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

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Introduction

Gender Bias in STEM Educational Materials

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 (Kim et al., 2018; Master, 2021).

Psychological Mechanisms Underlying Gender Stereotypes in STEM

Master (2021) explains that stereotype threat occurs when individuals become aware of

negative stereotypes about their social group. For example, when girls are reminded of the stereotype that "boys are better at math," they may experience heightened anxiety and reduced confidence, leading to lower performance. Over time, this repeated experience of underperformance can create a self-fulfilling prophecy, where girls disengage from STEM fields altogether to avoid the stress of confronting stereotypes. Social identity theory further explains how girls' sense of belonging and self-concept are influenced by group identification. This theory posits that individuals derive a significant part of their identity from the social groups to which they belong (Kim et al., 2018). For girls, strongly identifying with their gender may lead them to internalize the perception that STEM is a "male" domain, particularly when female scientists are absent in educational materials. This lack of female representation reinforces the belief that STEM is not a space where they belong, further discouraging them from participating in STEM activities (Kim et al., 2018; Master, 2021). Therefore, female figures in STEM textbooks are crucial; they provide positive examples that challenge gender stereotypes, demonstrating that women can thrive in STEM.

The Role of Structural Reasoning in Reducing Gender Disparities

Female representation not only inspires girls to consider STEM careers but also helps them understand structural barriers to gender equity, an approach more effective than individual reasoning; individual reasoning often places the burden on girls to overcome obstacles alone, while structural reasoning encourages them to view and address challenges as part of broader societal structures. When girls view gender gaps in STEM as personal limitations, it reinforces stereotypes and lowers self-efficacy; in contrast, structural reasoning reframes these gaps as outcomes of systemic barriers—such as biased educational resources or gender discrimination—that restrict women's participation in STEM (Amemiya & Bian, 2024). Female figures are pivotal in creating an environment that prevents individual reasoning. The representation can normalize women's presence in STEM, signaling that success in these fields is not limited to men, reducing stereotype threat (Master, 2021). Also, it can help girls begin to consider systemic factors rather than solely personal shortcomings as explanations for gender

disparities (Breda et al., 2023). Additionally, structural reasoning aligns with social identity theory by reinforcing that girls are not inherently excluded from STEM. Instead, they are part of a group facing societal bias, fostering a sense of belonging and empowering them to challenge structural inequities.

The Impact of Female Representation on STEM Engagement

Exposing girls to female representation in STEM can significantly enhance their motivation to pursue STEM careers and reduce gender biases. Diverse STEM female figures in media and educational settings foster a positive association of women with STEM fields from an early age (Kong et al., 2020). Moreover, encounters with female scientists can increase girls' STEM aspirations and counteract stereotypes (Breda et al., 2023; González-Pérez et al., 2020; Master, 2021)

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: usethis

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"
```

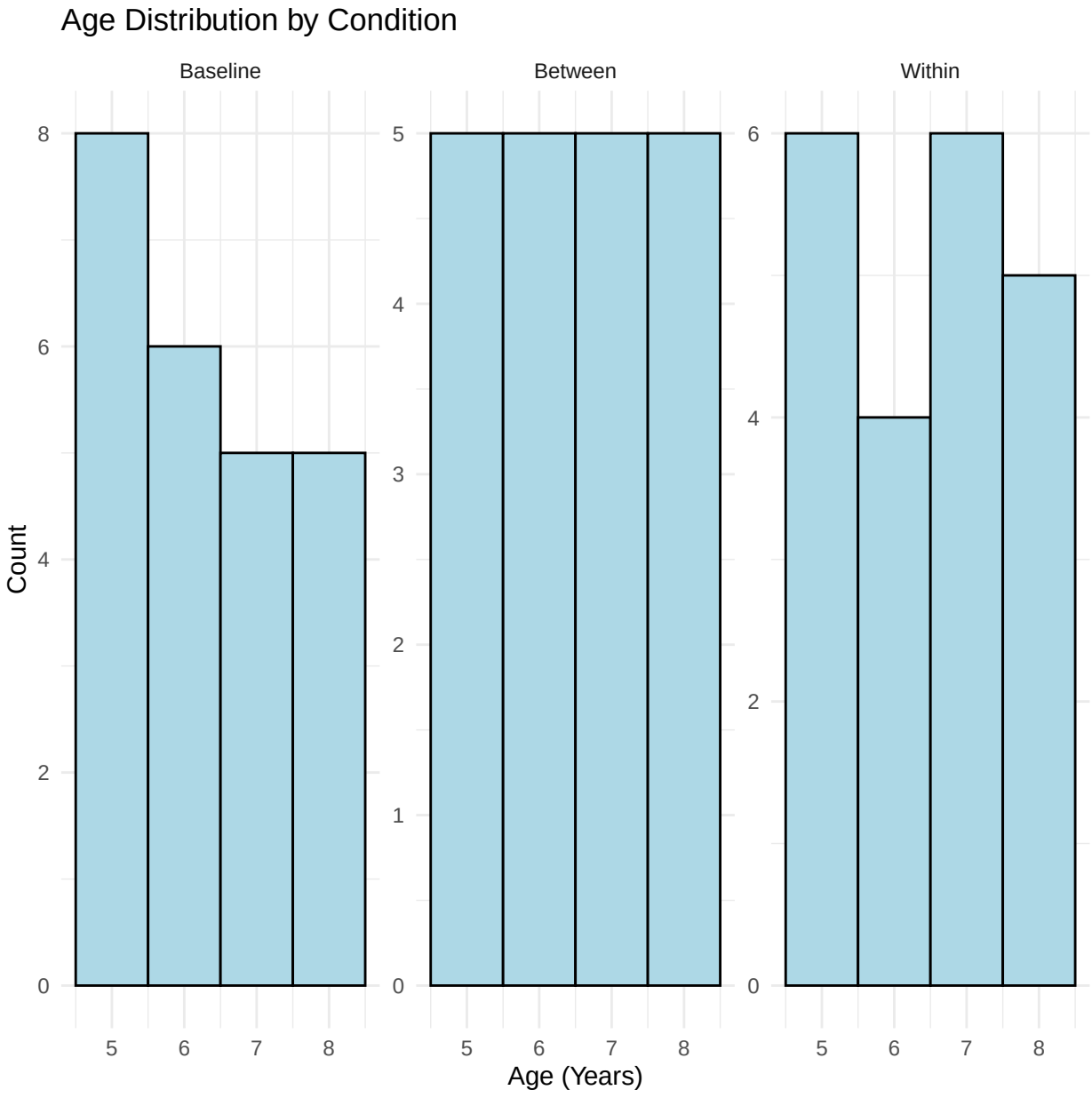
```
Attaching package: 'Hmisc'

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

    src, summarize

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

    format.pval, units
```

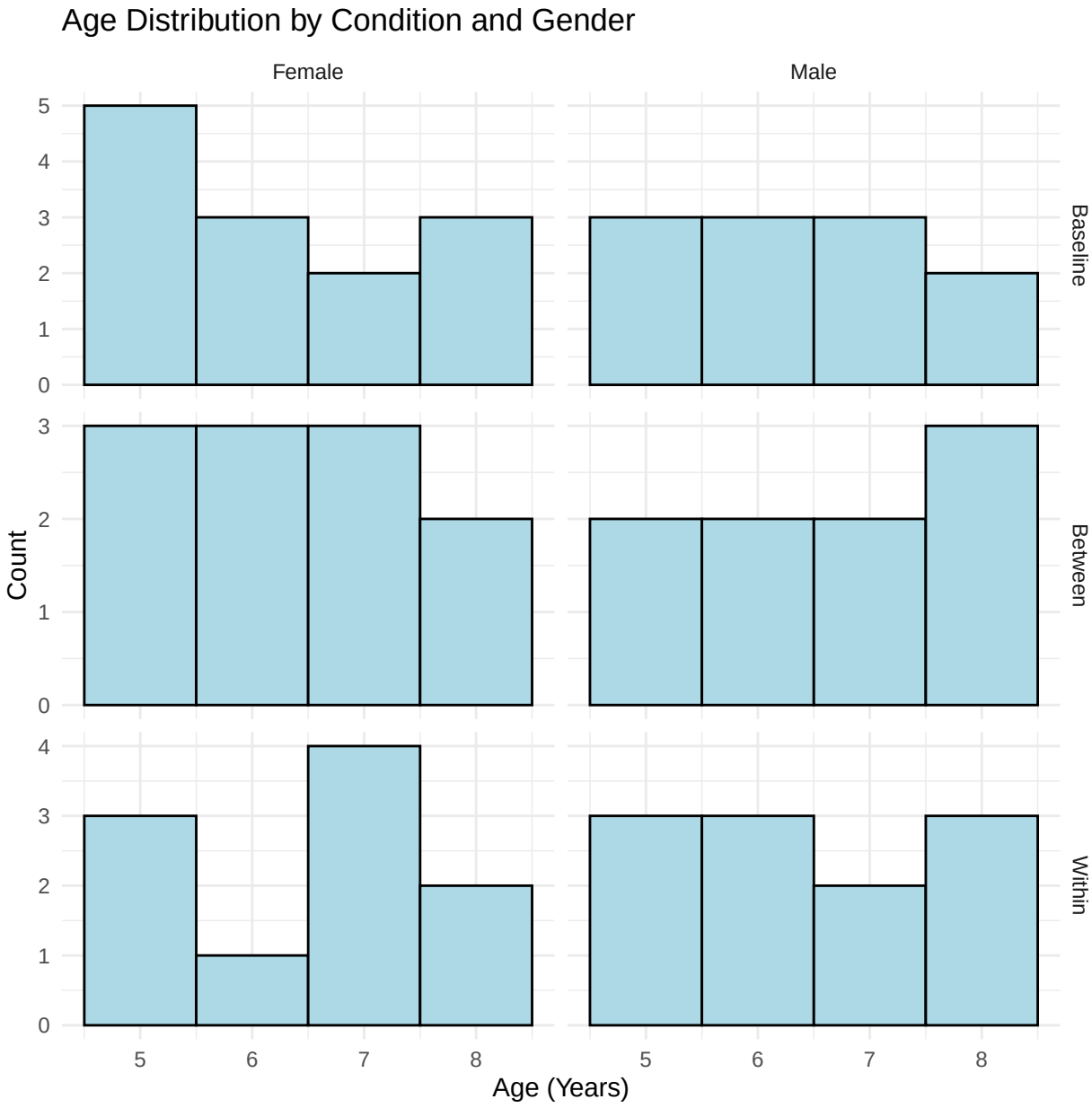
Descriptive Statistics

```
  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 facets for LO:15





Using str() for LO:11

```
  age5_count baseline_exists
1         19            TRUE
```

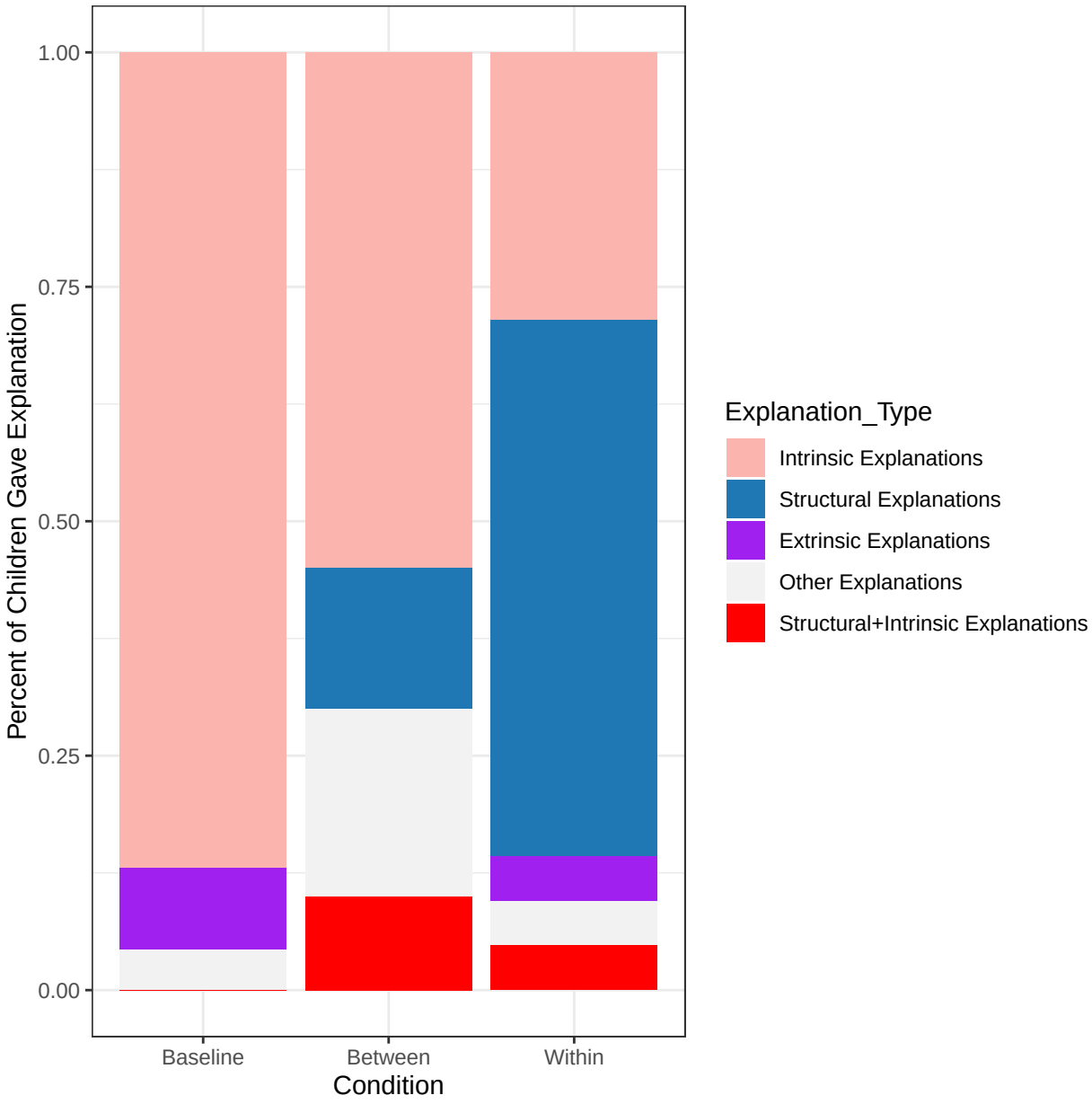
Robot Building Open-ended Questions

```
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
```

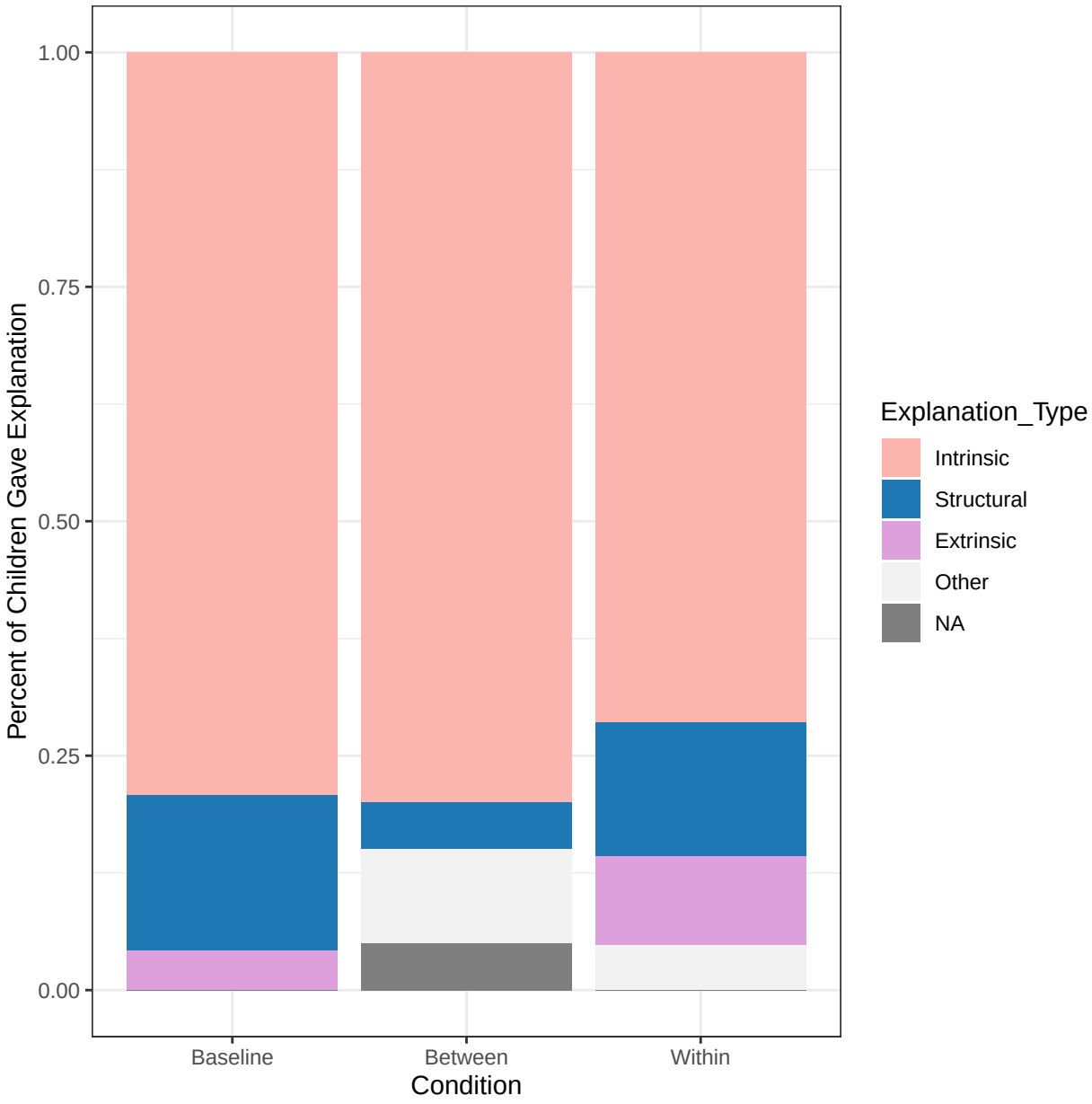
The test for Condition and robot_OE_cat revealed a significant association, $\chi^2(10) = 31.93$, $p = 0.00041$, indicating that participants' responses in the robot open-ended category varied significantly across conditions. In contrast, the chi-square test for Condition and puzzle_OE_cat did not yield significant results, $\chi^2(8) = 8.07$, $p = 0.4264$, suggesting that responses in the puzzle open-ended category were not significantly different across conditions.

	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



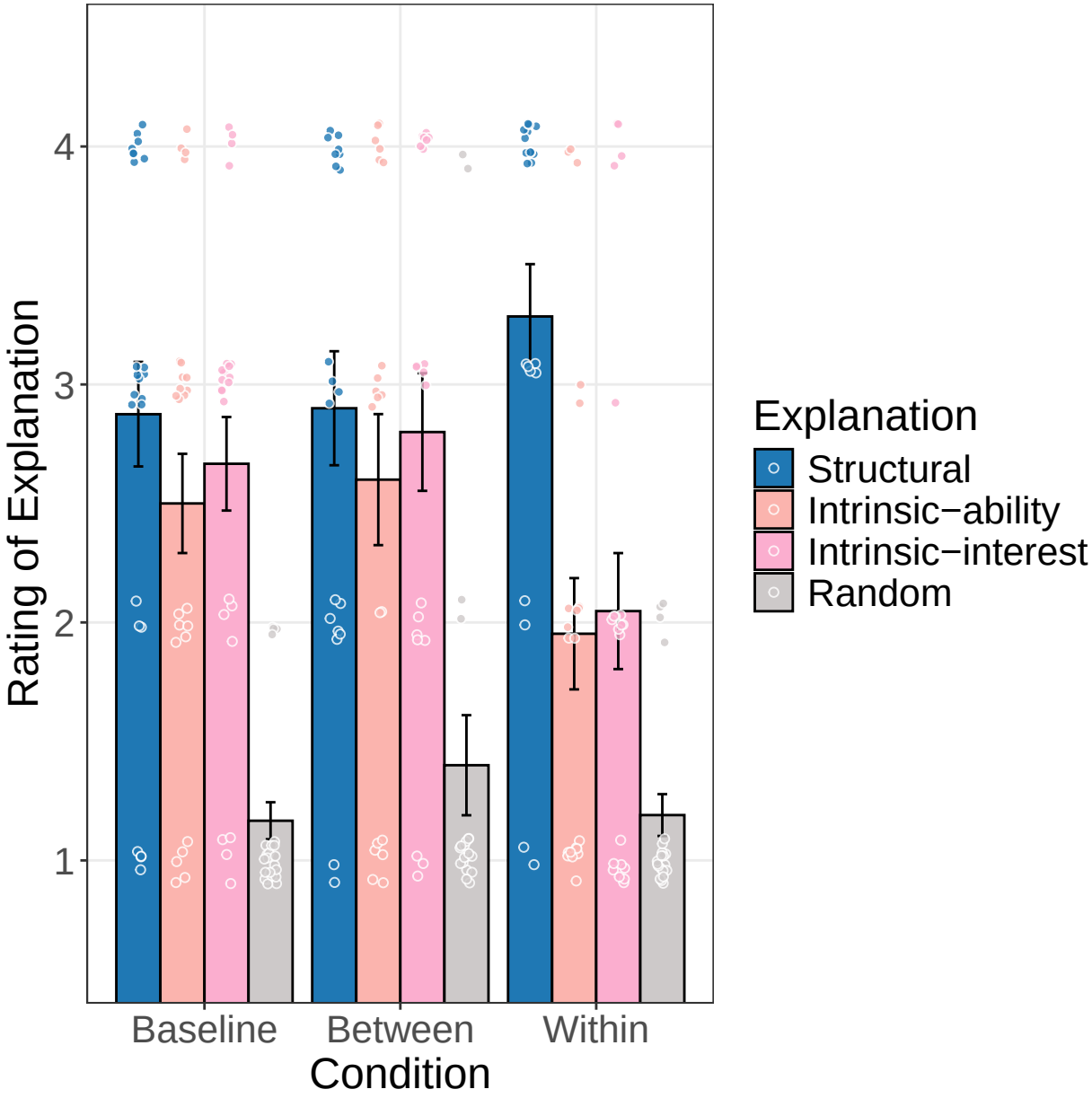
Closed-ended Questions

```
    Two Sample t-test


data:  robot_structural by Condition
t = -0.0769, df = 42, p-value = 0.9391
alternative hypothesis: true difference in means between group Baseline and group Betwee
95 percent confidence interval:
```

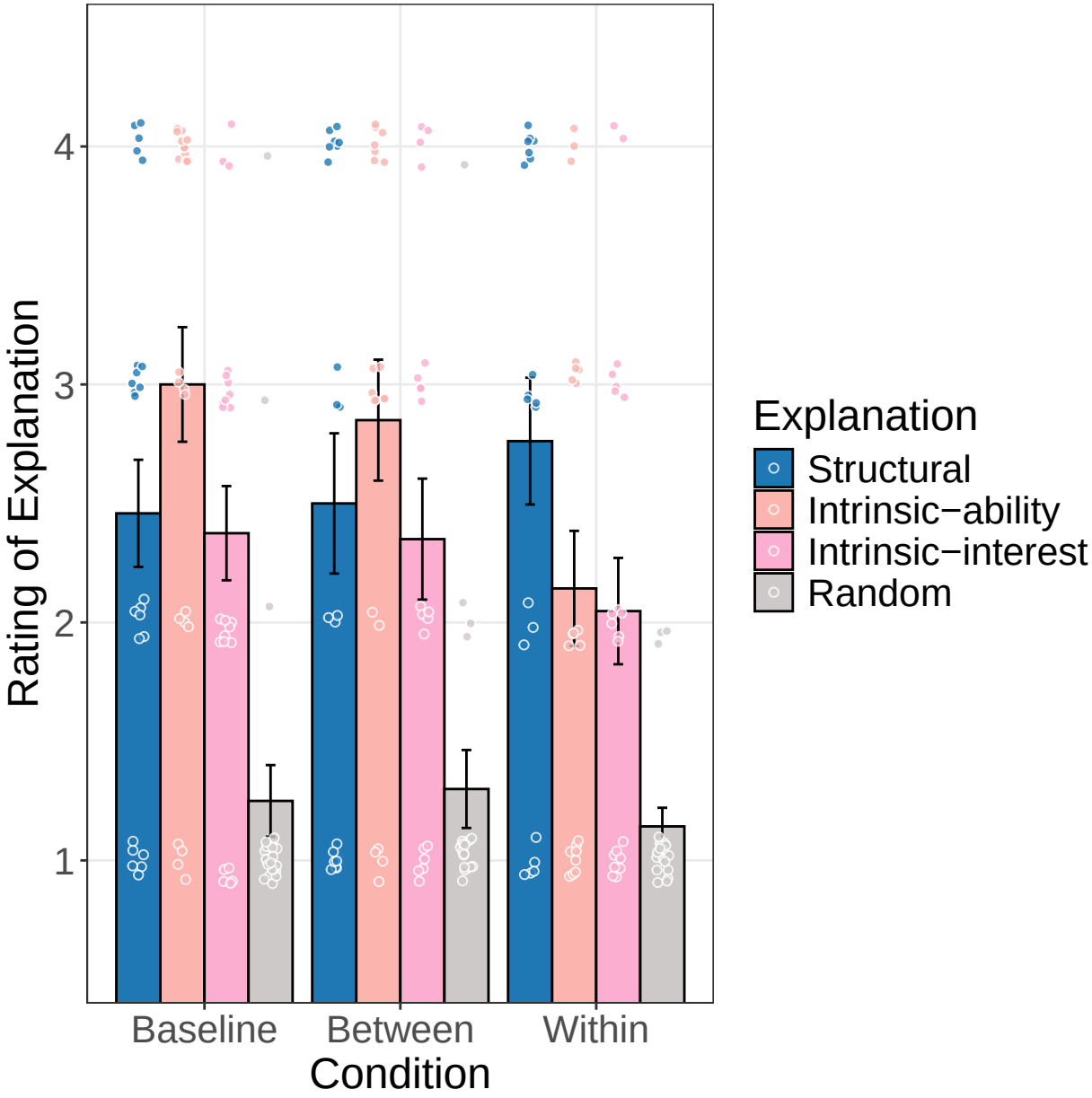
```
 -0.6810767  0.6310767
sample estimates:
mean in group Baseline  mean in group Between
                 2.875                  2.900


    Two Sample t-test

data:  robot_structural by Condition
t = -1.316, df = 43, p-value = 0.1952
alternative hypothesis: true difference in means between group Baseline and group Within
95 percent confidence interval:
 -1.0401225  0.2186939
sample estimates:
mean in group Baseline   mean in group Within
              2.875000               3.285714
```

A two-sample t-test was conducted to compare robot structural ratings between the Baseline and Between conditions. The results indicated no statistically significant difference between the two groups, t(42) = -0.08, p = .939, 95% CI [-0.68, 0.63]. A two-sample t-test was conducted to compare robot structural ratings between the Baseline and Within conditions. The results indicated that there was no statistically significant difference between the two groups, t(43) = -1.32, p = .195, 95% CI [-1.04, 0.22]. These findings suggest that Condition did not have a meaningful effect on robot structural ratings.

```
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

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