teaching_material_book

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Invalid Date

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Preface

Who ist this for

This tutorial is aimed at data scientists / analysts who want to write their first `teal` application. We expect you to already have some R experience and that you know what you want to achieve with the application. You do not need to know how to create a shiny application. The `teal` package aims to make the creation of (teal-specific) shiny applications relatively intuitive without the need to understand how shiny works exactly. Shiny knowledge is useful once you want to either modify an application, or write your own teal module from scratch.

What will you learn

How is it structured

All chapters in this book follow a common structure: First, the learning goals of a chapter is defined. We then go through the step-by-step process of using specific `teal` modules. In each chapter we combine what we learned into one code chunk with which we can create a functional teal application. As every `teal` app requires data, the app created in the introduction will be the fundamental building block of the apps in the subsequent chapters. In the *toy apps* created in each chapter you should be able to understand every line of code. The code for a more developed app (but built for the same purpose) and a deployed instance of that app is linked at the end of each chapter. What you learned in this chapter should give you a good understanding of how the more developed application works.

Where can you find more

1 Introduction

At the end of this chapter you should be able to

- understand the structure and utlility of `teal` apps
- understand the utility of `teal` apps
- determine whether `teal` apps are useful for *you*

1.1 Structure of teal apps

teal is a shiny-based modular framework. It provides an interactive user interface allowing users to customize tables and visualizations facilitating the exploration and analysis of clinical trial data. Dynamic analysis and display control, data filtering and code reproducibility are included in each module.

teal modules are laid out in three panels.

- The `Left Panel`, referred to as the encoding panel, includes elements used to adjust the output interactively.
- The `Center Panel`, referred to as the output panel, where the tables and visualizations are displayed.
- The `Right Panel`, referred to as the data filter panel, includes elements used to subset the data interactively.

The layout is pre-set within each module. However, user can decide overall tab order and nesting. See **?@fig-layout** for the typical teal app structure.

1.1.1 Modules

`teal` modules are modular building blocks for your `teal` app. They implement specific app functionalities, such as outlier exploration, data visualizations, and survival analysis. Although modules can be created from scratch, many `teal` modules have already been released and can be found in the following packages:

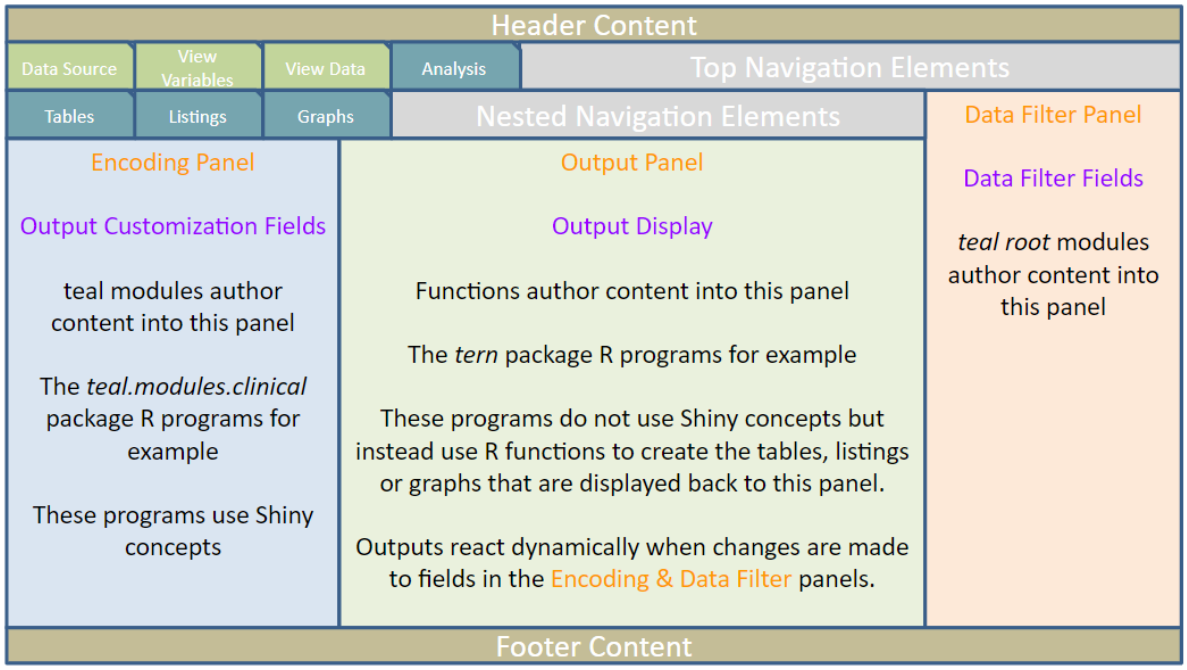

Figure 1.1: Typical teal app layout

- `teal.modules.general`: general modules for exploring relational/independent/CDISC data
- `teal.modules.clinical`: modules specific to CDISC data and clinical trial reporting
- `teal.modules.hermes`: modules for analyzing MultiAssayExperiment objects

are shiny modules built within the teal framework that specify analysis to be performed.

2 Data app

The App created at the end of this chapter will be the basic building block of all subsequent chapters in this book. The structure of the app code will remain consistent throughout the book — make sure you understand each line of code of the *toy* application at the end.

At the end of this chapter you should be able to

- understand the code structure of `teal` apps
- understand the workflow to create a `teal` app
- install and load the relevant packages
- write your own app that displays data

2.1 Setup

In this tutorial we will be working with realistic looking but simulated data.

```
if (!require("remotes")) install.packages("remotes")

# install teal
remotes::install_github("insightsengineering/teal@*release")

# install teal.modules.general
remotes::install_github("insightsengineering/teal.modules.general@*release")

# install teal.modules.hermes
remotes::install_github("insightsengineering/teal.modules.hermes@*release")
```

```
library(random.cdisc.data) # this package provides the data used
library(teal.data)
```

```
Loading required package: shiny
```

```
library(scda)
```

```
There are no scda.XXXX libraries installed, like scda.2022.
Please install an scda database to take full advantage of the scda package.
```

```
library(teal.modules.general)
```

```
Loading required package: ggmosaic
```

```
Loading required package: ggplot2
```

```
Loading required package: shinyTree
```

```
Loading required package: teal
```

```
Loading required package: teal.transform
```

```
Loading required package: magrittr
```

```
You are using teal version 0.12.0
```

```
library(sparkline)
library(teal)
library(tidyverse)
```

```
-- Attaching packages --------------------------------------- tidyverse 1.3.2 --

v tibble  3.1.8      v dplyr   1.0.10
v tidyr   1.2.1      v stringr 1.5.0
v readr   2.1.3      v forcats 0.5.2
v purrr   0.3.5
-- Conflicts ------------------------------------------ tidyverse_conflicts() --
x tidyr::extract()    masks magrittr::extract()
x dplyr::filter()     masks stats::filter()
x dplyr::lag()        masks stats::lag()
x tidyr::replace_na() masks random.cdisc.data::replace_na()
x purrr::set_names()  masks magrittr::set_names()
```

We first load two synthetic data sets. `random.cdisc.data::cadsl` is a Subject Level Analysis Dataset (ADSL) with one record (row) per subject. The unique identifier per subject is stored in the variable `USUBJID`. According to CDISC the main purpose of ADSL is to provide a "(…) source for denominators for populations of interest, stratification variables, and other important subject subgroups".

We can now load the three data-sets:

Data Structure for Adverse Event Analysis

```
ADSL <- random.cdisc.data::cadsl
ADAE <- random.cdisc.data::cadae
ADTTE <- random.cdisc.data::cadtte
```

Data-set name	Explanation	Meaning
ADSL	Analysis data-set subject level	
ADAE	Analysis data-set for adverse events	
ADTTE	Analysis data-set for time to event	

Analysis data-set for time to event (efficacy).

```
map(list(ADSL, ADAE, ADTTE), summary)
```

```
[[1]]
   STUDYID            USUBJID             SUBJID             SITEID
 Length:400         Length:400         Length:400         Length:400
 Class :character   Class :character   Class :character   Class :character
 Mode  :character   Mode  :character   Mode  :character   Mode  :character



      AGE            AGEU      SEX
 Min.   :20.00   YEARS:400   F:231
 1st Qu.:29.00               M:169
 Median :34.00
 Mean   :34.88
 3rd Qu.:39.00
 Max.   :69.00

                                        RACE                          ETHNIC
```

```
ASIAN                                          :208    NOT REPORTED          : 27
BLACK OR AFRICAN AMERICAN                      : 91   HISPANIC OR LATINO     : 48
WHITE                                          : 74   NOT HISPANIC OR LATINO:308
AMERICAN INDIAN OR ALASKA NATIVE               : 25   UNKNOWN                : 17
MULTIPLE                                       :  1
NATIVE HAWAIIAN OR OTHER PACIFIC ISLANDER:  1
(Other)                                        :  0
   COUNTRY    DTHFL      INVID              INVNAM
CHN    :219   N:330   Length:400         Length:400
USA    : 40   Y: 70   Class :character   Class :character
PAK    : 31           Mode  :character   Mode  :character
BRA    : 30
NGA    : 26
RUS    : 19
(Other): 35
            ARM         ARMCD                  ACTARM     ACTARMCD
A: Drug X     :134   ARM A:134   A: Drug X     :134   ARM A:134
B: Placebo    :134   ARM B:134   B: Placebo    :134   ARM B:134
C: Combination:132   ARM C:132   C: Combination:132   ARM C:132
```

```
           TRT01P                TRT01A                TRT02P
A: Drug X     :134   A: Drug X     :134   A: Drug X     :134
B: Placebo    :134   B: Placebo    :134   B: Placebo    :134
C: Combination:132   C: Combination:132   C: Combination:132
```

```
           TRT02A              REGION1    STRATA1 STRATA2      BMRKR1
A: Drug X     :134   Africa       : 26   A:122   S1:196   Min.    : 0.1654
B: Placebo    :134   Asia         :268   B:135   S2:204   1st Qu.: 3.3552
C: Combination:132   Eurasia      : 19   C:143            Median : 4.8392
                     Europe       :  9                    Mean   : 5.7628
                     North America: 48                    3rd Qu.: 7.4481
                     South America: 30                    Max.   :21.3934

   BMRKR2    ITTFL   SAFFL   BMEASIFL BEP01FL AEWITHFL     RANDDT
LOW   :135   Y:400   Y:400   Y:203    Y:197   Y: 23    Min.   :2019-02-22
MEDIUM:135                   N:197    N:203   N:377    1st Qu.:2019-09-13
HIGH  :130                                            Median :2020-02-16
```

```
                                                    Mean   :2020-02-20
                                                    3rd Qu.:2020-08-14
                                                    Max.   :2021-02-14

   TRTSDTM                          TRTEDTM
Min.   :2019-02-24 12:09:18.68   Min.   :2022-02-12 04:55:58.68
1st Qu.:2019-09-17 17:51:52.18   1st Qu.:2022-02-17 18:30:10.18
Median :2020-02-18 15:58:51.68   Median :2022-07-17 05:19:26.68
Mean   :2020-02-23 06:56:04.97   Mean   :2022-11-02 17:00:49.00
3rd Qu.:2020-08-18 00:04:25.18   3rd Qu.:2023-08-02 04:10:13.18
Max.   :2021-02-17 15:42:27.68   Max.   :2024-02-18 09:10:03.68
                                 NA's   :73
  TRT01SDTM                        TRT01EDTM
Min.   :2019-02-24 12:09:18.68   Min.   :2021-02-11 23:06:46.68
1st Qu.:2019-09-17 17:51:52.18   1st Qu.:2021-02-17 12:40:58.18
Median :2020-02-18 15:58:51.68   Median :2021-07-16 23:30:14.68
Mean   :2020-02-23 06:56:04.97   Mean   :2021-11-02 11:11:37.00
3rd Qu.:2020-08-18 00:04:25.18   3rd Qu.:2022-08-01 22:21:01.18
Max.   :2021-02-17 15:42:27.68   Max.   :2023-02-18 03:20:51.68
                                 NA's   :73
  TRT02SDTM                        TRT02EDTM
Min.   :2021-02-11 23:06:46.68   Min.   :2022-02-12 04:55:58.68
1st Qu.:2021-02-17 12:40:58.18   1st Qu.:2022-02-17 18:30:10.18
Median :2021-07-16 23:30:14.68   Median :2022-07-17 05:19:26.68
Mean   :2021-11-02 11:11:37.00   Mean   :2022-11-02 17:00:49.00
3rd Qu.:2022-08-01 22:21:01.18   3rd Qu.:2023-08-02 04:10:13.18
Max.   :2023-02-18 03:20:51.68   Max.   :2024-02-18 09:10:03.68
NA's   :73                       NA's   :73
   AP01SDTM                         AP01EDTM
Min.   :2019-02-24 12:09:18.68   Min.   :2021-02-11 23:06:46.68
1st Qu.:2019-09-17 17:51:52.18   1st Qu.:2021-02-17 12:40:58.18
Median :2020-02-18 15:58:51.68   Median :2021-07-16 23:30:14.68
Mean   :2020-02-23 06:56:04.97   Mean   :2021-11-02 11:11:37.00
3rd Qu.:2020-08-18 00:04:25.18   3rd Qu.:2022-08-01 22:21:01.18
Max.   :2021-02-17 15:42:27.68   Max.   :2023-02-18 03:20:51.68
                                 NA's   :73
   AP02SDTM                         AP02EDTM
Min.   :2021-02-11 23:06:46.68   Min.   :2022-02-12 04:55:58.68
1st Qu.:2021-02-17 12:40:58.18   1st Qu.:2022-02-17 18:30:10.18
Median :2021-07-16 23:30:14.68   Median :2022-07-17 05:19:26.68
Mean   :2021-11-02 11:11:37.00   Mean   :2022-11-02 17:00:49.00
3rd Qu.:2022-08-01 22:21:01.18   3rd Qu.:2023-08-02 04:10:13.18
Max.   :2023-02-18 03:20:51.68   Max.   :2024-02-18 09:10:03.68
```

```
NA's   :73                      NA's   :73
         EOSSTT              EOTSTT        EOSDT                EOSDY
COMPLETED   :207   COMPLETED   :207   Min.   :2022-02-12   Min.   : 369.0
DISCONTINUED:120   DISCONTINUED:120   1st Qu.:2022-02-17   1st Qu.: 868.0
ONGOING     : 73   ONGOING     : 73   Median :2022-07-17   Median :1096.0
                                      Mean   :2022-11-02   Mean   : 965.8
                                      3rd Qu.:2023-08-01   3rd Qu.:1096.0
                                      Max.   :2024-02-18   Max.   :1096.0
                                      NA's   :73           NA's   :73
              DCSREAS        DTHDT                          DTHCAUS
DEATH              : 70   Min.   :2022-02-14   ADVERSE EVENT      : 26
ADVERSE EVENT      : 14   1st Qu.:2022-03-01   DISEASE PROGRESSION: 20
PROTOCOL VIOLATION: 12   Median :2022-03-11   MISSING            :  7
LACK OF EFFICACY   :  7   Mean   :2022-03-13   LOST TO FOLLOW UP  :  6
PHYSICIAN DECISION:  7   3rd Qu.:2022-03-27   SUICIDE            :  5
(Other)            : 10   Max.   :2022-04-10   (Other)            :  6
NA's               :280   NA's   :330          NA's               :330
                DTHCAT       LDDTHELD    LDDTHGR1      LSTALVDT
ADVERSE EVENT      : 26   Min.   : 1.0   <=30: 39   Min.   :2022-02-14
OTHER              : 24   1st Qu.:12.0   >30 : 31   1st Qu.:2022-03-15
PROGRESSIVE DISEASE: 20   Median :25.0   NA's:330   Median :2022-08-07
NA's               :330   Mean   :26.2              Mean   :2022-11-23
                          3rd Qu.:39.0              3rd Qu.:2023-08-21
                          Max.   :50.0              Max.   :2024-03-07
                          NA's   :330               NA's   :73
    DTHADY       ADTHAUT    study_duration_secs
Min.   : 399.0   No  : 10   Min.   :63113904
1st Qu.: 567.8   Yes : 47   1st Qu.:63113904
Median : 765.5   NA's:343   Median :63113904
Mean   : 762.4              Mean   :63113904
3rd Qu.: 923.0              3rd Qu.:63113904
Max.   :1122.0              Max.   :63113904
NA's   :330

[[2]]
  STUDYID            USUBJID             SUBJID             SITEID
Length:1934        Length:1934        Length:1934        Length:1934
Class :character   Class :character   Class :character   Class :character
Mode  :character   Mode  :character   Mode  :character   Mode  :character
```

```
     AGE            AGEU       SEX
Min.   :20.00   YEARS:1934   F:1174
1st Qu.:29.00                M: 760
Median :34.00
Mean   :34.77
3rd Qu.:39.00
Max.   :69.00

                                          RACE                          ETHNIC
ASIAN                                       :979    NOT REPORTED         : 138
BLACK OR AFRICAN AMERICAN                   :469   HISPANIC OR LATINO    : 262
WHITE                                       :367   NOT HISPANIC OR LATINO:1470
AMERICAN INDIAN OR ALASKA NATIVE            :109   UNKNOWN               :  64
MULTIPLE                                    :  6
NATIVE HAWAIIAN OR OTHER PACIFIC ISLANDER:  4
(Other)                                     :  0
   COUNTRY     DTHFL       INVID              INVNAM
CHN    :1061   N:1609   Length:1934        Length:1934
USA    : 207   Y: 325   Class :character   Class :character
BRA    : 156            Mode  :character   Mode  :character
PAK    : 137
NGA    : 127
RUS    :  97
(Other): 149
            ARM         ARMCD                 ACTARM     ACTARMCD
A: Drug X     :609   ARM A:609   A: Drug X     :609   ARM A:609
B: Placebo    :622   ARM B:622   B: Placebo    :622   ARM B:622
C: Combination:703   ARM C:703   C: Combination:703   ARM C:703



           TRT01P                TRT01A                TRT02P
A: Drug X     :609   A: Drug X     :609   A: Drug X     :659
B: Placebo    :622   B: Placebo    :622   B: Placebo    :647
C: Combination:703   C: Combination:703   C: Combination:628



           TRT02A              REGION1     STRATA1 STRATA2       BMRKR1
A: Drug X     :625   Africa       : 127   A:590   S1: 882   Min.   : 0.1654
B: Placebo    :701   Asia         :1273   B:661   S2:1052   1st Qu.: 3.3426
```

```
C: Combination:608   Eurasia      :  97   C:683            Median : 5.0342
                     Europe       :  31                    Mean   : 5.8690
                     North America: 250                    3rd Qu.: 7.6002
                     South America: 156                    Max.   :21.3934

   BMRKR2    ITTFL    SAFFL    BMEASIFL BEP01FL AEWITHFL     RANDDT
LOW   :664   Y:1934   Y:1934   Y: 932   Y:984   Y: 136   Min.   :2019-02-22
MEDIUM:685                     N:1002   N:950   N:1798   1st Qu.:2019-09-13
HIGH  :585                                               Median :2020-02-17
                                                         Mean   :2020-02-22
                                                         3rd Qu.:2020-08-21
                                                         Max.   :2021-02-09

   TRTSDTM                          TRTEDTM
Min.   :2019-02-24 12:09:18.68   Min.   :2022-02-12 04:55:58.68
1st Qu.:2019-09-16 20:21:14.68   1st Qu.:2022-02-17 04:34:27.68
Median :2020-02-21 17:10:24.68   Median :2022-07-28 19:11:19.68
Mean   :2020-02-25 10:02:54.85   Mean   :2022-11-12 11:11:22.47
3rd Qu.:2020-08-24 06:57:06.18   3rd Qu.:2023-08-06 21:34:02.68
Max.   :2021-02-11 22:33:08.68   Max.   :2024-02-09 23:56:28.68
                                 NA's   :348
  TRT01SDTM                        TRT01EDTM
Min.   :2019-02-24 12:09:18.68   Min.   :2021-02-11 23:06:46.68
1st Qu.:2019-09-16 20:21:14.68   1st Qu.:2021-02-16 22:45:15.68
Median :2020-02-21 17:10:24.68   Median :2021-07-28 13:22:07.68
Mean   :2020-02-25 10:02:54.85   Mean   :2021-11-12 05:22:10.47
3rd Qu.:2020-08-24 06:57:06.18   3rd Qu.:2022-08-06 15:44:50.68
Max.   :2021-02-11 22:33:08.68   Max.   :2023-02-09 18:07:16.68
                                 NA's   :348
  TRT02SDTM                        TRT02EDTM
Min.   :2021-02-11 23:06:46.68   Min.   :2022-02-12 04:55:58.68
1st Qu.:2021-02-16 22:45:15.68   1st Qu.:2022-02-17 04:34:27.68
Median :2021-07-28 13:22:07.68   Median :2022-07-28 19:11:19.68
Mean   :2021-11-12 05:22:10.47   Mean   :2022-11-12 11:11:22.47
3rd Qu.:2022-08-06 15:44:50.68   3rd Qu.:2023-08-06 21:34:02.68
Max.   :2023-02-09 18:07:16.68   Max.   :2024-02-09 23:56:28.68
NA's   :348                      NA's   :348
   AP01SDTM                         AP01EDTM
Min.   :2019-02-24 12:09:18.68   Min.   :2021-02-11 23:06:46.68
1st Qu.:2019-09-16 20:21:14.68   1st Qu.:2021-02-16 22:45:15.68
Median :2020-02-21 17:10:24.68   Median :2021-07-28 13:22:07.68
Mean   :2020-02-25 10:02:54.85   Mean   :2021-11-12 05:22:10.47
3rd Qu.:2020-08-24 06:57:06.18   3rd Qu.:2022-08-06 15:44:50.68
```

```
Max.   :2021-02-11 22:33:08.68   Max.   :2023-02-09 18:07:16.68
                                  NA's   :348
   AP02SDTM                          AP02EDTM
Min.   :2021-02-11 23:06:46.68   Min.   :2022-02-12 04:55:58.68
1st Qu.:2021-02-16 22:45:15.68   1st Qu.:2022-02-17 04:34:27.68
Median :2021-07-28 13:22:07.68   Median :2022-07-28 19:11:19.68
Mean   :2021-11-12 05:22:10.47   Mean   :2022-11-12 11:11:22.47
3rd Qu.:2022-08-06 15:44:50.68   3rd Qu.:2023-08-06 21:34:02.68
Max.   :2023-02-09 18:07:16.68   Max.   :2024-02-09 23:56:28.68
NA's   :348                      NA's   :348
         EOSSTT              EOTSTT          EOSDT                EOSDY
COMPLETED   :1021   COMPLETED   :1021   Min.   :2022-02-12   Min.   : 369.0
DISCONTINUED: 565   DISCONTINUED: 565   1st Qu.:2022-02-17   1st Qu.: 892.0
ONGOING     : 348   ONGOING     : 348   Median :2022-07-28   Median :1096.0
                                        Mean   :2022-11-11   Mean   : 972.9
                                        3rd Qu.:2023-08-06   3rd Qu.:1096.0
                                        Max.   :2024-02-09   Max.   :1096.0
                                        NA's   :348          NA's   :348
             DCSREAS          DTHDT                          DTHCAUS
DEATH              : 325   Min.   :2022-02-14   ADVERSE EVENT      : 124
ADVERSE EVENT      :  81   1st Qu.:2022-03-01   DISEASE PROGRESSION: 101
LACK OF EFFICACY   :  44   Median :2022-03-13   MISSING            :  32
PROTOCOL VIOLATION:  39   Mean   :2022-03-14   LOST TO FOLLOW UP  :  22
PHYSICIAN DECISION:  34   3rd Qu.:2022-03-29   SUICIDE            :  20
(Other)            :  42   Max.   :2022-04-09   (Other)            :  26
NA's               :1369   NA's   :1609         NA's               :1609
                DTHCAT        LDDTHELD     LDDTHGR1       LSTALVDT
ADVERSE EVENT      : 124   Min.   : 1.00   <=30: 182   Min.   :2022-02-14
OTHER              : 100   1st Qu.:12.00   >30 : 143   1st Qu.:2022-03-16
PROGRESSIVE DISEASE: 101   Median :25.00   NA's:1609   Median :2022-08-12
NA's               :1609   Mean   :26.98               Mean   :2022-12-02
                           3rd Qu.:40.00               3rd Qu.:2023-08-29
                           Max.   :50.00               Max.   :2024-02-29
                           NA's   :1609                NA's   :348
    DTHADY       ADTHAUT     study_duration_secs      ASEQ
Min.   : 399.0   No  :  38   Min.   :63113904    Min.   : 1.000
1st Qu.: 579.0   Yes : 233   1st Qu.:63113904    1st Qu.: 2.000
Median : 757.0   NA's:1663   Median :63113904    Median : 3.000
Mean   : 767.4               Mean   :63113904    Mean   : 3.954
3rd Qu.: 936.0               3rd Qu.:63113904    3rd Qu.: 6.000
Max.   :1106.0               Max.   :63113904    Max.   :10.000
NA's   :1609
    AESEQ                  AETERM              AELLT              AEDECOD
```

```
Min.   : 1.000   trm B.2.2.3.1:217   llt B.2.2.3.1:217   dcd B.2.2.3.1:217
1st Qu.: 2.000   trm A.1.1.1.1:214   llt A.1.1.1.1:214   dcd A.1.1.1.1:214
Median : 3.000   trm A.1.1.1.2:208   llt A.1.1.1.2:208   dcd A.1.1.1.2:208
Mean   : 3.954   trm D.2.1.5.3:208   llt D.2.1.5.3:208   dcd D.2.1.5.3:208
3rd Qu.: 6.000   trm B.2.1.2.1:193   llt B.2.1.2.1:193   dcd B.2.1.2.1:193
Max.   :10.000   trm D.1.1.4.2:185   llt D.1.1.4.2:185   dcd D.1.1.4.2:185
                 (Other)      :709   (Other)      :709   (Other)      :709
        AEHLT            AEHLGT      AEBODSYS    AESOC          AESEV
hlt A.1.1.1:422   hlgt A.1.1:422   cl A.1:422   cl A:422   MILD    :639
hlt B.2.2.3:217   hlgt D.1.1:368   cl B.1:178   cl B:588   MODERATE:752
hlt D.2.1.5:208   hlgt B.2.2:217   cl B.2:410   cl C:348   SEVERE  :543
hlt B.2.1.2:193   hlgt D.2.1:208   cl C.1:182   cl D:576
hlt D.1.1.4:185   hlgt B.2.1:193   cl C.2:166
hlt D.1.1.1:183   hlgt C.1.1:182   cl D.1:368
(Other)    :526   (Other)   :344   cl D.2:208
AESER       AEACN           AEREL       AEOUT           AESDTH   AESCONG
N:1148   Length:1934        N:1017   Length:1934        N:1573   N:1627
Y: 786   Class :character   Y: 917   Class :character   Y: 361   Y: 307
         Mode  :character            Mode  :character
```

```
AESDISAB AESHOSP  AESLIFE  AESMIE   TRTEMFL  AECONTRT
N:1608   N:1584   N:1784   N:1494     :   1   N:1164
Y: 326   Y: 350   Y: 150   Y: 440   Y:1933   Y: 770
```

```
    ASTDTM                         AENDTM
Min.   :2019-03-23 01:00:00.0   Min.   :2019-07-14 02:00:00.00
1st Qu.:2020-09-13 14:00:00.0   1st Qu.:2021-07-03 02:00:00.00
Median :2021-05-16 14:00:00.0   Median :2021-12-18 01:00:00.00
Mean   :2021-05-31 05:39:38.9   Mean   :2022-01-26 14:53:10.49
3rd Qu.:2021-12-27 01:00:00.0   3rd Qu.:2022-09-27 02:00:00.00
Max.   :2024-01-02 01:00:00.0   Max.   :2024-01-23 01:00:00.00

    ASTDY            AENDY           LDOSEDTM                       AETOXGR
Min.   :   0.0   Min.   :   5.0   Min.   :2019-03-16 12:13:13.17   1:639
1st Qu.: 215.2   1st Qu.: 511.0   1st Qu.:2020-03-03 09:07:03.99   2:374
Median : 422.0   Median : 709.5   Median :2020-10-02 08:38:33.20   3:378
```

```
Mean   : 461.3   Mean   : 701.7   Mean   :2020-10-11 01:17:57.76   4:182
3rd Qu.: 674.8   3rd Qu.: 941.0   3rd Qu.:2021-03-23 07:46:41.46   5:361
Max.   :1095.0   Max.   :1097.0   Max.   :2023-09-25 18:45:44.75

  SMQ01NAM           SMQ02NAM           SMQ01SC            SMQ02SC
Length:1934        Length:1934        Length:1934        Length:1934
Class :character   Class :character   Class :character   Class :character
Mode  :character   Mode  :character   Mode  :character   Mode  :character



  CQ01NAM          ANL01FL                  AERELNST
Length:1934         : 348   CONCURRENT ILLNESS :576
Class :character   Y:1586   DISEASE UNDER STUDY:566
Mode  :character            NONE               :218
                            OTHER              :574



                           AEACNOTH
MEDICATION                     :353
NONE                           :391
PROCEDURE/SURGERY              :793
SUBJECT DISCONTINUED FROM STUDY:397



[[3]]
  STUDYID            USUBJID             SUBJID             SITEID
Length:2000        Length:2000        Length:2000        Length:2000
Class :character   Class :character   Class :character   Class :character
Mode  :character   Mode  :character   Mode  :character   Mode  :character



     AGE            AGEU       SEX
Min.   :20.00   YEARS:2000   F:1155
1st Qu.:29.00                M: 845
Median :34.00
Mean   :34.88
```

```
3rd Qu.:39.00
Max.   :69.00

                                          RACE                          ETHNIC
ASIAN                                    :1040    NOT REPORTED         : 135
BLACK OR AFRICAN AMERICAN                : 455   HISPANIC OR LATINO    : 240
WHITE                                    : 370   NOT HISPANIC OR LATINO:1540
AMERICAN INDIAN OR ALASKA NATIVE         : 125   UNKNOWN               :  85
MULTIPLE                                 :   5
NATIVE HAWAIIAN OR OTHER PACIFIC ISLANDER:   5
(Other)                                  :   0
   COUNTRY     DTHFL       INVID              INVNAM
CHN    :1095   N:1650   Length:2000        Length:2000
USA    : 200   Y: 350   Class :character   Class :character
PAK    : 155            Mode  :character   Mode  :character
BRA    : 150
NGA    : 130
RUS    :  95
(Other): 175
            ARM        ARMCD                ACTARM     ACTARMCD
A: Drug X     :670   ARM A:670   A: Drug X     :670   ARM A:670
B: Placebo    :670   ARM B:670   B: Placebo    :670   ARM B:670
C: Combination:660   ARM C:660   C: Combination:660   ARM C:660



           TRT01P               TRT01A               TRT02P
A: Drug X     :670   A: Drug X     :670   A: Drug X     :670
B: Placebo    :670   B: Placebo    :670   B: Placebo    :670
C: Combination:660   C: Combination:660   C: Combination:660



           TRT02A             REGION1     STRATA1 STRATA2       BMRKR1
A: Drug X     :670   Africa       : 130   A:610   S1: 980   Min.   : 0.1654
B: Placebo    :670   Asia         :1340   B:675   S2:1020   1st Qu.: 3.3552
C: Combination:660   Eurasia      :  95   C:715             Median : 4.8392
                     Europe       :  45                     Mean   : 5.7628
                     North America: 240                     3rd Qu.: 7.4481
                     South America: 150                     Max.   :21.3934
```

```
   BMRKR2    ITTFL    SAFFL    BMEASIFL BEP01FL  AEWITHFL     RANDDT
LOW   :675   Y:2000   Y:2000   Y:1015   Y: 985   Y: 115   Min.   :2019-02-22
MEDIUM:675                     N: 985   N:1015   N:1885   1st Qu.:2019-09-13
HIGH  :650                                                Median :2020-02-16
                                                          Mean   :2020-02-20
                                                          3rd Qu.:2020-08-14
                                                          Max.   :2021-02-14

   TRTSDTM                          TRTEDTM
Min.   :2019-02-24 12:09:18.68   Min.   :2022-02-12 04:55:58.68
1st Qu.:2019-09-17 17:51:52.18   1st Qu.:2022-02-17 18:28:14.68
Median :2020-02-18 15:58:51.68   Median :2022-07-17 05:19:26.68
Mean   :2020-02-23 06:56:04.97   Mean   :2022-11-02 17:00:49.00
3rd Qu.:2020-08-18 00:04:25.18   3rd Qu.:2023-08-02 12:16:13.68
Max.   :2021-02-17 15:42:27.68   Max.   :2024-02-18 09:10:03.68
                                 NA's   :365
  TRT01SDTM                        TRT01EDTM
Min.   :2019-02-24 12:09:18.68   Min.   :2021-02-11 23:06:46.68
1st Qu.:2019-09-17 17:51:52.18   1st Qu.:2021-02-17 12:39:02.68
Median :2020-02-18 15:58:51.68   Median :2021-07-16 23:30:14.68
Mean   :2020-02-23 06:56:04.97   Mean   :2021-11-02 11:11:37.00
3rd Qu.:2020-08-18 00:04:25.18   3rd Qu.:2022-08-02 06:27:01.68
Max.   :2021-02-17 15:42:27.68   Max.   :2023-02-18 03:20:51.68
                                 NA's   :365
  TRT02SDTM                        TRT02EDTM
Min.   :2021-02-11 23:06:46.68   Min.   :2022-02-12 04:55:58.68
1st Qu.:2021-02-17 12:39:02.68   1st Qu.:2022-02-17 18:28:14.68
Median :2021-07-16 23:30:14.68   Median :2022-07-17 05:19:26.68
Mean   :2021-11-02 11:11:37.00   Mean   :2022-11-02 17:00:49.00
3rd Qu.:2022-08-02 06:27:01.68   3rd Qu.:2023-08-02 12:16:13.68
Max.   :2023-02-18 03:20:51.68   Max.   :2024-02-18 09:10:03.68
NA's   :365                      NA's   :365
   AP01SDTM                         AP01EDTM
Min.   :2019-02-24 12:09:18.68   Min.   :2021-02-11 23:06:46.68
1st Qu.:2019-09-17 17:51:52.18   1st Qu.:2021-02-17 12:39:02.68
Median :2020-02-18 15:58:51.68   Median :2021-07-16 23:30:14.68
Mean   :2020-02-23 06:56:04.97   Mean   :2021-11-02 11:11:37.00
3rd Qu.:2020-08-18 00:04:25.18   3rd Qu.:2022-08-02 06:27:01.68
Max.   :2021-02-17 15:42:27.68   Max.   :2023-02-18 03:20:51.68
                                 NA's   :365
   AP02SDTM                         AP02EDTM
Min.   :2021-02-11 23:06:46.68   Min.   :2022-02-12 04:55:58.68
1st Qu.:2021-02-17 12:39:02.68   1st Qu.:2022-02-17 18:28:14.68
```

```
Median :2021-07-16 23:30:14.68   Median :2022-07-17 05:19:26.68
Mean   :2021-11-02 11:11:37.00   Mean   :2022-11-02 17:00:49.00
3rd Qu.:2022-08-02 06:27:01.68   3rd Qu.:2023-08-02 12:16:13.68
Max.   :2023-02-18 03:20:51.68   Max.   :2024-02-18 09:10:03.68
NA's   :365                      NA's   :365
         EOSSTT              EOTSTT         EOSDT                EOSDY
COMPLETED   :1035   COMPLETED   :1035   Min.   :2022-02-12   Min.   : 369.0
DISCONTINUED: 600   DISCONTINUED: 600   1st Qu.:2022-02-17   1st Qu.: 865.0
ONGOING     : 365   ONGOING     : 365   Median :2022-07-17   Median :1096.0
                                        Mean   :2022-11-02   Mean   : 965.8
                                        3rd Qu.:2023-08-02   3rd Qu.:1096.0
                                        Max.   :2024-02-18   Max.   :1096.0
                                        NA's   :365          NA's   :365
              DCSREAS         DTHDT                          DTHCAUS
DEATH              : 350   Min.   :2022-02-14   ADVERSE EVENT      : 130
ADVERSE EVENT      :  70   1st Qu.:2022-03-01   DISEASE PROGRESSION: 100
PROTOCOL VIOLATION:  60   Median :2022-03-11   MISSING            :  35
LACK OF EFFICACY   :  35   Mean   :2022-03-13   LOST TO FOLLOW UP  :  30
PHYSICIAN DECISION:  35   3rd Qu.:2022-03-28   SUICIDE            :  25
(Other)            :  50   Max.   :2022-04-10   (Other)            :  30
NA's               :1400   NA's   :1650         NA's               :1650
                DTHCAT        LDDTHELD    LDDTHGR1       LSTALVDT
ADVERSE EVENT      : 130   Min.   : 1.0   <=30: 195   Min.   :2022-02-14
OTHER              : 120   1st Qu.:12.0   >30 : 155   1st Qu.:2022-03-15
PROGRESSIVE DISEASE: 100   Median :25.0   NA's:1650   Median :2022-08-07
NA's               :1650   Mean   :26.2               Mean   :2022-11-23
                           3rd Qu.:39.0               3rd Qu.:2023-08-23
                           Max.   :50.0               Max.   :2024-03-07
                           NA's   :1650               NA's   :365
    DTHADY       ADTHAUT     study_duration_secs      ASEQ          TTESEQ
Min.   : 399.0   No  :  50   Min.   :63113904    Min.   :1.00   Min.   :1.00
1st Qu.: 564.0   Yes : 235   1st Qu.:63113904    1st Qu.:1.75   1st Qu.:1.75
Median : 765.5   NA's:1715   Median :63113904    Median :2.50   Median :2.50
Mean   : 762.4               Mean   :63113904    Mean   :2.50   Mean   :2.50
3rd Qu.: 924.0               3rd Qu.:63113904    3rd Qu.:3.25   3rd Qu.:3.25
Max.   :1122.0               Max.   :63113904    Max.   :4.00   Max.   :4.00
NA's   :1650                                     NA's   :400    NA's   :400
                          PARAM     PARAMCD         AVAL           AVALU
Duration of Confirmed Response:400   CRSD:400   Min.   :   0.00   COUNT: 400
Event Free Survival           :400   EFS :400   1st Qu.:  35.74   DAYS :1600
Overall Survival              :400   OS  :400   Median : 209.89
Progression Free Survival     :400   PFS :400   Mean   : 395.45
Total Number of Exacerbations :400   TNE :400   3rd Qu.: 531.73
```

```
                                                  Max.   :4708.68

      ADTM                          ADY              CNSR
 Min.   :2019-03-14 01:00:00   Min.   :   0.0   Min.   :0.000
 1st Qu.:2020-09-24 02:00:00   1st Qu.: 211.0   1st Qu.:0.000
 Median :2021-05-16 02:00:00   Median : 434.0   Median :0.000
 Mean   :2021-05-28 14:42:18   Mean   : 460.8   Mean   :0.307
 3rd Qu.:2021-12-11 07:00:00   3rd Qu.: 678.2   3rd Qu.:1.000
 Max.   :2024-01-07 01:00:00   Max.   :1095.0   Max.   :1.000
 NA's   :400                   NA's   :400
   EVNTDESC           CNSDTDSC           lgTMATRSK
 Length:2000        Length:2000        Min.   :-7.3986
 Class :character   Class :character   1st Qu.:-2.2568
 Mode  :character   Mode  :character   Median :-1.4884
                                       Mean   :-1.7128
                                       3rd Qu.:-0.8414
                                       Max.   : 1.1114
                                       NA's   :1600
```

2.2 Your first app

As is generally the case when you start a project, you should have an approximate idea of what you would like to achieve. In this case, the aim is to create an app that visualizes variables of three connected study data-sets.

2.3 Code structure

First, you want to define the project metadata. This can include the author name, the study name, the molecule name, etc. then, we have a section where we can define parameters for the app. This can be simple parameter values but they can also be short code snippets that would otherwise often be repeated throughout the application, e.g. preselected variables of interest.

After that, we define the app using the `init()` function. This function takes data, modules, and html input and returns a list (usually named `app`) containing the user interface (the `ui` object) and back end (the `server` object) of the application. In the final step we instantiate the app by calling `shinyApp(app$ui, app$server)`.

2.4 `init()`

The most crucial function of the `teal` package(s) is the `teal::init()` function, which is structured as follows:

```
init(
  data,
  modules,
  title = NULL,
  filter = list(),
  header = tags$p("Add Title Here"),
  footer = tags$p("Add Footer Here"),
  id = character(0))
```

The `init()` function sets up a shiny app that consists of `teal` modules. Let's go through the arguments:

`data`

In the `data` argument we define one or more data-frames for the application. If more than one data-frames are specified, they should be combined as a list, e.g. `data = list(ADSL, ADTR)`. For ADaM data-sets, the package `teal.data` provides helper functions with which the `data` argument of `init()` can be specified, — the `cdisc_data()` and the `cdisc_dataset()` functions. They allow the teal app to know the merge key variables of the data-sets. The `cdisc_data`function returns an S6 object.

`keys` are prespecified variables in ADaM data to merge data-sets. Each type of data-set requires specific keys to be specified. The package `teal.data` automatically chooses the correct key variables based on the `dataname` for the following data-sets: ADSL, ADAE, ADEG, ADTTE, ADAETTE, ADCM, ADEX, ADLB, ADMH, ADQS, ADRS, ADSAFTTE, ADVS, ADDV, ADSUB, ADHY.
If you want to work with other ADaM data-sets you must specify the keys manually. ADTR is a Tumor Results Analysis data-set where there is one record (row) per subject. As of now, this is not part of the default cdisc keys in the `teal.data` package, so we would have to specify them manually:

```
ADTR <- random.cdisc.data::cadtr


cdisc_data(
  cdisc_dataset("ADSL", ADSL),
  cdisc_dataset("ADTR", ADTR, keys = c("STUDYID", "USUBJID", "PARAMCD", "AVISIT")))
```

Note that all keys have to be specified.

pre-processing

Generally, it is recommended to collect all data pre-processing steps in a separate R-script, which can then directly be applied to the '`cdisc_data()`' output. One such preprocessing steps could be the creation of a new variable in the ADSL data-set which splits patients into two age groups where patients younger than 40 are `AGEGR = 0` and patients older than 40 are `AGEGR = 1`.

```
# you would write this in a seperate file directly, without the writeLines command.
writeLines(
  text = c("ADSL <- ADSL %>%
      dplyr::mutate(AGEGR = if_else(AGE < 40, 0, 1, NA_real_))"),
  con = "ADSL_preproc.R"
)
```

The resulting R file looks something like this:
ADSL <- ADSL %>% dplyr::mutate(AGEGR = if_else(AGE < 40, 0, 1, NA_real_))

```
ADSL_processed <- ADSL %>%
  cdisc_dataset("ADSL", .) %>%
  mutate_dataset(script = "ADSL_preproc.R")
# check if the new variable exists:
ADSL_processed$get_raw_data()$AGEGR
```

```
  [1] 0 0 0 0 1 1 0 0 0 0 1 0 1 0 0 1 1 0 0 1 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0
 [38] 0 0 1 1 0 0 0 0 0 1 0 0 0 0 1 1 0 0 1 0 0 0 0 0 1 0 0 1 0 0 1 0 0 0 0 0 0
 [75] 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 1 0 1
[112] 0 0 0 1 0 1 0 0 1 0 1 0 0 0 0 0 0 1 0 1 0 0 0 0 1 1 0 1 0 0 0 1 1 0 0 0 0
[149] 0 1 1 0 1 0 0 1 0 0 0 1 0 1 0 0 1 1 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0
[186] 1 0 0 1 0 0 0 0 0 0 0 1 0 1 0 0 1 0 1 0 0 1 0 1 0 0 0 0 0 0 0 1 1 0 0 0 0
[223] 0 0 0 0 0 1 0 0 1 0 0 0 0 0 1 0 0 0 1 0 0 1 0 0 0 1 0 0 1 0 0 0 0 1 1 0 0
[260] 0 1 1 0 0 1 0 0 1 0 0 0 1 0 1 0 0 1 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0
[297] 0 0 0 0 0 0 1 0 1 0 1 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 1 0 0
[334] 1 0 0 1 1 1 1 0 1 1 0 0 1 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 1 1
[371] 0 0 1 0 0 1 0 1 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1
```

In a real world case we would not necessarily want to separately save the preprocessed `ADSL` in our environment. Instead, we would apply the preprocessing within the `data` argument of the `init()` function, e.g., like this:

```
app <- teal::init(data = cdisc_data(
  cdisc_dataset("ADSL", ADSL) %>%
    mutate_dataset(script = "ADSL_preproc.R"),
  cdisc_dataset("ADAE", ADAE),
  cdisc_dataset("ADTTE", ADTTE)
  # <<additional dataset code>>
  ),
  #  <<additional init arguments code>>
```

2.4.1 `modules`

header

footer

id

Combining everything above, our `init()` function looks like this:

```
app <- teal::init(
  data = cdisc_data(
    cdisc_dataset("ADSL", ADSL) %>%
      mutate_dataset(script = "ADSL_preproc.R"),
    cdisc_dataset("ADAE", ADAE),
    cdisc_dataset("ADTTE", ADTTE)
  ),
  modules = modules(tm_variable_browser(label = "View Variables")),
  header = "My first application",
  footer = "footer"
)
```

2.5 Toy app

```
# data app
## ---- load packages data app ----
library(random.cdisc.data) # this package provides the data used
library(teal.data)
library(scda)
library(teal.modules.general)
library(sparkline)
library(teal)
library(tidyverse)

## ---- parameter data app ----
author <- "Stefan Thoma"
molecule <- "hexadromedar"


## ---- load data data app ----
ADSL <- random.cdisc.data::cadsl
ADAE <- random.cdisc.data::cadae
ADTTE <- random.cdisc.data::cadtte


## ---- init data app ----
app <- teal::init(
  data = cdisc_data(
    cdisc_dataset("ADSL", ADSL) %>%
```

```
      mutate_dataset(script = "ADSL_preproc.R"),
    cdisc_dataset("ADAE", ADAE),
    cdisc_dataset("ADTTE", ADTTE)
  ),
  modules = modules(tm_variable_browser(label = "View Variables")),
  header = "My first application",
  footer = "footer"
)


## ---- run data app ----
shinyApp(app$ui, app$server)
```

The output should look something like this:

2.6 Production app

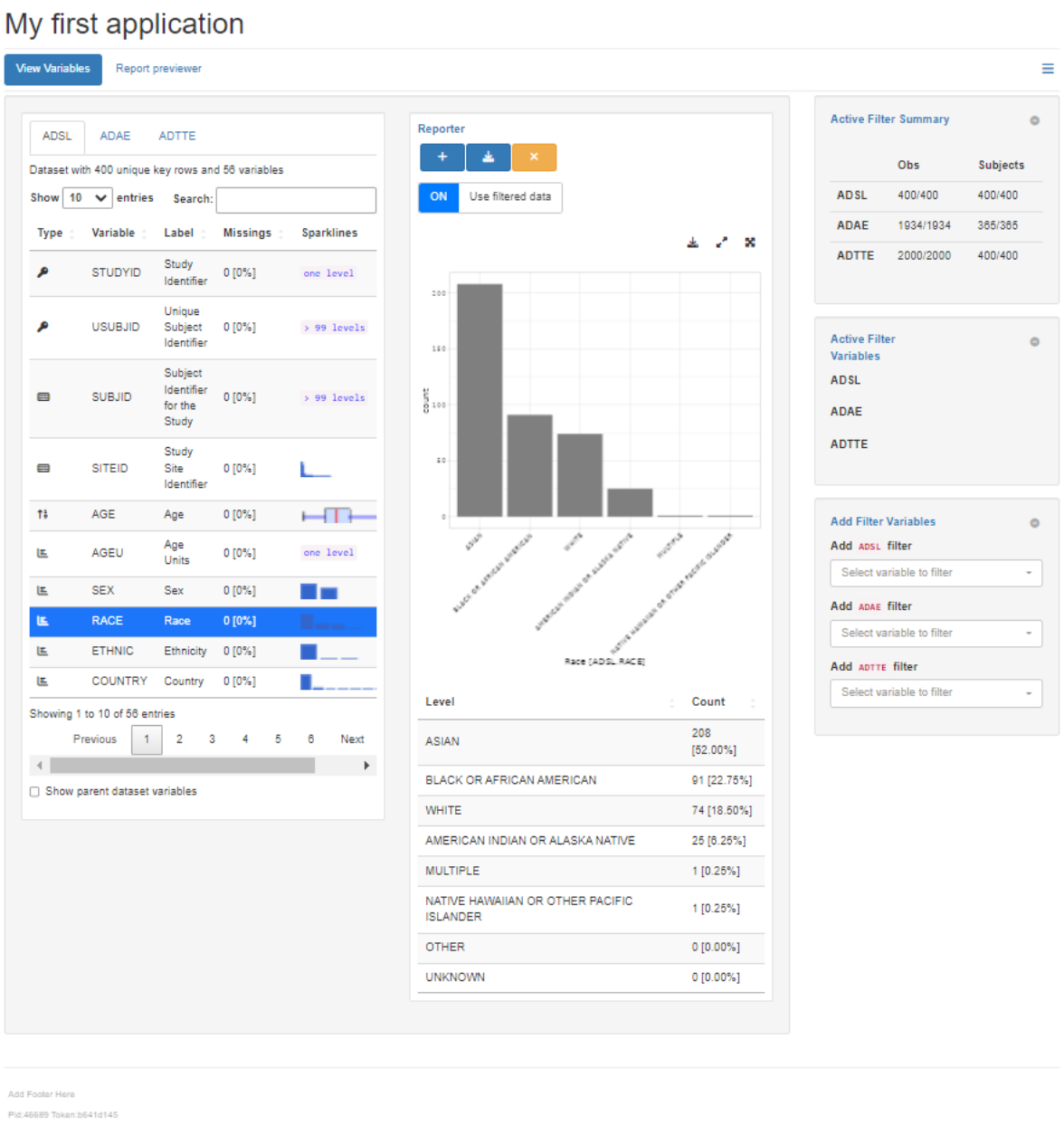

Figure 2.1: Data App preview

3 efficacy

http://docs.roche.com/#/agile-R/2022_01_28/teal/sample_apps/sample-app-efficacy/

4 Summary

In summary, this book has no content whatsoever.

```
1 + 1
```

```
[1] 2
```

References