2023-07-06_sql-vs-rd-pattern-analysis_raw

July 6, 2023

1 Preregistration — SQL vs. Visual Diagrams for Matching Relational Query Patterns — June 2023 Study

We are preregistering this study based on the OSF Google Docs template, which is one of several preregistration templates that OSF provides. Our experimental setup is inspired by Leventidis et al. (2020).

1.1 Study Information

- **Title:** The effect of SQL vs. Visual Diagrams on time and correctness matching relational query patterns
- **Authors:** *Anonymous for peer review. The online form on osf.io will list authors upon publication or embargo expiration.*
- **Description:** Pilot testing has indicated that visual diagrams (RD) improve participant speed at correctly identifying relational query patterns, contrasting with formatted SQL. We will measure participant time and the proportion of correct answers for two conditions (RD and SQL) and 4 relational query patterns across 32 questions.
- **Hypotheses:** We are testing for a total of `3` hypotheses:
  - ***Time:*** Let θ_X denote the median time per question in seconds for a given condition X per participant. We hypothesize that (1) θ_{RD} / $\theta_{SQL} < 1$, thus participants are relatively faster using `RD` compared to `SQL` and (2) that this holds for each half of the study individually.
  - ***Correctness:*** Let δ_X denote the mean proportion of correct responses for a given condition X. We hypothesize that (3) $\delta_{RD} \simeq \delta_{SQL}$, i.e., participants make a comparable number of correct responses using `RD` or `SQL`.

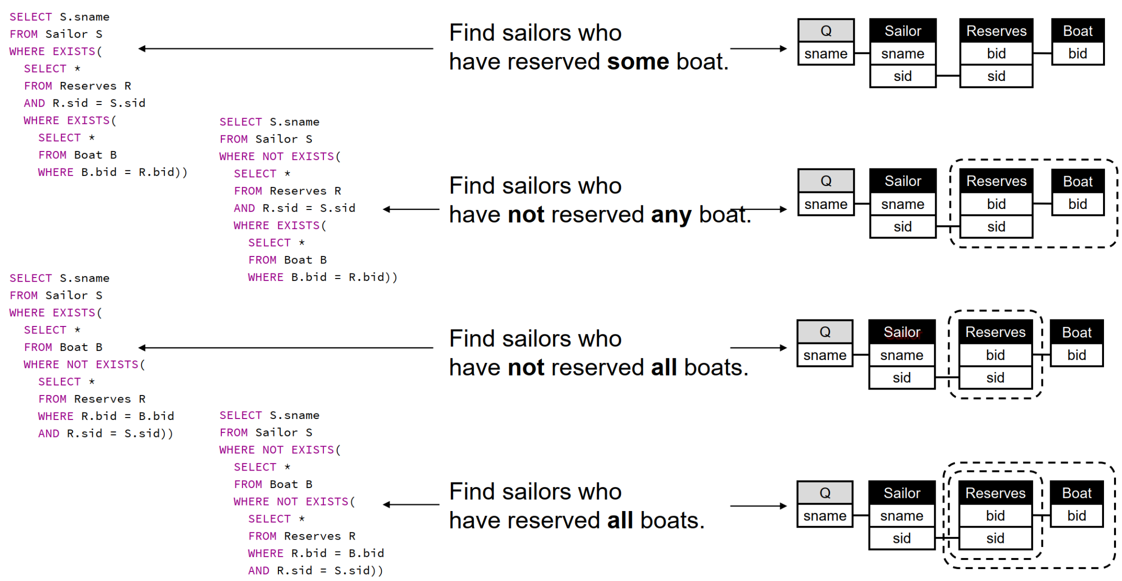
1.2 Design Plan

- **Study type:** Experiment.
- **Blinding:** No blinding is involved in this study.
- **Study design:** We have a within-subjects design, i.e., each participant sees questions in both of our modes: `RD` and `SQL`. Each participant will see a total of `32` questions: `2` modes × `4` patterns × `2` instances in each half × `2` halves. I.e., they will see each pattern-mode combination `2` times per half. For each question, the participant will be given a SQL query

presented using one of the modes. They must choose the most appropriate of 4 natural-language interpretations of the query, each corresponding to one of our 4 patterns. Their sequence number determines the mode presented to each participant for a given question — described under the randomization bullet. The stimuli for each mode is:

- SQL — A conventional SQL representation with appropriate indentation. The SQL text is indented and SQL keywords are color-coded appropriately.
- RD — A visual diagram we created of the query.

  See the included `supplement/tutorial.pdf` file for a sample of the stimuli and how to read them, one page extracted here:



- **Randomization:** To reduce ordering effects caused by which mode is presented first, we assign participants as they arrive to alternately start with SQL (sequence number 0) or RD (sequence number 1). We then alternate the modes the presenter sees with each question. I.e., [SQL, RD, SQL, RD...]. We randomize the order that patterns are presented in each half separately, ensuring that each combination appears the same number of times and that both halves have the same number of each pattern-mode combination.

1.3 Sampling Plan

- **Existing data:** Registration before creating data: As of the date of submission of this research plan for preregistration, the data have not yet been collected, created, or realized. Only pilot data has been collected.
- **Explanation of existing data:** N/A.
- **Data collection procedures:**
  - ***Population:*** Participants will be recruited through Amazon Mechanical Turk (AMT), a popular crowdsourcing website used for a variety of tasks, including academic studies.
  - ***Recruitment efforts:*** A Human Intelligence Task (HIT) will be posted on AMT. We may repeatedly re-post the HIT as recruitment slows over time.

- ***Inclusion criteria:*** Participants could accept the AMT HIT if they are all of the following:
  1. Residing in the USA and, thus, we expect English proficiency.
  2. Adults (over 18 years old).
  3. Experienced SQL users, self-determined with the prompt: "Workers should be familiar with SQL at the level of an advanced undergraduate database class, in particular with nested SQL queries."
  4. Have submitted over `500` approved HITs on AMT.
  5. Have more than `97%` approved HIT assignments on AMT.
- ***Exclusion criteria:*** None. Pilot study participants were collected from our institution so did not need to be excluded on AMT.
- ***Timeline:*** Data will be collected from when we start until our **Stopping rule** below is met.
- ***Payment:***
  * *AMT Rejection criteria:* A HIT will be accepted and the participant paid only if they correctly answered $\geq$ `16/32` questions within `50` minutes. Otherwise, the HIT will be rejected.
  * *Base pay:* `$6.00` USD.
  * *Correctness bonus:* For every correctly answered question after the `16th` the participant receive a bonus payment of `$0.20` USD for a total pay of `$9.20` USD.
  * *Time bonus:* Based on total test completion time, the participant will receive a percentage bonus on total pay (including the correctness bonus). Completion within `11` minutes awards a `5%` bonus for a maximum pay of `$9.66`. Each minute faster gets you an additional `5%` bonus up to `40%` for completing within `4` minutes, with a maximum pay of `$12.88`.

- **Sample size:** Our target sample size is `50` participants.

- **Sample size rationale:** As all 13 pilot participants were faster with `RD` than `SQL`, we did not use a power analysis to choose the sample size. Instead, `50` was chosen as a meaningfully large and round number that is still a multiple of 2 to ensure that we have an equal number of participants among the sequences (see **Randomization**, above)

- **Stopping rule:** We will terminate data collection once our number of complete HITs has reached our maximum target sample size. Given the strict ***Inclusion criteria*** in our study, it is possible that we won't be able to hit our target sample size. In that case, we shall restrict our analysis to the data we can collect before paper submission. We will continue collecting data until we reach the maximum target sample size or the camera-ready paper submission deadline.

1.4 Variables

- **Manipulated Variables:**
  - *Mode:* `[SQL, RD]`. See Study Information.

- **Measured Variables:**
  - For each participant and each question they answer, we record:
    * ***Time (quantitative):*** The time they take to answer the question.

    - ***Pattern (categorical/integer):*** The pattern they were provided in one of the modes for that question.
    - ***Choice (integer):*** Their selected pattern from the 4-option multiple choice question.
    - ***Correct (boolean/integer):*** Whether their answer for the 4-option multiple choice question was correct.
  - For each participant, we also record:
    - ***Sequence (categorical):*** The sequence the participant was randomly assigned to (see Design Plan).
    - ***Free-text feedback (string):*** The participant's optional answers to a feedback prompt.

- **Indices:** From our collected study data, we will calculate:
  - ***Indices for time***
    - **`Median time per mode per participant:`** This is calculated by taking the median of the `16` ***Time*** records for each mode for each participant. Using that information, we can calculate the median time across all participants.
    - **`Ratio of median time of RD relative to SQL per participant:`** Using the `Median time per mode per participant`, we will calculate `RD/SQL`.
    - **`Quartiles and CIs of median time per mode across all participants:`** Using the `Median time per mode per participant`, we will calculate the 1st, 2nd (median), 3rd quartiles.
    - **`Quartiles and CIs of median time of RD relative to SQL across all participants:`** Using the `Ratio of median time of RD relative to SQL per participant`, we will calculate the 1st, 2nd (median), 3rd quartiles as well as 95% Confidence Intervals using Bias Corrected and Accelerated (BCa) bootstrapping (Efron (1987)).
    - **`Per-half indices:`** We will compute both the `Quartiles and CIs of median time...` indices for each half.
  - ***Indices for correctness***
    - **`Proportion of correct responses per mode per participant:`** For each participant, calculate the proportion of correct responses per mode as: `correct responses / total questions per mode`.
    - **`Mean and CIs of proportion of correct responses per mode across all participants:`** The mean proportion of correct responses across all participants is calculated by taking the arithmetic mean of all the `Proportion of correct responses per mode per participant` values for a given mode across all participants. We will calculate 95% Confidence Intervals using Bias Corrected and Accelerated (BCa) bootstrapping.

1.5 Analysis Plan

- **Statistical Models:**

  - ***Distribution testing:*** We will examine the distributions of our data visually, including for each mode, to ensure there are no problematic distributions.
  - ***Hypothesis Testing:*** We will visually examine the 95% BCa bootstrapped confidence intervals for each mean and median.

- **Transformations:** N/A.

- **Inference criteria:** We will interpret the results using Interval Estimation rather than dichotomous p-value cutoffs (e.g., we will not use p<.05 to determine statistical significance). See Dragicevik (2016) and Besançon & Dragicevic (2019) for a discussion of using estimation for these types of analyses.

- **Data exclusion:** To perform a concrete analysis of our data, we would like to minimize the set of outlier points as they will negatively affect the quality of our statistical analysis and introduce unwanted/non-existent bias. After collecting our data, we will examine the time distribution of each worker. In particular, we will examine how long each worker took to answer the question on a per-question basis. We expect two types of outlier points in our experiments.

  1. **Speeders:** Workers that answered a question much faster than the vast majority of participants (usually in the order of a few seconds, i.e., workers tried to rush answering each question without thinking). The range could vary, but a rough indication of a speeder would be if their time per question is 2-3 standard deviations lower than the mean time per question.
  2. **Unusually delayed answers:** This refers to workers who took unusually long to answer a question. This is most likely attributed to some distraction that made the worker not focus on our question while the timer was running (i.e., a phone call, text message, bathroom break, etc.). As an online test, we can't know exactly what was the cause of it, but usually, we can identify such data points by noticing their much larger value in time. Since we capture a time distribution, it is expected to be left-skewed, and thus a rough measure of an *unusually delayed answer* would be about ≥ 3 times the mean time per question.
  3. **Cheaters:** Previous studies have indicated that workers can leak answers to enable other workers to answer all the questions correctly and quickly. We have used technical measures to limit this possibility and give each user different sets of stimuli. However, if we identify cheaters through log analysis, we will exclude them.
  4. **Median:** To minimize the effect of outliers for all the above reasons and to provide a statistically valid unbiased estimator for the ratio of times, we use the median instead of the mean aggregation for time analysis.

- **Missing data:** We will unlikely have missing data because for a participant to submit their results, they must answer all the questions. However, if we have missing data points from an individual, we will remove the individual completely from our analysis.

1.6 Other

- **Discrepancies between preregistration prose and analysis code:** The intent of our study design is explained in this section. In case of any discrepancy between the analysis code below and this section, what is written in this section takes precedence for the preregistration.

2 Scripts to analyze the study data

(Q1) TIMING PER PARTICIPANT (SQL vs RD) 1. Per participant, calculate the median time in seconds spent on SQL and RD (32/2=16 per mode and participant, irrespective of correctness) 2. Q1a: show violin plot figure with median times per user compared via gray lines 3. Calculate their ratio per user (also gives fraction of users who are faster with one or the other) 4. Calculate the median of those fractions and the 95% CI 5. Q1b: show violin plot figure with fractions, and also 95% CI

(Q2) TIMING PER PARTICIPANT (SQL vs RD / 1st vs. 2nd half) 1. Per participant, calculate the median time over all questions answered in 1st half in RD (32/2/2=8) and SQL, and in 2nd half. 2. Q2: show repeated measure violin plot figure, showing improvements over time, of 2 halfs 3. Calculate the relative ratio for timing 2nd/1st for RD, and SQL including 95% CI

(Q3) TIMING PATTERNS ACROSS PARTICIPANTS 1. calculate the median time per pattern (4) across the two modes (2). Thus 8 values. 2. show repeated measure violin plot figure

(Q4) CORRECTNESS (SQL vs RD) 1. take mean correct over all questions and all users answered in SQL (32/2*13), or in RD (2 values) 2. calculate 95% CI for each, and sampled p-value (perhaps with difference?)

2.1 Load packages

[ ]:
```
import pandas as pd
import numpy as np
import seaborn as sns
sns.set(style="whitegrid",font_scale=2)
import matplotlib.pyplot as plt
from scipy.stats import bootstrap as scipybootstrap
from IPython.display import display

# Tell matplotlib to export svg text as text not paths
plt.rcParams['svg.fonttype'] = 'none'
plt.rcParams['axes.axisbelow'] = True    # draw axes and grids behind everything␣
 ↪else

# Set Jupyter and Pandas to show 3 decimal places, does not work for lists of␣
 ↪numbers
%precision 3
pd.options.display.float_format = '{:,.3f}'.format
np.set_printoptions(precision=3)
# np.set_printoptions(formatter={'float': lambda x: "{0:0.3f}".format(x)})    ␣
 ↪      # TODO: does not work for lists
def print(*args):
    __builtins__.print(*("%.3f" % a if isinstance(a, float) else a
                         for a in args))
```

2.2 Global Variables Setup

[ ]:
```
# A set of constant global variables used throughout the notebook
num_questions = 32
modes = ['SQL', 'RD']
mode_to_name = {0: 'SQL', 1: 'RD'}

BOOTSTRAPCONFIDENCE = 0.95      # confidence level used for bootstrap
BOOTSTRAPMETHOD = 'BCa'         # method used for bootstrap, appears to be␣
↪better than the textbook version for mean (but not for median), also␣
↪available as 'percentage'
BOOTSTRAPSAMPLES = 10000        # number of resamples
filename = 'data/anonymized_data.csv'    # file with appropriately transformed␣
↪data ready for analysis
TRANSFORMDATA = False            # used only once to transform the original data
```

2.3 Define subfolder where figures are stored

By default, figures will not be saved. If you want to save figures, set savefig to `True`. Learned from: https://github.com/jorvlan/open-visualizations/blob/master/Python/tutorial_2/repeated_measures_python_2.ipynb

[ ]:
```
savefig = True
if savefig:
    import os
    from os.path import isdir
    cwd = os.getcwd()   # Get current working directory, but you can specify␣
↪your own directory of course.
    if  os.path.exists(cwd + "/figs"):
        print("Directory already exists")
        fig_dir = cwd + "/figs"     # Assign the existing directory to a␣
↪variable
    elif not os.path.exists(cwd + "/figs"):
        print("Directory does not exist and will be created ......")
        os.makedirs(cwd + "/figs")
        if isdir(cwd + "/figs"):
            print('Directory was created succesfully')
        fig_dir = cwd + "/figs"     # Assign the created directory to a variable
    else:
        print("Something went wrong")
```

2.4 Loading original data, transforming it, and saving it anonymized

Loading the original data, anonymizing it, transforming it to make available for later analysis and saving it

[ ]:
```
if TRANSFORMDATA:
    ANONYMIZE = False
```

```python
# --- Load original study data TODO: This should point to our full study data when it is available
studyfilename = 'data/users-table-pilot.csv'
encodingfilename = 'data/worker_ids.csv'
df = pd.read_csv(studyfilename)

# --- Turn string to array
from ast import literal_eval             # to turn string to array
df['pattern_order']= df['pattern_order'].apply(literal_eval)
display(df)

# --- Anonymize the workers with randomized categories (https://pandas.pydata.org/docs/user_guide/categorical.html#working-with-categories)
if ANONYMIZE:
    c = df.worker_id.astype('category')
    d = dict(enumerate(c.cat.categories))

    from random import shuffle
    keys = list(d.keys())
    shuffle(keys)
    d = dict(zip(d.values(), keys))            # randomize the category assignment s.t. categorical numbers are identical with alphabetical order

    with open(encodingfilename, 'w') as f:      # save the category encoding
        for key in d.keys():
            f.write("%s,%s\n"%(key,d[key]))

    df["worker_id"] = df["worker_id"].map(d)    # replace worker_ids with randomized categories

# display(df)
# The "current page" is the section of the study the workers are doing to save their state & prevent them cheating

# --- The following code block transforms the data frame to have one question per row. That simplifies the later analysis.
# reshape df (melt, pivot) to bring multiple question times (e.g. 'q7_time') per row into separate rows
# https://towardsdatascience.com/wide-to-long-data-how-and-when-to-use-pandas-melt-stack-and-wide-to-long-7c1e0f462a98
df2 = df.melt(id_vars=['worker_id', 'sequence_num', 'pattern_order',
                       'q1', 'q2','q3', 'q4','q5', 'q6','q7', 'q8', 'q9', 'q10',
                       'q11', 'q12','q13', 'q14','q15', 'q16','q17', 'q18', 'q19', 'q20',
```

```
                          'q21', 'q22','q23', 'q24','q25', 'q26','q27', 'q28',␣
↪'q29', 'q30',
                          'q31', 'q32'], value_vars=['q1_time', 'q2_time',␣
↪'q3_time', 'q4_time','q5_time', 'q6_time', 'q7_time', 'q8_time', 'q9_time',␣
↪'q10_time',
                                                       'q11_time', 'q12_time',␣
↪'q13_time', 'q14_time', 'q15_time', 'q16_time', 'q17_time', 'q18_time',␣
↪'q19_time', 'q20_time',
                                                       'q21_time', 'q22_time',␣
↪'q23_time', 'q24_time', 'q25_time', 'q26_time', 'q27_time', 'q28_time',␣
↪'q29_time', 'q30_time',
                                                       'q31_time', 'q32_time'],␣
↪var_name='question', value_name='time')

    # replace time in msec with sec in column 'time'
    df2['time'] = df2['time'] / 1000

    # replace question string 'q7_time' with number '7' in column 'question'
    from re import search as re_search                # regular expression
    new_column = []
    for values in df2['question']:
        new_column.append(int(re_search(r'\d+', values).group()))
    df2['question'] = new_column

    # choose the right pattern from the list 'pattern_order' and add as column␣
↪'pattern'
    new_column = []
    for (pattern_order_list, ind) in zip(df2['pattern_order'], df2['question']):
        new_column.append(pattern_order_list[ind-1])
    df2['pattern'] = new_column

    # determine the 'mode' (SQL or RD) from 'sequence_num' and 'question'
    #   sequence_num = 0 means that the first question is shown in SQL, 1 means␣
↪we start instead with RD. Then alternate between the two.
    #   Thus (sequence_num + question_num) % 2 == 1 means SQL
    #   Thus (sequence_num + question_num) % 2 == 0 means RD
    new_column = []
    for (sequence, question) in zip(df2['sequence_num'], df2['question']):
        mode = 'SQL' if (sequence + question) % 2 == 1 else 'RD'
        new_column.append(mode)
    df2['mode'] = new_column

    # determine the 'choice' (among the 4 patterns) made by the user for this␣
↪question. Requires all the 32 question choices (e.g. 'q7') and index of the␣
↪question at hand ('question')
```

```
    questionarray = df2[['q1', 'q2','q3', 'q4','q5', 'q6','q7', 'q8', 'q9',␣
↪'q10',
                          'q11', 'q12','q13', 'q14','q15', 'q16','q17', 'q18',␣
↪'q19', 'q20',
                          'q21', 'q22','q23', 'q24','q25', 'q26','q27', 'q28',␣
↪'q29', 'q30',
                          'q31', 'q32']].to_numpy()
    questionindex = df2[["question"]].to_numpy()

    new_array = np.take_along_axis(questionarray,questionindex-1,1)     # take␣
↪the 'questionindex'-th entry from each row of the questionarray (notice␣
↪1-index vs 0-indexin)
    df2['choice'] = new_array

    # determine whether the choice was correct by comparing the ground truth␣
↪('pattern') against the choice made ('choice'). Saved as 0/1 value in new␣
↪column 'correct'
    new_column = []
    for (pattern, choice) in zip(df2['pattern'], df2['choice']):
        correct = 1 if pattern == choice else 0
        new_column.append(correct)
    df2['correct'] = new_column

    # sort by worker and question number, and reset the inde
    df2.sort_values(by=['worker_id', 'question'], inplace=True)
    df2.reset_index(drop=True, inplace=True)
    # display(df2)

    # select only the relevant subset of columns
    df_anonymized_data = df2[['worker_id', 'question', 'time', 'pattern',␣
↪'mode', 'choice', 'correct']]
    # display(df3)

    # pd.write_csv(filename)
    df_anonymized_data.to_csv(filename,
                              index=False,
                              )
```

2.5 Loading anonymized data

[ ]:
```
df_anonymized_data = pd.read_csv(filename)
display(df_anonymized_data)
```

3 Total time users took

[ ]:
```
dftemp = df_anonymized_data.groupby(['worker_id']).time.agg(['sum'])
dftemp['sum'] = dftemp['sum'] / 60
display(dftemp)
```

4 Question 1. Figure 1a

[ ]:
```
# create two columns mode and median, with 2 rows per worker (used for Fig 1a␣
↪violines)
dfq1a = df_anonymized_data.groupby(['worker_id', 'mode']).time.agg(['median'])
dfq1a.reset_index(inplace=True)
print('dfq1a:')
display(dfq1a)

# pivot to have one row per worker (used for Fig 1a individual points)
dfq1b = pd.pivot_table(dfq1a, values=['median'], index=['worker_id'],␣
↪columns=['mode'])
dfq1b=dfq1b.droplevel(0, axis=1)
print('dfq1b:')
display(dfq1b)

modes = ['RD', 'SQL']
median_time = {}
ci = {}
ci_delta = {}
for mode in modes:
    median_time[mode] = np.median(dfq1b[mode])
    ci[mode] = scipybootstrap((dfq1b[mode],), statistic=np.median,␣
↪n_resamples=BOOTSTRAPSAMPLES, confidence_level=BOOTSTRAPCONFIDENCE,␣
↪method='percentile', axis=0).confidence_interval        #convert array to␣
↪sequence
    ci_delta[mode] = [median_time[mode] - ci[mode].low, ci[mode].high -␣
↪median_time[mode]]

    print(f'Median time {mode}: {median_time[mode]:.2f}, 95% CI [{ci[mode].low:.
↪2f}, {ci[mode].high:.2f}]')
```

[ ]:
```
# Define pre-settings
figwidth = 10
figheight = 6
xlab_size = 20
ylab_size = 20
figfont_size = 24

# Define consistent color maps
```

```
my_cmap_sns_light = [(0.9921568627450981, 0.8156862745098039, 0.
↪6352941176470588), (0.7764705882352941, 0.8588235294117647, 0.
↪9372549019607843)]        # light blue, light orange
my_cmap_sns_dark = [(0.9019607843137255, 0.3333333333333333, 0.
↪050980392156862744), (0.19215686274509805, 0.5098039215686274, 0.
↪7411764705882353)]      # dark blue, dark orange
my_cmap_dark = sns.color_palette(my_cmap_sns_dark, as_cmap=True)
my_cmap_light = sns.color_palette(my_cmap_sns_light, as_cmap=True)


# Create empty figure and plot the individual datapoints
fig, ax = plt.subplots(figsize=(figwidth,figheight))


# 1. Violinplots
axsns = sns.violinplot(x='median', y='mode', data=dfq1a,
                       hue=True, hue_order=[False, True], split=True,   # half␣
↪violinplots https://stackoverflow.com/questions/53872439/
↪half-not-split-violin-plots-in-seaborn
                       inner='quartile',
                       cut=0,                 # 0 means ending sharp at end points
                       width=.7,
                       orient = 'h',
                       zorder=20,)

# change the medium default line to full (https://stackoverflow.com/questions/
↪60638344/quartiles-line-properties-in-seaborn-violinplot)
for l in axsns.lines[1::3]:
    l.set_linestyle('-')
    l.set_linewidth(1.2)
    l.set_color('black')
    l.set_alpha(0.8)
# for i in [0, 2, 3, 5]:          # remove the 25% and 75% quartiles
#     l = axsns.lines[i]
#     l.set_linestyle('-')
#     l.set_linewidth(0)
#     l.set_color('red')
#     l.set_alpha(0.8)

# Apply colorscheme to violinplots https://stackoverflow.com/questions/70442958/
↪seaborn-how-to-apply-custom-color-to-each-seaborn-violinplot
from matplotlib.collections import PolyCollection
for ind, violin in enumerate(axsns.findobj(PolyCollection)):
    violin.set_facecolor(my_cmap_light[ind])


# 2. Plot individual points
```

```python
y_tilt = -0.25                                      # Set some delta for the␣
↪points below the violinplot
y_base = np.zeros(dfq1b.values.shape[0]) + y_tilt   # base vector to which to␣
↪broadcast y-tilt values

for i, col in enumerate(modes):
    ax.plot(dfq1b[col],
            y_base + i,
            # 'o',          # circles
            '^',            # triangles_up
            alpha=1,
            zorder=20,      # higher means more visible
            markersize=11,
            markeredgewidth=0,
            # markerfacecolor='none',
            markerfacecolor=my_cmap_dark[i],
            markeredgecolor=my_cmap_dark[i],)
    ax.plot(dfq1b[col],
            y_base + i,
            # 'o',          # circles
            '^',            # triangles_up
            markersize=11,
            markerfacecolor='white',
            markeredgewidth=1,
            color ='white',
            linewidth = None,
            zorder=1,)


# 3. Plot gray lines connecting modes
for i, idx in enumerate(dfq1b.index):
    ax.plot(dfq1b.loc[idx, modes],
            [y_tilt, y_tilt+1],
            color ='gray', linewidth = 2, linestyle ='-', alpha = .2,
            zorder=0)


# 4. Plot red line connecting medians
ax.plot(np.median(dfq1b, axis=0), [0, 1], color ='red', linewidth = 2,␣
↪linestyle ='-', alpha = .4)


# 5. CI Errorbars
for i, mode in enumerate(modes):
    plt.errorbar(median_time[mode], i, xerr=np.array([[ci_delta[mode][0],␣
↪ci_delta[mode][1]]]).T,
                 fmt='o', markersize=10,
```

```
                  # lw = 3,           # if end line for CI
                  lw = 5,             # if no ned line for CI
                  alpha=1,
                  zorder=100,         # higher means more visible
                  capsize = 10,
                  # capthick = 4,     # end line for CI
                  capthick = 0,       # no end line for CI
                  # color = 'black',
                  color = my_cmap_dark[i],
                  )   # my_cmap[1])
    ax.text(median_time[mode],
            # i+0.36,
            i-0.16,
            f'{median_time[mode]:.1f}', horizontalalignment='center',
            # color='black',
            color= my_cmap_dark[i],
            fontsize=figfont_size)
    # ax.text(ci[mode].low, i+0.1, f'{ci[mode].low:.1f}',␣
 ↪horizontalalignment='center', color='black', fontsize=20)
    # ax.text(ci[mode].high, i+0.1, f'{ci[mode].high:.1f}',␣
 ↪horizontalalignment='center', color='black', fontsize=20)


#Additional settings
ax.set_yticks(range(len(dfq1b.columns)))
ax.set_yticklabels(modes, size= ylab_size)
ax.set_ylim(-0.5, 1.5)
ax.set_xlabel('Median time per worker (sec)', size = xlab_size)
ax.set_ylabel(None)
ax.set_yticklabels(['FigX', 'SQL', ])
# ax.set_title('Median times per worker', size = title_size)
sns.despine()
ax.legend_.remove()

plt.grid(axis = 'x', linewidth = 0.5, color = 'lightgray')

if savefig:
    plt.savefig(fig_dir + "/q1_figure1.pdf", bbox_inches='tight')
    plt.savefig(fig_dir + "/q1_figure1.svg", bbox_inches='tight')
```

5 Question 1. Figure 1b

[ ]:

```

```

```
dfq1c = df_anonymized_data.groupby(['worker_id', 'mode']).time.agg(['median']) ␣
↪                               # for each worker, calculate median for both␣
↪modes
dfq1c = pd.pivot_table(dfq1c, values=['median'], index=['worker_id'],␣
↪columns=['mode'])        # pivot to have one row per worker
dfq1c['ratio median'] = dfq1c['median','RD'] / dfq1c['median','SQL']           ␣
↪                 # add the ratio between medians of the two modes

sample = np.array(dfq1c['ratio median'])                                         ␣
↪               # extract the sample and then create the boostrapped medians
data_ratio = dfq1c['ratio median']

median_ratio = np.median(data_ratio)
ci_ratio = scipybootstrap((data_ratio,), statistic=np.median,␣
↪n_resamples=BOOTSTRAPSAMPLES, confidence_level=BOOTSTRAPCONFIDENCE,␣
↪method=BOOTSTRAPMETHOD, axis=0).confidence_interval        #convert array to␣
↪sequence
ci_ratio_delta = [median_ratio - ci_ratio.low, ci_ratio.high - median_ratio]

print(f'Median ratio: {median_ratio:.3f}, 95% CI [{ci_ratio.low:.3f}, {ci_ratio.
↪high:.3f}]')
```

[ ]:
```
# Define figure settings
figwidth = 10
figheight = 3
xlab_size = 20
ylab_size = 20
figfont_size = 24

# Define consistent color maps
my_cmap_sns_dark = [(0.8392156862745098, 0.15294117647058825, 0.
↪1568627450980392)]
my_cmap_sns_light = [(0.984313725490196, 0.6039215686274509, 0.6)]
my_cmap_dark = sns.color_palette(my_cmap_sns_dark, as_cmap=True)
my_cmap_light = sns.color_palette(my_cmap_sns_light, as_cmap=True)

# Create data frame for split violinplot
dfvp = pd.DataFrame()
dfvp["values"] = sample
dfvp["all"] = ""                                        # attribute that is␣
↪shared by all entries
# print(dfvp)

# Create empty figure and plot the individual datapoints
fig, ax = plt.subplots(figsize=(figwidth,figheight))
```

```
# 1. Violinplot
axsns = sns.violinplot(x='values', y='all',     # y='all' just need to group␣
 ↪both types together
                       data=dfvp,
                       hue = True, hue_order = [False, True],
                       split = True, inner = 'quartile',
                       cut=0,                   # 0 means ending sharp at end␣
 ↪points
                       width=.6, scale = 'width',
                       # dodge = False,         # When using ``hue`` nesting,␣
 ↪setting this to ``True`` will separate the strips for different hue levels␣
 ↪along the categorical axis.
                       orient = 'h',
                       color=my_cmap_light[0])

# change the medium default linke to full
for l in axsns.lines[1::3]:
    l.set_linestyle('-')
    l.set_linewidth(1.5)
    l.set_color('black')
    l.set_alpha(0.8)
# for i in [0, 2]:          # remove the 25% and 75% quartiles
#     l = axsns.lines[i]
#     l.set_linestyle('-')
#     l.set_linewidth(0)
#     l.set_color('red')
#     l.set_alpha(0.8)


# 2. Plot individual points
y_tilt = -0.13                                  # Set some delta for the␣
 ↪points below the violinplot
y_base = np.zeros(len(data_ratio)) + y_tilt     # base vector to which to␣
 ↪broadcast y-tilt values

ax.plot(data_ratio, y_base,
        # 'o',
        '^',
        alpha=1,
        zorder=20,      # higher means more visible
        markersize=11,
        markeredgewidth=0,
        # markerfacecolor='none',
        markerfacecolor=my_cmap_dark[0],
        markeredgecolor=my_cmap_dark[0],
        )
```

```python
# 3. CI Errorbars & show numbers
axeb = plt.errorbar(median_ratio, 0, xerr=np.array([[ci_ratio_delta[0],␣
↪ci_ratio_delta[1]]]).T,
                    fmt='o',
                    markersize=10, alpha=1,
                    # lw = 3,
                    lw = 5,
                    zorder=100,      # higher means more visible
                    capsize = 10,
                    # capthick = 4,
                    capthick = 0,
                    # color = 'black',
                    color = my_cmap_dark[0],
                    )

med = np.median(sample)
# ax.text(med, 0.32, f'{100*med:.1f}%', horizontalalignment='center',␣
↪color='black', fontsize=20)
# ax.text(med, 0.32, f'{med:.2f}', horizontalalignment='center', color='black',␣
↪fontsize=20)
ax.text(med, -0.1, f'{med:.2f}', horizontalalignment='center',
        # color='black',
        color = my_cmap_dark[0],
        fontsize=figfont_size)
# ax.text(ci_ratio.low, 0.04, f'{100*ci_ratio.low:.1f}%',␣
↪horizontalalignment='center', color='black', fontsize=20)
# ax.text(ci_ratio.high, 0.04, f'{100*ci_ratio.high:.1f}%',␣
↪horizontalalignment='center', color='black', fontsize=20)


# Additional settings
# ax.set_ylim(-0.2, 0.4)
ax.set_ylim(-0.25, 0.35)
ax.set_ylabel(None)         # remove the 'all'
ax.set_xlim(0.2, 0.8)
# ax.set_xlabel('Ratio of median time per worker (RD / SQL)', size = xlab_size)
ax.set_xlabel('Ratio of median time per worker (FigX / SQL)', size = xlab_size)
sns.despine()               # remove bounding box
plt.grid(axis = 'x', linewidth = 0.5, color = 'lightgray')
ax.legend_.remove()

import matplotlib.ticker as mtick
# ax.xaxis.set_major_formatter(mtick.PercentFormatter(1.0))           # show in␣
↪percentage
```

```python
if savefig:
    plt.savefig(fig_dir + "/q1_figure2.pdf", bbox_inches='tight')
    plt.savefig(fig_dir + "/q1_figure2.svg", bbox_inches='tight')
```

6 Question 2

[ ]:
```python
# Create df6, df7

df = df_anonymized_data[['worker_id', 'question', 'time', 'mode']]

df['H1'] = np.where(df['question'].between(1, 16, inclusive='both'), 'H1', '') ␣
↪        # TODO: creates warning but works for now
df['H2'] = np.where(df['question'].between(17, 32, inclusive='both'), 'H2', '')␣
↪        # TODO: creates warning but works for now

df1 = df[['worker_id','question','time','mode','H1']].rename(columns={'H1':␣
↪'section'}) # Two sections: 1st half (H1) and 2nd half (H2)
df2 = df[['worker_id','question','time','mode','H2']].rename(columns={'H2':␣
↪'section'})
df4 = pd.concat([df1, df2])
df4 = df4.loc[df4['section'] != '']
df4 = df4.reset_index(inplace=False, drop=True)
# display(df4)

df5 = df4.groupby(['worker_id', 'mode', 'section']).time.agg(['median'])        ␣
↪        # for each worker, calculate median for both modes and section
df5.reset_index(inplace=True)
# display(df5)

# pivot to have one row per worker
df6 = pd.pivot_table(df5, values=['median'], index=['worker_id'],␣
↪columns=['mode', 'section'])
df6=df6.droplevel(0, axis=1)

# relative improvements per user
df6['RD', 'ratio'] = df6['RD', 'H2'] / df6['RD', 'H1']
df6['SQL', 'ratio'] = df6['SQL', 'H2'] / df6['SQL', 'H1']
display(df6)

# Median of median task time for each mode and section
modes = ['RD', 'SQL']
sections = ['H1', 'H2', 'ratio']
median_time = {}
ci = {}
ci_delta = {}
```

```
for mode in modes:
    for section in sections:
        column = (mode, section)
        median_time[column] = np.median(df6[column])
        ci[column] = scipybootstrap((df6[column],), statistic=np.median,
                                    n_resamples=BOOTSTRAPSAMPLES,
                                    confidence_level=BOOTSTRAPCONFIDENCE,
                                    method='percentile',
                                    axis=0).confidence_interval        #convert␣
↪array to sequence
        ci_delta[column] = [median_time[column] - ci[column].low, ci[column].
↪high - median_time[column]]

        print(f'{mode}, {section}: {median_time[column]:.3f}, 95% CI␣
↪[{ci[column].low:.3f}, {ci[column].high:.3f}]')

# uses df5 to make df7 (used for later plot)
modes = ['SQL', 'RD']
sections = ['H1', 'H2']
df7 = df5.loc[df5['section'].isin(sections)]
# display(df7)
```

[ ]:
```
# Plot (uses df6, df7)

# Define pre-settings
figwidth = 10
figheight = 7
xlab_size = 20
ylab_size = 20
figfont_size = 24

# Define consistent color maps
my_cmap_sns_light = [(0.7764705882352941, 0.8588235294117647, 0.
↪9372549019607843), (0.9921568627450981, 0.8156862745098039, 0.
↪6352941176470588)]         # light orange, light blue
my_cmap_sns_dark = [(0.19215686274509805, 0.5098039215686274, 0.
↪7411764705882353), (0.9019607843137255, 0.3333333333333333, 0.
↪050980392156862744)]       # dark orange, dark blue
my_cmap_dark = sns.color_palette(my_cmap_sns_dark, as_cmap=True)
my_cmap_light = sns.color_palette(my_cmap_sns_light, as_cmap=True)


# Create empty figure and plot the individual datapoints
fig, ax = plt.subplots(figsize=(figwidth,figheight))


# 1. Violinplots
```

```
axsns = sns.violinplot(x='median', y='section', data=df7,
                       hue='mode',
                       hue_order=['SQL', 'RD'],
                       split=True,   # half violinplots https://stackoverflow.
↪com/questions/53872439/half-not-split-violin-plots-in-seaborn
                       inner='quartile',
                       cut=0,               # 0 means ending sharp at end points
                       width=.4,
                       orient = 'h',
                       zorder=20,
                       palette = my_cmap_light,)

# change the medium default line to full (https://stackoverflow.com/questions/
↪60638344/quartiles-line-properties-in-seaborn-violinplot)
for l in axsns.lines[1::3]:
    l.set_linestyle('-')
    l.set_linewidth(1.2)
    l.set_color('black')
    # l.set_alpha(0.8)

# for i in [0, 2, 3, 5]:          # remove the 25% and 75% quartiles
#     l = axsns.lines[i]
#     l.set_linestyle('-')
#     l.set_linewidth(0)
#     l.set_color('red')
#     l.set_alpha(0.8)


# 2. Plot individual points
y_base = np.zeros(df6.values.shape[0])  # base vector to which to broadcast␣
↪y-tilt values
y_tilt_mode = [0.3, 0.38]
y_tilt_section = [0, 1]
for i, mode in enumerate(modes):
    for j, section in enumerate(sections):
        column = (mode, section)
        ax.plot(df6[column],
                y_base + y_tilt_mode[i] + y_tilt_section[j],
                # 'o',
                # '|',
                '^',
                alpha=1,
                zorder=20,       # higher means more visible
                markersize=11,
                markeredgewidth=0,
                # markerfacecolor='none',
                markerfacecolor=my_cmap_sns_dark[i],
```

```
                markeredgecolor=my_cmap_sns_dark[i],)
        ax.plot(df6[column],          # white background
                y_base + y_tilt_mode[i] + y_tilt_section[j],
                # 'o',
                # '|',
                '^',
                markersize=11,
                markeredgewidth=1,
                markerfacecolor='white',
                color ='white',
                linewidth = None,
                zorder=1,)


# # 3. Plot lines connecting points
# for idx in df6.index:
#     for i, mode in enumerate(modes):
#         for j in range(len(sections)-1):
#             start = (mode, sections[j])
#             end = (mode, sections[j+1])
#             ax.plot(df6.loc[idx, [start, end]],
#                     [y_tilt_mode[i] + y_tilt_section[j], y_tilt_mode[i] +␣
↪y_tilt_section[j+1]],
#                     color=my_cmap_sns_dark[i], linewidth=2, linestyle='-',␣
↪alpha=.2, zorder=0)


# 4. CI Errorbars & numbers
y_tilt_mode = [0.5, 0.55]
# y_tilt_section_bar = [0.23, 0.8]
# y_tilt_section_number = [0.19, 0.89]
for i, mode in enumerate(modes):
    for j, section in enumerate(sections):
        column = (mode, section)
        plt.errorbar(median_time[column], y_tilt_mode[i]+y_tilt_section[j],
                     xerr=np.array([[ci_delta[column][0]␣
↪,ci_delta[column][1]]]).T,
                     fmt='o', markersize=10,
                     lw = 3, alpha=1,
                     zorder=100,        # higher means more visible
                     #              capsize = 10, capthick = 4,
                     color = my_cmap_sns_dark[i]    # 'black'
                     )
        ax.text(median_time[column], y_tilt_mode[i]+y_tilt_section[j] + 0.18,␣
↪f'{median_time[column]:.1f}',
                horizontalalignment='center', color = my_cmap_sns_dark[i],
                fontsize=figfont_size)
```

```
# 5. Plot red line connecting medians
for i, mode in enumerate(modes):
    ax.plot([median_time[(mode, 'H1')], median_time[(mode, 'H2')]],
            [y_tilt_mode[i]+y_tilt_section[0],␣
 ↪y_tilt_mode[i]+y_tilt_section[1]],
            color=my_cmap_sns_dark[i], linewidth = 3, linestyle ='-',
            alpha=.3,
            zorder=0)


# #Additional settings
ax.set_xlabel('Median time per worker and quartiles (sec)', size = xlab_size)
ax.set_ylabel(None)
ax.set_xlim(0, 35)
ax.set_ylim(1.9, -0.25)
leg = plt. legend(loc='lower right',
                  borderaxespad= 0.2,
                  frameon = True,)
leg.get_frame().set_alpha(1)
leg.get_frame().set_linewidth(0.0)
for text, text2 in zip(leg.get_texts(), ['SQL', 'FigX']):
    text.set_text(text2)

plt.grid(axis = 'x', linewidth = 0.5, color = 'lightgray')
sns.despine()               # remove bounding box

if savefig:
    plt.savefig(fig_dir + "/q2_figure.pdf", bbox_inches='tight')
    plt.savefig(fig_dir + "/q2_figure.svg", bbox_inches='tight')
```

7 Question 3: four patterns

(1) calculate the median time per pattern (4) across the two modes (2). Thus 8 values.
(2) show repeated measure violin plot figure

[ ]:
```
# Create df8

df = df_anonymized_data[['worker_id', 'pattern', 'time', 'mode']]
# print(df)

df8 = df.groupby(['worker_id', 'mode', 'pattern']).time.agg(['median'])        ␣
 ↪# for each worker, calculate median for both modes
df8.reset_index(inplace=True)
display(df8)
```

```
# Pivot to have one row per worker
df9 = pd.pivot_table(df8, values=['median'], index=['worker_id'],␣
↪columns=['mode', 'pattern'])
df9=df9.droplevel(0, axis=1)
display(df9)

# Median of median task time for each mode and section (for error plots)
modes = ['RD', 'SQL']
patterns = [1, 2, 3, 4]
median_time = {}
ci = {}
ci_delta = {}
for mode in modes:
    for pattern in patterns:
        column = (mode, pattern)
        median_time[column] = np.median(df9[column])
        ci[column] = scipybootstrap((df9[column],), statistic=np.median,
                                    n_resamples=BOOTSTRAPSAMPLES,
                                    confidence_level=BOOTSTRAPCONFIDENCE,
                                    method='percentile',
                                    axis=0).confidence_interval        #convert␣
↪array to sequence
        ci_delta[column] = [median_time[column] - ci[column].low, ci[column].
↪high - median_time[column]]
# print(median_time)
# print(ci)
# print(ci_delta)
```

[ ]:

```
# needs df8 for violin, df9 for points, dictionaries (median_time, ci,␣
↪ci_delta) for error plots, df6 for individual points

modes = ['SQL', 'RD']
patterns = [1, 2, 3, 4]
y_tilt_section = [0, 1, 2, 3]

# Define pre-settings
figwidth = 10
figheight = 9
xlab_size = 20
ylab_size = 20
figfont_size = 20

# Define consistent color maps
my_cmap_sns_light = [(0.7764705882352941, 0.8588235294117647, 0.
↪9372549019607843), (0.9921568627450981, 0.8156862745098039, 0.
↪6352941176470588)]        # light orange, light blue
```

```
my_cmap_sns_dark = [(0.19215686274509805, 0.5098039215686274, 0.
↪7411764705882353), (0.9019607843137255, 0.3333333333333333, 0.
↪050980392156862744)]      # dark orange, dark blue
my_cmap_dark = sns.color_palette(my_cmap_sns_dark, as_cmap=True)
my_cmap_light = sns.color_palette(my_cmap_sns_light, as_cmap=True)

# Create empty figure and plot the individual datapoints
fig, ax = plt.subplots(figsize=(figwidth,figheight))


# 1. Violinplots
axsns = sns.violinplot(x='median', y='pattern', data=df8,
                       hue='mode',
                       hue_order=['SQL', 'RD'],
                       split=True,    # half violinplots https://stackoverflow.
↪com/questions/53872439/half-not-split-violin-plots-in-seaborn
                       inner='quartile',
                       cut=0,                 # 0 means ending sharp at end points
                       width=.4,
                       orient = 'h',
                       zorder=20,
                       palette = my_cmap_light,)

# change the medium default line to full (https://stackoverflow.com/questions/
↪60638344/quartiles-line-properties-in-seaborn-violinplot)
for l in axsns.lines[1::3]:
    l.set_linestyle('-')
    l.set_linewidth(1.2)
    l.set_color('black')
    l.set_alpha(0.8)
# for i in [0, 2, 3, 5]:          # remove the 25% and 75% quartiles
#     l = axsns.lines[i]
#     l.set_linestyle('-')
#     l.set_linewidth(0)
#     l.set_color('red')
#     l.set_alpha(0.8)


# 2. Plot individual points
y_base = np.zeros(df6.values.shape[0])  # base vector to which to broadcast␣
↪y-tilt values
y_tilt_mode = [0.3, 0.39]
for i, mode in enumerate(modes):
    for j, pattern in enumerate(patterns):
        column = (mode, pattern)
        ax.plot(df9[column],
                y_base + y_tilt_mode[i] + y_tilt_section[j],
```

```
                '^',
                alpha=1,
                zorder=20,       # higher means more visible
                markersize=10,
                markeredgewidth=0,
                # markerfacecolor='none',
                markerfacecolor=my_cmap_sns_dark[i],
                markeredgecolor=my_cmap_sns_dark[i],)
        ax.plot(df9[column],     # white background behind the markers, but in␣
 ↪front of the connecting lines
                y_base + y_tilt_mode[i] + y_tilt_section[j],
                '^',
                markersize=10,
                markeredgewidth=1,
                markerfacecolor='white',
                color ='white',
                linewidth = None,
                zorder=1,)


# # 3. Plot lines connecting individual points
# for idx in df9.index:
#     for i, mode in enumerate(modes):
#         for j in range(len(patterns)-1):
#             start = (mode, patterns[j])
#             end = (mode, patterns[j+1])
#             ax.plot(df9.loc[idx, [start, end]],
#                     [y_tilt_mode[i] + y_tilt_section[j], y_tilt_mode[i] +␣
 ↪y_tilt_section[j+1]],
#                     color =my_cmap_sns_dark[i], linewidth = 2, linestyle␣
 ↪='-', alpha = .2, zorder=0)


# 4. CI Errorbars & numbers
y_tilt_mode = [0.5, 0.57]
for i, mode in enumerate(modes):
    for j, section in enumerate(patterns):
        column = (mode, section)
        plt.errorbar(median_time[column],
                     y_tilt_mode[i]+y_tilt_section[j],
                     xerr=np.array([[ci_delta[column][0]␣
 ↪,ci_delta[column][1]]]).T,
                     fmt='o', markersize=10,
                     lw = 3, alpha=1,
                     zorder=100,        # higher means more visible
                     color = my_cmap_sns_dark[i])    # 'black'
```

```
        ax.text(median_time[column], y_tilt_mode[i]+y_tilt_section[j] + 0.22,␣
 ↪f'{median_time[column]:.1f}',
                horizontalalignment='center', color = my_cmap_sns_dark[i],
                fontsize=figfont_size)


# 5. Plot red line connecting medians
for i, mode in enumerate(modes):
    for j in range(len(patterns)-1):
        start = (mode, patterns[j])
        end = (mode, patterns[j+1])
        ax.plot([median_time[start], median_time[end], ],
                [y_tilt_mode[i] + y_tilt_section[j], y_tilt_mode[i] +␣
 ↪y_tilt_section[j+1]],
                color =my_cmap_sns_dark[i], linewidth = 3, linestyle ='-',␣
 ↪alpha = .3, zorder=0)



# # #Additional settings
ax.set_xlabel('Median time per worker (sec)', size = xlab_size)
ax.set_ylabel(None)
ax.set_yticklabels(['P1', 'P2', 'P3', 'P4'])
ax.set_xlim(0, 50)
ax.set_ylim(3.9, -0.25)
leg = plt.legend(loc='lower right',
                 borderaxespad= 0.2,
                 frameon = True,)
leg.get_frame().set_alpha(1)
leg.get_frame().set_linewidth(0.0)

for text, text2 in zip(leg.get_texts(), ['SQL', 'FigX']):
    text.set_text(text2)

plt.grid(axis = 'x', linewidth = 0.5, color = 'lightgray')
sns.despine()               # remove bounding box

if savefig:
    plt.savefig(fig_dir + "/q3_figure.pdf", bbox_inches='tight')
    plt.savefig(fig_dir + "/q3_figure.svg", bbox_inches='tight')
```

8 Question 4: Correctness

(1) take mean correct over all questions and all users answered in SQL or RD (32/2*13) and the difference in correctness score
(2) calculate 95% CI for each

```
[ ]: # dfq4a: Create two columns mode and mean, with 2 rows per worker
dfq4a = df_anonymized_data.groupby(['worker_id', 'mode']).correct.agg(['mean'])
dfq4a.reset_index(inplace=True)
# display(dfq4a)

# dfq4b: Pivot to have one row per worker
dfq4b = pd.pivot_table(dfq4a, values=['mean'], index=['worker_id'],␣
 ↪columns=['mode'])
dfq4b=dfq4b.droplevel(0, axis=1)
dfq4b['diff'] = dfq4b['RD'] - dfq4b['SQL']
print("dfq4b:\n")
display(dfq4b)

# Calculate fraction of those better in either mode
num_SQLbetter = np.where(dfq4b['SQL'] > dfq4b['RD'], 1, 0).sum()
num_RDbetter = np.where(dfq4b['SQL'] < dfq4b['RD'], 1, 0).sum()
num_workers =len(dfq4b)
print(f'{num_SQLbetter}/{num_workers} ({num_SQLbetter/num_workers:.3f}) better␣
 ↪with SQL.')
print(f'{num_RDbetter}/{num_workers} ({num_RDbetter/num_workers:.3f}) better␣
 ↪with RD.')
print(f'{num_workers-num_RDbetter-num_RDbetter}/{num_workers}␣
 ↪({(num_workers-num_RDbetter-num_RDbetter)/num_workers:.3f}) equally good.')

# Mean of mean correctness for each mode Plus 95% CI
modes_diff = ['RD', 'SQL', 'diff']
mean_correct = {}
ci = {}
ci_delta = {}
for mode in modes_diff:
    mean_correct[mode] = np.mean(dfq4b[mode])
    ci[mode] = scipybootstrap((dfq4b[mode],), statistic=np.mean,␣
 ↪n_resamples=BOOTSTRAPSAMPLES, confidence_level=BOOTSTRAPCONFIDENCE,␣
 ↪method='percentile', axis=0).confidence_interval        #convert array to␣
 ↪sequence
    ci_delta[mode] = [mean_correct[mode] - ci[mode].low, ci[mode].high -␣
 ↪mean_correct[mode]]

print(f"mean RD correct = {mean_correct['RD']:.3f}, 95% CI [{ci['RD'].low:.3f},␣
 ↪{ci['RD'].high:.3f}]")
print(f"mean SQL correct = {mean_correct['SQL']:.3f}, 95% CI [{ci['SQL'].low:.
 ↪3f}, {ci['SQL'].high:.3f}]")
print(f"mean difference in correctness = {mean_correct['diff']:.3f}, 95% CI␣
 ↪[{ci['diff'].low:.3f}, {ci['diff'].high:.3f}]")
```

[ ]:
```python
# Removing 'diff' from variables
dfq4c=dfq4b.copy()
dfq4c.drop('diff', inplace=True, axis=1)
modes = ['RD', 'SQL']

# Define pre-settings
figwidth = 9.7
figheight = 6
xlab_size = 20
ylab_size = 20
figfont_size = 24

# Define consistent color maps
my_cmap_sns_light = [(0.9921568627450981, 0.8156862745098039, 0.
↪6352941176470588), (0.7764705882352941, 0.8588235294117647, 0.
↪9372549019607843)]        # light blue, light orange
my_cmap_sns_dark = [(0.9019607843137255, 0.3333333333333333, 0.
↪050980392156862744), (0.19215686274509805, 0.5098039215686274, 0.
↪7411764705882353)]      # dark blue, dark orange
my_cmap_dark = sns.color_palette(my_cmap_sns_dark, as_cmap=True)
my_cmap_light = sns.color_palette(my_cmap_sns_light, as_cmap=True)

# Create empty figure and plot the individual datapoints
fig, ax = plt.subplots(figsize=(figwidth,figheight))

# 1. Violinplots
axsns = sns.violinplot(x='mean', y='mode', data=dfq4a,
                       hue=True, hue_order=[False, True], split=True,   # half␣
↪violinplots https://stackoverflow.com/questions/53872439/
↪half-not-split-violin-plots-in-seaborn
                       inner='quartile',
                       cut=0,               # 0 means ending sharp at end points
                       width=.6,
                       orient = 'h',
                       zorder=20,)

# change the medium default line to full (https://stackoverflow.com/questions/
↪60638344/quartiles-line-properties-in-seaborn-violinplot)
for l in axsns.lines[1::3]:
    l.set_linestyle('-')
    l.set_linewidth(1.2)
    l.set_color('black')
    l.set_alpha(0.8)
for i in [0, 2, 3, 5]:         # remove the 25% and 75% quartiles
    l = axsns.lines[i]
    l.set_linestyle('-')
    l.set_linewidth(0)
```

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    l.set_color('red')
    l.set_alpha(0.8)

# Apply colorscheme to violinplots https://stackoverflow.com/questions/70442958/seaborn-how-to-apply-custom-color-to-each-seaborn-violinplot
from matplotlib.collections import PolyCollection
for ind, violin in enumerate(axsns.findobj(PolyCollection)):
    violin.set_facecolor(my_cmap_light[ind])
# plt.setp(ax.collections, alpha=.999)  # semi-transparent (https://stackoverflow.com/questions/62597959/seaborn-violinplot-transparency)


# 2. Plot individual points [new dot plot]
# Set the amount of jitter and create a dataframe containing the jittered x-axis values [kept for legacy reasons, could be simplified with new dot plot
jitter = 0.0     # 0.1
y_tilt = -0.5

# np.random.seed(3)
df_jitter = pd.DataFrame(
    np.random.uniform(low=y_tilt, high=y_tilt + jitter, size=dfq4c.values.shape),
    columns=dfq4c.columns)
df_jitter += np.arange(len(dfq4c.columns)) #Add to dataframe a number based on the length on the columns. Otherwise all datapoints would be at the same x-axis location.

# for i, col in enumerate(dfq4c):
#     ax.plot(dfq4c[col], df_jitter[col],
#             '^',
#             alpha=1,
#             zorder=20,      # higher means more visible
#             markersize=10,
#             markeredgewidth=1.5,
#             # markerfacecolor='none',
#             markerfacecolor=my_cmap_dark[i],
#             markeredgecolor=my_cmap_dark[i],)


# sns.swarmplot(x = "species", y = "petal_length", data = df)
def dotplot(input_x, y0, delta, **args):
    unique_values, counts = np.unique(input_x, return_counts=True)  # Count how many times does each value occur

    # Convert 1D input into 2D array
    scatter_x = [] # x values
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    scatter_y = [] # corresponding y values
    for idx, value in enumerate(unique_values):
        for counter in range(0, counts[idx]):
            scatter_x.append(value)
            scatter_y.append(y0+counter*delta)
    plt.scatter(scatter_x, scatter_y, **args)

for i, col in enumerate(dfq4c):
    dotplot(input_x=dfq4c[col], y0=df_jitter[col][0], delta=0.03,
            marker='^',
            alpha=1,
            zorder=20,       # higher means more visible
            color=my_cmap_dark[i],
            s=200,
            linewidth=0,)


# 4. Plot red line connecting means
ax.plot(np.mean(dfq4c, axis=0), [0, 1], color ='red', linewidth = 2, linestyle␣
 ↪='-',
        alpha = .3,
        zorder=4,
        )

# 5. CI Errorbars
for i, mode in enumerate(modes):
    plt.errorbar(mean_correct[mode], i, xerr=np.array([[ci_delta[mode][0],␣
 ↪ci_delta[mode][1]]]).T,
                 fmt='o', markersize=10,
                 lw = 5, alpha=1,
                 zorder=100,         # higher means more visible
                 capsize = 10,
                 # capthick = 4,
                 capthick = 0,
                 # color = 'black',
                 color=my_cmap_dark[i],
                 )   # my_cmap[1])

    # ax.text(median_time[column], y_tilt_mode[i]+y_tilt_section[j] + 0.18,␣
 ↪f'{median_time[column]:.1f}',
    #         horizontalalignment='center', color = my_cmap_sns_dark[i],␣
 ↪fontsize=20)
    ax.text(mean_correct[mode],
            i-0.2,
            f'{mean_correct[mode]:.2f}', horizontalalignment='center',
            # color='black',
            color=my_cmap_dark[i],
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            fontsize=figfont_size)
    # ax.text(ci[mode].low, i+0.1, f'{ci[mode].low:.2f}',␣
 ↪horizontalalignment='center', color='black', fontsize=20)
    # ax.text(ci[mode].high, i+0.1, f'{ci[mode].high:.2f}',␣
 ↪horizontalalignment='center', color='black', fontsize=20)


#Additional settings
# ax.set_yticklabels(modes, size= ylab_size)
# ax.set_xlim(0.7499, 1.0003)
ax.set_xlim(0.74, 1.01)
ax.set_ylim(-0.6, 1.5)
ax.set_xlabel('Mean correctness per worker', size = xlab_size)
ax.set_ylabel(None)
ax.set_yticklabels(['FigX', 'SQL'])
ax.legend_.remove()
plt.grid(axis = 'x', linewidth = 0.5, color = 'lightgray')
sns.despine()               # remove bounding box

if savefig:
    plt.savefig(fig_dir + "/q4_figure.pdf", bbox_inches='tight')
    plt.savefig(fig_dir + "/q4_figure.svg", bbox_inches='tight')
```