Empowering Girls in STEM: The Role of Female Representation in Shaping Children's

Structural Reasoning About Gender Disparities

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Abstract

Gender bias in STEM educational materials remains a significant barrier to gender equity, with textbooks and online resources often underrepresenting female scientists. This study investigates how exposure to female representation in STEM textbooks influences children's structural reasoning about gender disparities in STEM achievement. 96 children aged 5–8 were assigned to one of three conditions Findings show that .

Keywords: Gender Bias in STEM, Structural Reasoning, Educational Materials

Empowering Girls in STEM: The Role of Female Representation in Shaping Children's Structural Reasoning About Gender Disparities

Introduction

Gender bias in STEM often hides in plain sight, subtly embedded in textbooks and classroom materials. Women are significantly underrepresented in school textbooks, particularly in professional STEM contexts (Crawfurd et al., 2024; Kerkhoven et al., 2016). An analysis of over 1,200 textbooks from 34 countries found that female figures appear less frequently in STEM contexts, reinforcing traditional gender roles and shaping students' perceptions of who is suited for science fields (Crawfurd et al., 2024). Similarly, online science education materials tend to portray male characters as more engaged in STEM activities, reinforcing the association of STEM with masculinity (Kerkhoven et al., 2016). When girls consistently see male scientists, mathematicians, and engineers conveyed as the primary figures of success, they receive an implicit message about who "belongs" in these fields, which can discourage them from envisioning themselves as future STEM professionals (Master, 2021). Thus, balanced gender representation in educational materials is important, as biased portrayals can dissuade girls from pursuing STEM by influencing their beliefs about their abilities and potential in these fields.

How does exposure to structural information, such as the gender of scientists in STEM textbooks, impact children's structural reasoning about gender-based disparities in STEM achievement? We hypothesize that exposure to structural information demonstrating that the gender of scientists in STEM textbooks influences girls' achievement in STEM activities will increase children's likelihood of attributing gender disparities in STEM achievement to structural factors. Grounded in social identity and stereotype threat theories, such exposure helps children view gender disparities as societal barriers rather than personal limitations, reducing stereotype threat and fostering belonging (Master, 2021; Kim et al., 2018).

Method

Participants

The study will recruit 96 girls aged 5–8 from a university infant database. This sample size and age range were chosen based on a prior study, which investigated children's structural reasoning and demonstrated that structural reasoning begins developing around age 5 (Amemiya & Bian, 2024).

Procedure

Participants will be tested via Zoom, using Qualtrics surveys. Each participant will receive a $5 Amazon gift card as compensation.

Children will be presented with two hypothetical scenarios involving competitions in a fictional town: a robot-building competition and a puzzle-solving competition. First, children will be randomly assigned to one of three conditions in the robot-building scenario: baseline, within, or between conditions. In all conditions, participants will be told that children in the scenario read a textbook on robot building and participate in a robot-building competition spanning four hypothetical years. In the baseline condition, the textbook will not feature any specific scientists, and boys will win the competition in all years. In the within condition, the textbook will feature female scientists for the first two years and male scientists for the last two years, with winners' genders corresponding to the gender of the scientists. In the between condition, the textbook will feature male scientists across all four years, with boys winning each year. A condition featuring only female scientists will not be included because, in all conditions, children will be asked to reason why girls are underrepresented in STEM activities, requiring at least one year where boys win. This design also reflects reality, as most scientists children hear about are male. The goal is to test whether children can identify this lack of female scientists as a structural barrier for girls. Then, the puzzle-solving competition, included as a baseline condition, will be presented to children to assess whether they can generalize their structural reasoning to another context or not.

After each scenario, open-ended questions will prompt them to explain why no girls won in the last year, and closed-ended questions will ask them to evaluate intrinsic, random, and

structural explanations provided by fictional characters as accurate or inaccurate.

Results

```
Loading required package: carData


Attaching package: 'boot'


The following object is masked from 'package:car':


    logit


Loading required package: Matrix


-- Attaching core tidyverse packages ---------------------- tidyverse 2.0.0 --
v dplyr     1.1.4      v readr     2.1.5
v forcats   1.0.0      v stringr   1.5.1
v lubridate 1.9.4      v tibble    3.2.1
v purrr     1.0.2      v tidyr     1.3.1
-- Conflicts --------------------------------------- tidyverse_conflicts() --
x tidyr::expand() masks Matrix::expand()
x dplyr::filter() masks stats::filter()
x dplyr::lag()    masks stats::lag()
x tidyr::pack()   masks Matrix::pack()
x dplyr::recode() masks car::recode()
x purrr::some()   masks car::some()
x tidyr::unpack() masks Matrix::unpack()
i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to


Attaching package: 'rcompanion'
```

The following object is masked from 'package:effectsize':

    phi

Attaching package: 'nlme'

The following object is masked from 'package:dplyr':

    collapse

The following object is masked from 'package:lme4':

    lmList

[1] "#FBB4AE" "#B3CDE3" "#CCEBC5" "#DECBE4" "#FED9A6" "#FFFFCC" "#E5D8BD"
[8] "#FDDAEC" "#F2F2F2"

Attaching package: 'Hmisc'

The following objects are masked from 'package:dplyr':

    src, summarize

The following objects are masked from 'package:base':

```
    format.pval, units
```

Descriptive Statistics

	count	mean_age	sd_age	min_age	max_age	median_age
1	65	6.415385	1.144174	5	8	6

	Condition	n	Proportion
1	Baseline	24	36.92308
2	Between	20	30.76923
3	Within	21	32.30769

Using str() for LO:11

	age5_count	baseline_exists
1	19	TRUE

Robot Building Open-ended Questions

Warning in chisq.test(data$Condition, data$robot_OE_cat): Chi-squared
approximation may be incorrect

    Pearson's Chi-squared test

data: data$Condition and data$robot_OE_cat
X-squared = 31.934, df = 10, p-value = 0.0004107

Warning in chisq.test(data$Condition, data$puzzle_OE_cat): Chi-squared
approximation may be incorrect

    Pearson's Chi-squared test

data: data$Condition and data$puzzle_OE_cat
X-squared = 8.0726, df = 8, p-value = 0.4264

to check if Condition (Baseline, Between, Within) is associated with robot_OE_cat and puzzle_OE_cat.

```
Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

Call:
glm(formula = robot.open.struc ~ Condition * AgeYears * Gender,
    family = "binomial", data = data)


Deviance Residuals:
     Min        1Q     Median        3Q        Max
 -1.59865  -0.00005  -0.00005   0.00000    1.58012


Coefficients:
                                        Estimate Std. Error z value Pr(>|z|)
(Intercept)                            -2.057e+01  2.628e+04  -0.001    0.999
ConditionBetween                       -1.254e+02  3.678e+04  -0.003    0.997
ConditionWithin                         2.019e+01  2.628e+04   0.001    0.999
AgeYears                               -2.150e-07  4.144e+03   0.000    1.000
GenderMale                             -1.961e-06  4.164e+04   0.000    1.000
ConditionBetween:AgeYears               1.825e+01  5.245e+03   0.003    0.997
ConditionWithin:AgeYears                1.900e-01  4.144e+03   0.000    1.000
ConditionBetween:GenderMale            -4.490e+00  5.784e+04   0.000    1.000
ConditionWithin:GenderMale             -2.988e+00  4.164e+04   0.000    1.000
AgeYears:GenderMale                     3.036e-07  6.498e+03   0.000    1.000
ConditionBetween:AgeYears:GenderMale    6.478e-01  8.210e+03   0.000    1.000
ConditionWithin:AgeYears:GenderMale     3.014e-01  6.498e+03   0.000    1.000


(Dispersion parameter for binomial family taken to be 1)
```

```
    Null deviance: 70.227  on 64  degrees of freedom
Residual deviance: 33.040  on 53  degrees of freedom
AIC: 57.04
```

```
Number of Fisher Scoring iterations: 19
```

To check whether different conditions, age, or gender influence the likelihood of providing a structural explanation.
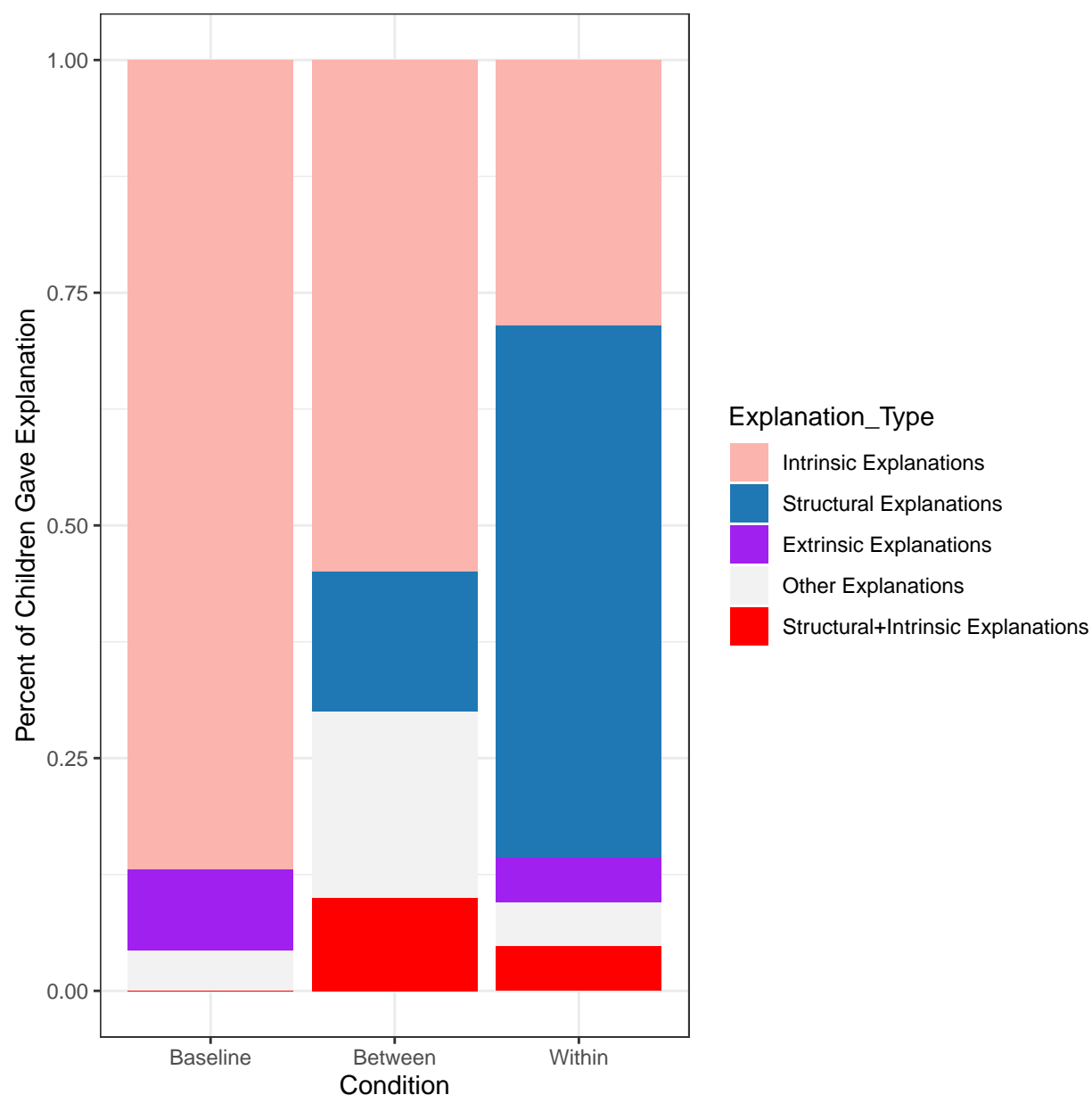
```
ConditionBetween
    3.337319e-55
```

```
ConditionWithin
     584983822
```

The odds ratio tells us how much more or less likely children in Between and Within conditions are to give structural explanations, compared to Baseline.

	extrinsic	intrinsic	other	structural	structural + intrinsic
Baseline	1	2	20	1	0	0
Between	0	0	11	4	3	2
Within	0	1	6	1	12	1

Puzzle Solving Open-ended Questions

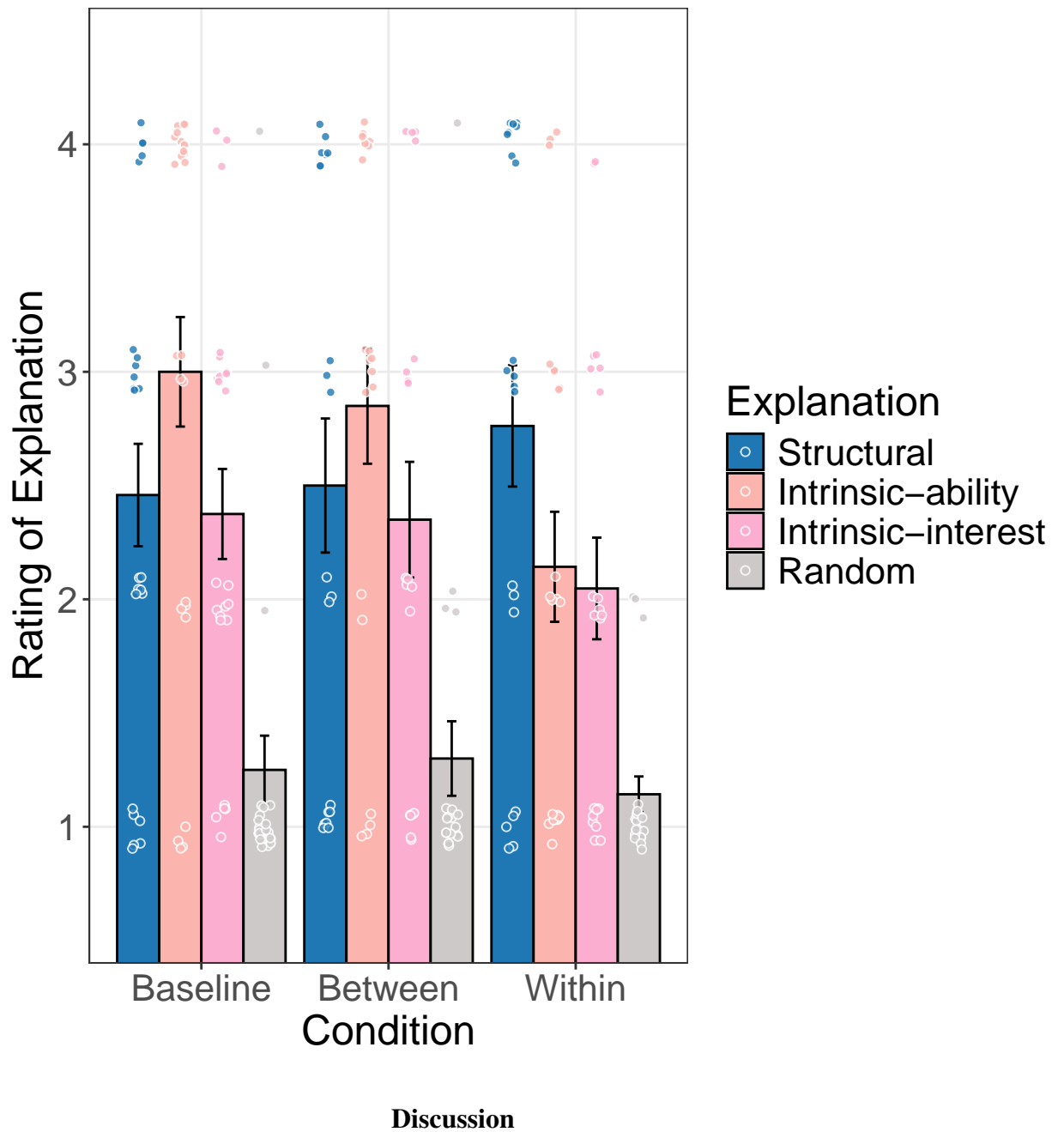|	extrinsic	intrinsic	other	structural	structural+intrinsic
Baseline	1	19	0	4	0
Between	0	16	2	1	1
Within	2	15	1	3	0
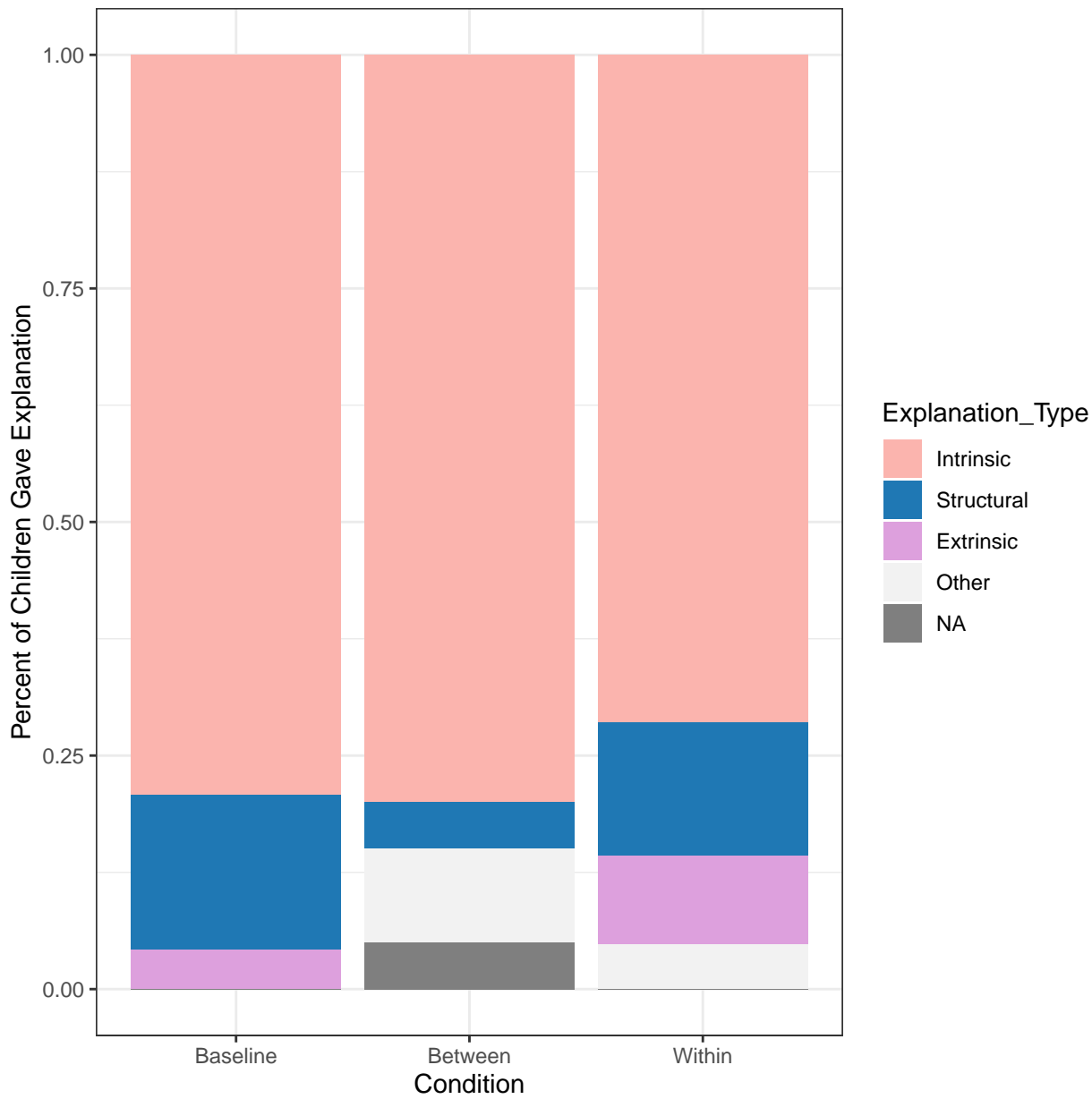
#Closed-ended Questions

Close-ended Questions

```
No summary function supplied, defaulting to `mean_se()`
```
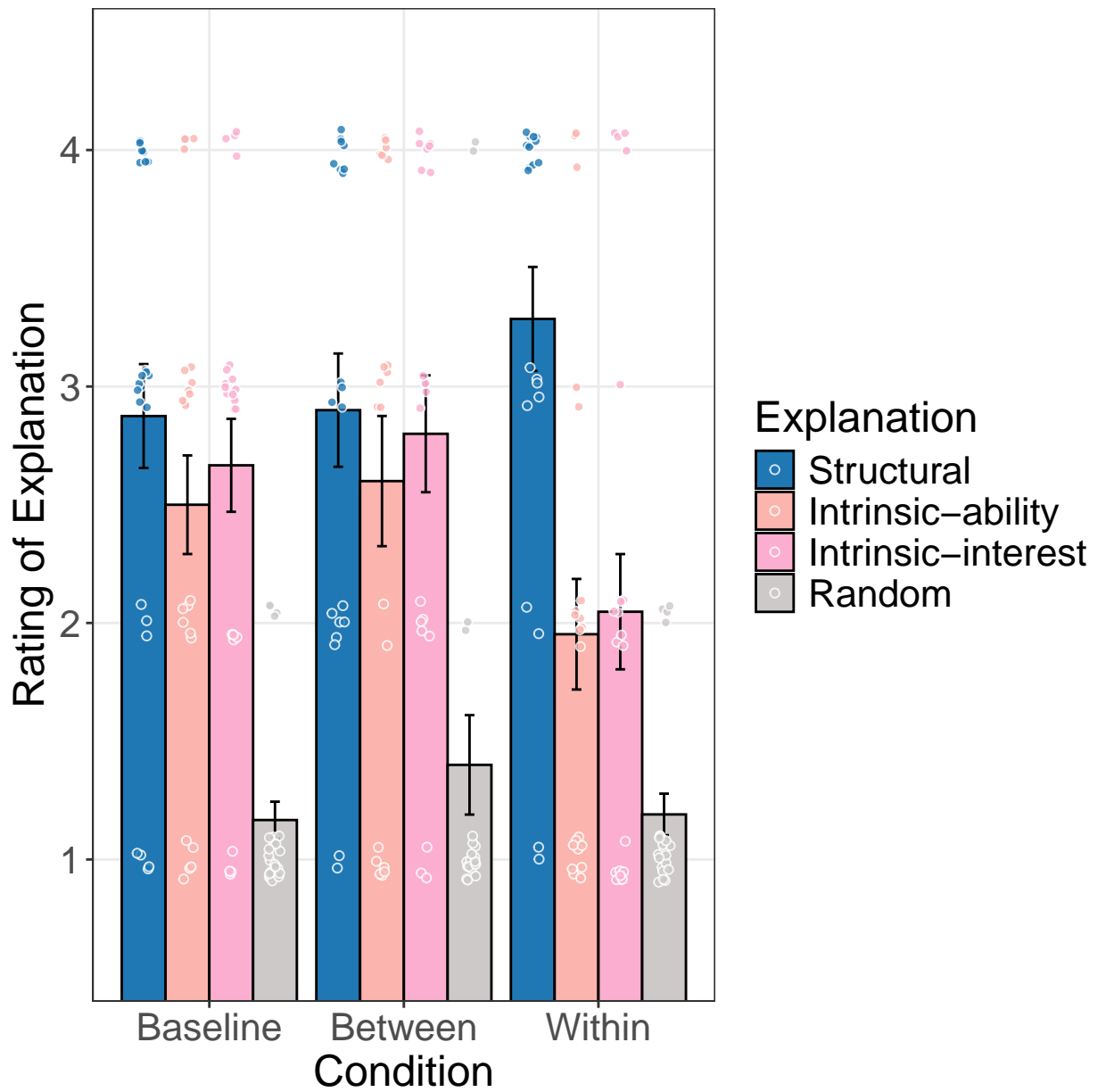
No summary function supplied, defaulting to `mean_se()`

Discussion

think about how we can help children generalize it to another scenario (discussion section)

Limitations and Future Directions

Conclusion

Appendix

Title for Appendix