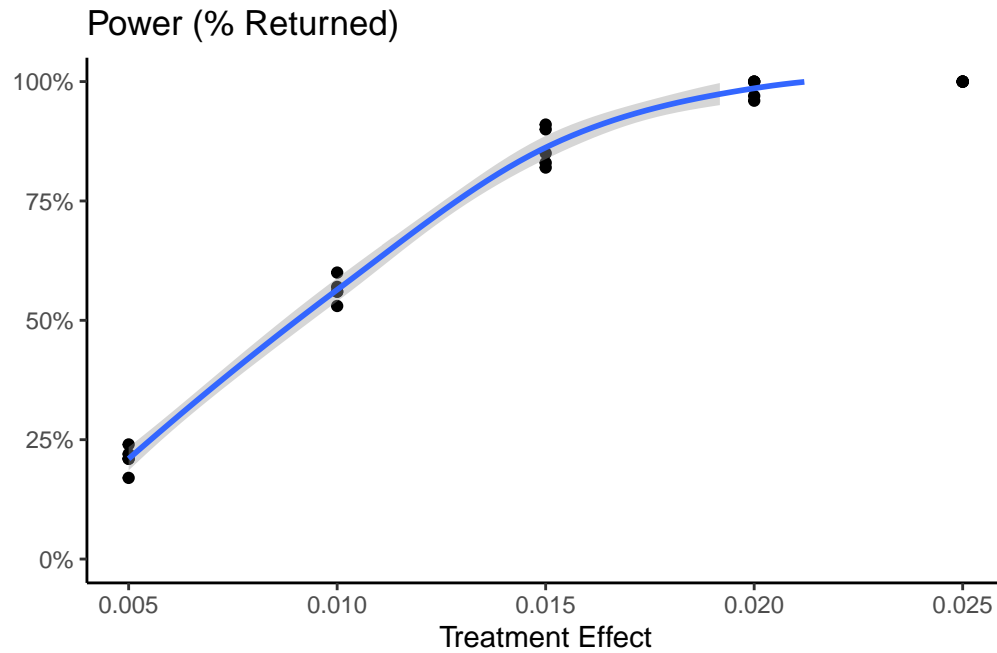
`geom\_smooth()` using method = 'loess' and formula = 'y ~ x'



```
ggplot(
  trust_power %>% filter(teffect_sent_grate == 0),
  aes(x = teffect_pct_returned, y = power_pct_returned)
) + geom_point() + geom_smooth() +
  scale_y_continuous(limits = c(0, 1), labels = scales::percent) +
  labs(title = "Power (% Returned)", x = "Treatment Effect", y = "") +
  theme_classic()
```

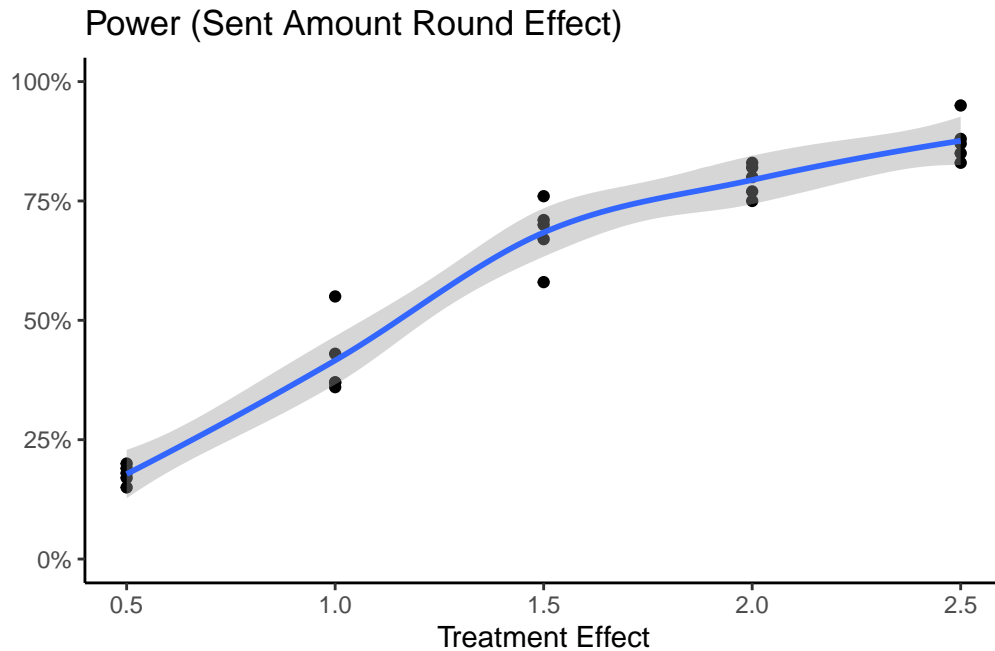
`geom\_smooth()` using method = 'loess' and formula = 'y ~ x'

Warning: Removed 15 rows containing missing values (`geom\_smooth()`).



```
ggplot(
  trust_power %>% filter(teffect_sent == 0),
  aes(x = teffect_sent_grate, y = power_sent_round)
) + geom_point() + geom_smooth() +
  scale_y_continuous(limits = c(0, 1), labels = scales::percent) +
  labs(title = "Power (Sent Amount Round Effect)", x = "Treatment Effect", y = "") +
  theme_classic()
```

`geom\_smooth()` using method = 'loess' and formula = 'y ~ x'



```
ggplot(
  trust_power %>% filter(teffect_sent == 0),
  aes(x = teffect_pct_returned_grate, y = power_pct_returned_round)
) + geom_point() + geom_smooth() +
  scale_y_continuous(limits = c(0, 1), labels = scales::percent) +
  labs(title = "Power (% Returned Round Effect)", x = "Treatment Effect", y = "") +
  theme_classic()
```

``geom_smooth()`` using method = 'loess' and formula = 'y ~ x'

Warning: Removed 22 rows containing missing values (``geom_smooth()``).



