Reproducible RMarkdown with GitHub HW:

V1 of IQ Report w/`999` Outlier

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Abstract

In this report, the relationship between residential proximity to a lead-emitting smelter and IQ scores in children was briefly explored using a subset of data from a 1975 CDC study. Descriptive statistics and visualizations revealed a potentially erroneous IQ value of 999 in the `FAR` group, which inflated the mean and standard deviation for that group. Before drawing any final conclusions about the effect of smelter proximity on neurological function, this outlying observation must be addressed.

Background

Lead is a highly toxic substance that affects nearly every organ system in the body when ingested directly. At lower, indirect exposure levels, the primary biological effect is damage to the nervous system, though the threshold for safe lead exposure remains a subject of scientific debate. To examine the relationship between low-level lead absorption and neurological function, researchers led by the CDC conducted a study of children aged 3 to 15 years in El Paso, Texas, who lived at varying distances from a large lead-emitting ore smelter (Landrigan et al., 1975). This brief exploratory analysis uses a subset of the original data, comprising 124 observations without any filtering and consisting of just two variables: residential proximity to the smelter (categorized as NEAR if within 1 mile or FAR otherwise) and IQ scores measured using the Wechsler Intelligence Scale for Children (WISC). The data come from the study *Neuropsychological dysfunction in children with chronic low-level lead absorption*, published in The Lancet.

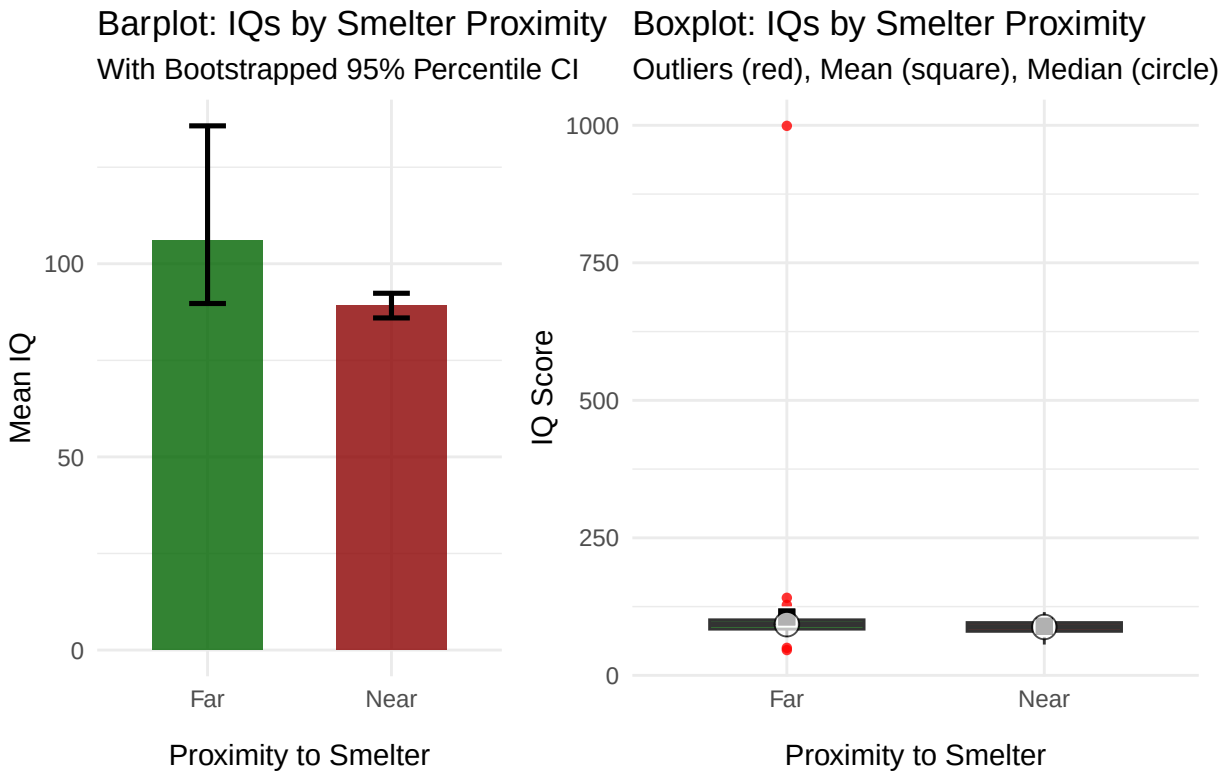
Comparing IQ Scores of Children Near or Far to Smelter

To compare the IQ levels of children who lived NEAR the smelter (within 1 mile) and were assumed to have greater lead exposure versus children who lived FAR and were presumably less exposed, a barplot and boxplot were created side by side in **Figure 1** to evaluate the distribution of IQ for each group. The barplot includes a bootstrapped percentile confidence interval to compare the variability between groups, whereas the boxplot displays outliers and indicates potential skewness. Common descriptive statistics were also included in **Table 1** (shown first).

Table 1: **IQ Scores of Children by Their Smelter Proximity**

Variable	N	Smelter Proximity	
		Far N = 67	**Near** N = 57
IQ Score	124		
Mean (SD)		106.1 (111.9)	89.2 (12.2)
Median (Q1, Q3)		93.0 (83.0, 101.0)	88.0 (80.0, 96.0)
Range (Min, Max)		46.0, 999.0	56.0, 115.0

Figure 1: **Distribution of IQs by Smelter Proximity**



Discussion & Conclusions

The descriptive statistics in **Table 1** and visualizations in **Figure 1** show that the `FAR` group contains a potentially incorrect IQ value of 999, which can be a data entry error or missing value code rather than a real observation. Without any type of filtering, the calculated mean IQ score for children `FAR` from a smelter was 106.1, whereas for children `NEAR` a smelter the mean IQ score was 89.2. This single outlying value inflates the `FAR` group's mean and increases its standard deviation. In **Figure 1**, the barplot suggests that children who lived far from the smelter have a large confidence interval, which could indicate the presence of outliers or a wide distribution with much variance, whereas the `NEAR` group displays a very narrow confidence interval and could be normally distributed. In the boxplot the potential outlier compresses the y-axis and does not allow for a meaningful comparison between groups. Additionally, the mean in the `FAR` group is visibly pulled upward by the potential outlier, whereas the overlap of the mean and median in the `NEAR` group points to a potentially normal IQ distribution. Before drawing any final conclusions about the relationship between smelter proximity and IQ scores, this `999` observation must be considered.

Code Appendix

```r
# loading packages
library(knitr)
library(tidyverse)
library(ggplot2)
library(patchwork) # used to combine plots into one

# defining setup options
opts_chunk$set(tidy = F)

# NOTE: All r chunks are displayed in the Appendix section at the end

# NOTE: Before creating this RMarkdown file, the folder structure for this project
# was established using the `CIDAtools` package.
# See "/Code/creating_project_wCIDAtools.R",
# which was run once to set up the directory structure.
#
# Additionally, because this RMarkdown file was written on Posit Cloud
# (browser-based RStudio),
# the instructions in "/Code/connecting_PositCloud_wGitHub.R" were followed to ensure
# proper version control and reproducibility.

# NOTE, one must commit before pushing, which sends committed changes to GitHub
# loading IQ data
IQ_data <- read.csv("../DataRaw/lead-iq-01.csv")

# changing columns to appropriate data type
IQ_data <- IQ_data %>%
  mutate(Smelter = as.factor(Smelter),
         IQ = as.integer(IQ))

n <- nrow(IQ_data)
library(ggplot2)
library(dplyr)
library(patchwork)

# establishing colors for plots
smelter_colors <- c("Far" = "darkgreen",
                    "Near" = "darkred")

# creating box plot
p_box <- ggplot(IQ_data, aes(x = Smelter, y = IQ, fill = Smelter)) +
  geom_boxplot(outlier.colour = "red",
               outlier.shape = 16,
               width = 0.6,
               alpha = 0.80) +

  # mean points
  stat_summary(
```

```
    fun = mean,
    geom = "point",
    shape = 22,
    size = 3.5,
    fill = "black",
    color = "white",
    alpha = 1
  ) +

  # median points
  stat_summary(
    fun = median,
    geom = "point",
    shape = 21,
    size = 4,
    fill = "white",
    color = "black",
    alpha = 0.7
  ) +

  scale_fill_manual(values = smelter_colors) +
  labs(
    x = "Proximity to Smelter",
    y = "IQ Score",
    title = "Boxplot: IQs by Smelter Proximity",
    subtitle = "Outliers (red), Mean (square), Median (circle)"
  ) +
  theme_minimal(base_size = 11) +
  theme(
    legend.position = "none",
    panel.grid.minor.x = element_blank(),
    axis.title.x = element_text(margin = margin(t = 12))    # <-- added spacing
  )


# creating bootstrapped bar plot
set.seed(123)

bootstrap_ci <- IQ_data %>%
  group_by(Smelter) %>%
  summarise(
    mean_IQ = mean(IQ),
    boot_mean = list(replicate(2000, mean(sample(IQ, replace = TRUE))))
  ) %>%
  mutate(
    CI_lower = sapply(boot_mean, function(x) quantile(x, 0.025)),
    CI_upper = sapply(boot_mean, function(x) quantile(x, 0.975))
  )

p_bar <- ggplot(bootstrap_ci, aes(x = Smelter, y = mean_IQ, fill = Smelter)) +
```

```
  geom_col(width = 0.6, alpha = 0.80) +
  geom_errorbar(
    aes(ymin = CI_lower, ymax = CI_upper),
    width = 0.2,
    linewidth = 0.9
  ) +
  scale_fill_manual(values = smelter_colors) +
  labs(
    title = "Barplot: IQs by Smelter Proximity",
    subtitle = "With Bootstrapped 95% Percentile CI",
    x = "Proximity to Smelter",
    y = "Mean IQ"
  ) +
  theme_minimal(base_size = 11) +
  theme(
    legend.position = "none",
    panel.grid.minor.x = element_blank(),
    axis.title.x = element_text(margin = margin(t = 12))    # <-- added spacing
  )


# displaying plots side-by-side
library(ggtext) # for correct bolding in title

(p_bar + p_box + plot_layout(widths = c(5, 7))) +
  plot_annotation(
    title = "Figure 1: **Distribution of IQs by Smelter Proximity**",
    theme = theme(
      plot.title = element_markdown(
        hjust = 0.5,
        size = 12
      )
    )
  )

# loading gtsummary
library(gtsummary)

# gtsummary table with full descriptive statistics
IQ_data %>%
  tbl_summary(
    by = Smelter,
    include = IQ,
    statistic = all_continuous() ~ c(
      "{mean} ({sd})",
      "{median} ({p25}, {p75})",
      "{min}, {max}"
    ),
    type = all_continuous() ~ "continuous2",
    label = IQ ~ "IQ Score",
```

```
    digits = all_continuous() ~ 1    # <-- ensures at least 1 decimal place
  ) %>%
  add_stat_label(
    label = all_continuous() ~ c(
      "Mean (SD)",
      "Median (Q1, Q3)",
      "Range (Min, Max)"
    )
  ) %>%
  add_n() %>%
  modify_header(label ~ "**Variable**") %>%
  modify_spanning_header(all_stat_cols() ~ "**Smelter Proximity**") %>%
  modify_caption("**IQ Scores of Children by Their Smelter Proximity**") %>%
  bold_labels()
# calculating means by Smelter
mean_far <- mean(IQ_data$IQ[IQ_data$Smelter == "Far"])
mean_near <- mean(IQ_data$IQ[IQ_data$Smelter == "Near"])
```

GitHub Project Repository (public): https://github.com/PostData-solutions/Pla_Project_01