Supplementary Material for 'Lexidate Selection Set Analysis: Varying Selection Schemes To Assess Generalizability Of Evolved Machine Learning Pipelines'

Jose Guadalupe Hernandez, Anil Kumar Saini, Jason H. Moore

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Contents

Chapter 1

Introduction

This is not intended as a stand-alone document, but as a companion to our manuscript.

1.1 About our supplemental material

As you may have noticed (unless you're reading a pdf version of this), our supplemental material is hosted using GitHub pages. We compiled our data analyses and supplemental documentation into this nifty web-accessible book using bookdown.

The code used for this supplemental material can be found in this GitHub repository.

Our supplemental material includes the following:

- Helper functions (Section 2)

1.2 Contributing authors

- Jose Guadalupe Hernandez
- Anil Kumar Saini
- Jason H. Moore

Chapter 2

Helper functions

Here we show the functions being used to generate the supplementary material. All of the following functions are compsed of R code and are used to generate the figures, tables, and statitics.

2.1 Setup

```
library(ggplot2)
library(cowplot)
library(dplyr)
library(PupillometryR)


NAMES = c('tournament', 'lexicase')
SHAPE <- c(21, 21)
cb_palette <- c('#DC1E34', '#004D40')
data_dir <- './'
c_task_id_lists <- c(146818,359954,359955,190146,168757,359956,
                        359958,359959,2073,359960,168784,359962)

p_theme <- theme(
  plot.title = element_text(face = "bold", size = 17, hjust=0.5),
  panel.border = element_blank(),
  panel.grid.minor = element_blank(),
  legend.title=element_text(size=17),
  legend.text=element_text(size=17),
  axis.title = element_text(size=17),
  axis.text = element_text(size=11),
  axis.text.y = element_text(angle = 90, hjust = 0.5),
  legend.position="bottom",
  panel.background = element_rect(fill = "#f1f2f5",
                                  colour = "white",
                                  size = 0.5, linetype = "solid"))

results <- read.csv("./data.csv")
results$selection <- factor(results$selection, levels = NAMES)
```

2.2 Test set plot

```
test_plot <- function(data) { return(
    ggplot(data,
    aes(x = selection, y = testing_performance, color = selection,
                fill = selection, shape = selection)) +
    geom_flat_violin(position = position_nudge(x = 0.1, y = 0),
                    scale = "width", alpha = 0.2, width = 1.5) +
    geom_boxplot(color = "black", width = .08, outlier.shape = NA,
                alpha = 0.0, linewidth = 0.8,
                position = position_nudge(x = .15, y = 0)) +
    geom_point(position = position_jitter(width = 0.03,
                height = 0.0), size = 1.5, alpha = 1.0) +
    scale_y_continuous(
    name = "Accuracy %",
    labels = scales::percent,

    ) +
    scale_x_discrete(
    name = "Selection scheme"
    ) +
    scale_shape_manual(values = SHAPE,) +
    scale_colour_manual(values = cb_palette,) +
    scale_fill_manual(values = cb_palette,) +
    ggtitle('Accuracy on test set') +
    p_theme +
    guides(
    shape=guide_legend(nrow = 1, title.position = "left",
                        title = "Selection scheme"),
    color=guide_legend(nrow = 1, title.position = "left",
                        title = "Selection scheme"),
    fill=guide_legend(nrow = 1, title.position = "left",
                        title = "Selection scheme")) +
    theme(axis.ticks.x = element_blank(),
            axis.text.x = element_blank(),
            axis.title.x = element_blank(),
            axis.text.y = element_text(angle = 90, hjust = 0.5))
)}
```

2.3 Test set results summary

```
test_results_summary <- function(data) {
    return(
        data %>%
        group_by(selection) %>%
        dplyr::summarise(
            count = n(),
            na_cnt = sum(is.na(testing_performance)),
            min = min(testing_performance, na.rm = TRUE),
            median = median(testing_performance, na.rm = TRUE),
            mean = mean(testing_performance, na.rm = TRUE),
            max = max(testing_performance, na.rm = TRUE),
```

```
            IQR = IQR(testing_performance, na.rm = TRUE))
    )
}
```

2.4 Permutaiton test results

```
# permutation test with t-test statistic
# assuming we are using an alpha of 0.05
permutation_test <- function(x, y, seed, alternative) {
  # Set the random seed for reproducibility
  set.seed(seed)

  # Number of permutations
  n_permutations = 100000

  # Calculate the observed difference in means
  observed_diff <- t.test(x, y, var.equal = FALSE)$statistic
  print(paste('observed_diff:', observed_diff))

  # Combine both samples
  combined <- c(x, y)
  n_x <- length(x)

  # Generate permutation differences
  permutation_diffs <- numeric(n_permutations)

  # Use a reproducible random sequence for each permutation
  # Generate unique seeds for each permutation
  seeds <- sample.int(1e9, n_permutations)

  for (i in 1:n_permutations) {
    # Set seed for this permutation
    set.seed(seeds[i])
    # Shuffle the combined data
    permuted <- sample(combined)
    # First n_x elements to group 1
    perm_x <- permuted[1:n_x]
    # Remaining elements to group 2
    perm_y <- permuted[(n_x + 1):length(combined)]
    # Calculate the difference in t-test statistics
    permutation_diffs[i] <- t.test(perm_x, perm_y,
                                   var.equal = FALSE)$statistic
  }

  # sort permutation_diffs
  permutation_diffs <- sort(permutation_diffs)

  if (alternative == "l") {
    # is the observed difference < than the 5th percentile
    print(paste('permutation_diffs[0.05 * n_permutations]:',
            permutation_diffs[0.05 * n_permutations]))

    if (observed_diff < permutation_diffs[0.05 * n_permutations]) {
```

```
    print('reject null hypothesis')
  }
  else {
    print('fail to reject null hypothesis')
  }

  # if p_value is 0
  p_value <- mean(permutation_diffs < observed_diff)
  if (p_value == 0.0) {
    print(paste('p-value:', 1/n_permutations))
  } else {
     print(paste('p-value:', p_value))
  }

  # make histogram plot
  df <- data.frame(difference = permutation_diffs)
  df$category <- ifelse(df$difference < observed_diff, 'not', 'extreme')

  plot <- ggplot(df, aes(x = difference, fill = category)) +
      geom_histogram(bins = 100,
                     color = "black",
                     alpha = 0.7) +
      geom_vline(xintercept = observed_diff,
                 color = "red",
                 linetype = "dotted",
                 size = 1
                 ) +
      labs(title = "Permutation Test: Frequency of T-test Satistic Differences",
              x = "Difference in t-test statistics",
              y = "Frequency"
              ) +
      theme_minimal() +
      scale_colour_manual(values = c('black', 'green')) +
      scale_fill_manual(values = c('black', 'green'))

print(plot)

} else if (alternative == "g") {
  # is the observed difference > than the 95th percentile
  print(paste('permutation_diffs[0.95 * n_permutations]:',
          permutation_diffs[0.95 * n_permutations]))

  if (permutation_diffs[0.95 * n_permutations] < observed_diff) {
    print('reject null hypothesis')
  }
  else{
    print('fail to reject null hypothesis')
  }

  # if p_value is 0
  p_value <- mean(permutation_diffs > observed_diff)
  if (p_value == 0.0) {
    print(paste('p-value:', 1/n_permutations))
  } else {
     print(paste('p-value:', p_value))
  }
```

```
  # make histogram plot
  df <- data.frame(difference = permutation_diffs)
  df$category <- ifelse(df$difference < observed_diff, 'not', 'extreme')

  plot <- ggplot(df, aes(x = difference, fill = category)) +
      geom_histogram(bins = 100,
                     color = "black",
                     alpha = 0.7) +
      geom_vline(xintercept = observed_diff,
                 color = "red",
                 linetype = "dotted",
                 size = 1
                 ) +
      labs(title = "Permutation Test: Frequency of T-test Satistic Differences",
              x = "Difference in t-test statistics",
              y = "Frequency"
              ) +
      theme_minimal() +
      scale_shape_manual(values = SHAPE,) +
      scale_colour_manual(values = c('green', 'black')) +
      scale_fill_manual(values = c('green', 'black'))

print(plot)
} else if (alternative == "t") {
  # is the observed difference within 2.5th and 97.5th percentile
  lower <- observed_diff < permutation_diffs[0.025 * n_permutations]
  print(paste('lower:', permutation_diffs[0.025 * n_permutations]))
  upper <- observed_diff > permutation_diffs[0.975 * n_permutations]
  print(paste('upper:', permutation_diffs[0.975 * n_permutations]))

  if (lower | upper) {
    print('reject null hypothesis')
  }
  else{
    print('fail to reject null hypothesis')
  }

  # if p_value is 0
  p_value <- mean(abs(permutation_diffs) > abs(observed_diff))
  if (p_value == 0.0) {
    print(paste('p-value:', 1/n_permutations))
  } else {
     print(paste('p-value:', p_value))
  }

  # make histogram plot
  df <- data.frame(difference = abs(permutation_diffs))
  df$category <- ifelse(df$difference > abs(observed_diff), 'extreme', 'not')

  plot <- ggplot(df, aes(x = difference, fill = category)) +
      geom_histogram(bins = 100,
                     color = "black",
                     alpha = 0.7) +
      geom_vline(xintercept = abs(observed_diff),
                 color = "red",
```

```
                    linetype = "dotted",
                    size = 1
                    ) +
        labs(title = "Permutation Test: Frequency of T-test Satistic Differences",
                x = "Difference in t-test statistics",
                y = "Frequency"
                ) +
        theme_minimal() +
        scale_shape_manual(values = SHAPE,) +
        scale_colour_manual(values = c('green', 'black')) +
        scale_fill_manual(values = c('green', 'black'))

  print(plot)

  } else {
    stop("Invalid alternative (less, greater, or two-sided.")
  }
}
```

2.5 Selection set plot

```
selection_plot <- function(data) { return(
    ggplot(data,
    aes(x = selection, y = training_performance, color = selection,
                fill = selection, shape = selection)) +
    geom_flat_violin(position = position_nudge(x = 0.1, y = 0),
                    scale = "width", alpha = 0.2, width = 1.5) +
    geom_boxplot(color = "black", width = .08, outlier.shape = NA,
                alpha = 0.0, linewidth = 0.8,
                position = position_nudge(x = .15, y = 0)) +
    geom_point(position = position_jitter(width = 0.03,
                height = 0.0), size = 1.5, alpha = 1.0) +
    scale_y_continuous(
    name = "Accuracy %",
    labels = scales::percent,

    ) +
    scale_x_discrete(
    name = "Selection set"
    ) +
    scale_shape_manual(values = SHAPE,) +
    scale_colour_manual(values = cb_palette,) +
    scale_fill_manual(values = cb_palette,) +
    ggtitle('Accuracy on selection set') +
    p_theme +
    guides(
    shape=guide_legend(nrow = 1, title.position = "left",
                        title = "Selection scheme"),
    color=guide_legend(nrow = 1, title.position = "left",
                        title = "Selection scheme"),
    fill=guide_legend(nrow = 1, title.position = "left",
                        title = "Selection scheme")) +
    theme(axis.ticks.x = element_blank(),
```

```
            axis.text.x = element_blank(),
            axis.title.x = element_blank(),
            axis.text.y = element_text(angle = 90, hjust = 0.5))
)}
```

2.6 Selection set results summary

```
selection_results_summary <- function(data) {
    return(
        data %>%
        group_by(selection) %>%
        dplyr::summarise(
            count = n(),
            na_cnt = sum(is.na(training_performance)),
            min = min(training_performance, na.rm = TRUE),
            median = median(training_performance, na.rm = TRUE),
            mean = mean(training_performance, na.rm = TRUE),
            max = max(training_performance, na.rm = TRUE),
            IQR = IQR(training_performance, na.rm = TRUE))
    )
}
```

Chapter 3

Task 146818

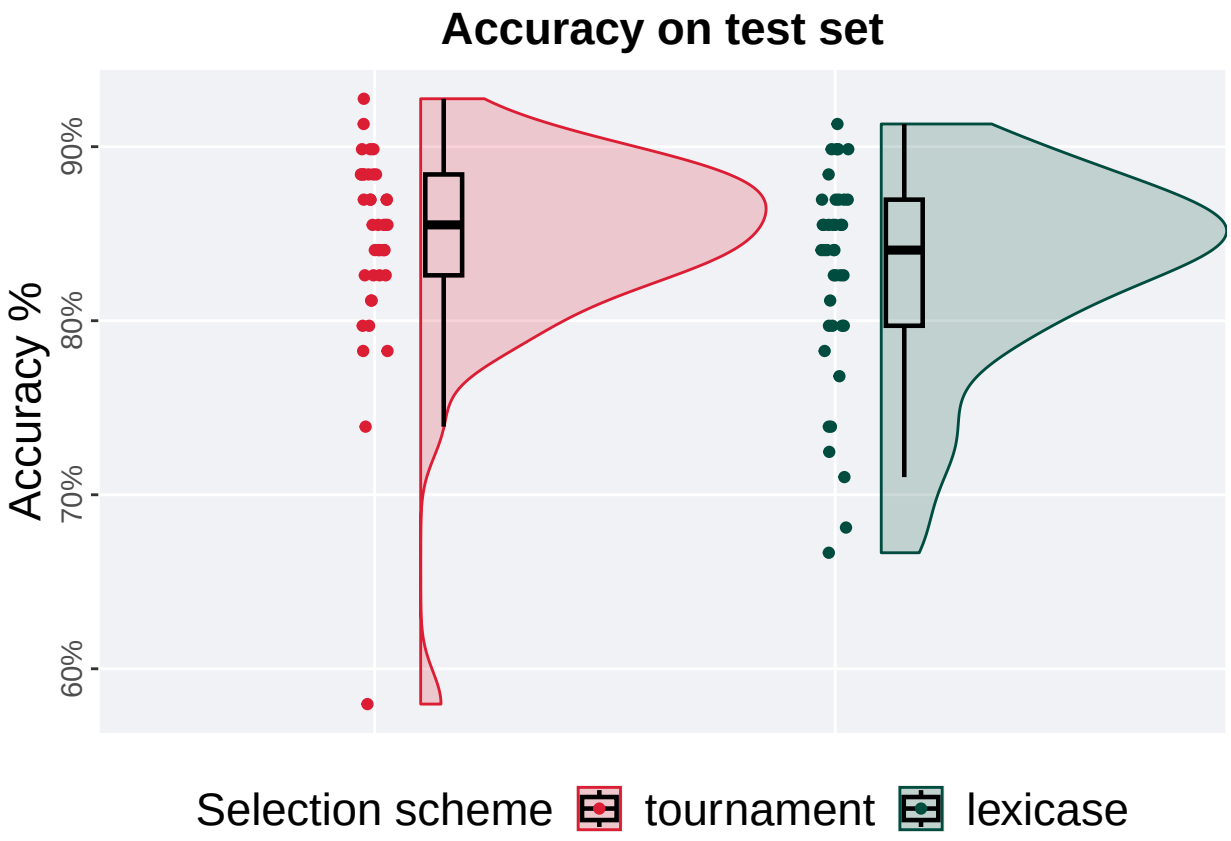
We present the results of our analysis of `task 146818` with the different selection set splits used in our study.

```
task_data <- filter(results, task_id == 146818)
```

3.1 5%

3.1.1 Testing set accuracy

```
test_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

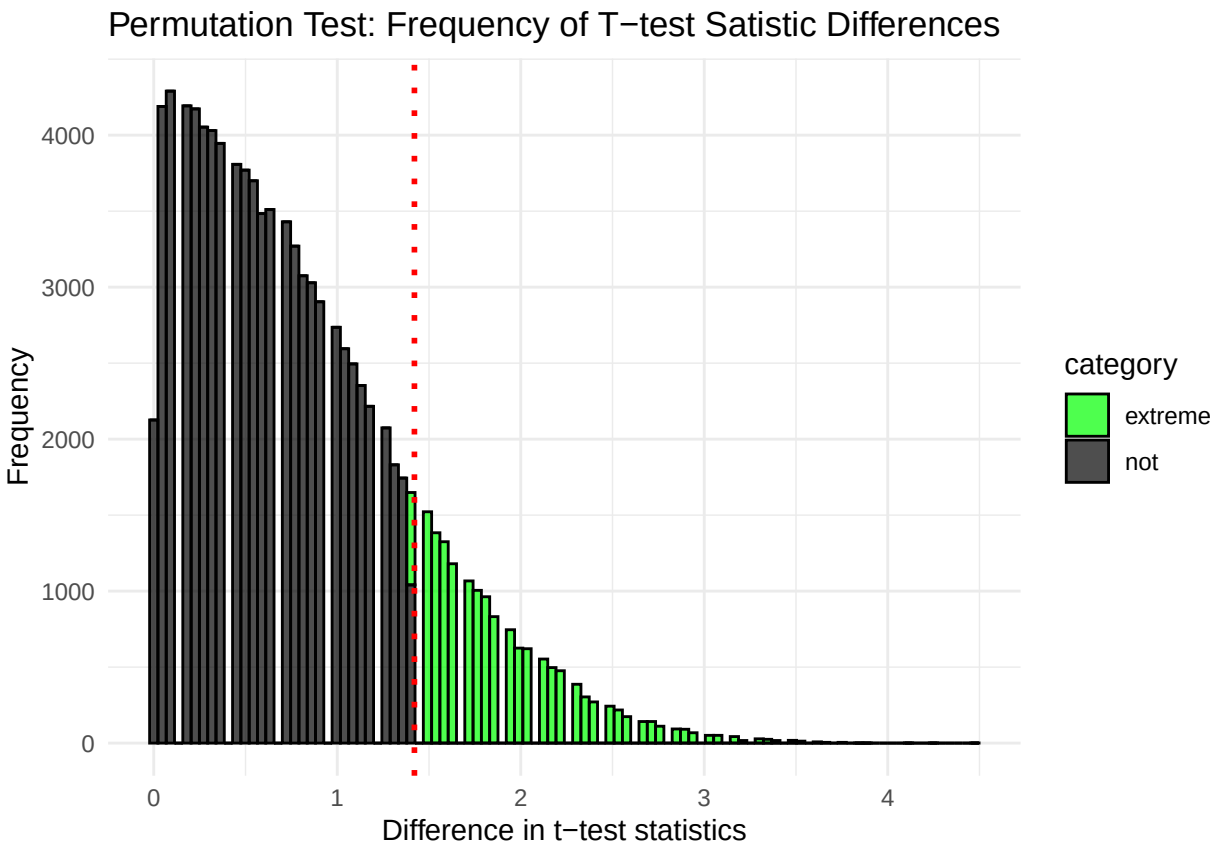
```
test_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.580  0.855 0.845 0.928 0.0580
## 2 lexicase      40      0 0.667  0.841 0.826 0.913 0.0725
```

The permutation test revealed that the results are:

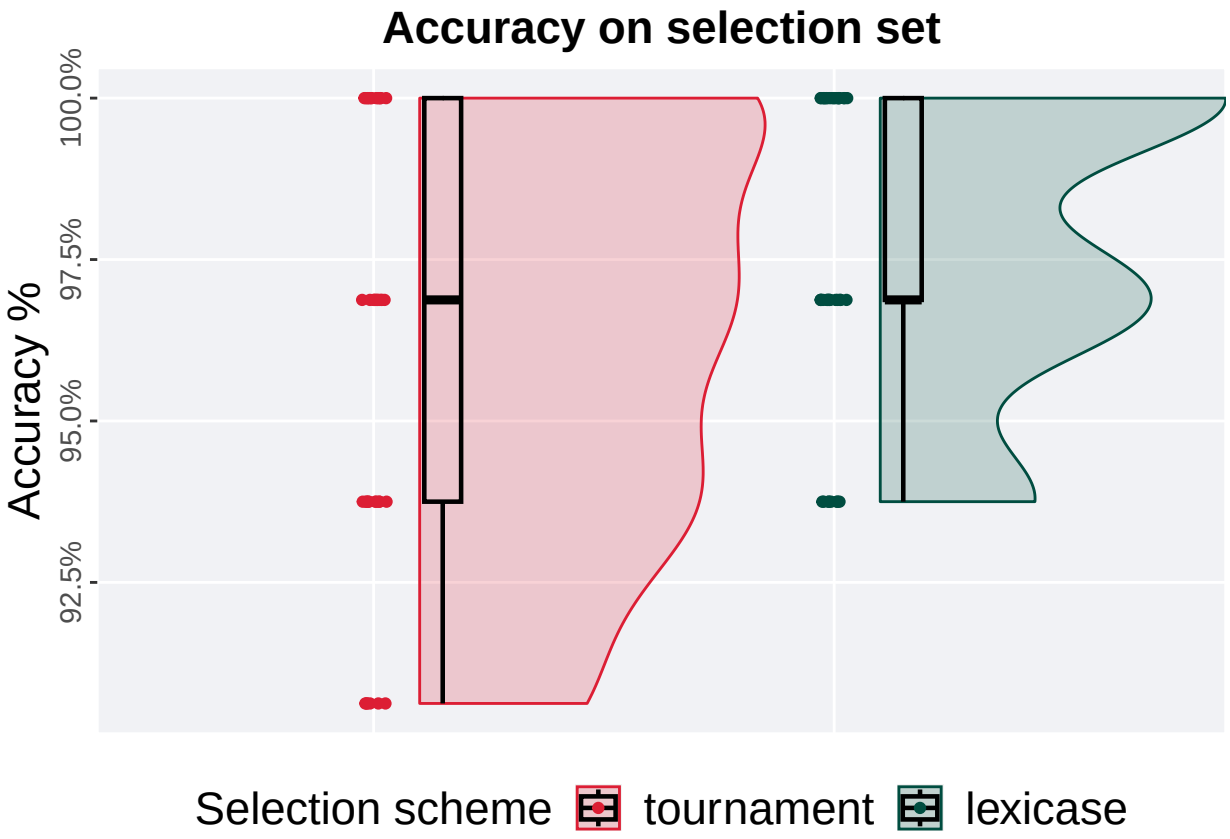
```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 1,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.42058620905175"
## [1] "lower: -1.99072649993754"
## [1] "upper: 1.99072649993754"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.15934"
```



3.1.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

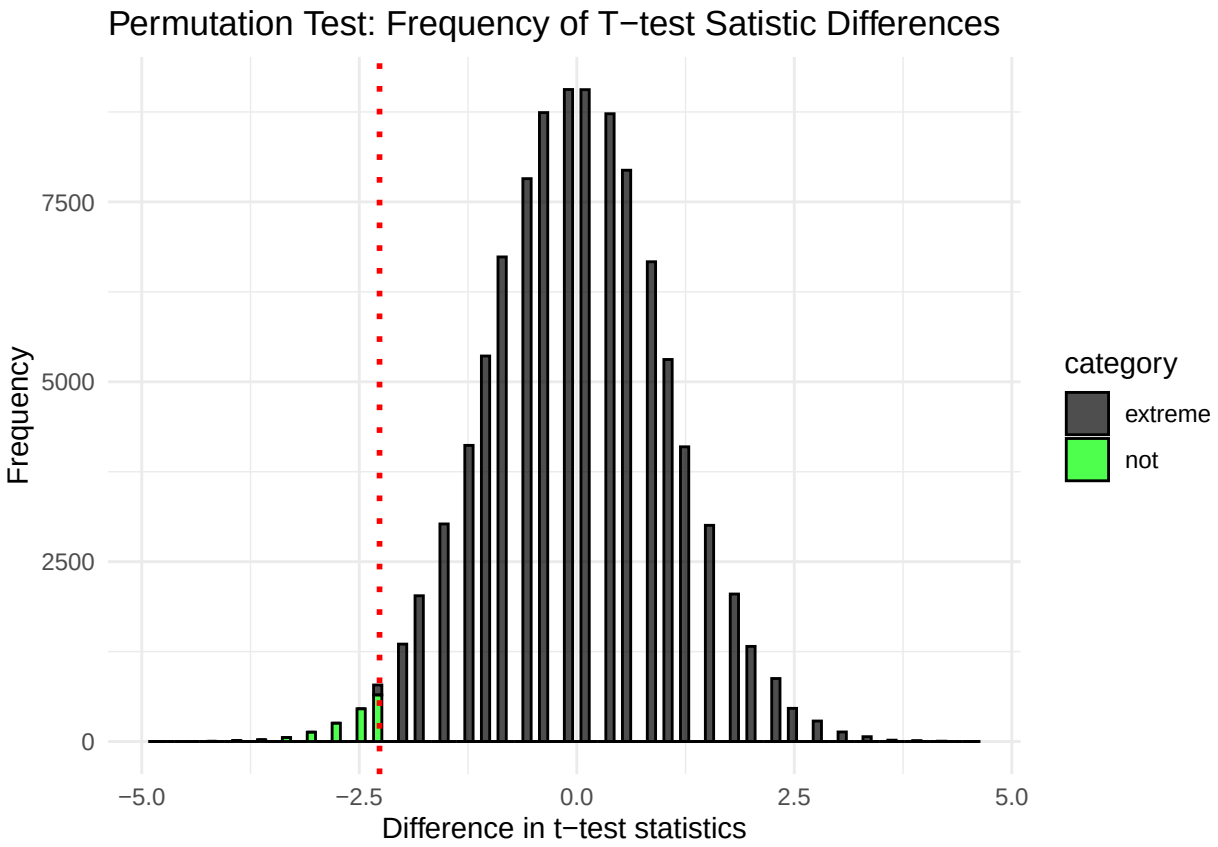
```
selection_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.906  0.969 0.962     1 0.0625
## 2 lexicase      40      0 0.938  0.969 0.977     1 0.0312
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 2,
                 alternative = "l")
```

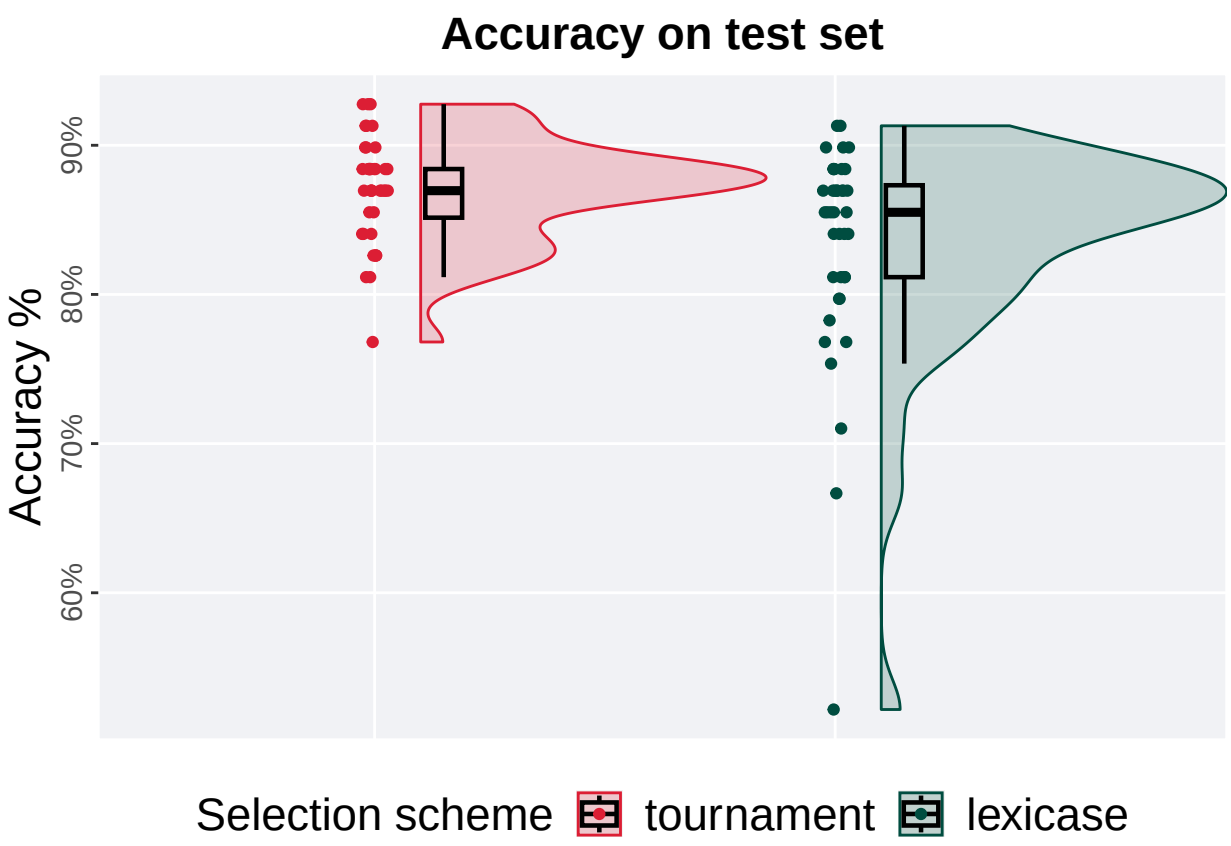
```
## [1] "observed_diff: -2.26720028939778"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.76808181038323"
## [1] "reject null hypothesis"
## [1] "p-value: 0.01586"
```



3.2 10%

3.2.1 Testing set accuracy

```
test_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

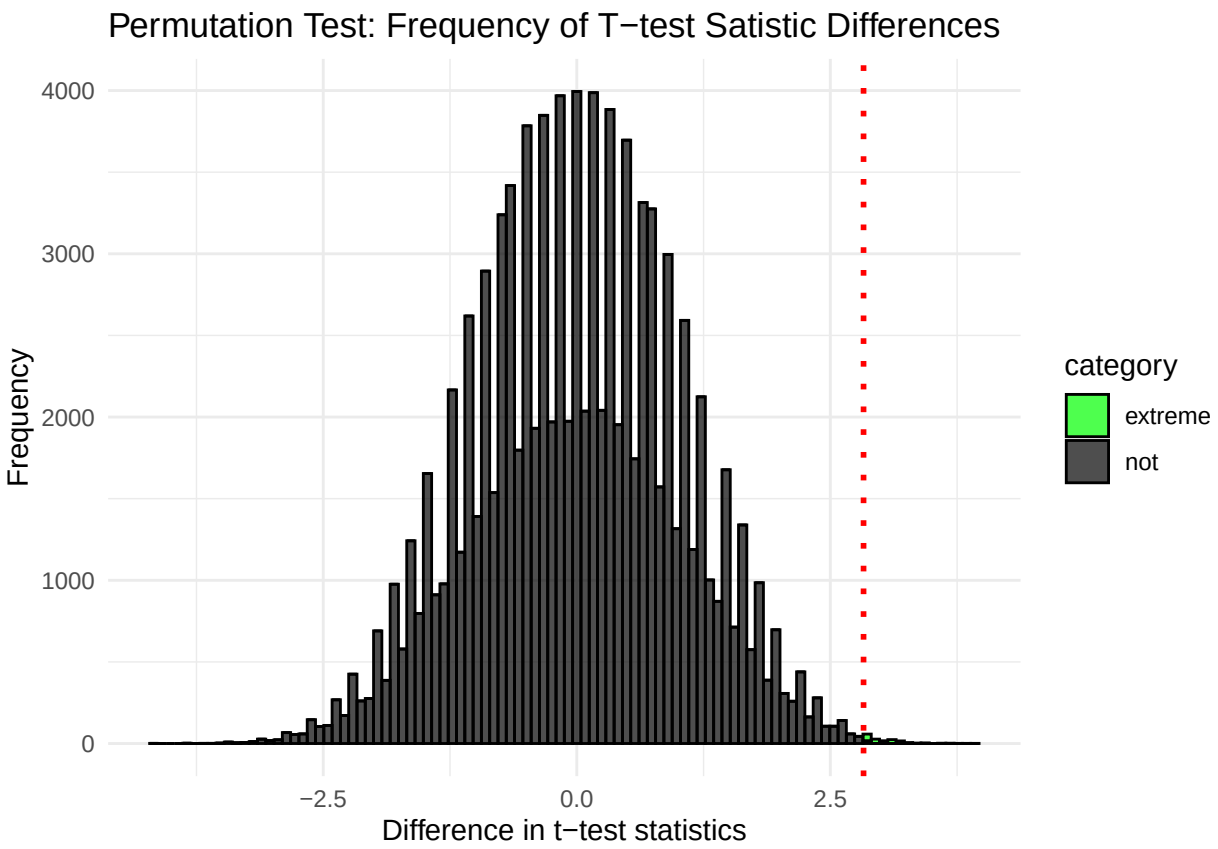
```
test_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.768  0.870 0.870 0.928 0.0326
## 2 lexicase      40      0 0.522  0.855 0.834 0.913 0.0616
```

The permutation test revealed that the results are:

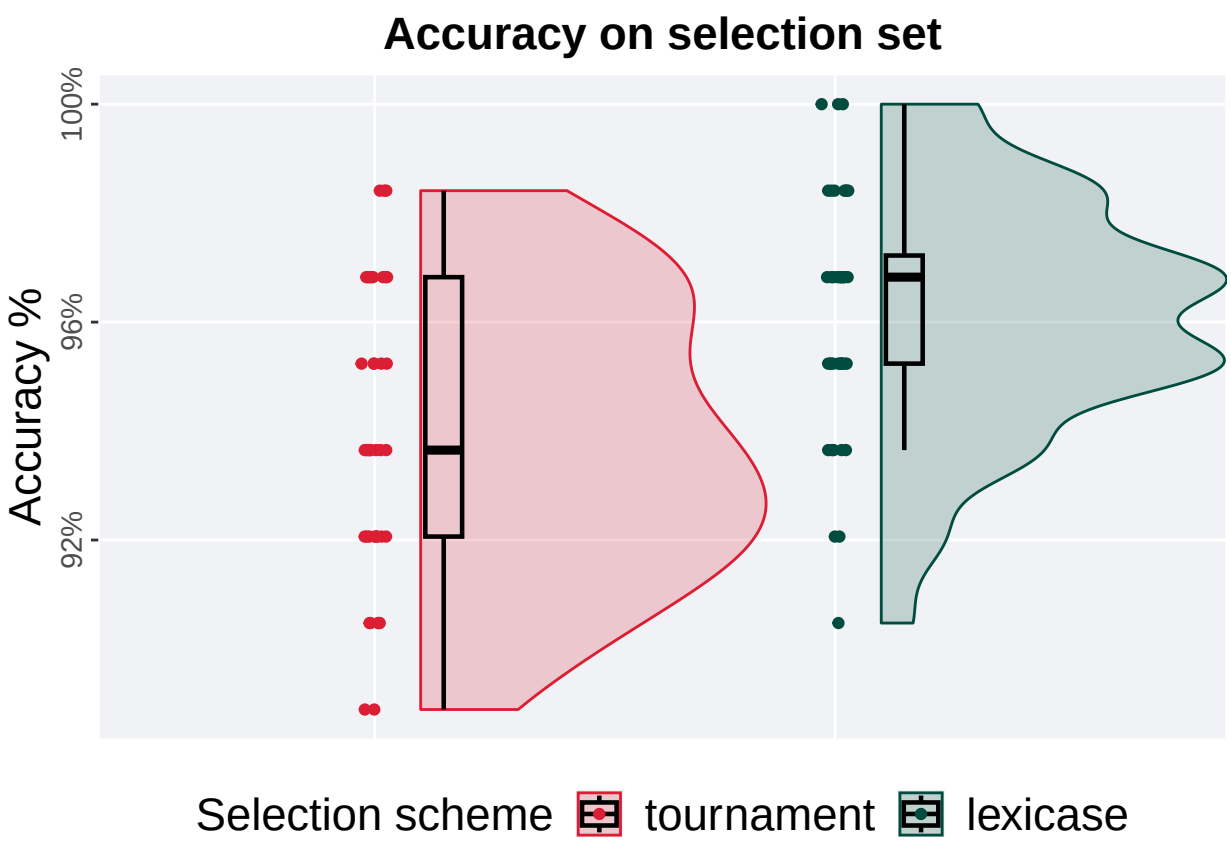
```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 3,
                 alternative = "g")
```

```
## [1] "observed_diff: 2.82771300817792"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.65479687273561"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00146"
```



3.2.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

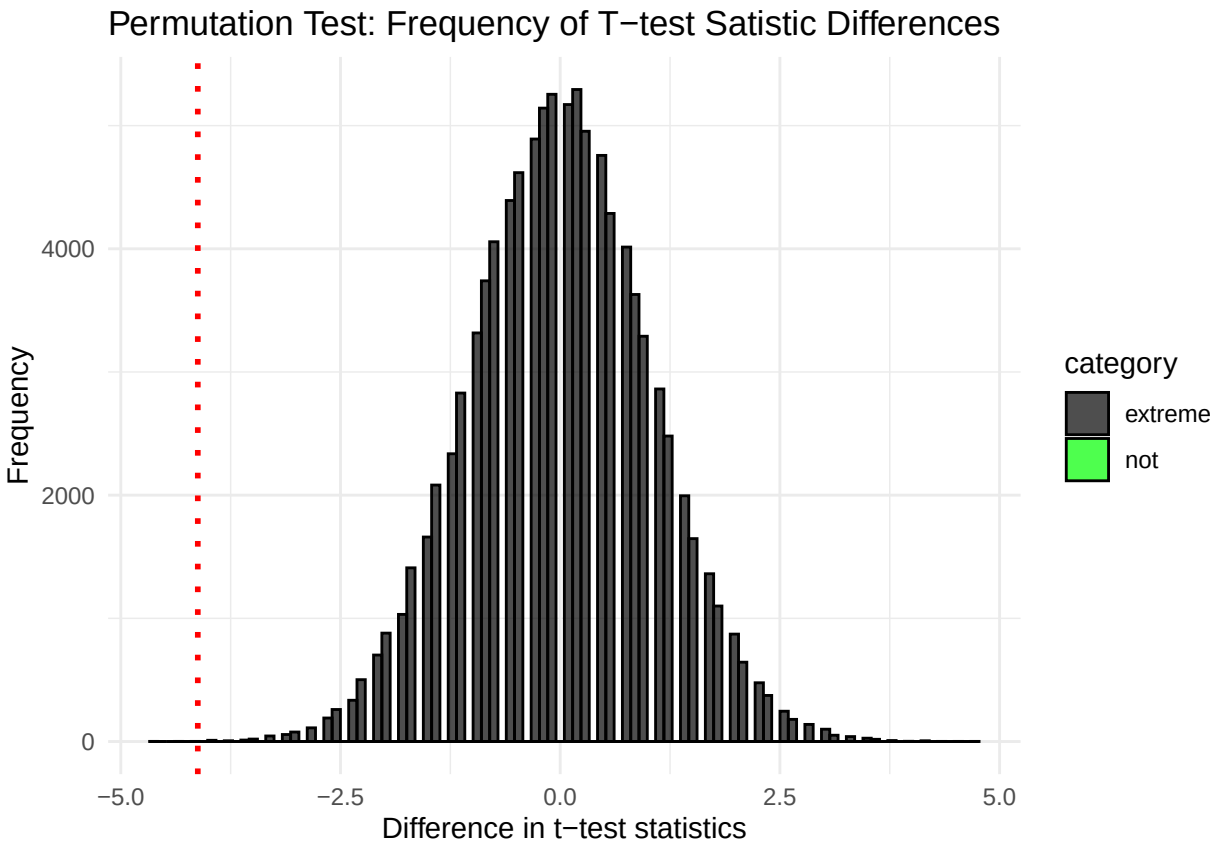
```
selection_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.889  0.937 0.938 0.984 0.0476
## 2 lexicase      40      0 0.905  0.968 0.961 1     0.0198
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 4,
                 alternative = "l")
```

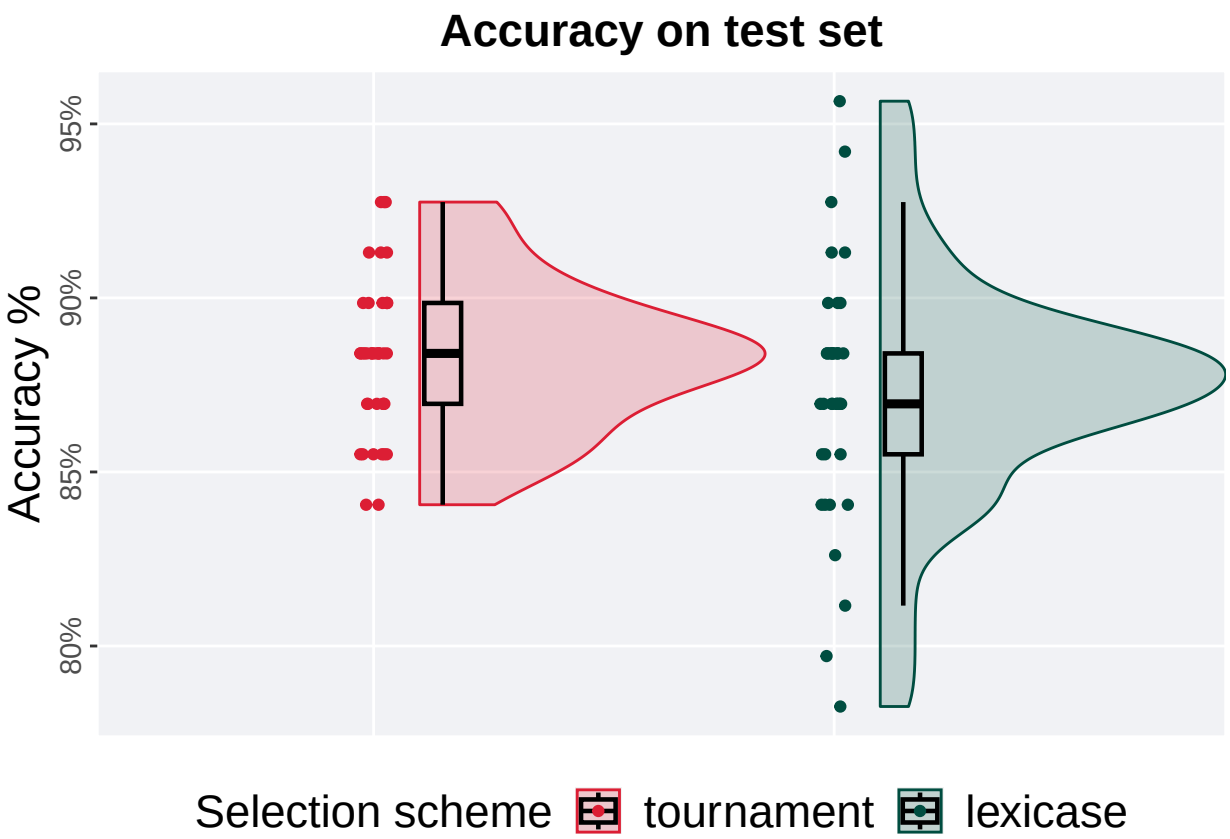
```
## [1] "observed_diff: -4.12382195839694"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.66780738405742"
## [1] "reject null hypothesis"
## [1] "p-value: 2e-05"
```



3.3 50%

3.3.1 Testing set accuracy

```
test_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

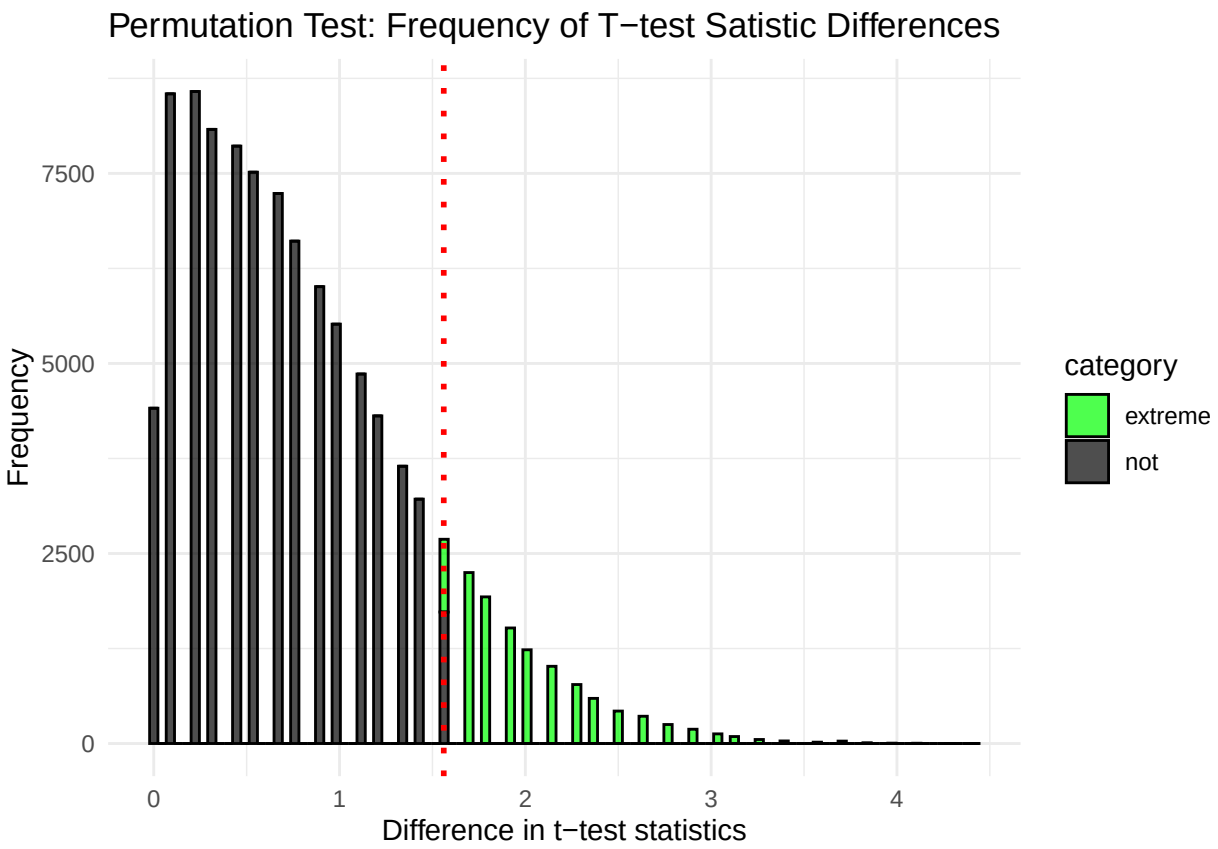
```
test_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.841  0.884 0.883 0.928 0.0290
## 2 lexicase      40      0 0.783  0.870 0.873 0.957 0.0290
```

The permutation test revealed that the results are:

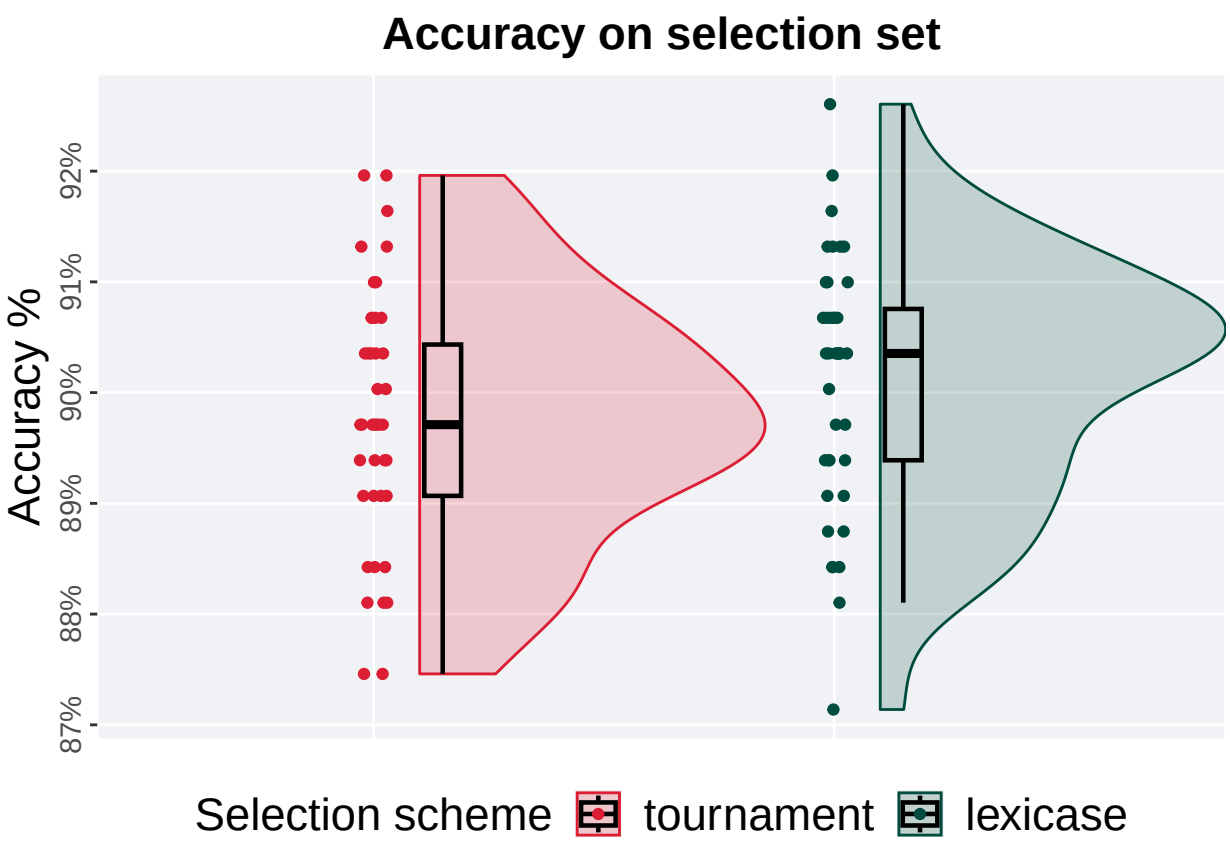
```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 5,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.5608765017161"
## [1] "lower: -2.02762682929956"
## [1] "upper: 2.02762732023459"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.11875"
```



3.3.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

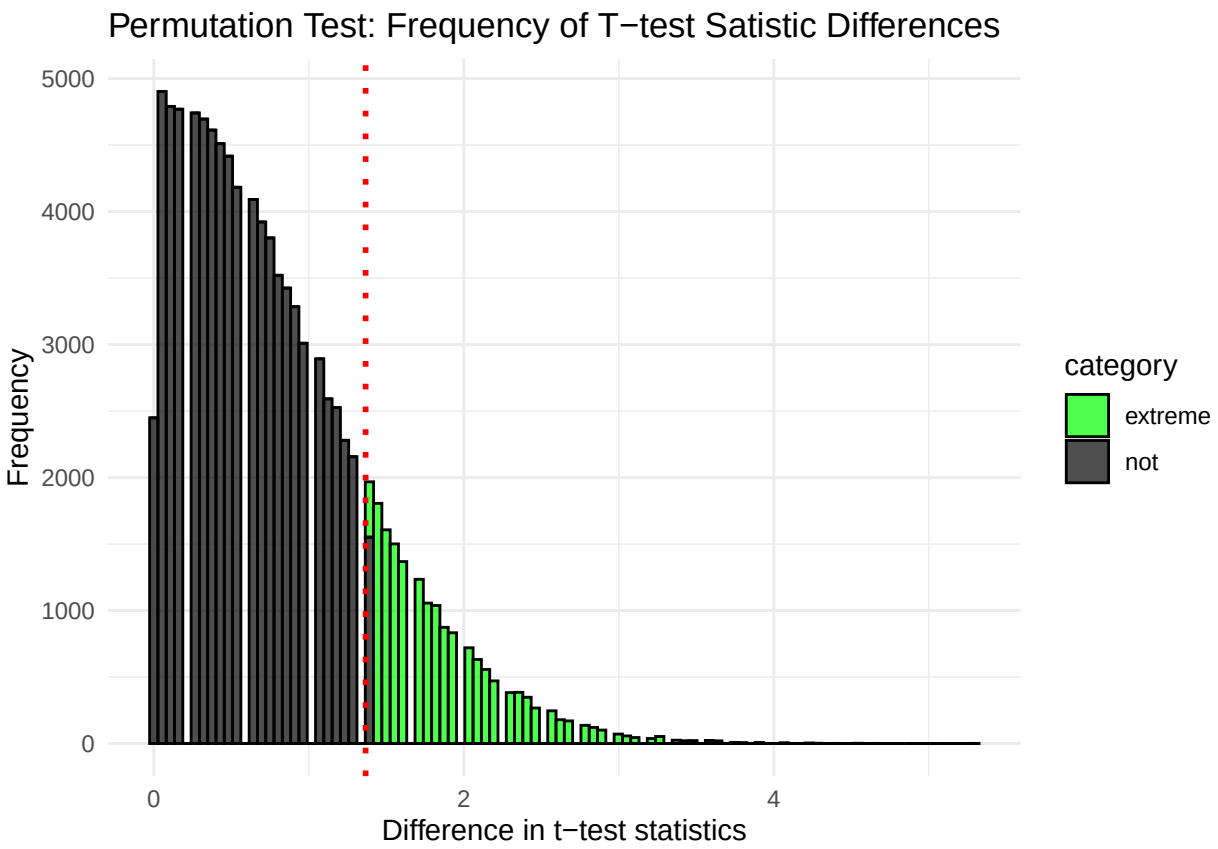
```
selection_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.875  0.897 0.898 0.920 0.0137
## 2 lexicase      40      0 0.871  0.904 0.901 0.926 0.0137
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 6,
                 alternative = "t")
```

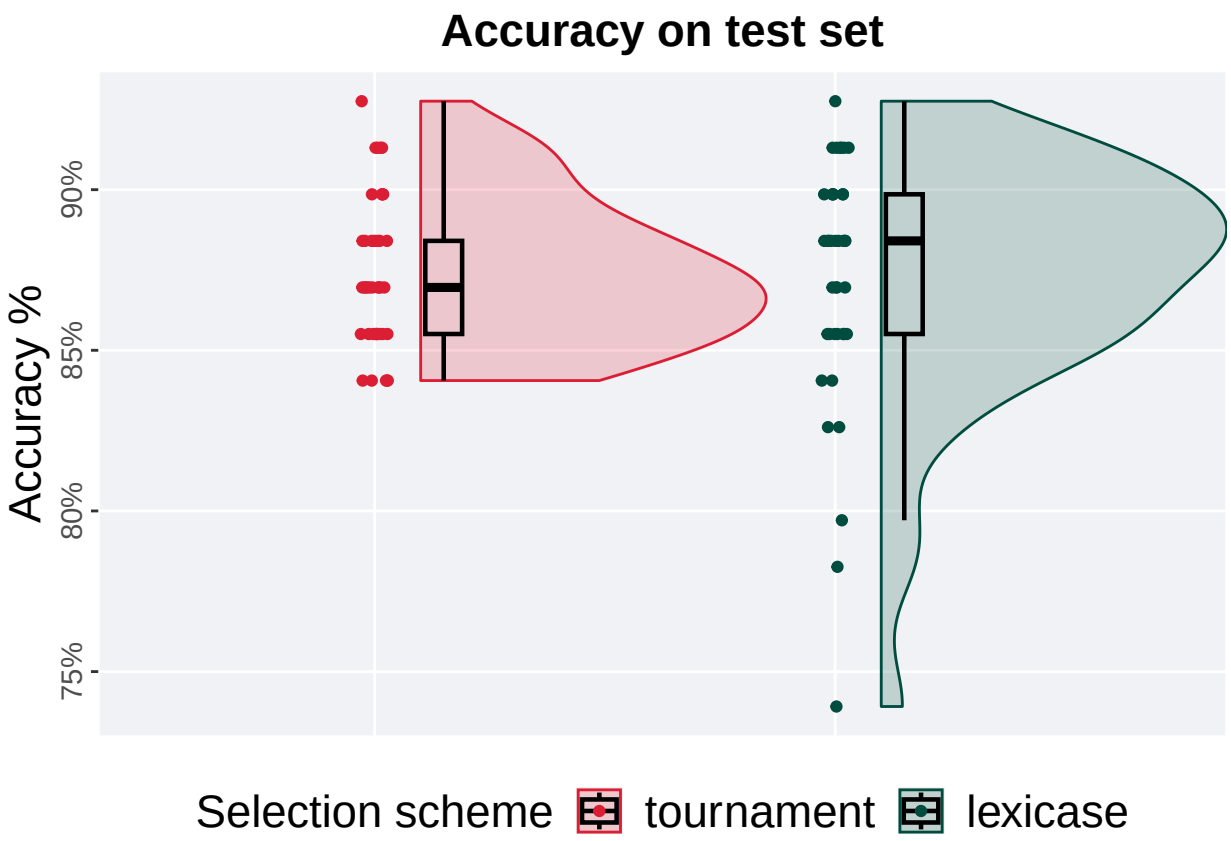
```
## [1] "observed_diff: -1.3666761390605"
## [1] "lower: -2.01498791705763"
## [1] "upper: 2.01499018334096"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.16869"
```



3.4 90%

3.4.1 Testing set accuracy

```
test_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

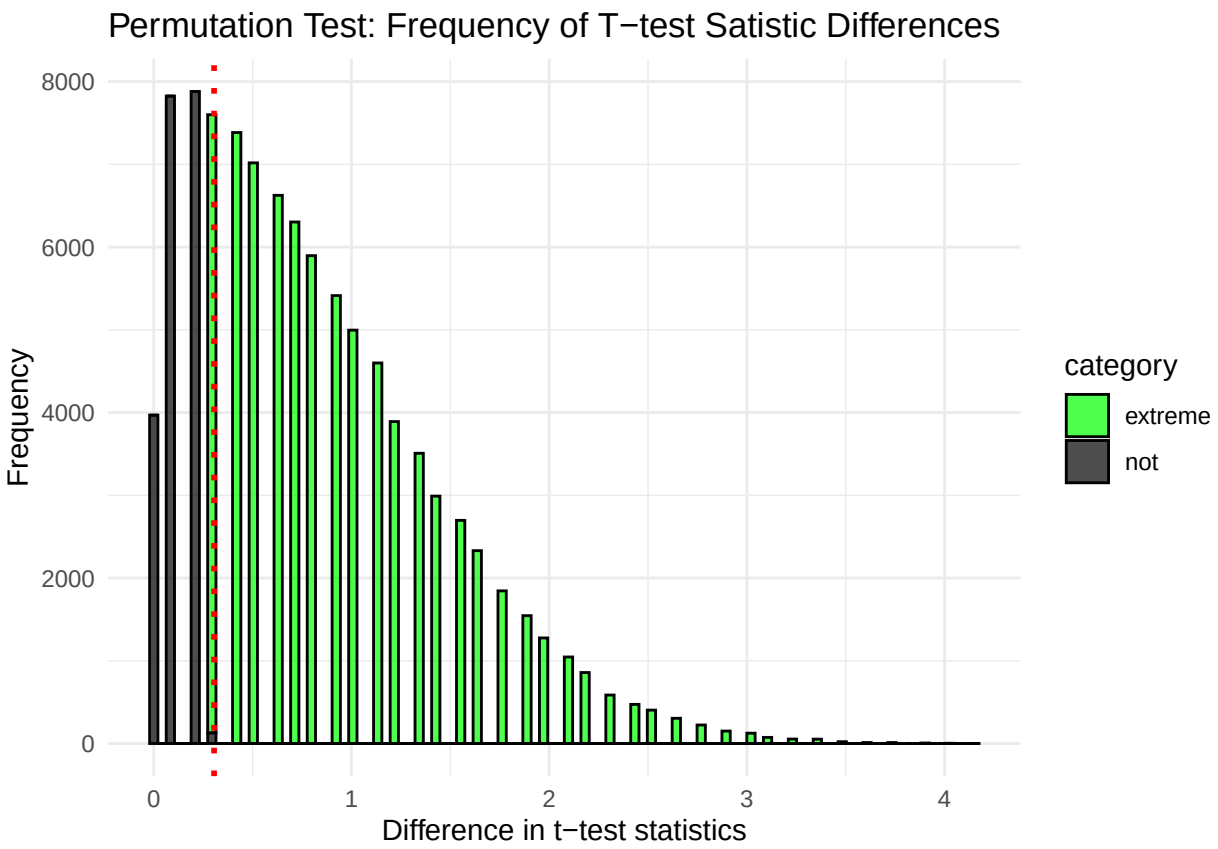
```
test_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.841  0.870 0.874 0.928 0.0290
## 2 lexicase      40      0 0.739  0.884 0.872 0.928 0.0435
```

The permutation test revealed that the results are:

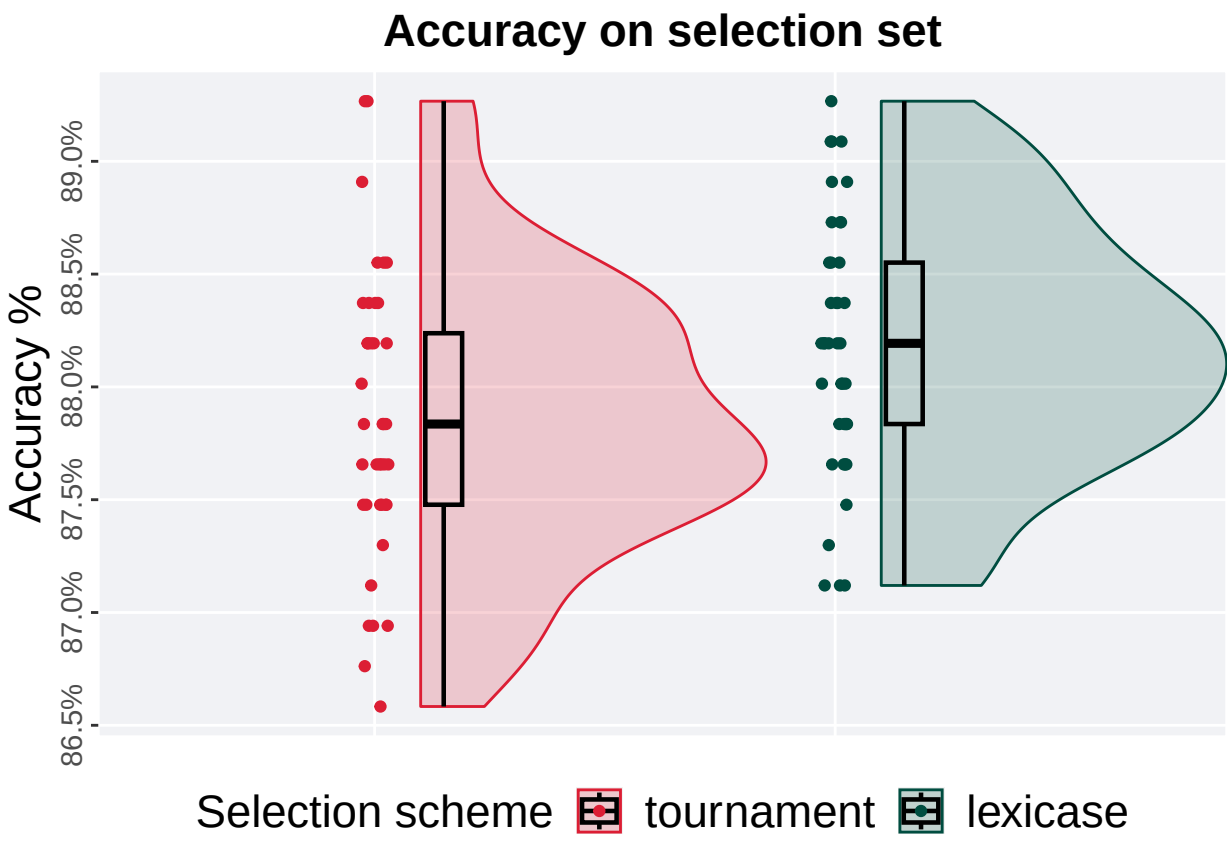
```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 7,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.304925249770556"
## [1] "lower: -1.97785745966913"
## [1] "upper: 1.97785745966913"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.80197"
```



3.4.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

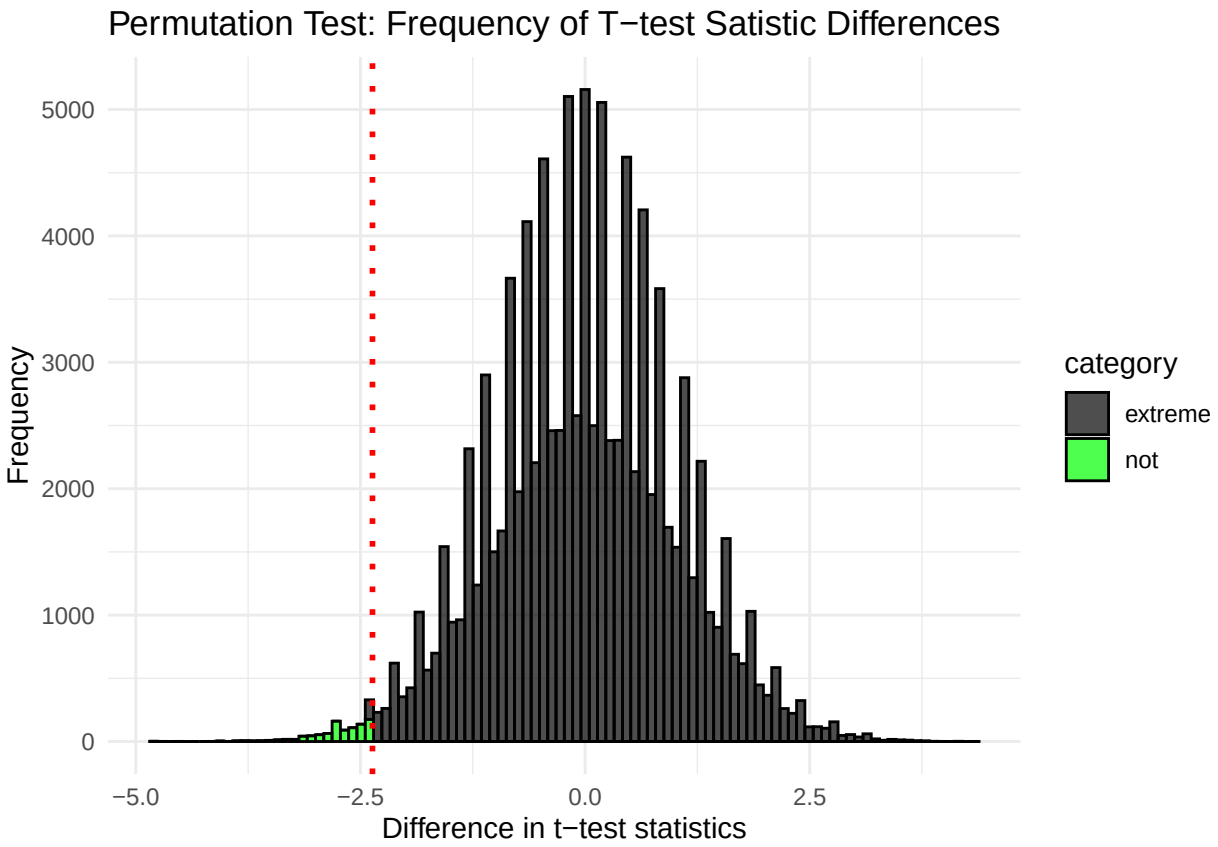
```
selection_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.866  0.878 0.879 0.893 0.00760
## 2 lexicase      40      0 0.871  0.882 0.882 0.893 0.00716
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 8,
                 alternative = "l")
```

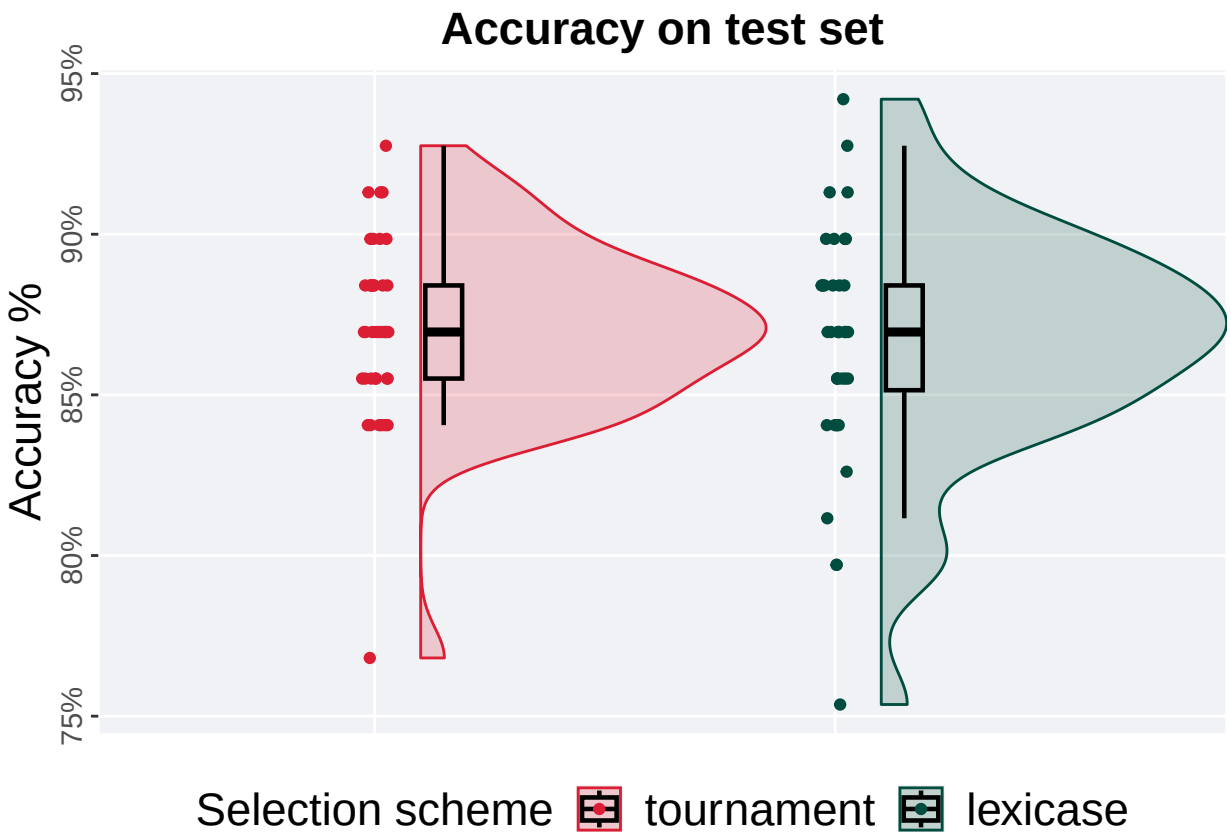
```
## [1] "observed_diff: -2.3660300252374"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.67076701407627"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00964"
```



3.5 95%

3.5.1 Testing set accuracy

```
test_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

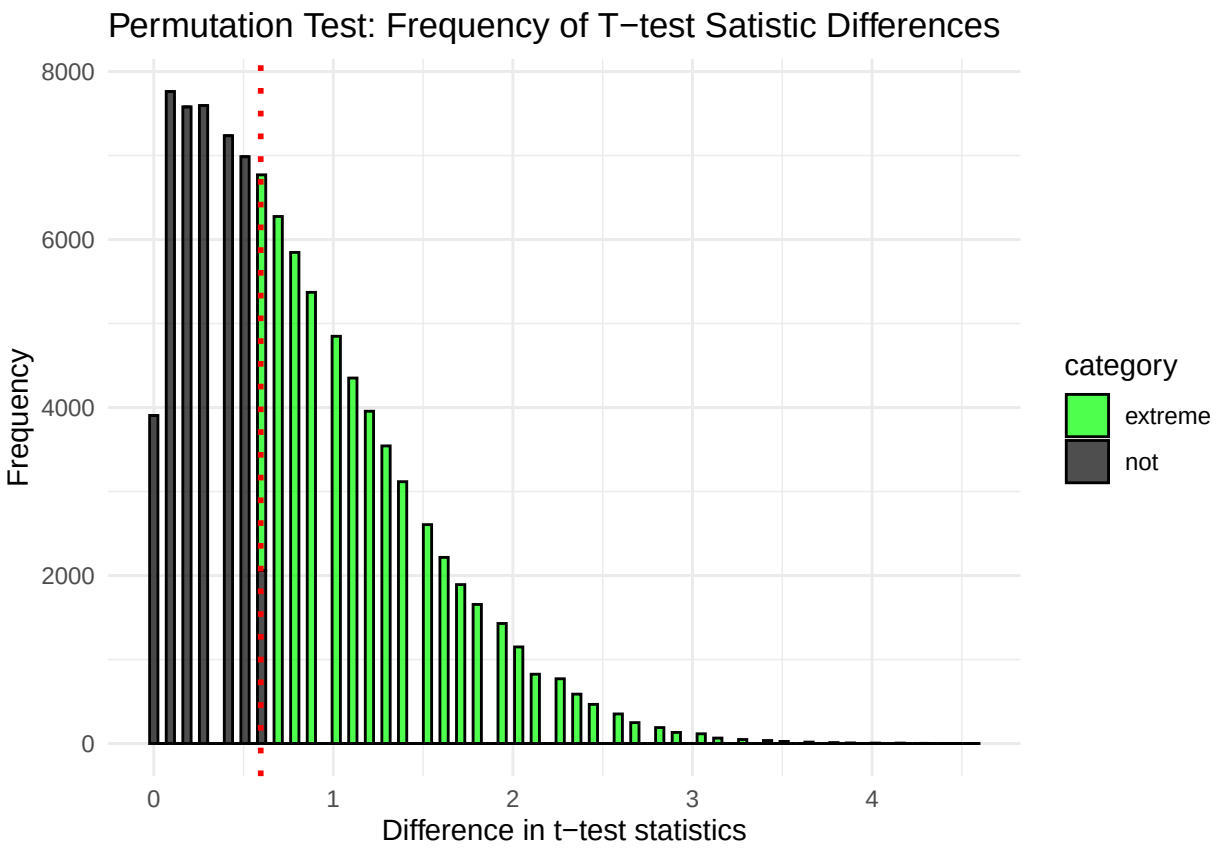
```
test_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.768  0.870 0.871 0.928 0.0290
## 2 lexicase      40      0 0.754  0.870 0.866 0.942 0.0326
```

The permutation test revealed that the results are:

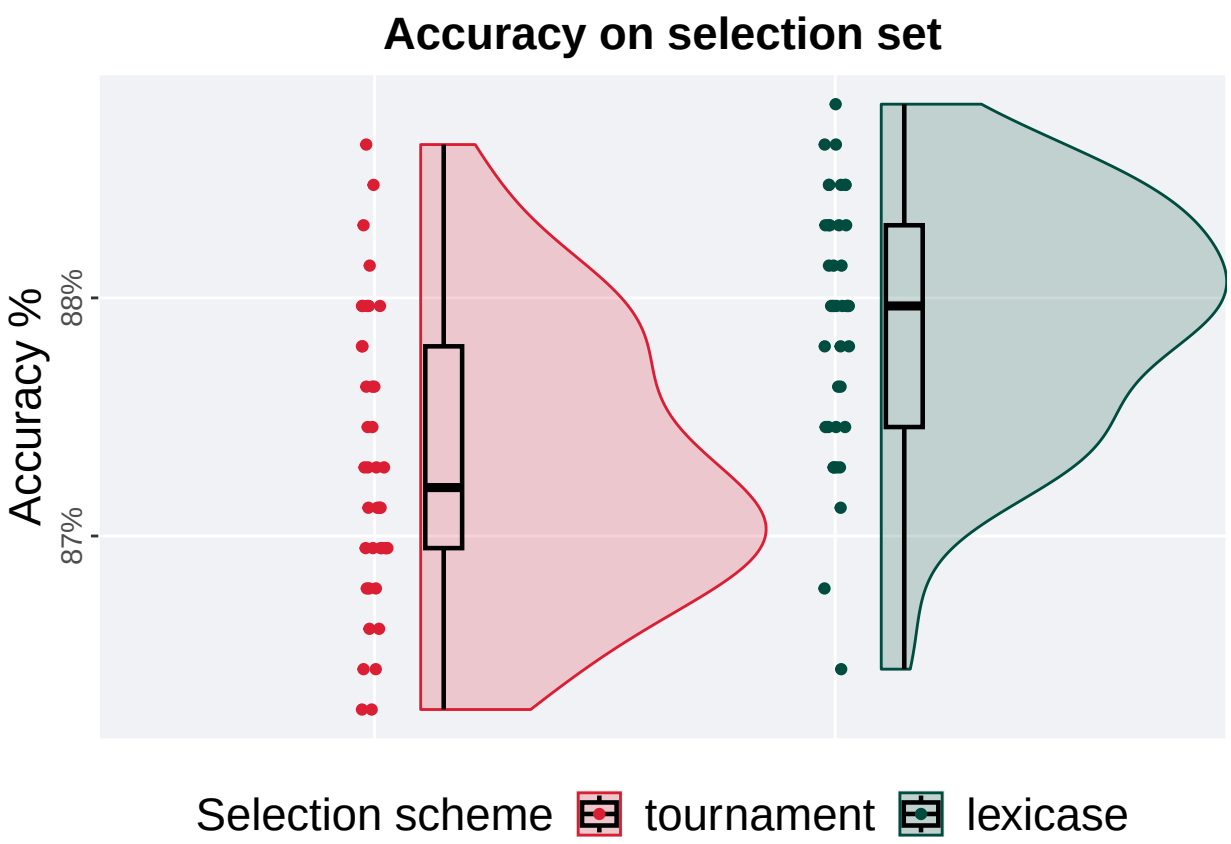
```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 9,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.595624911096808"
## [1] "lower: -2.03270741712368"
## [1] "upper: 2.03270741712368"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.56878"
```



3.5.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

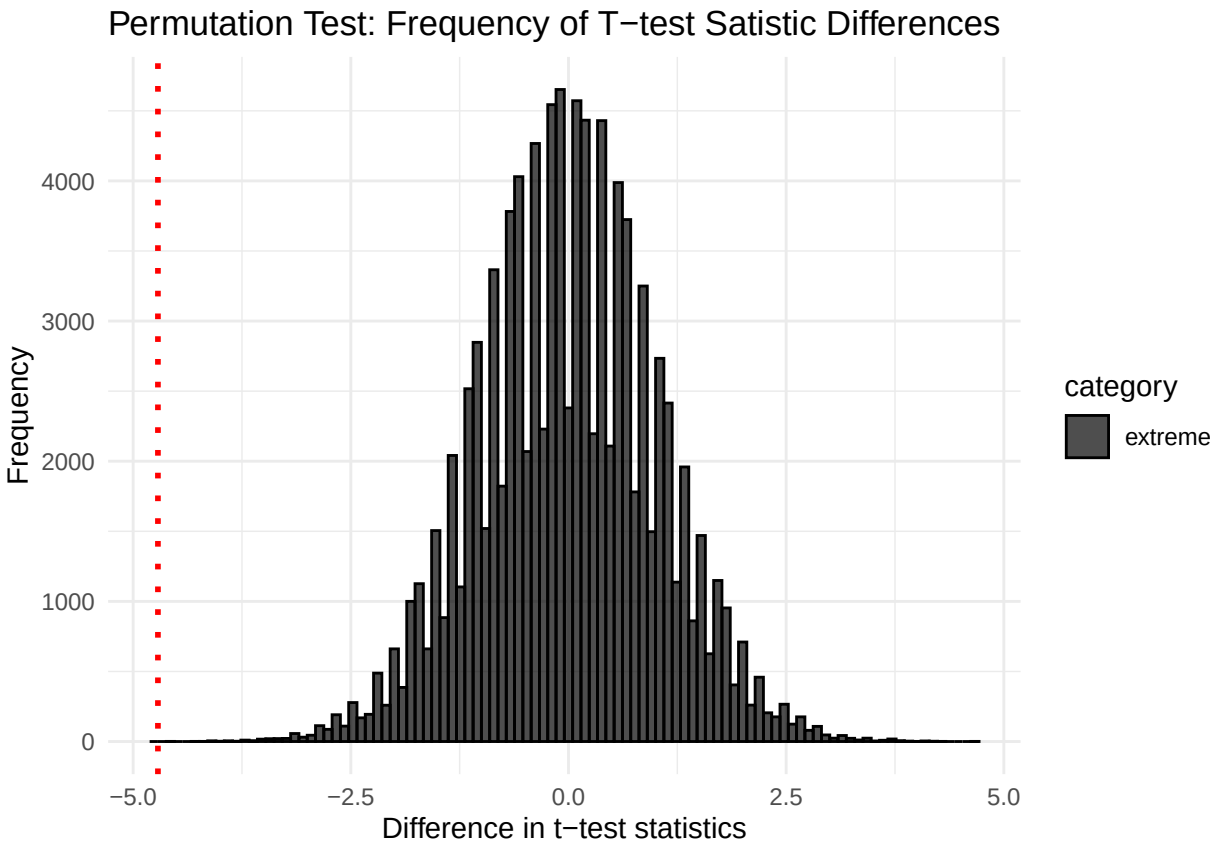
```
selection_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.863  0.872 0.873 0.886 0.00847
## 2 lexicase      40      0 0.864  0.880 0.879 0.888 0.00847
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 10,
                 alternative = "l")
```

```
## [1] "observed_diff: -4.71550186673307"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.6695026702645"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```


Permutation Test: Frequency of T−test Satistic Differences
Frequency
4000
3000
2000
1000
0
−5.0
−2.5
0.0
2.5
5.0
Difference in t−test statistics
category
extreme

Chapter 4

Task 359954

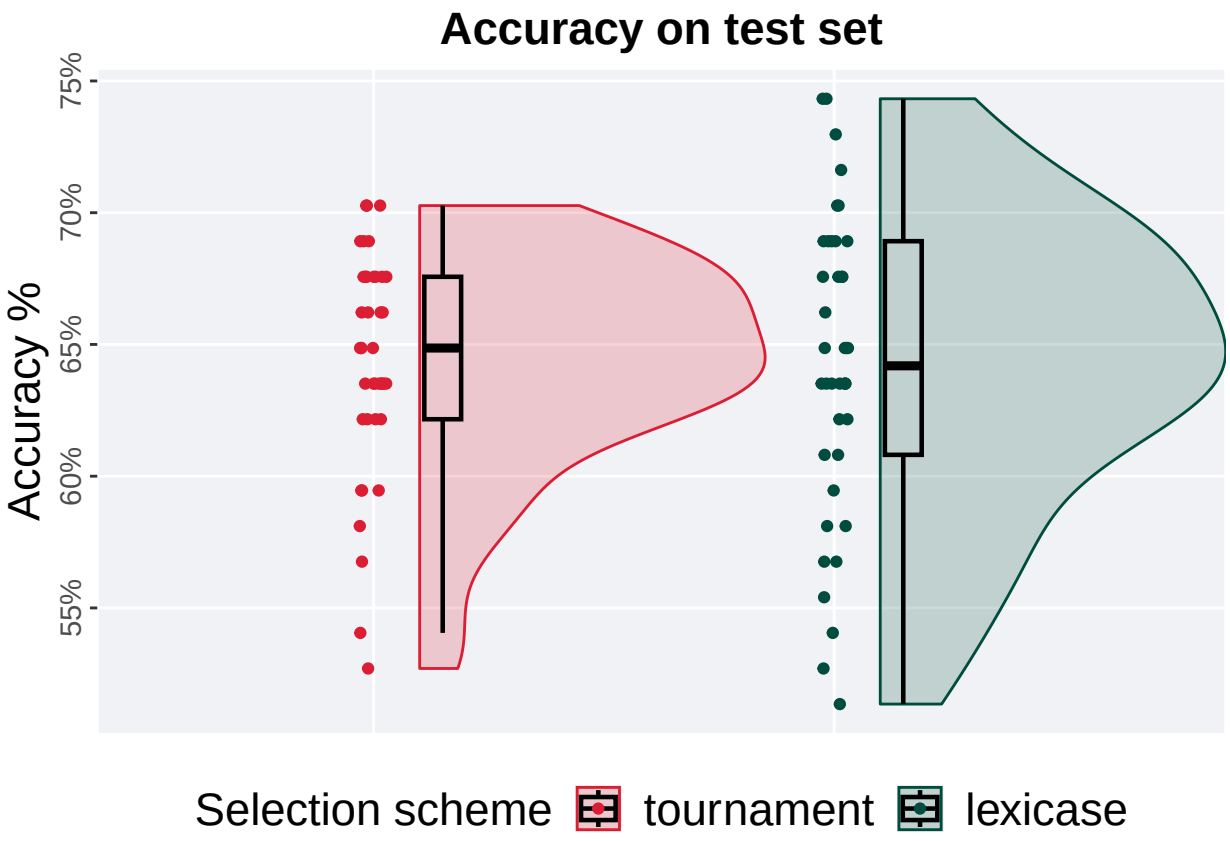
We present the results of our analysis of `task 359954` with the different selection set splits used in our study.

```
task_data <- filter(results, task_id == 359954)
```

4.1 5%

4.1.1 Testing set accuracy

```
test_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

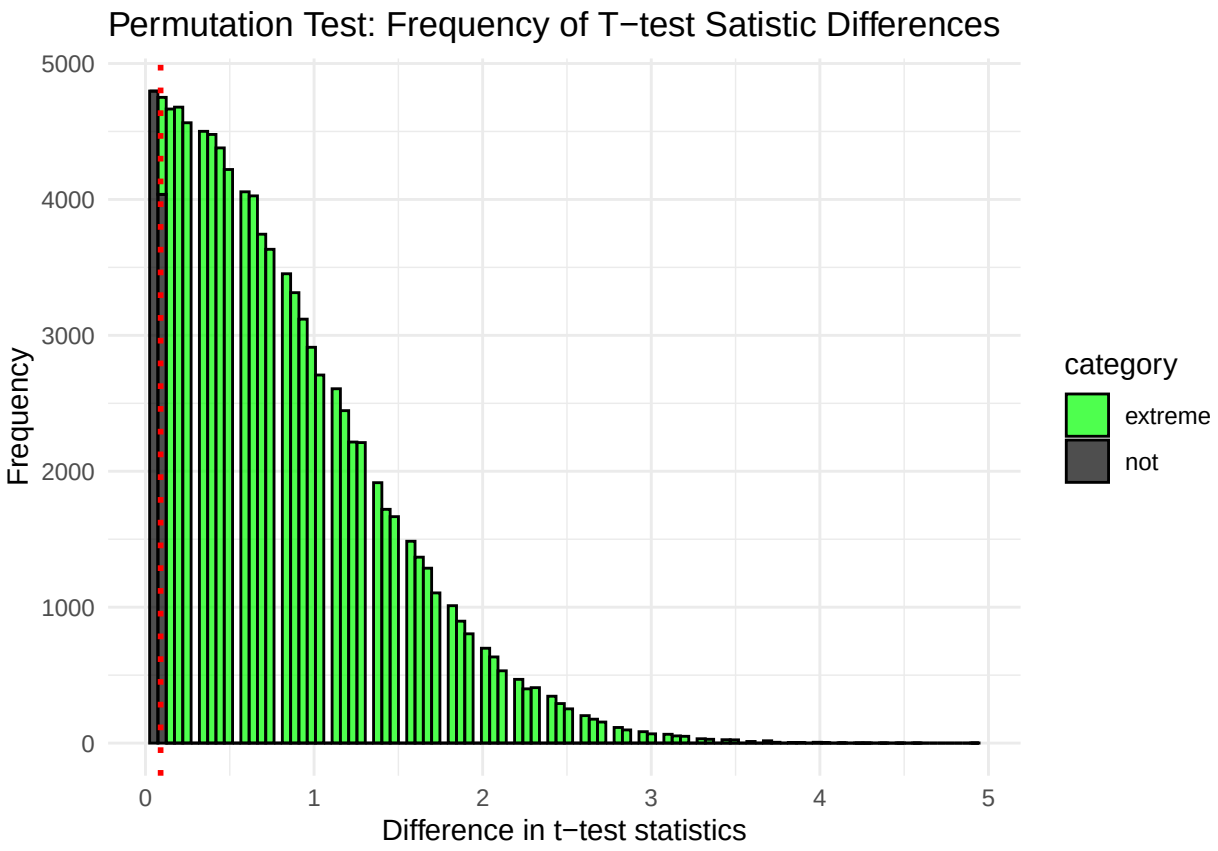
```
test_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.527  0.649 0.643 0.703 0.0541
## 2 lexicase      40      0 0.514  0.642 0.642 0.743 0.0811
```

The permutation test revealed that the results are:

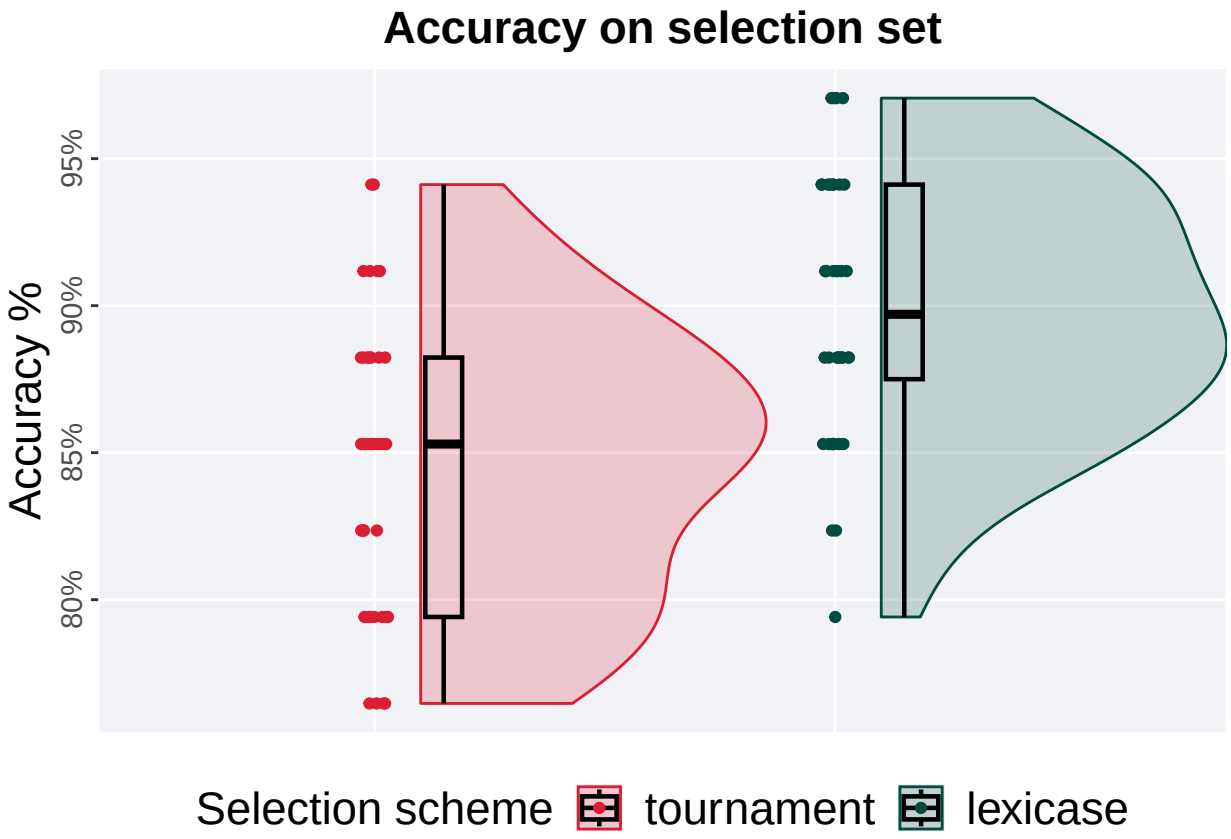
```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 11,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.089899097880169"
## [1] "lower: -1.99686947621326"
## [1] "upper: 1.99686947621326"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.91166"
```



4.1.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

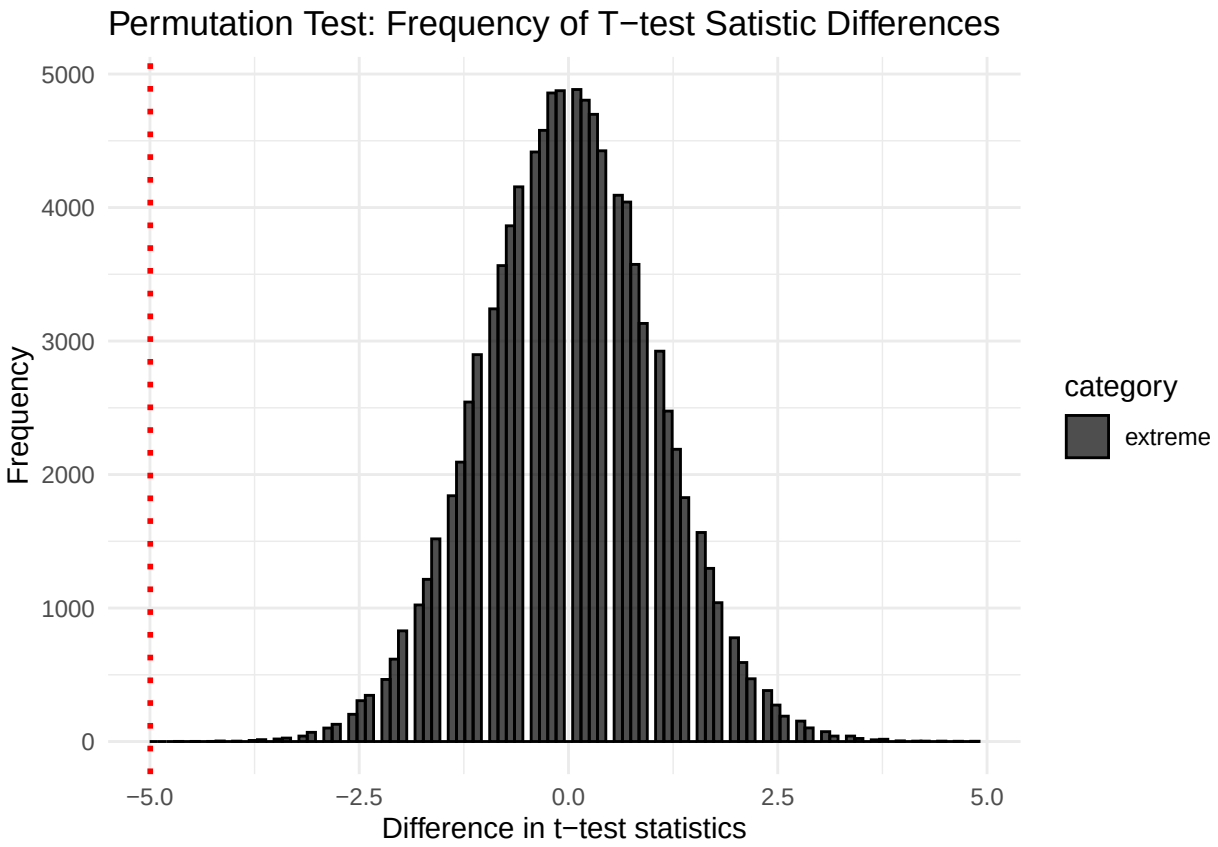
```
selection_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.765  0.853 0.846 0.941 0.0882
## 2 lexicase      40      0 0.794  0.897 0.899 0.971 0.0662
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 12,
                 alternative = "l")
```

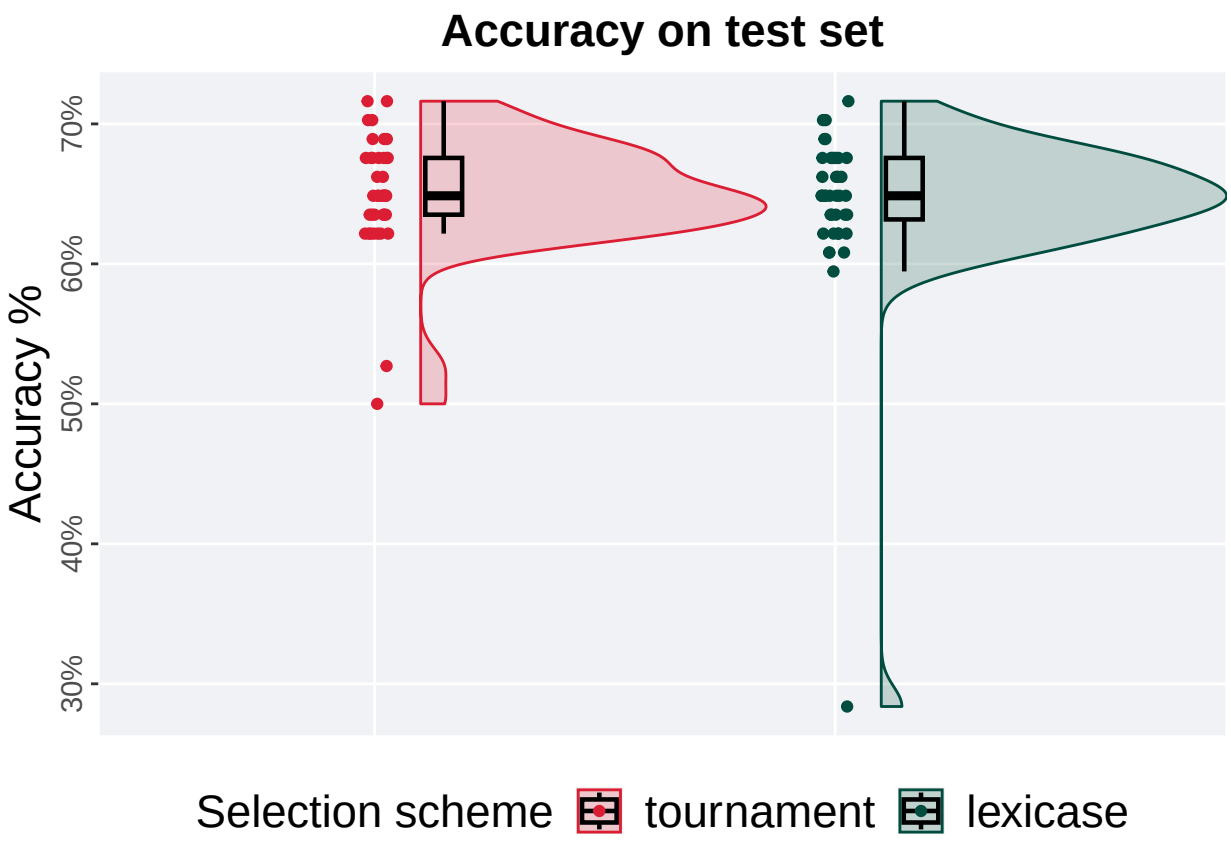
```
## [1] "observed_diff: -4.99649396670713"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.68354186553216"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```



4.2 10%

4.2.1 Testing set accuracy

```
test_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

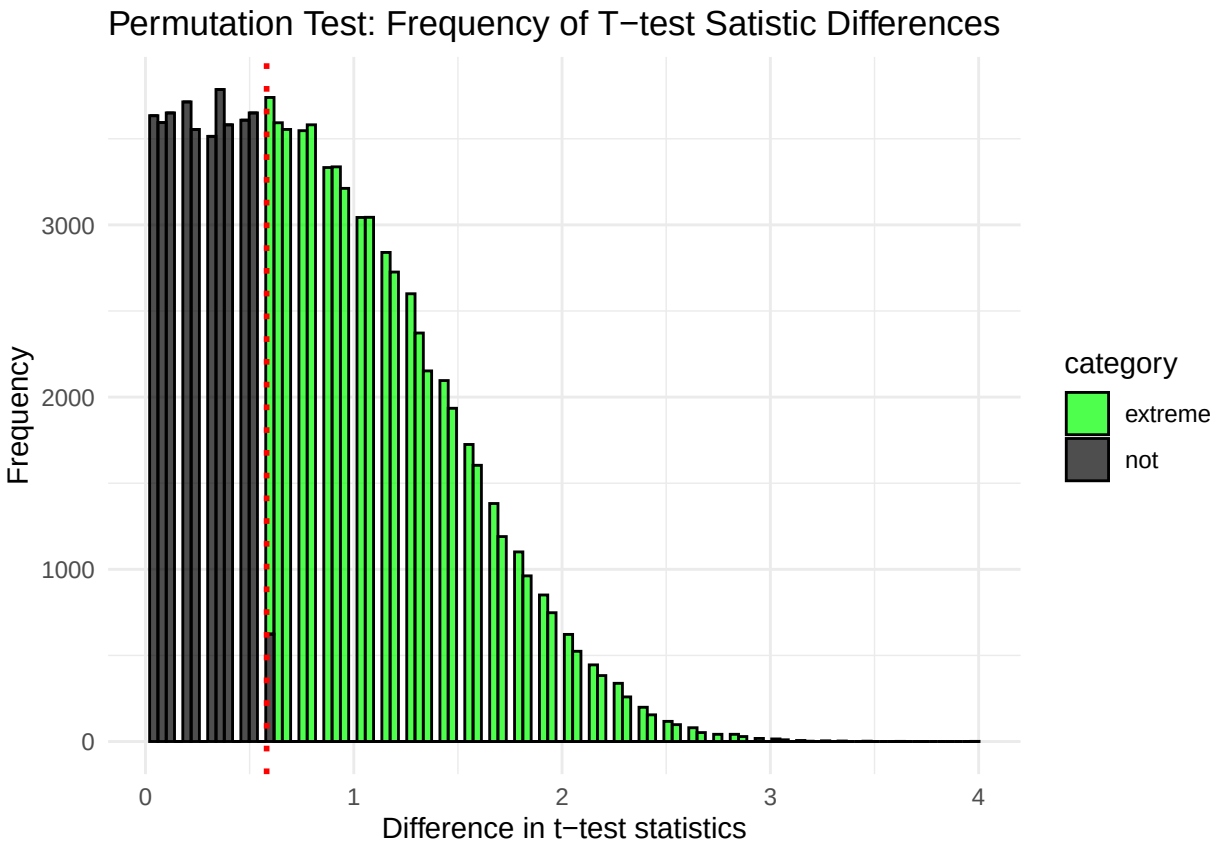
```
test_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.5    0.649 0.650 0.716 0.0405
## 2 lexicase      40      0 0.284  0.649 0.643 0.716 0.0439
```

The permutation test revealed that the results are:

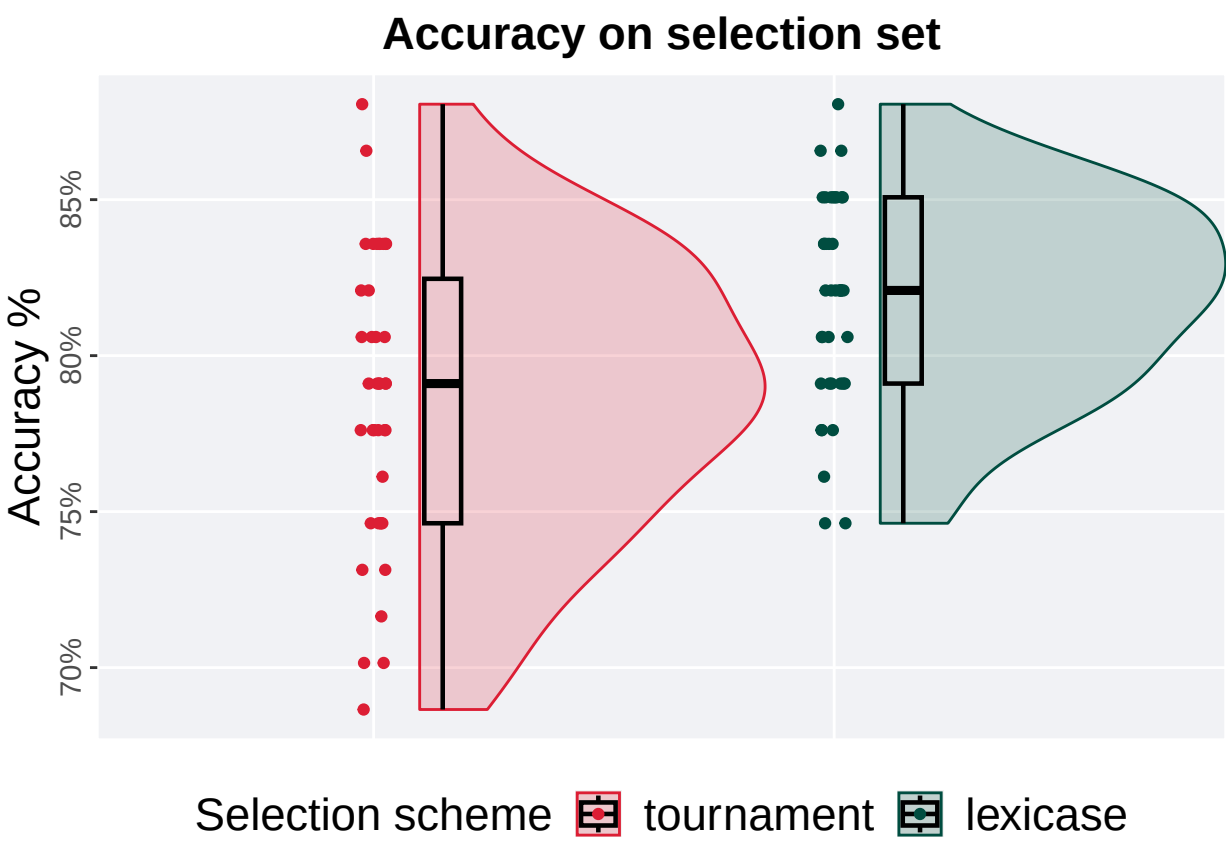
```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 13,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.581706669215585"
## [1] "lower: -1.89401584174984"
## [1] "upper: 1.89401627937136"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.63091"
```



4.2.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

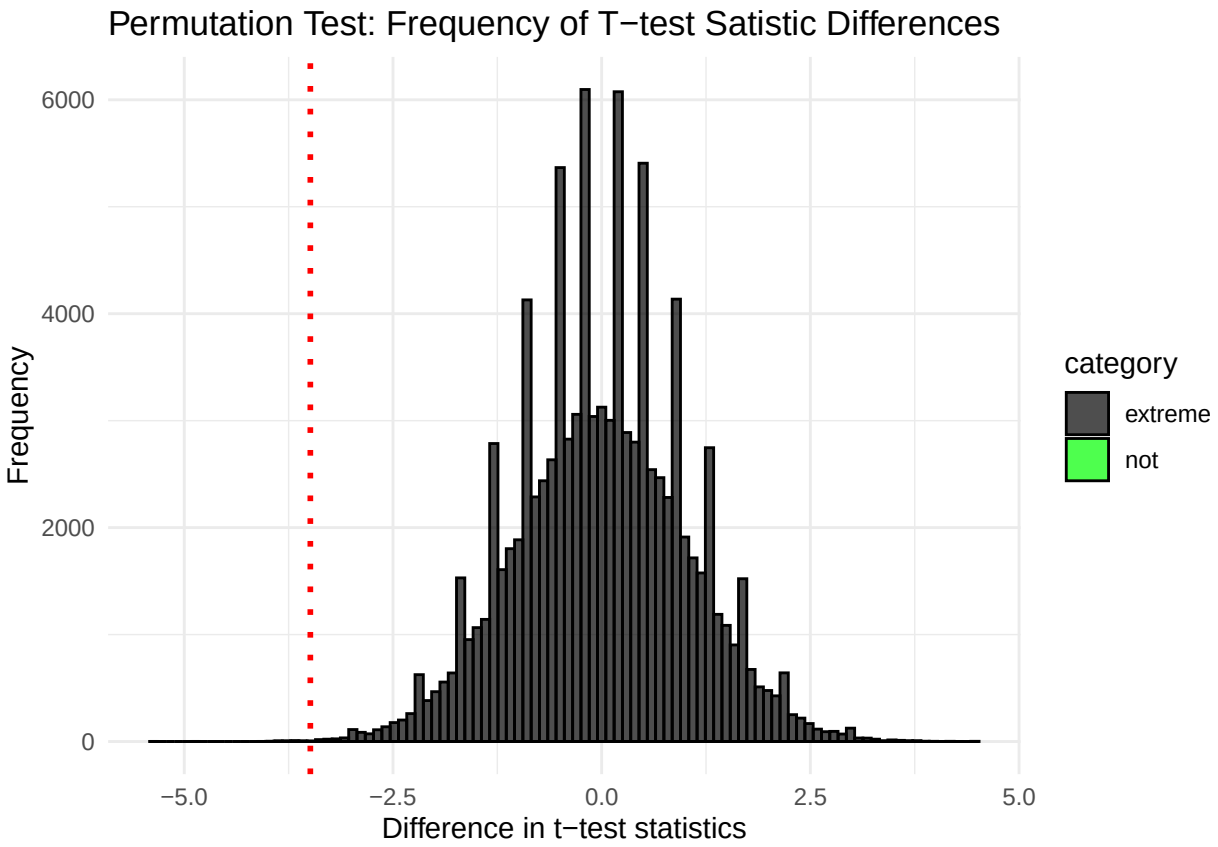
```
selection_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.687  0.791 0.787 0.881 0.0784
## 2 lexicase      40      0 0.746  0.821 0.818 0.881 0.0597
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 14,
                 alternative = "l")
```

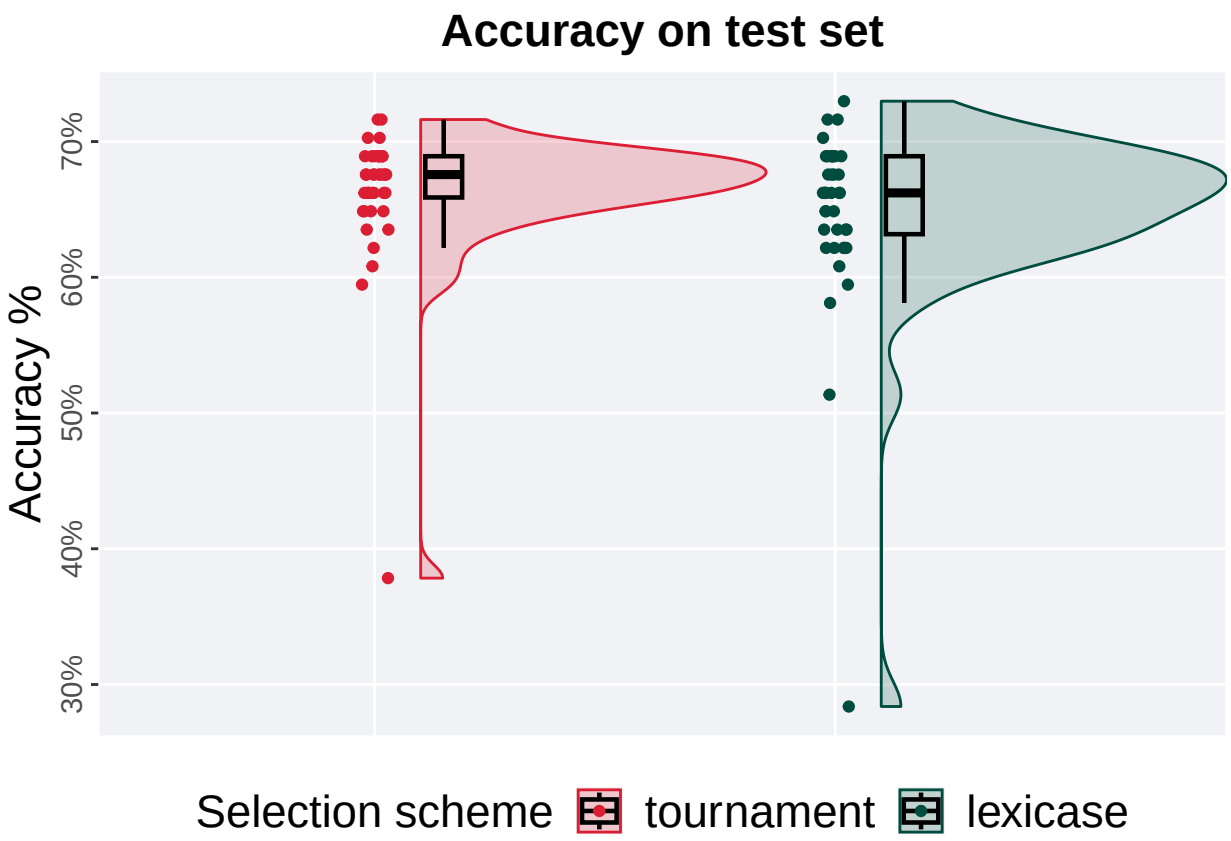
```
## [1] "observed_diff: -3.49007120627971"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.65102702194372"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00027"
```



4.3 50%

4.3.1 Testing set accuracy

```
test_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

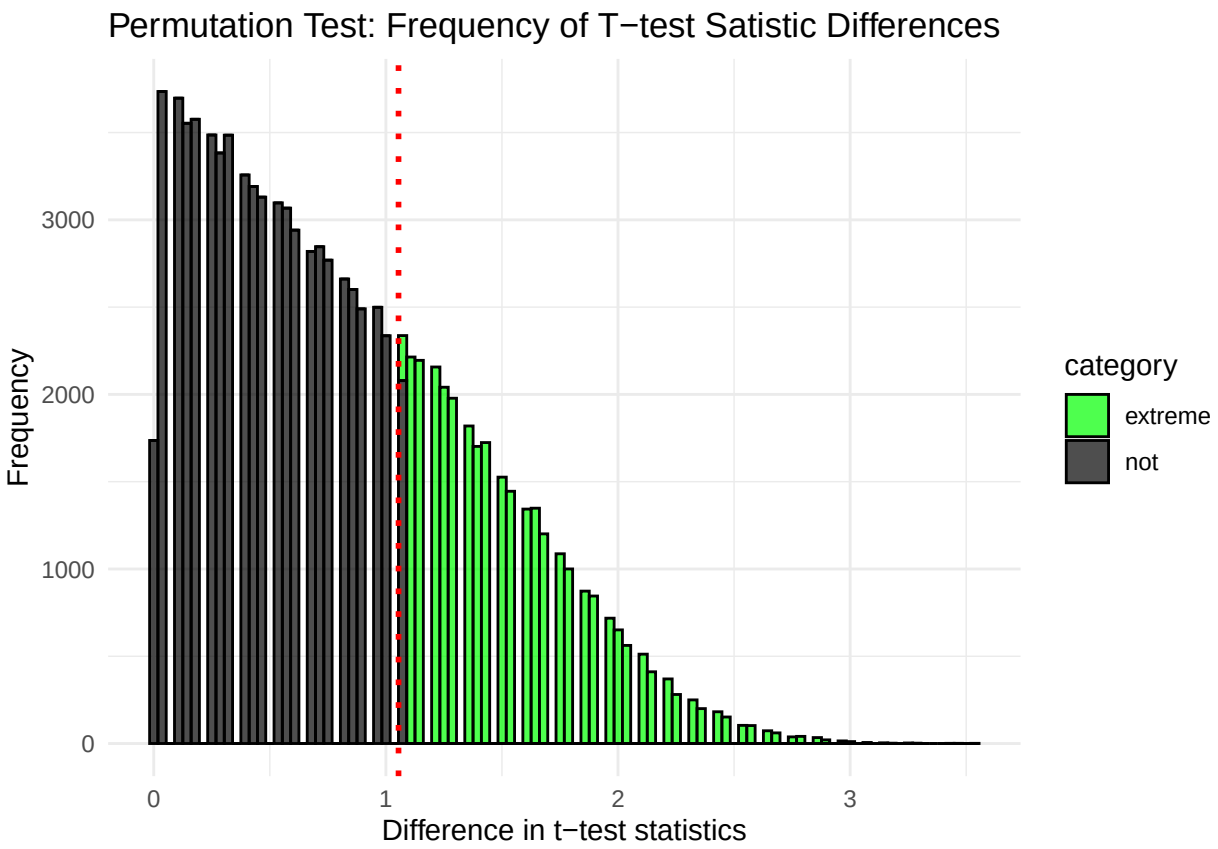
```
test_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.378  0.676 0.662 0.716 0.0304
## 2 lexicase      40      0 0.284  0.662 0.647 0.730 0.0574
```

The permutation test revealed that the results are:

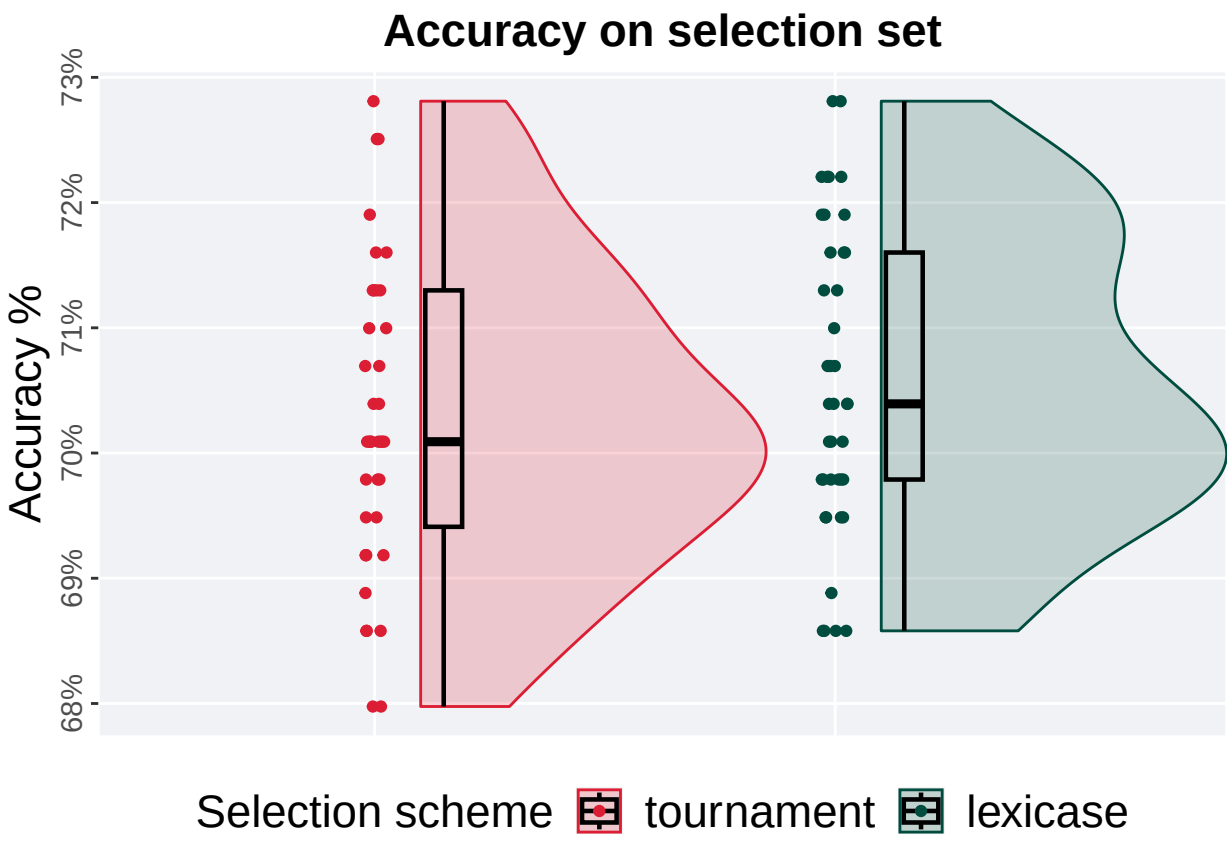
```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 15,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.05447797672778"
## [1] "lower: -1.89851953697627"
## [1] "upper: 1.89851953697627"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.31566"
```



4.3.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

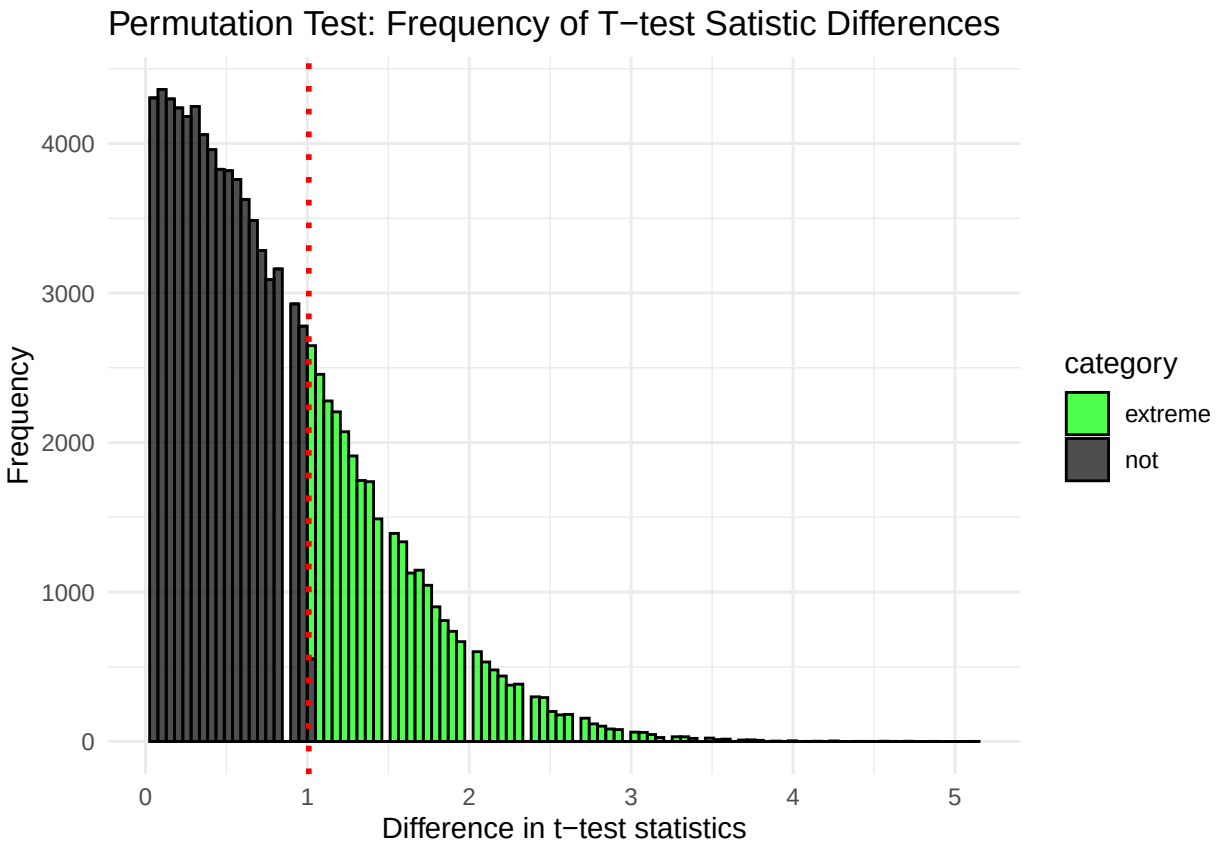
```
selection_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.680  0.701 0.703 0.728 0.0189
## 2 lexicase      40      0 0.686  0.704 0.706 0.728 0.0181
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 16,
                 alternative = "t")
```

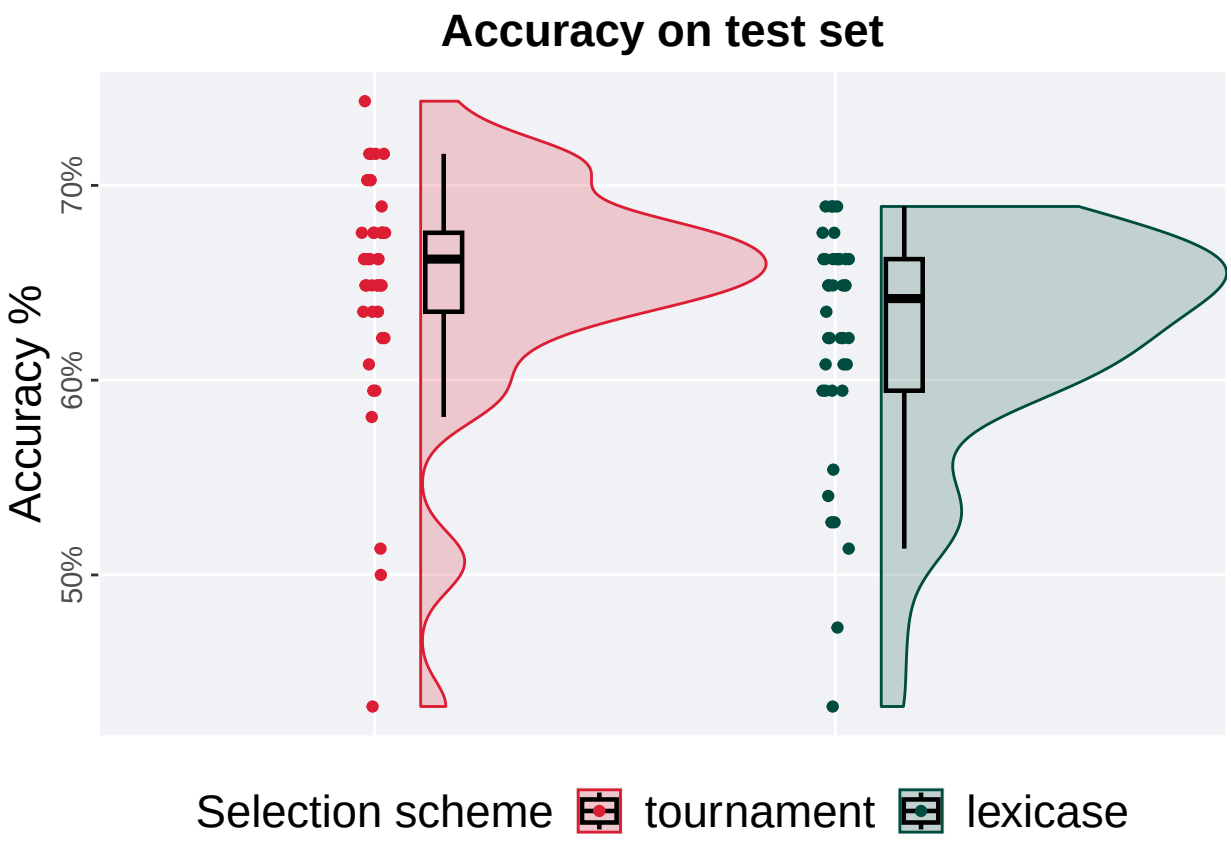
```
## [1] "observed_diff: -1.0089201210214"
## [1] "lower: -1.97083964694619"
## [1] "upper: 1.9708394540355"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.32044"
```



4.4 90%

4.4.1 Testing set accuracy

```
test_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

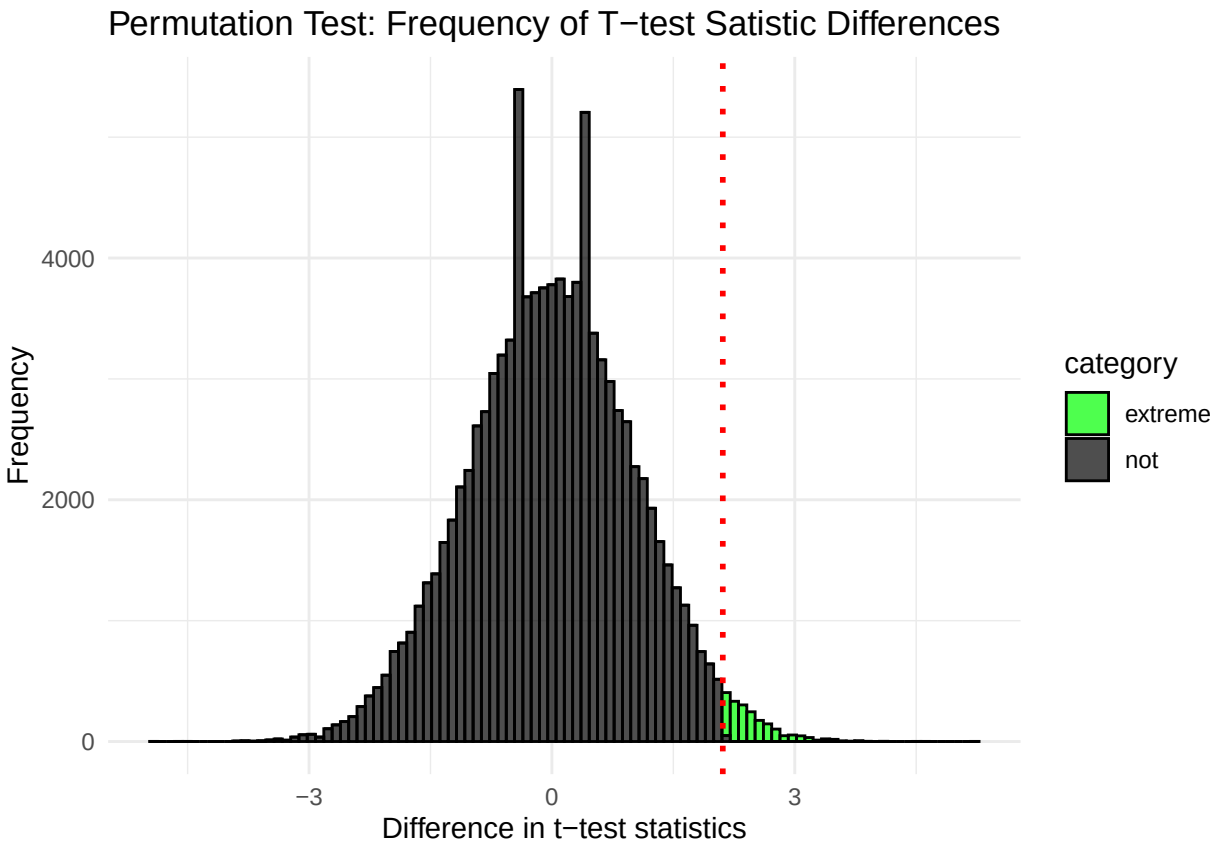
```
test_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.432  0.662 0.649 0.743 0.0405
## 2 lexicase      40      0 0.432  0.642 0.620 0.689 0.0676
```

The permutation test revealed that the results are:

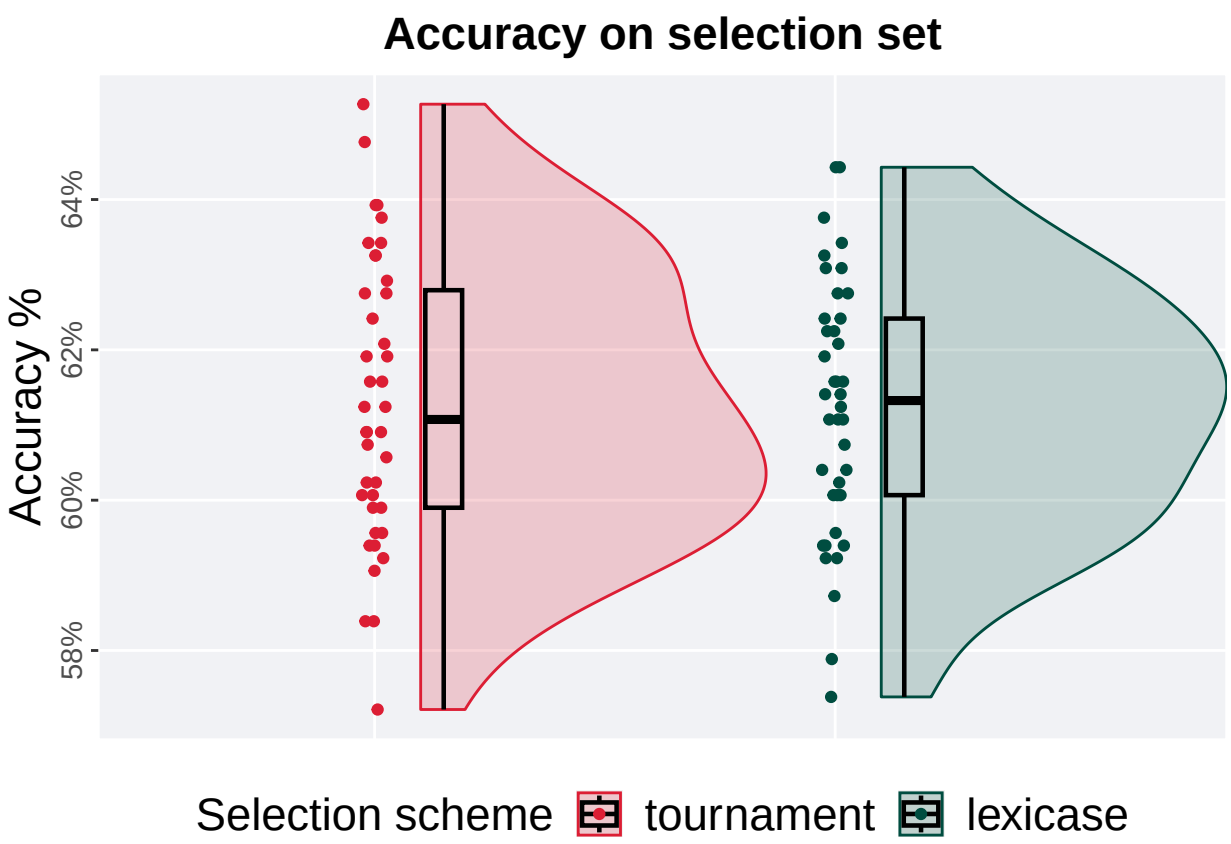
```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 17,
                 alternative = "g")
```

```
## [1] "observed_diff: 2.11112337167441"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.64634620519505"
## [1] "reject null hypothesis"
## [1] "p-value: 0.01917"
```



4.4.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

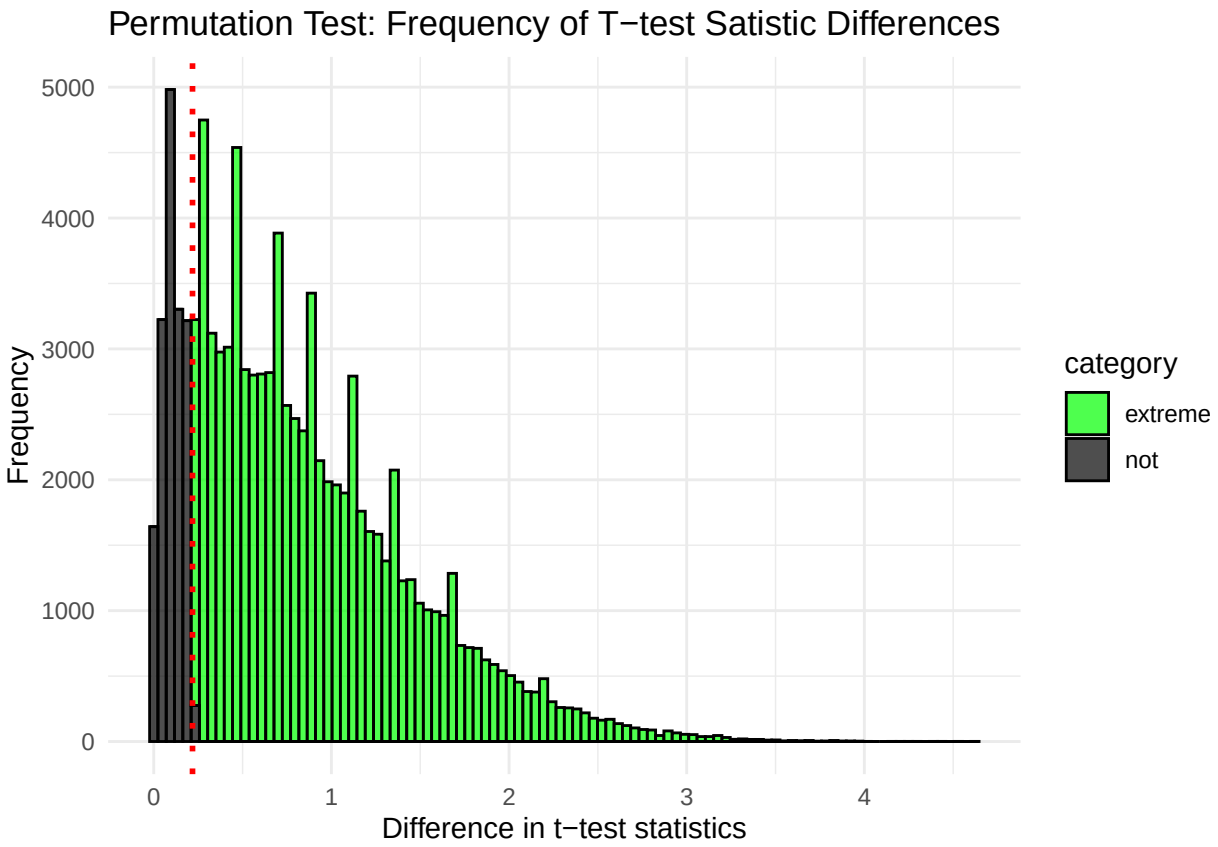
```
selection_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.572  0.611 0.613 0.653 0.0289
## 2 lexicase      40      0 0.574  0.613 0.612 0.644 0.0235
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 18,
                 alternative = "t")
```

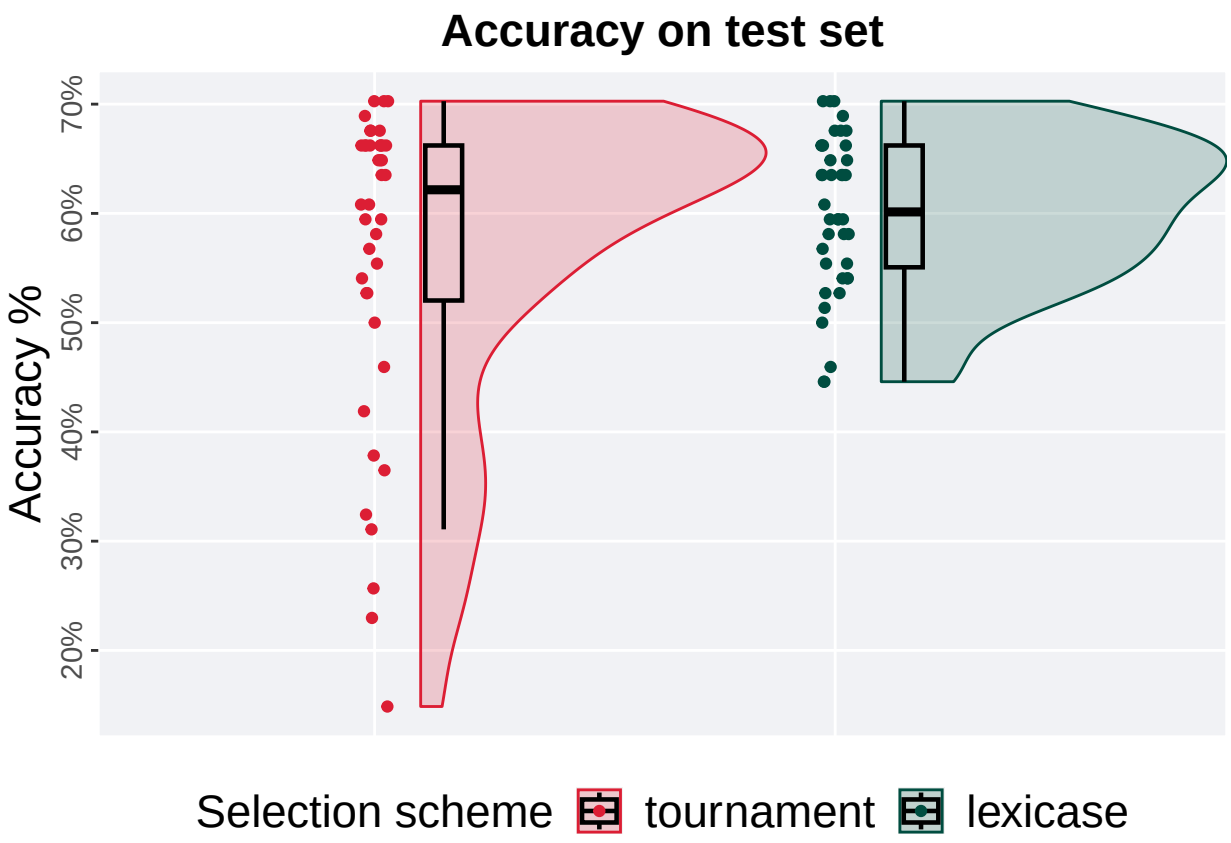
```
## [1] "observed_diff: 0.218175712374656"
## [1] "lower: -1.99095942630688"
## [1] "upper: 1.99096129334562"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.83358"
```



4.5 95%

4.5.1 Testing set accuracy

```
test_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

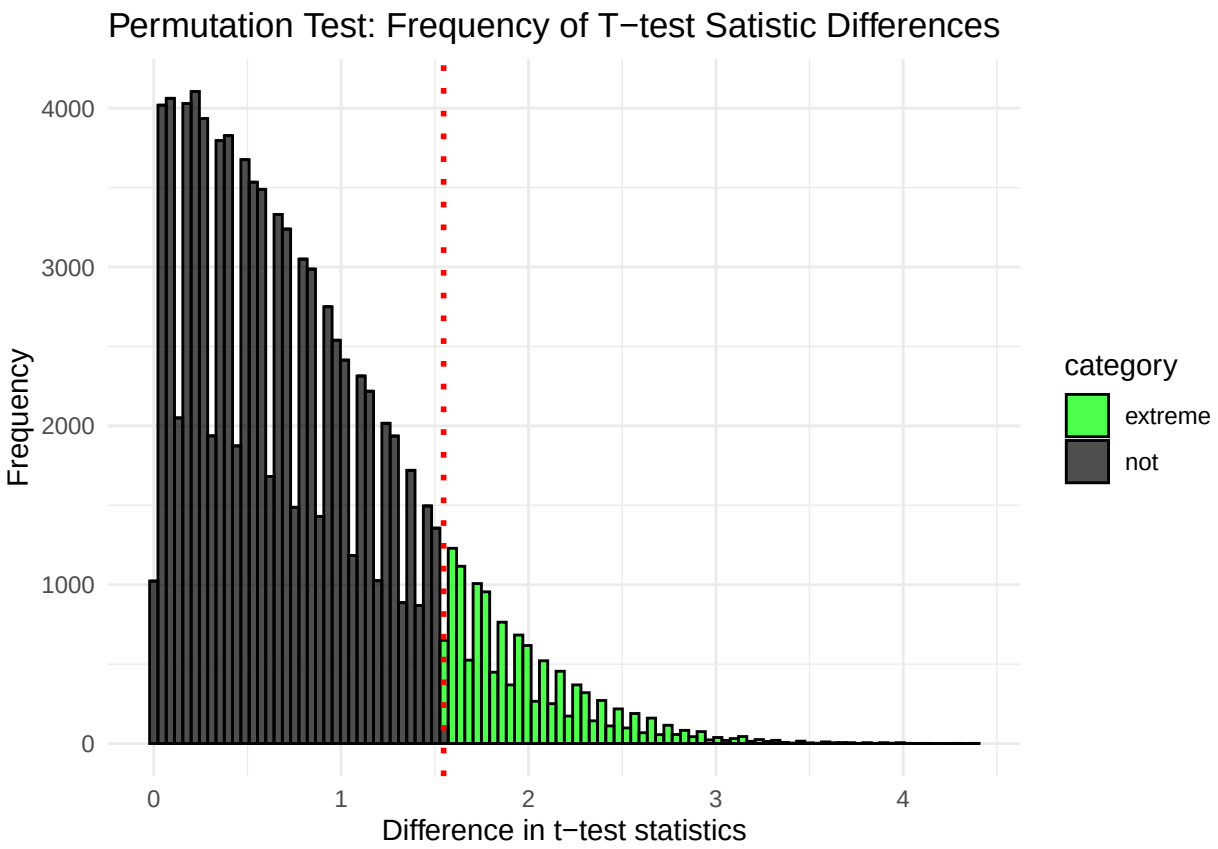
```
test_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max   IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl> <dbl>
## 1 tournament    40      0 0.149  0.622 0.561 0.703 0.142
## 2 lexicase      40      0 0.446  0.601 0.601 0.703 0.111
```

The permutation test revealed that the results are:

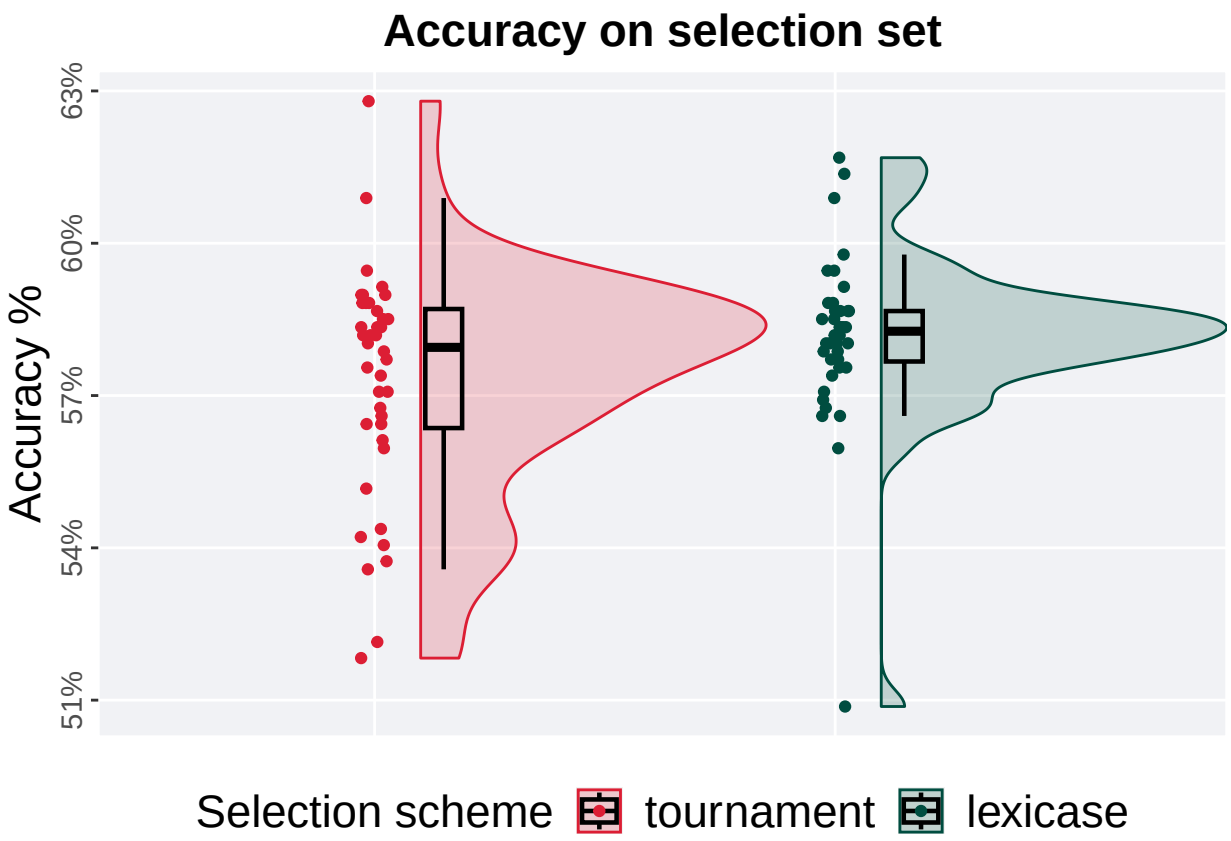
```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 19,
                 alternative = "t")
```

```
## [1] "observed_diff: -1.54710562137524"
## [1] "lower: -1.95772948677679"
## [1] "upper: 1.95772969216945"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.12617"
```



4.5.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

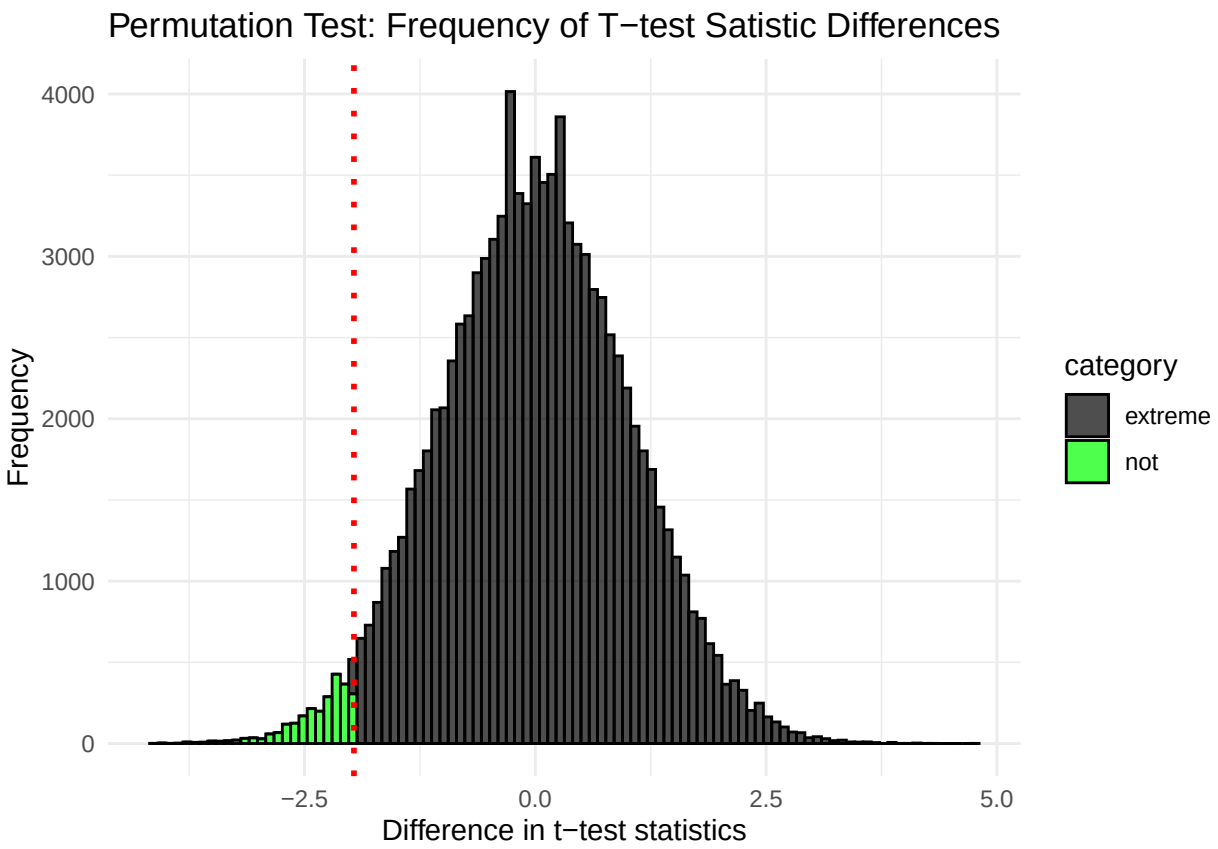
```
selection_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.518  0.579 0.573 0.628 0.0234
## 2 lexicase      40      0 0.509  0.583 0.582 0.617 0.00994
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 20,
                 alternative = "l")
```

```
## [1] "observed_diff: -1.96456434004405"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.64935315376094"
## [1] "reject null hypothesis"
## [1] "p-value: 0.02535"
```


Permutation Test: Frequency of T−test Satistic Differences
Frequency
4000
3000
2000
1000
0
−2.5
0.0
2.5
5.0
Difference in t−test statistics
category
extreme
not

Chapter 5

Task 359955

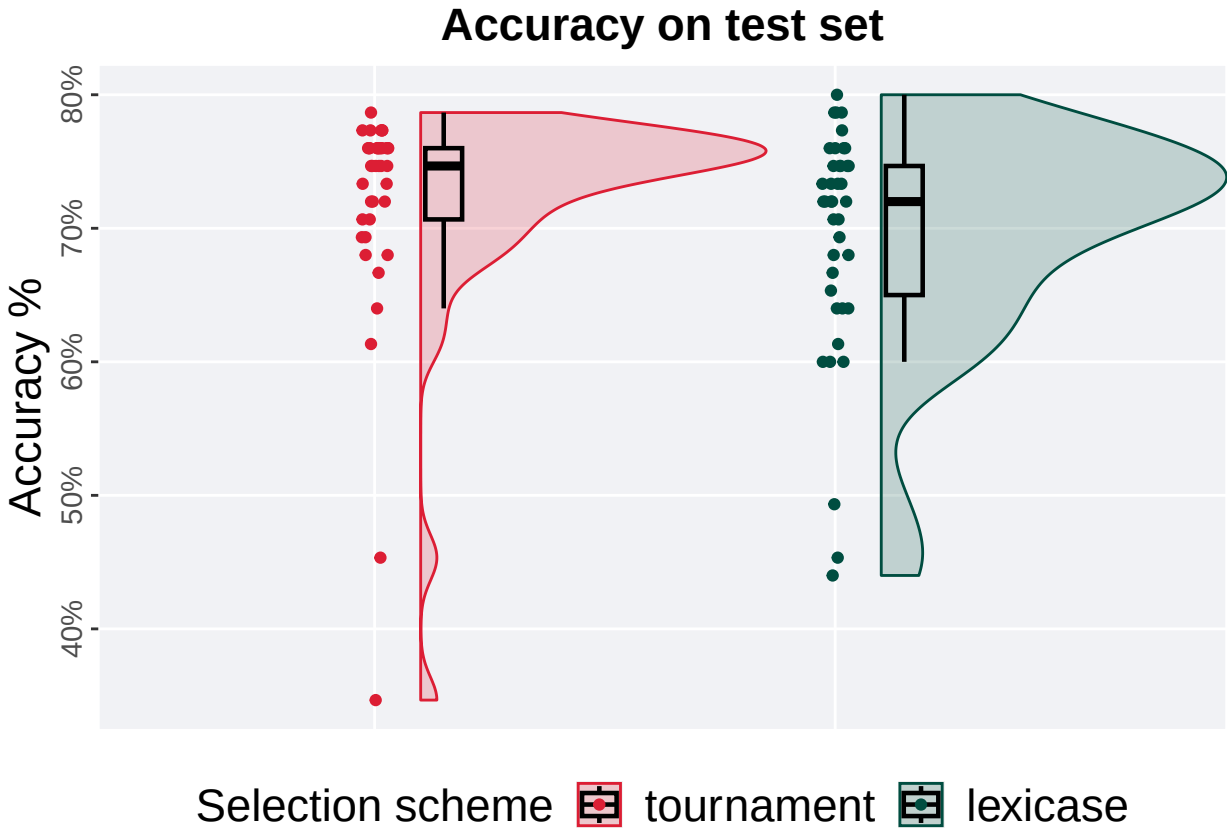
We present the results of our analysis of `task 359955` with the different selection set splits used in our study.

```
task_data <- filter(results, task_id == 359955)
```

5.1 5%

5.1.1 Testing set accuracy

```
test_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

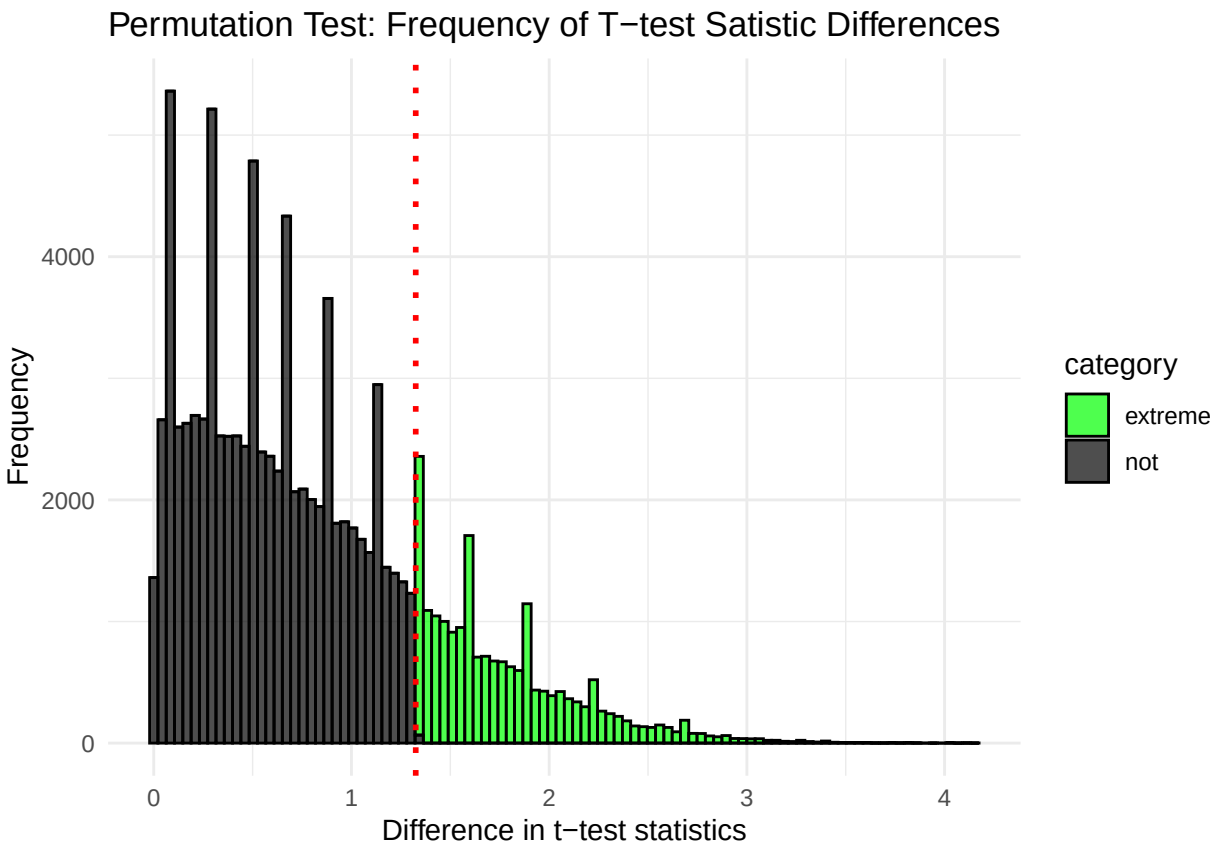
```
test_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.347  0.747 0.719 0.787 0.0533
## 2 lexicase      40      0 0.44   0.72  0.694 0.8   0.0967
```

The permutation test revealed that the results are:

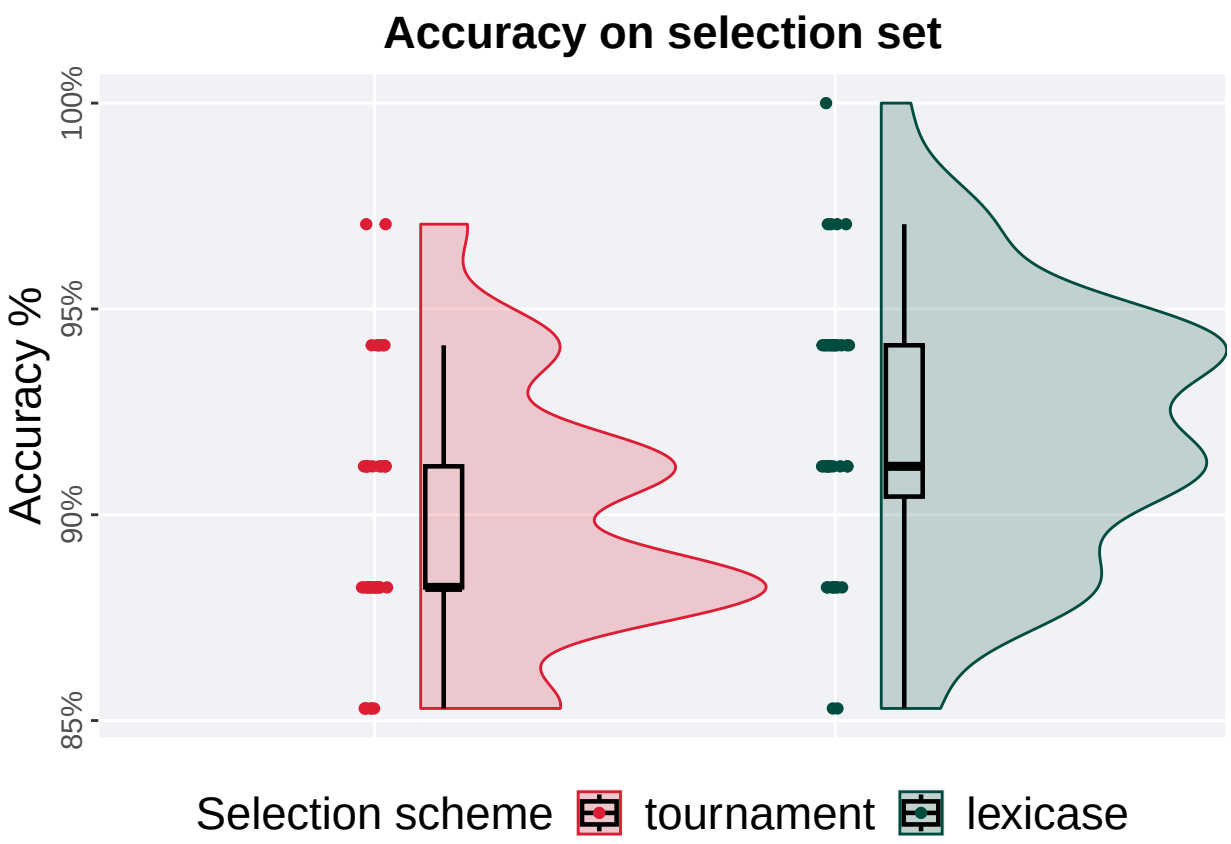
```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 31,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.32499897361024"
## [1] "lower: -1.97890029487314"
## [1] "upper: 1.97890051754304"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.19871"
```



5.1.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

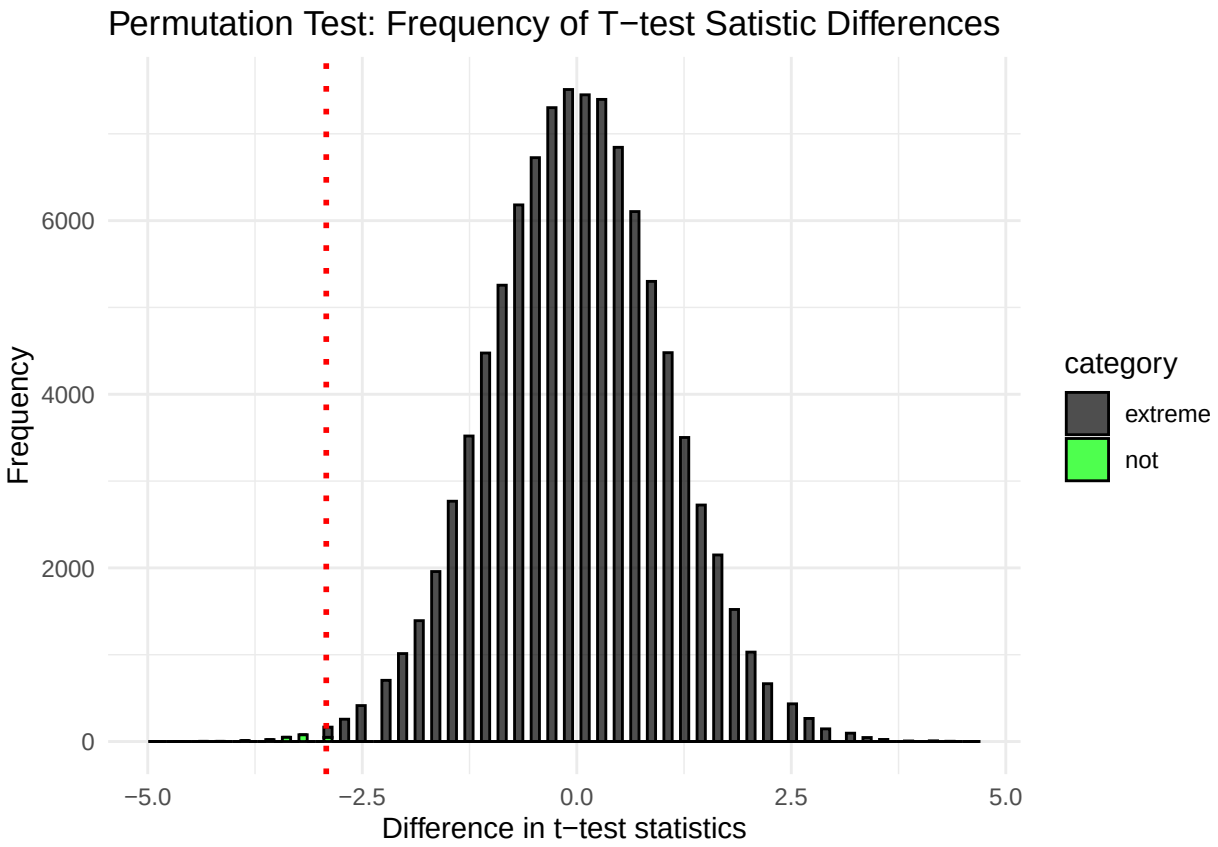
```
selection_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.853  0.882 0.899 0.971 0.0294
## 2 lexicase      40      0 0.853  0.912 0.921 1     0.0368
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 32,
                 alternative = "l")
```

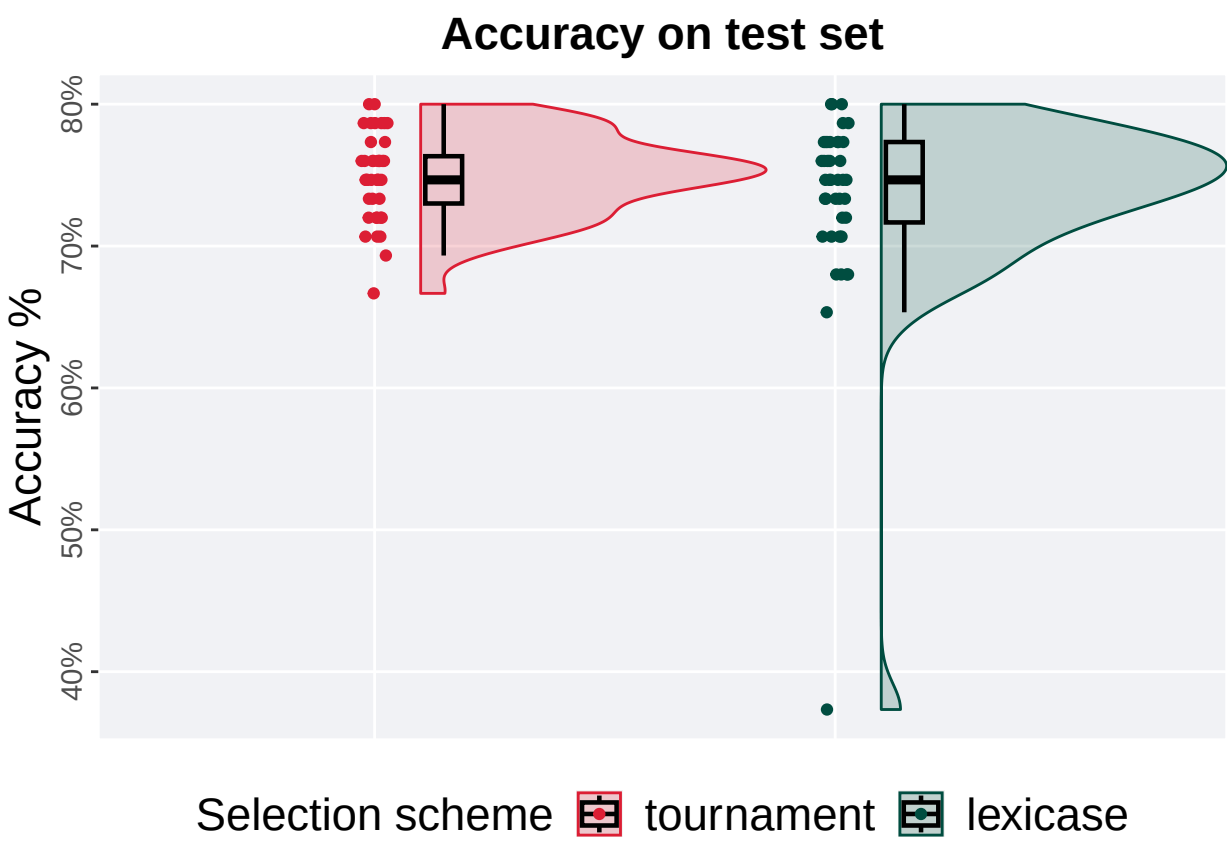
```
## [1] "observed_diff: -2.91990855742165"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.65338713426272"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00214"
```



5.2 10%

5.2.1 Testing set accuracy

```
test_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

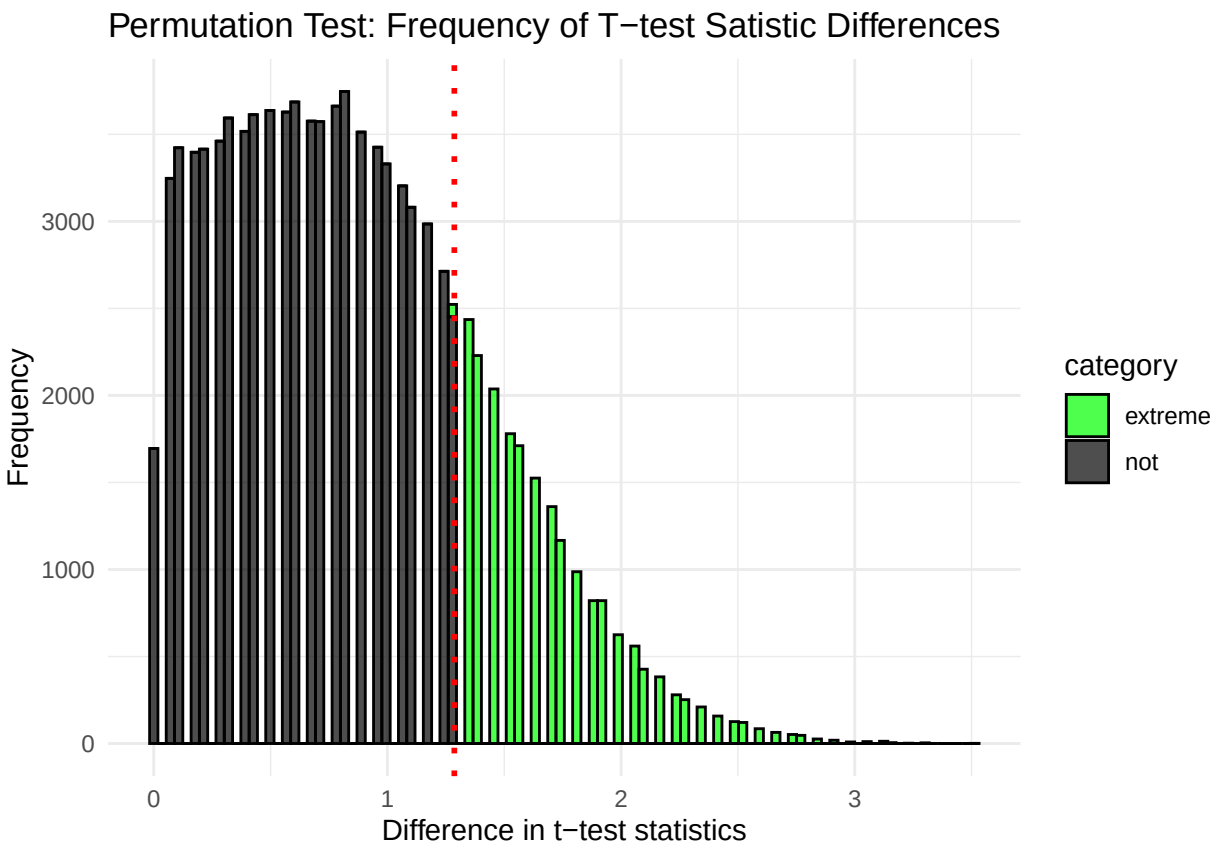
```
test_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.667  0.747 0.749   0.8 0.0333
## 2 lexicase      40      0 0.373  0.747 0.734   0.8 0.0567
```

The permutation test revealed that the results are:

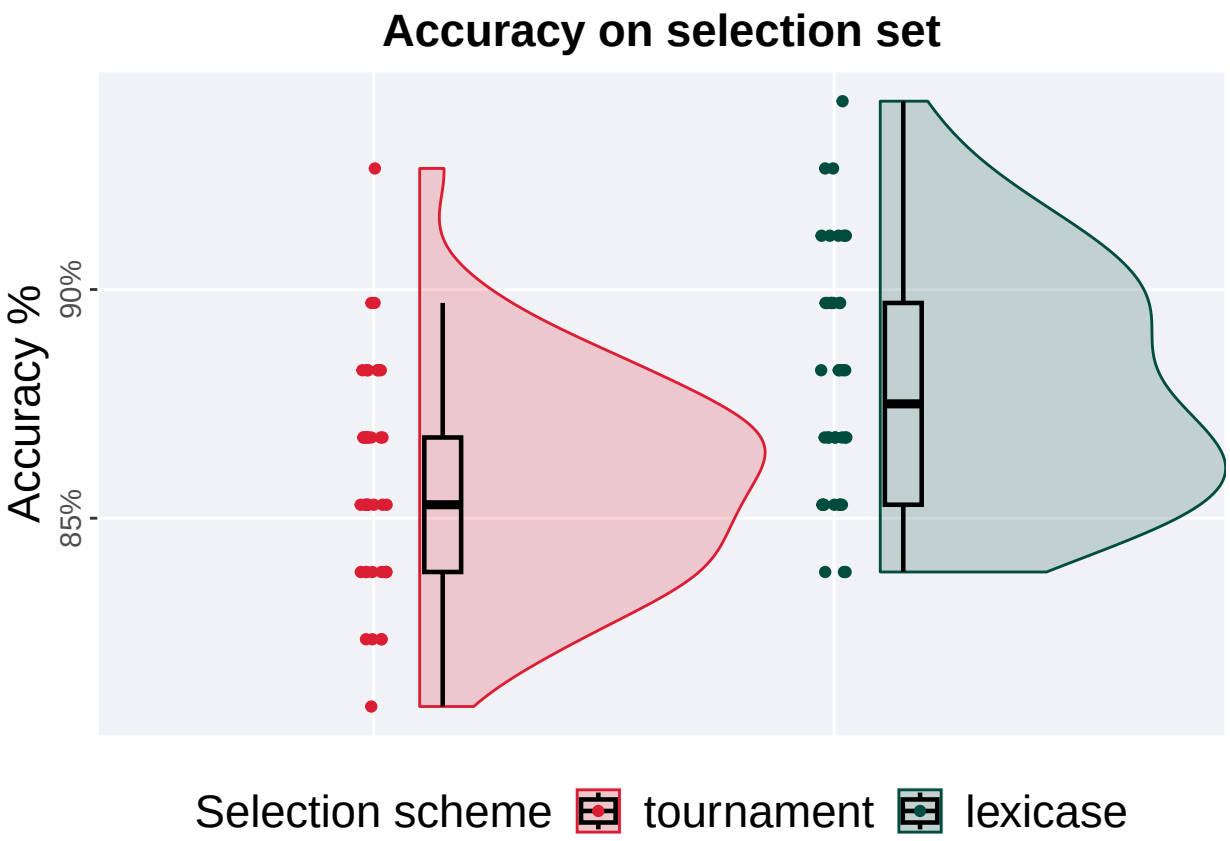
```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 33,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.28638411846571"
## [1] "lower: -1.86676173626107"
## [1] "upper: 1.80778536386294"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.20426"
```



5.2.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

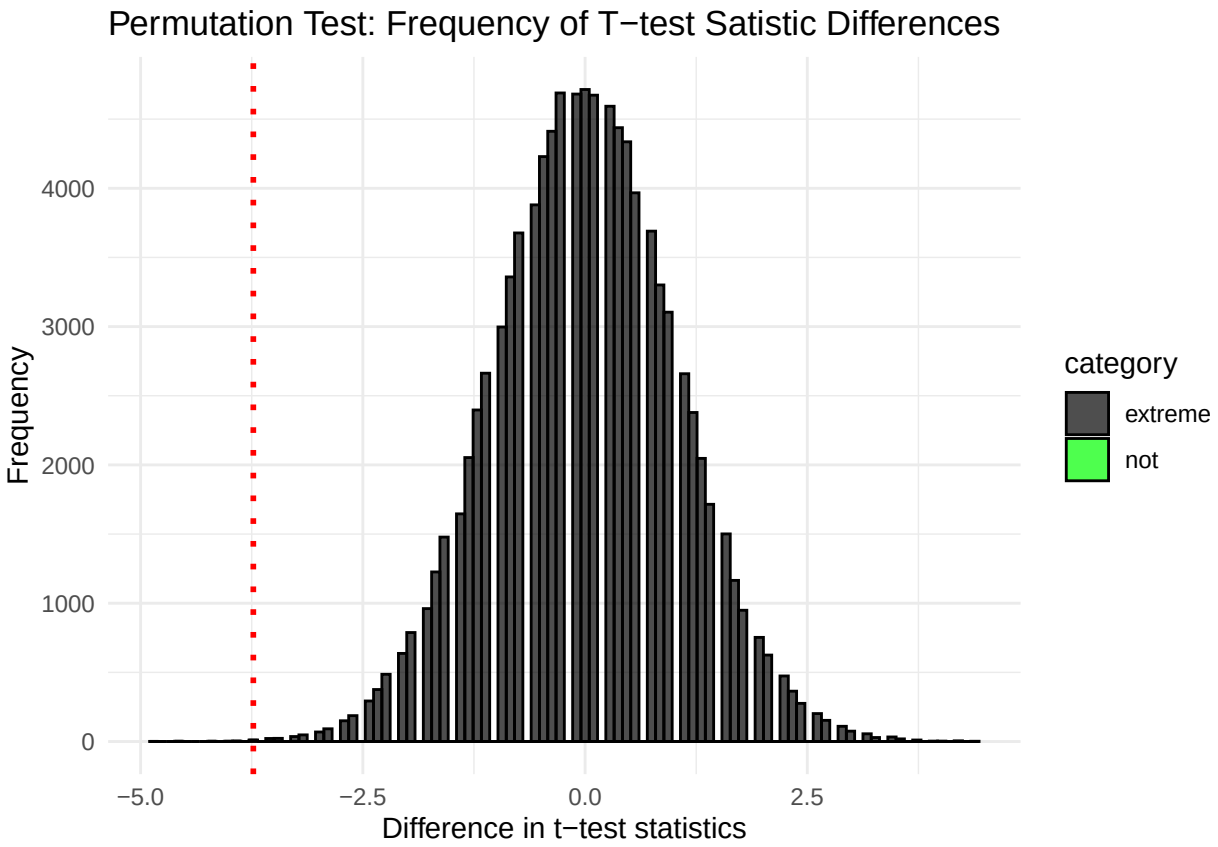
```
selection_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.809  0.853 0.858 0.926 0.0294
## 2 lexicase      40      0 0.838  0.875 0.879 0.941 0.0441
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 34,
                 alternative = "l")
```

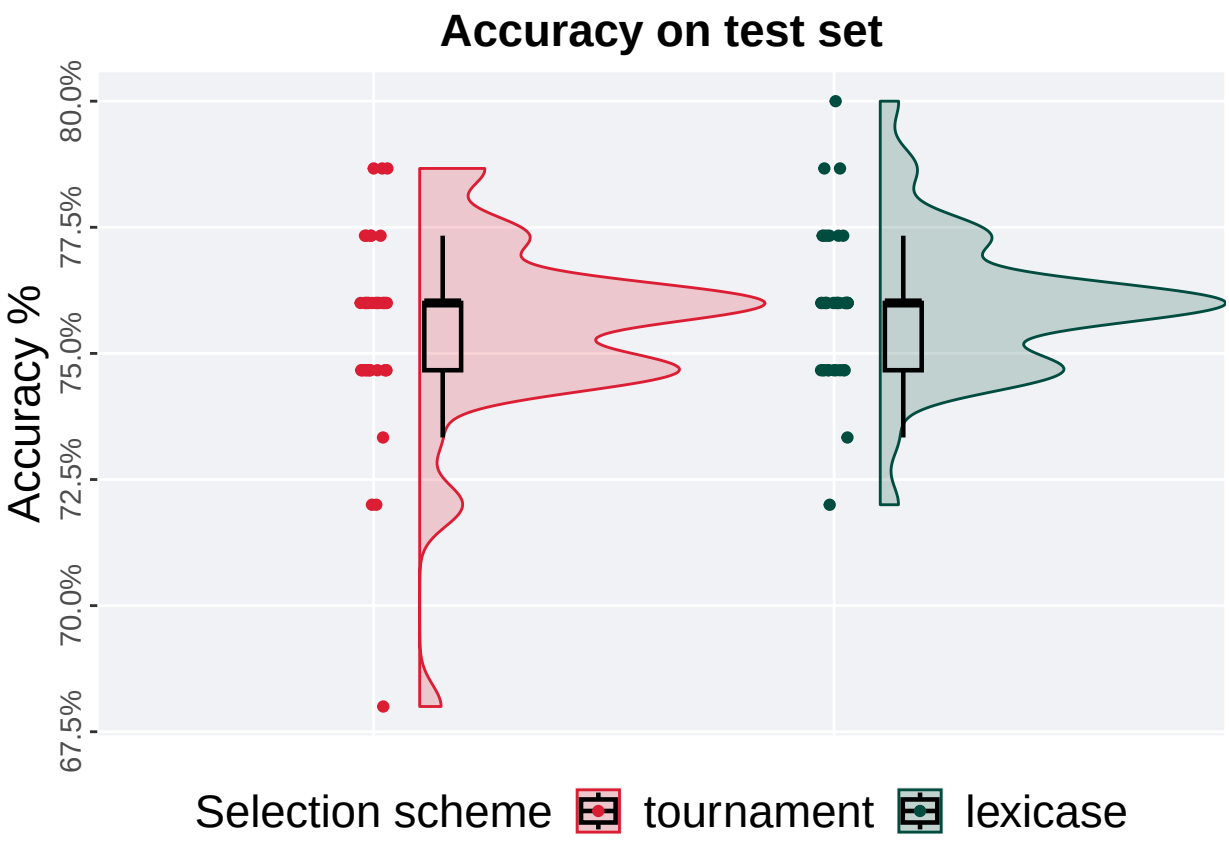
```
## [1] "observed_diff: -3.7319412515713"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.68964535023223"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00019"
```



5.3 50%

5.3.1 Testing set accuracy

```
test_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

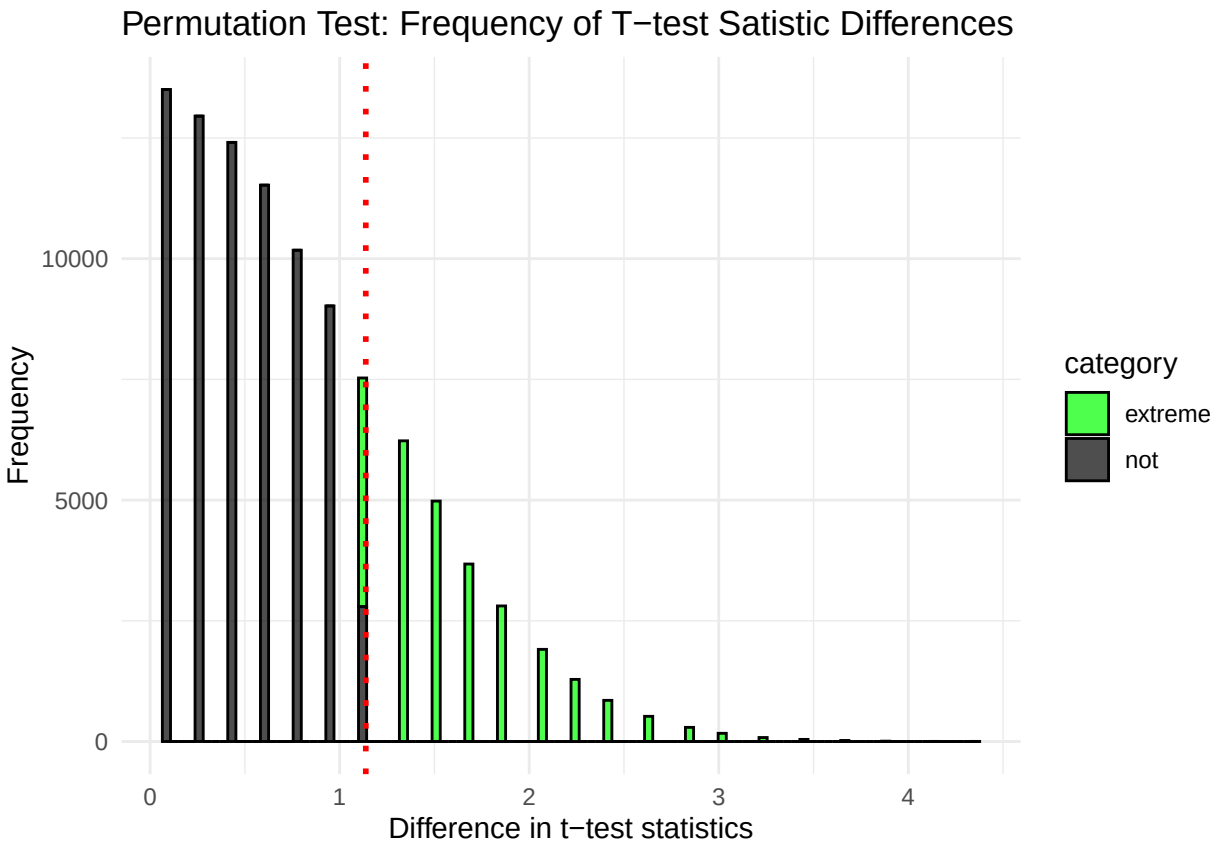
```
test_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0  0.68   0.76 0.755 0.787 0.0133
## 2 lexicase      40      0  0.72   0.76 0.759 0.8   0.0133
```

The permutation test revealed that the results are:

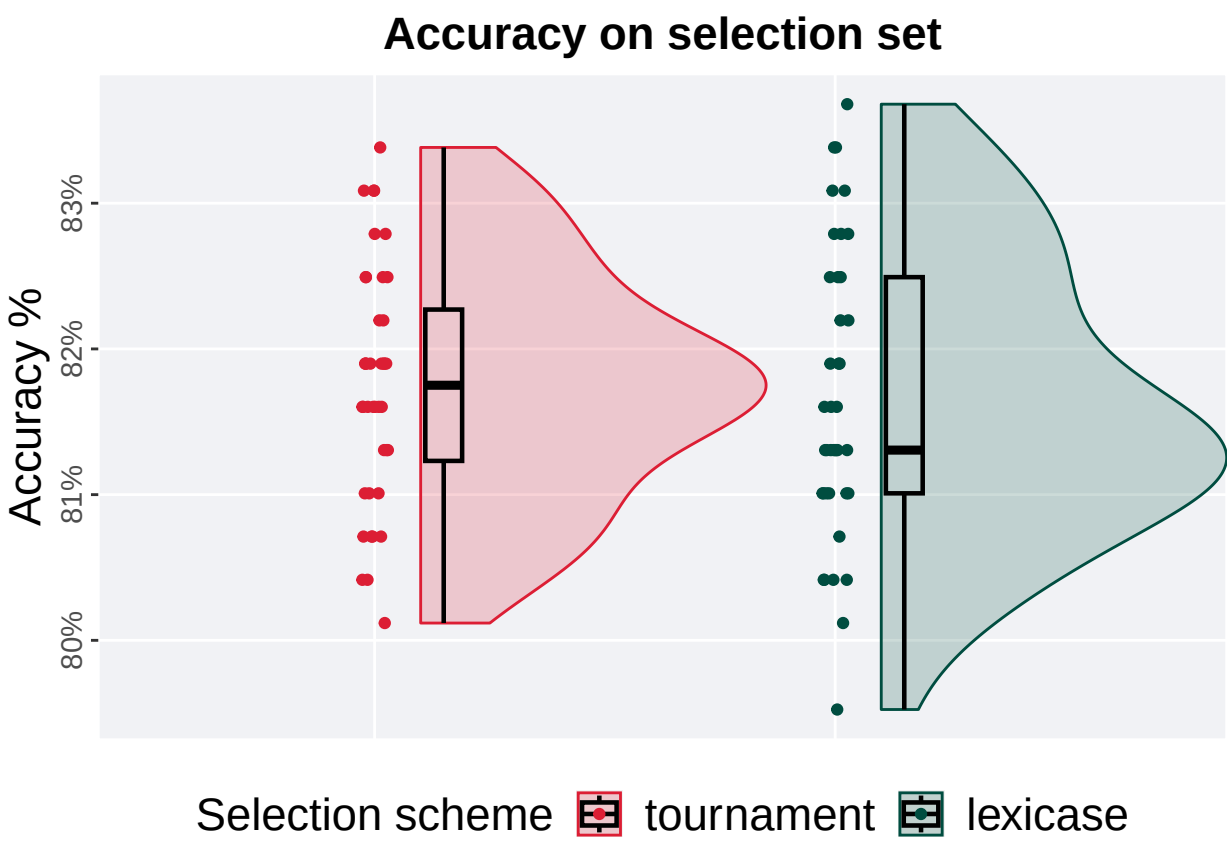
```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 35,
                 alternative = "t")
```

```
## [1] "observed_diff: -1.13782106538951"
## [1] "lower: -2.04962738612793"
## [1] "upper: 2.04962752699874"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.27624"
```



5.3.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

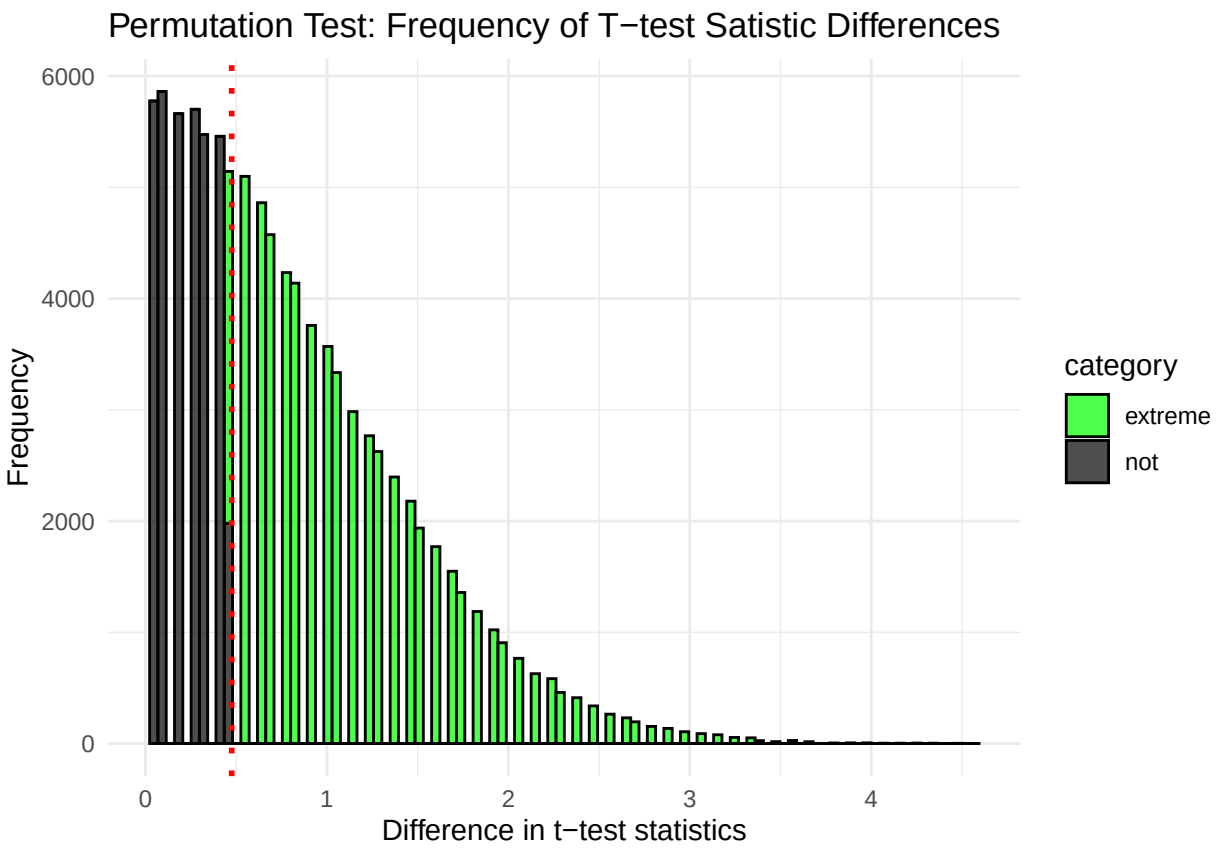
```
selection_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.801  0.818 0.817 0.834 0.0104
## 2 lexicase      40      0 0.795  0.813 0.816 0.837 0.0148
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 36,
                 alternative = "t")
```

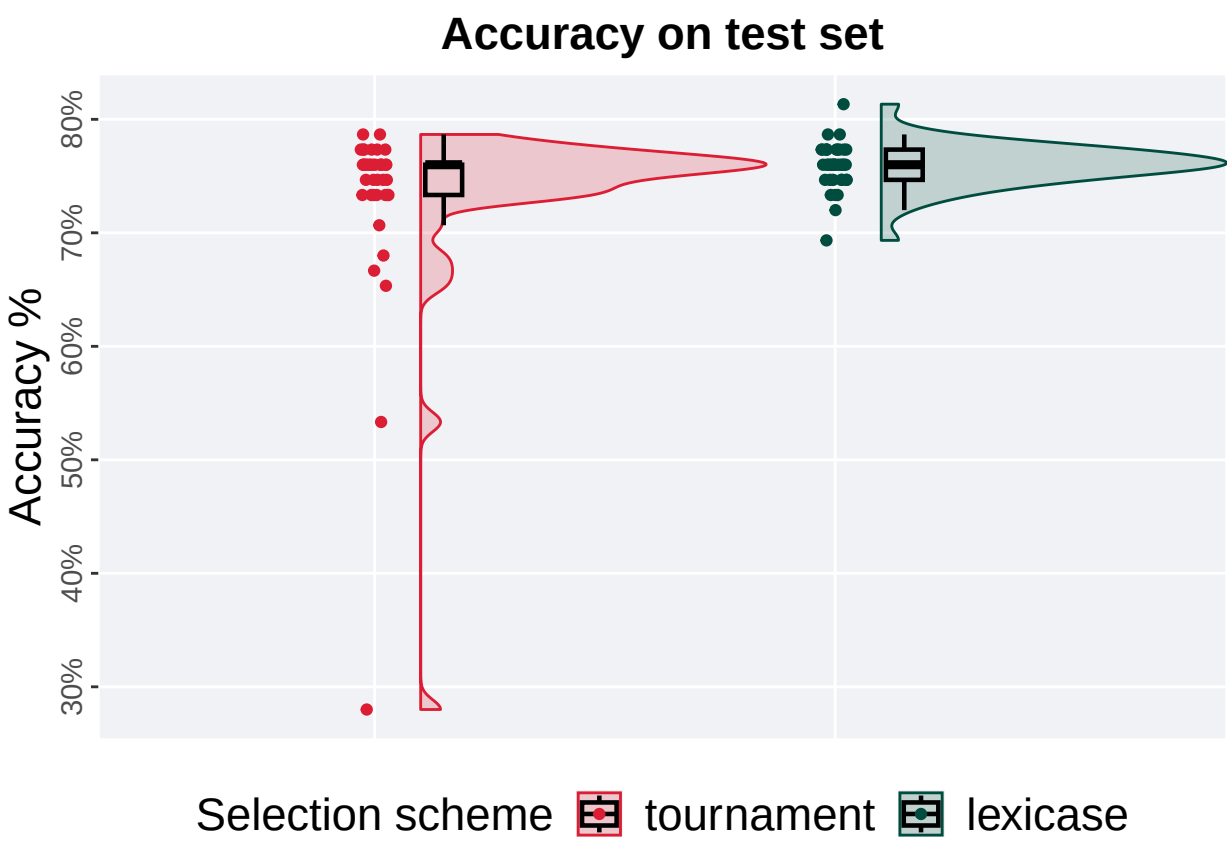
```
## [1] "observed_diff: 0.475399664870139"
## [1] "lower: -1.9835828407878"
## [1] "upper: 1.98358257581197"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.64083"
```



5.4 90%

5.4.1 Testing set accuracy

```
test_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

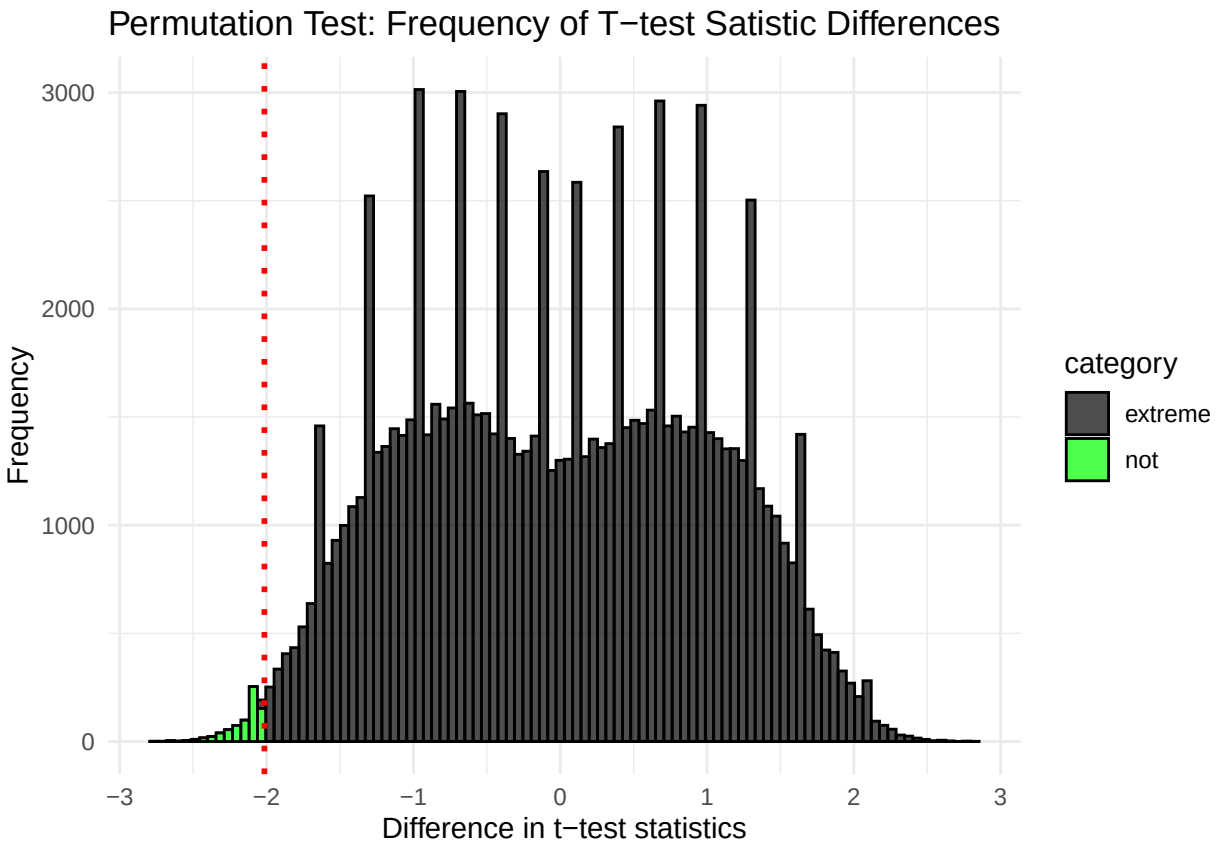
```
test_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.28    0.76 0.731 0.787 0.0267
## 2 lexicase      40      0 0.693   0.76 0.759 0.813 0.0267
```

The permutation test revealed that the results are:

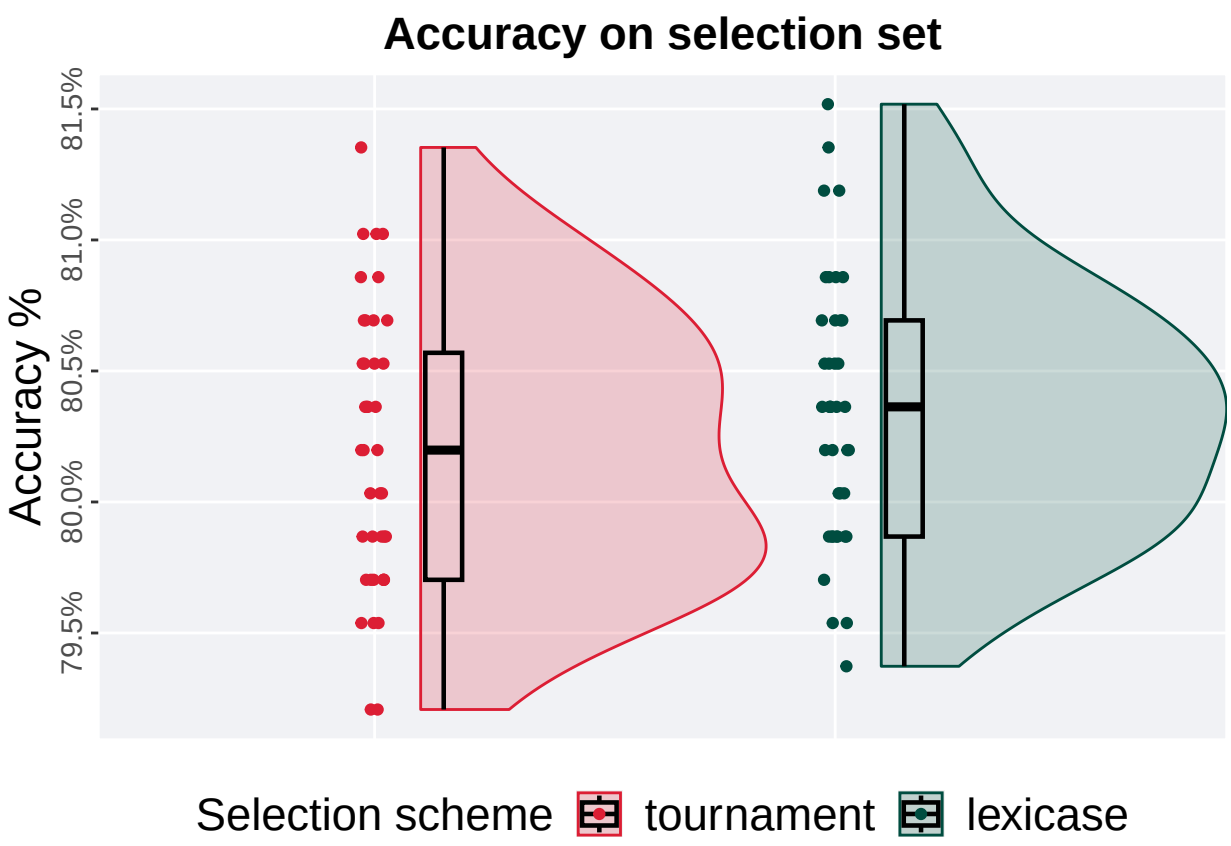
```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 37,
                 alternative = "l")
```

```
## [1] "observed_diff: -2.01490383284339"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.56760535956015"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00738"
```



5.4.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

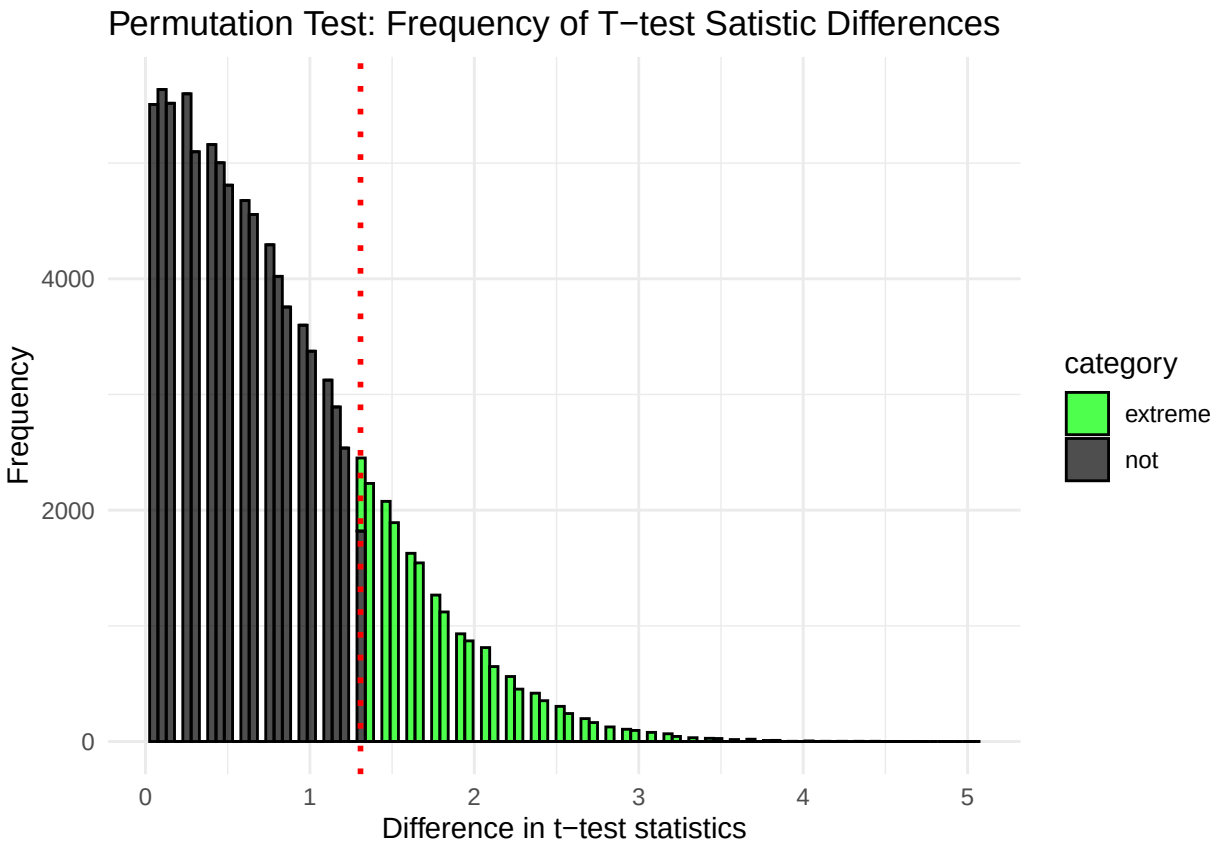
```
selection_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.792  0.802 0.802 0.814 0.00866
## 2 lexicase      40      0 0.794  0.804 0.803 0.815 0.00825
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 38,
                 alternative = "t")
```

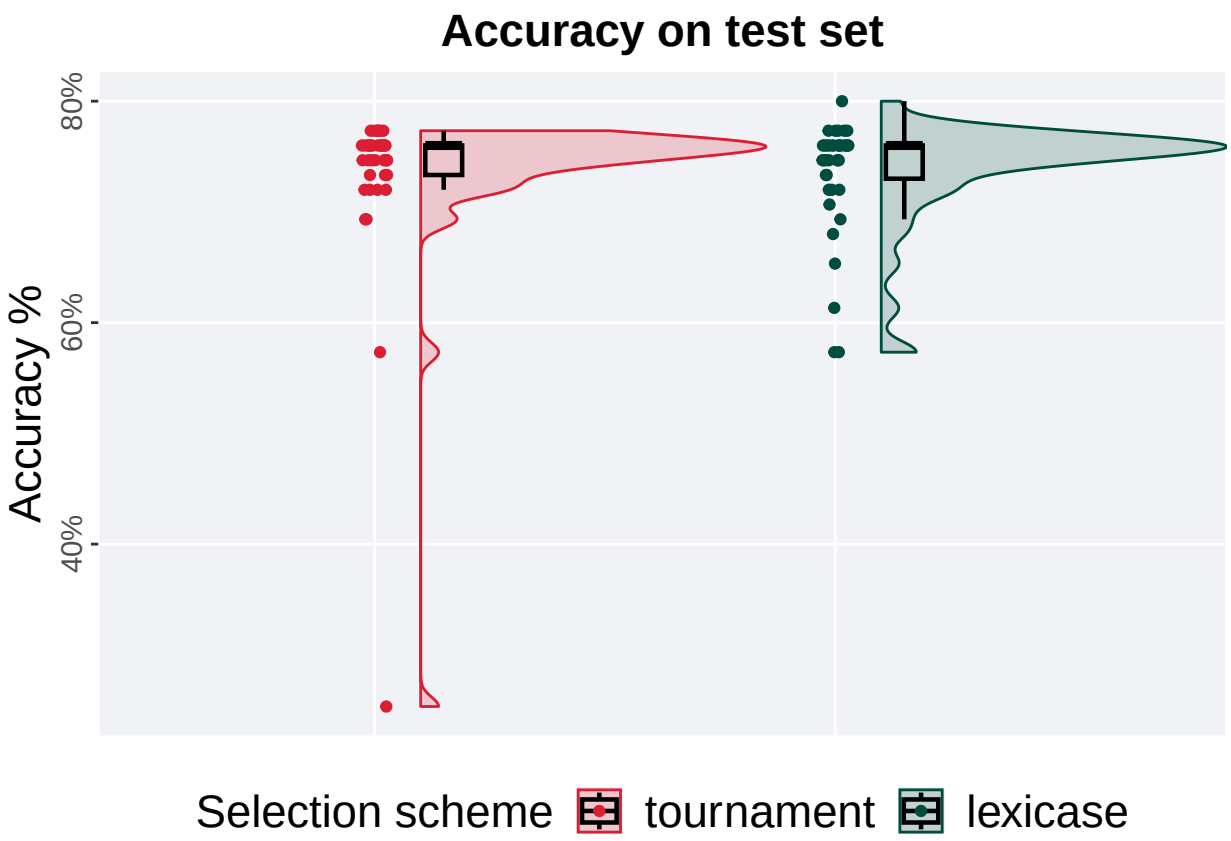
```
## [1] "observed_diff: -1.30766861645993"
## [1] "lower: -1.97012862430494"
## [1] "upper: 1.97013135879071"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.19023"
```



5.5 95%

5.5.1 Testing set accuracy

```
test_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

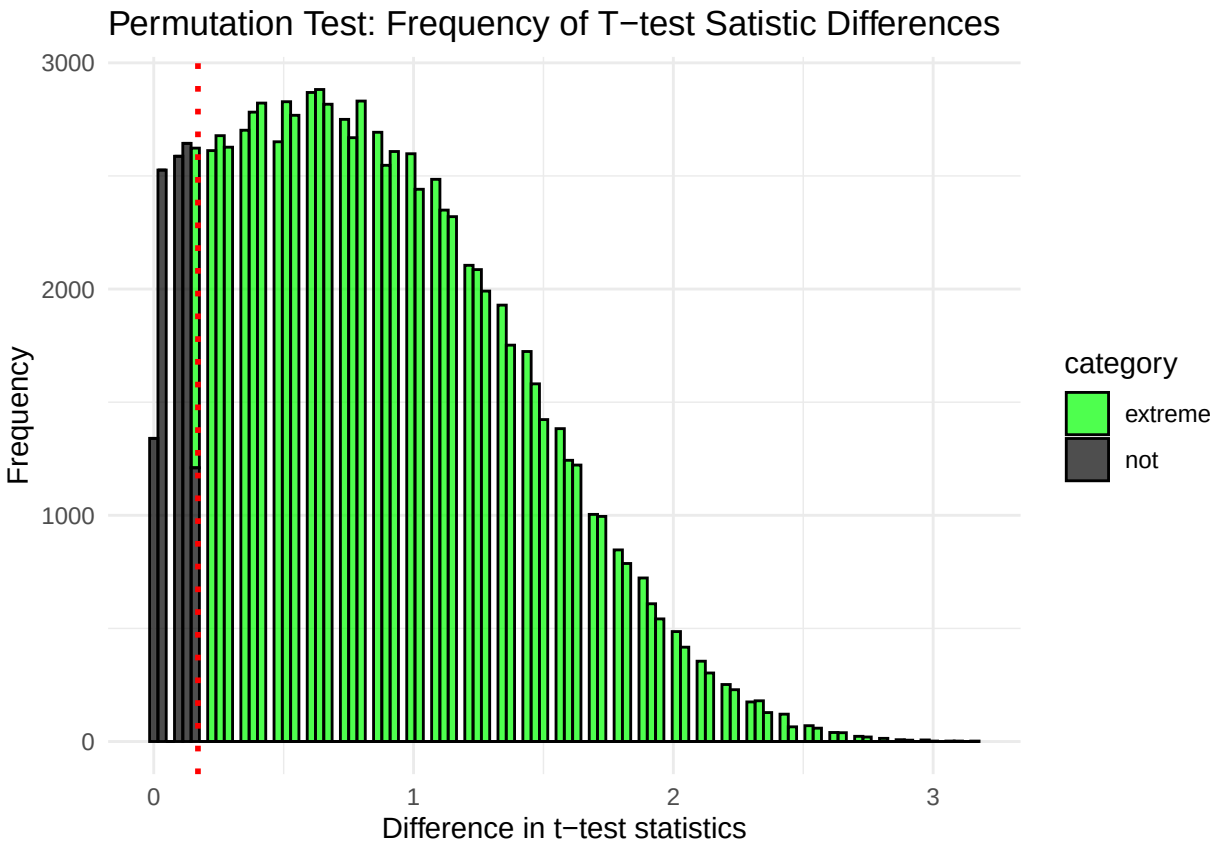
```
test_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.253   0.76 0.733 0.773 0.0267
## 2 lexicase      40      0 0.573   0.76 0.735 0.8   0.0300
```

The permutation test revealed that the results are:

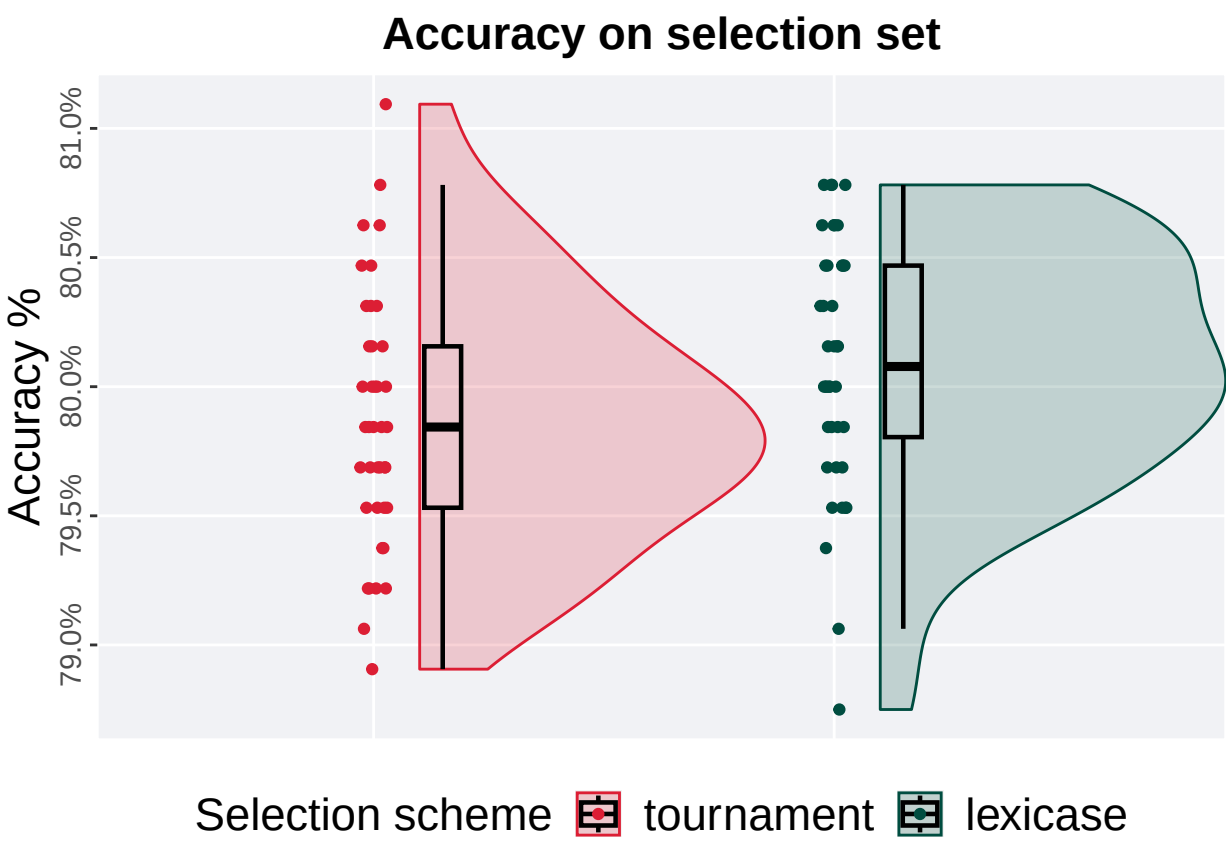
```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 39,
                 alternative = "t")
```

```
## [1] "observed_diff: -0.170085425997122"
## [1] "lower: -1.82321742524129"
## [1] "upper: 1.8232173573514"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.89693"
```



5.5.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

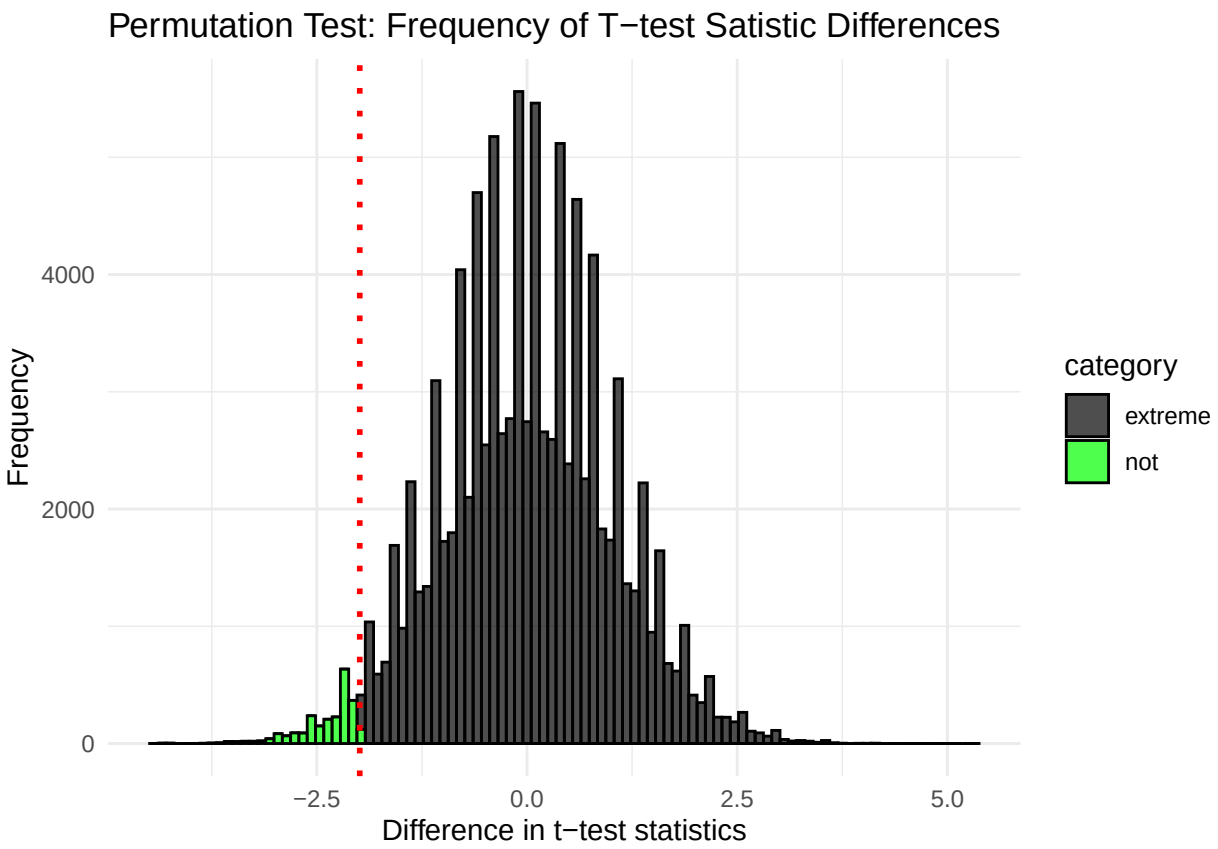
```
selection_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.789  0.798 0.799 0.811 0.00625
## 2 lexicase      40      0 0.788  0.801 0.801 0.808 0.00664
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 40,
                 alternative = "l")
```

```
## [1] "observed_diff: -1.98968011416173"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.69407255656074"
## [1] "reject null hypothesis"
## [1] "p-value: 0.0243"
```


Permutation Test: Frequency of T−test Satistic Differences
Frequency
4000
2000
0
−2.5
0.0
2.5
5.0
Difference in t−test statistics
category
extreme
not

Chapter 6

Task 190146

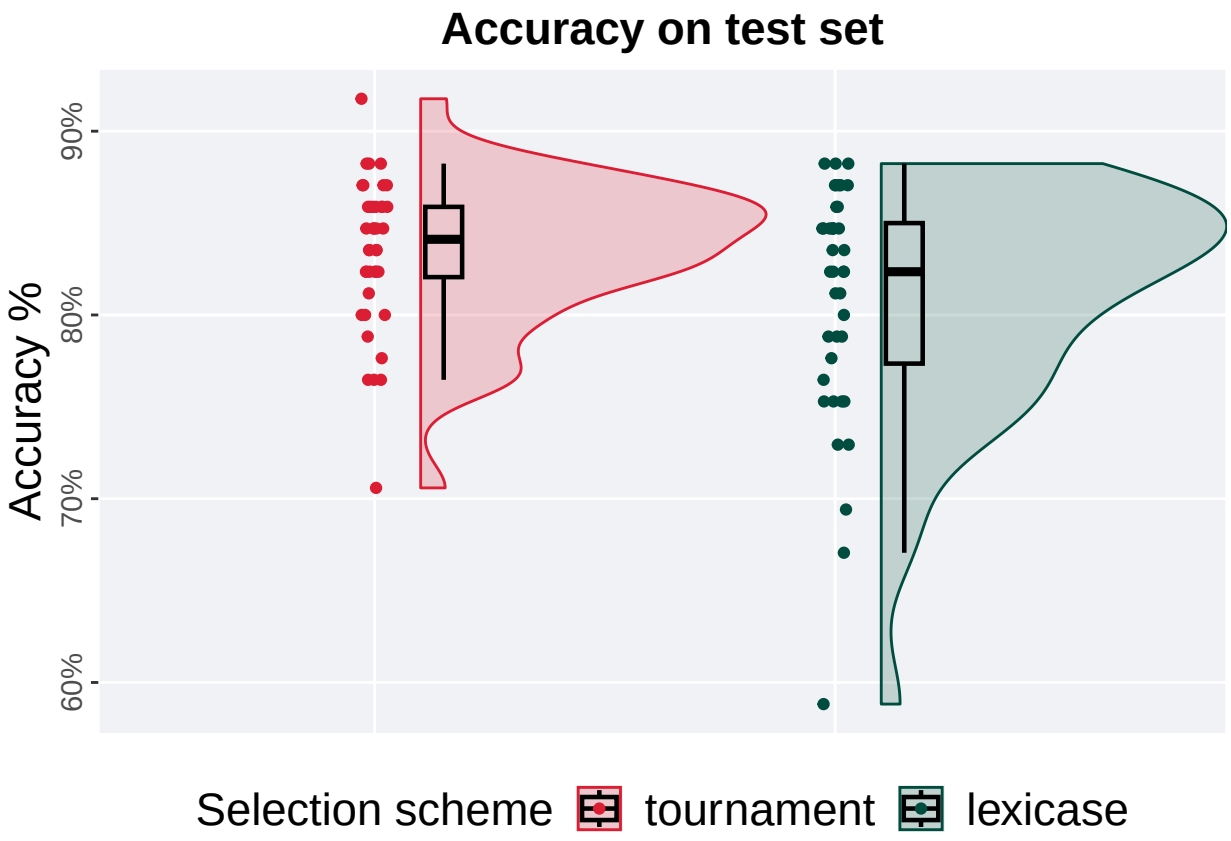
We present the results of our analysis of `task 190146` with the different selection set splits used in our study.

```
task_data <- filter(results, task_id == 190146)
```

6.1 5%

6.1.1 Testing set accuracy

```
test_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

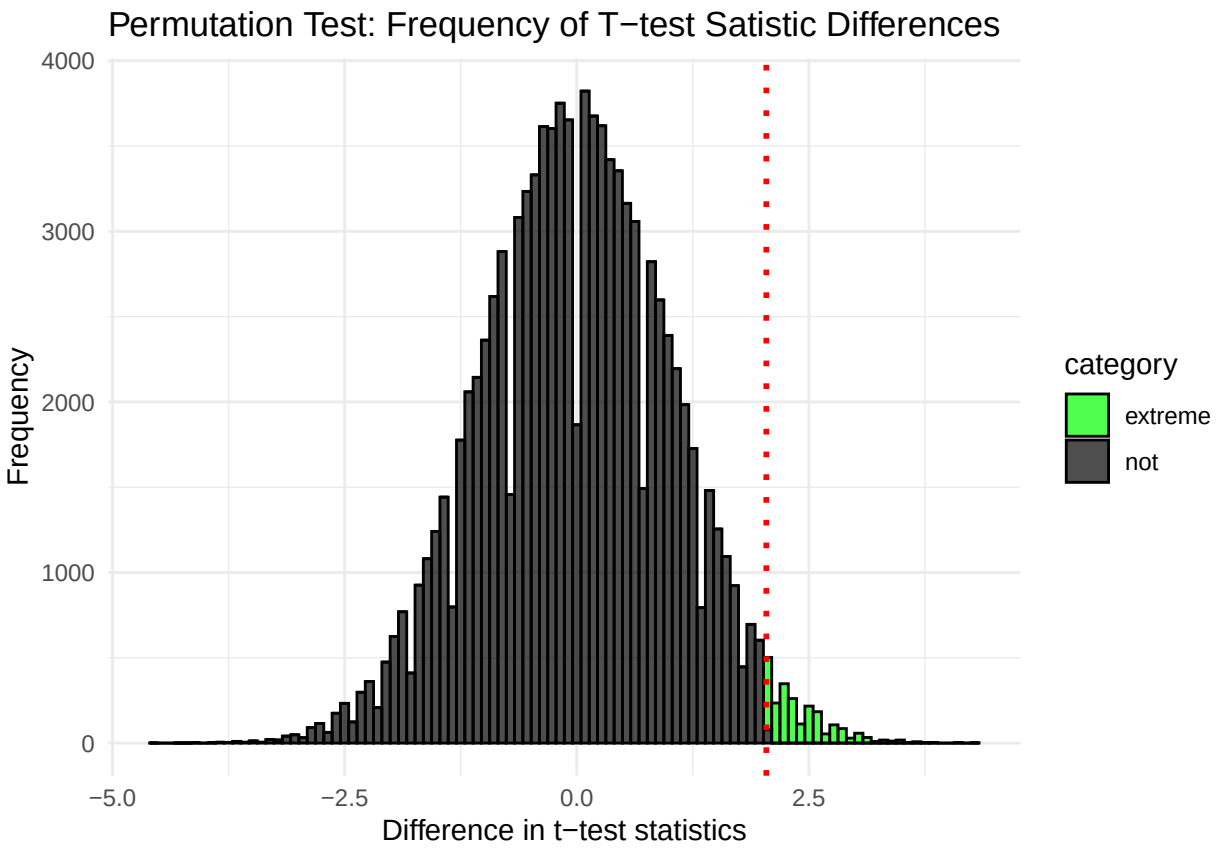
```
test_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.706  0.841 0.834 0.918 0.0382
## 2 lexicase      40      0 0.588  0.824 0.809 0.882 0.0765
```

The permutation test revealed that the results are:

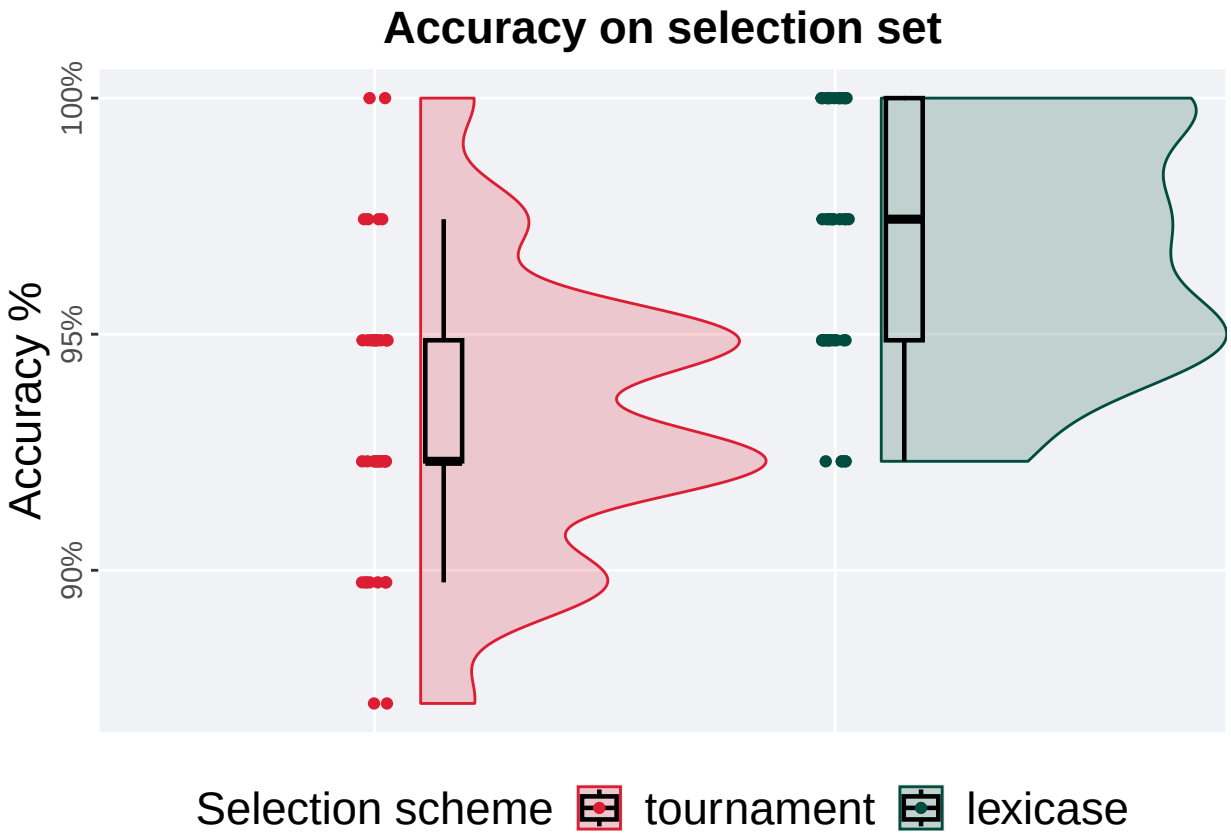
```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 41,
                 alternative = "g")
```

```
## [1] "observed_diff: 2.04108926085368"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.63730880862319"
## [1] "reject null hypothesis"
## [1] "p-value: 0.02222"
```



6.1.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

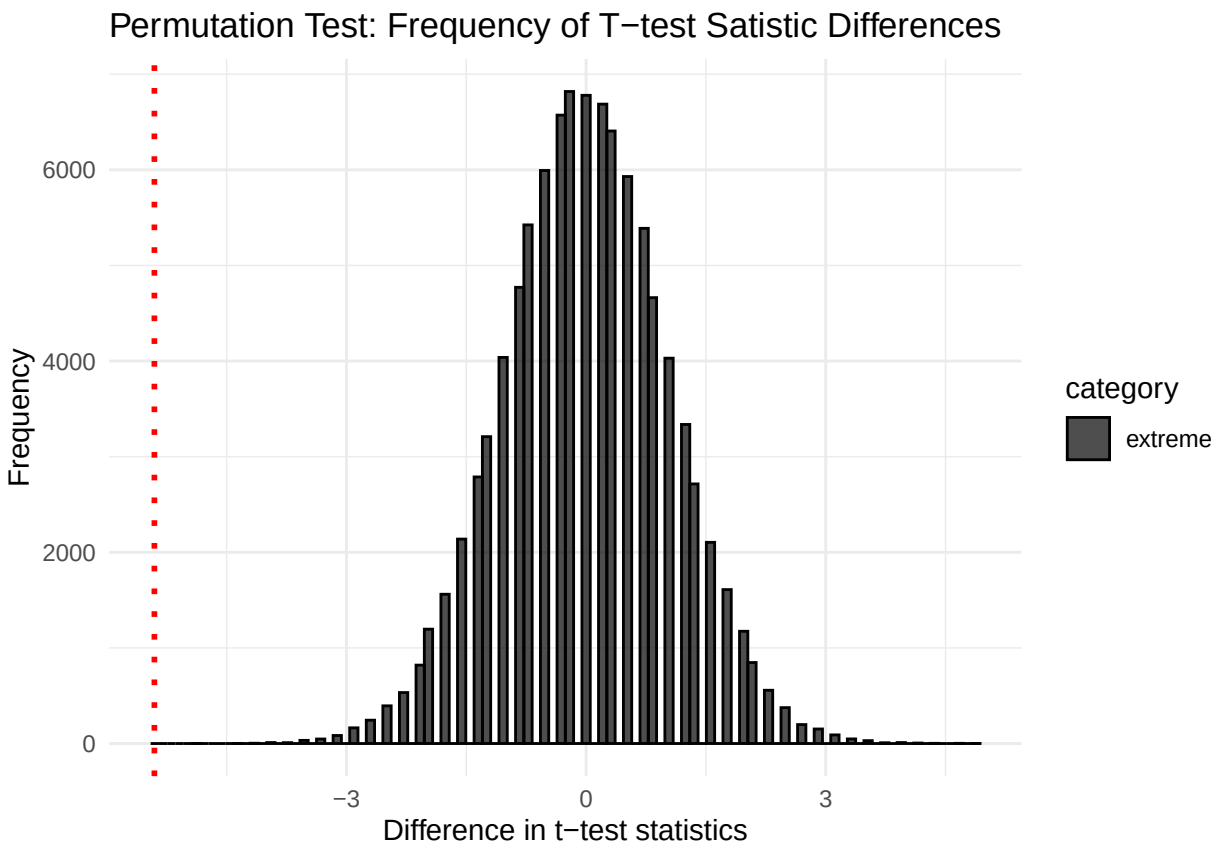
```
selection_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.872  0.923 0.933     1 0.0256
## 2 lexicase      40      0 0.923  0.974 0.967     1 0.0513
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 42,
                 alternative = "l")
```

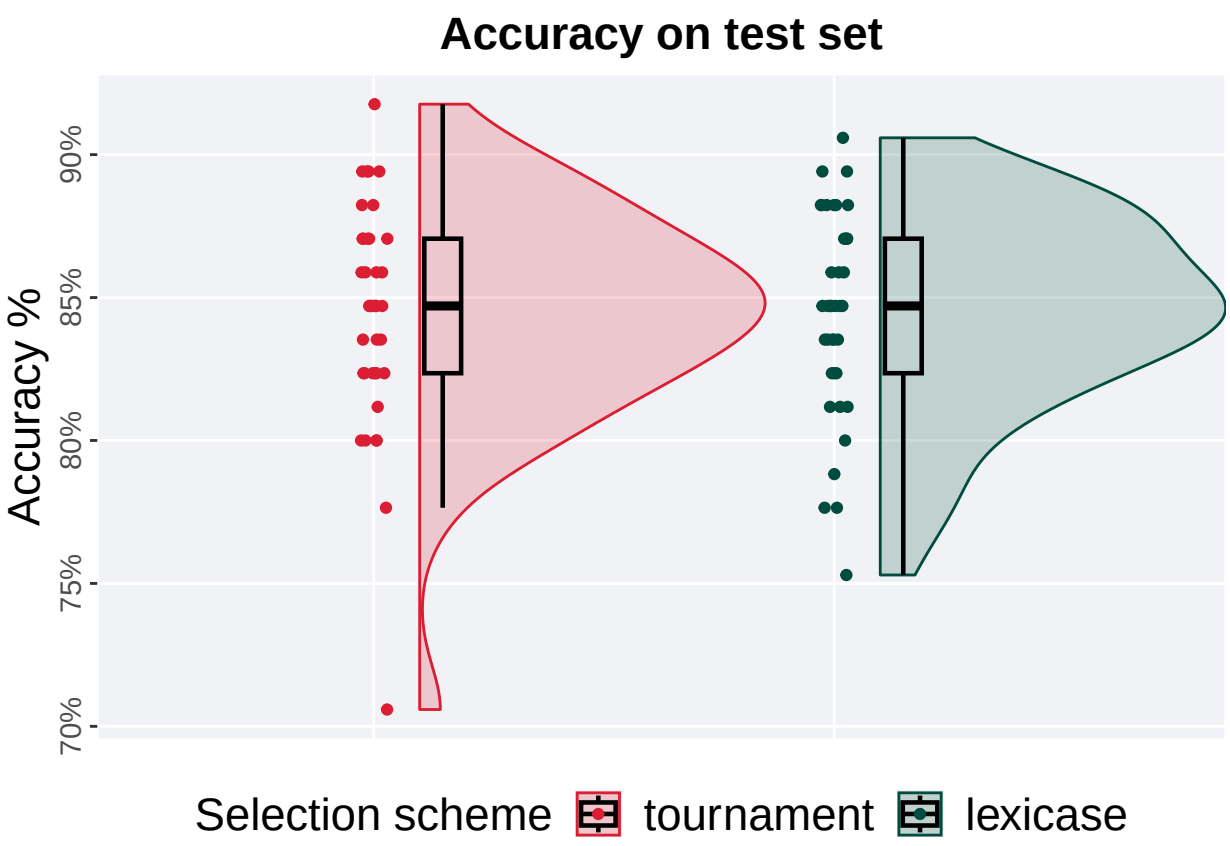
```
## [1] "observed_diff: -5.40415884185913"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.74010014099775"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```



6.2 10%

6.2.1 Testing set accuracy

```
test_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

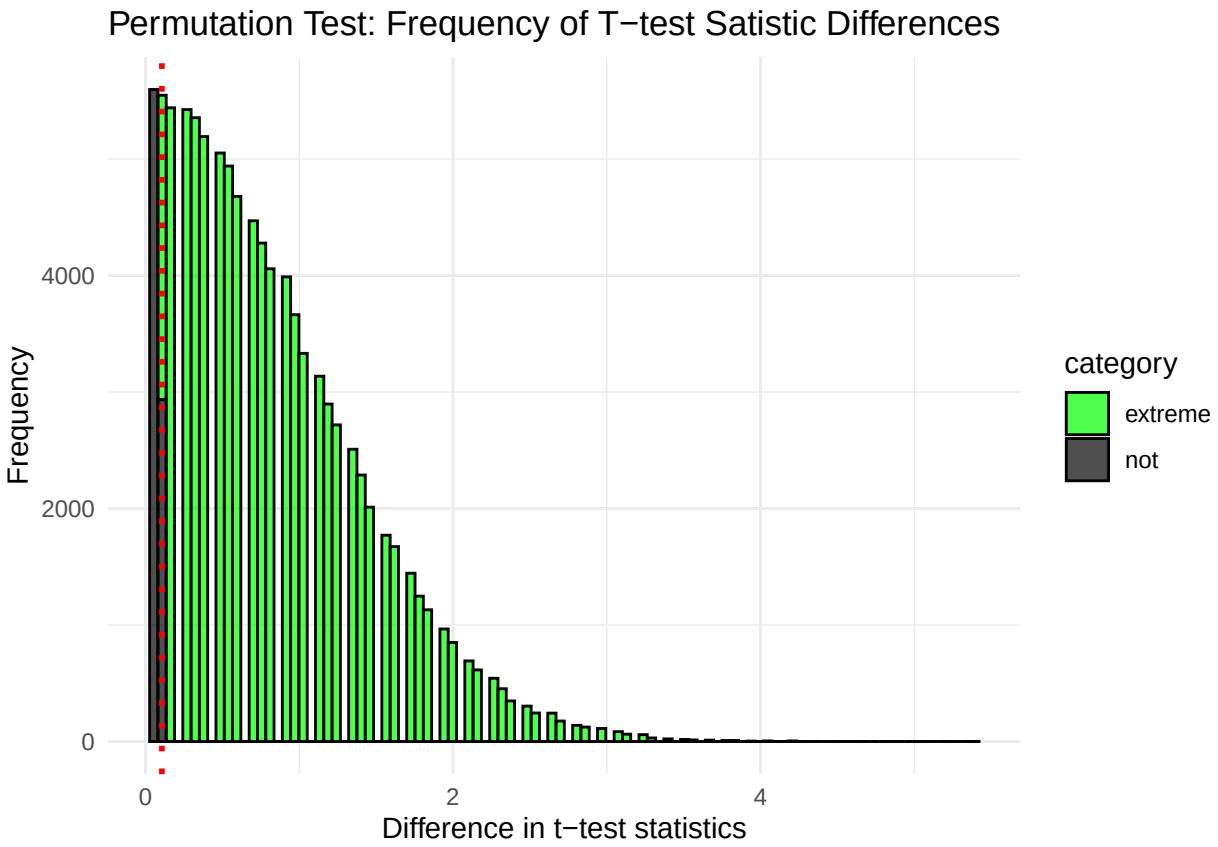
```
test_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.706  0.847 0.844 0.918 0.0471
## 2 lexicase      40      0 0.753  0.847 0.845 0.906 0.0471
```

The permutation test revealed that the results are:

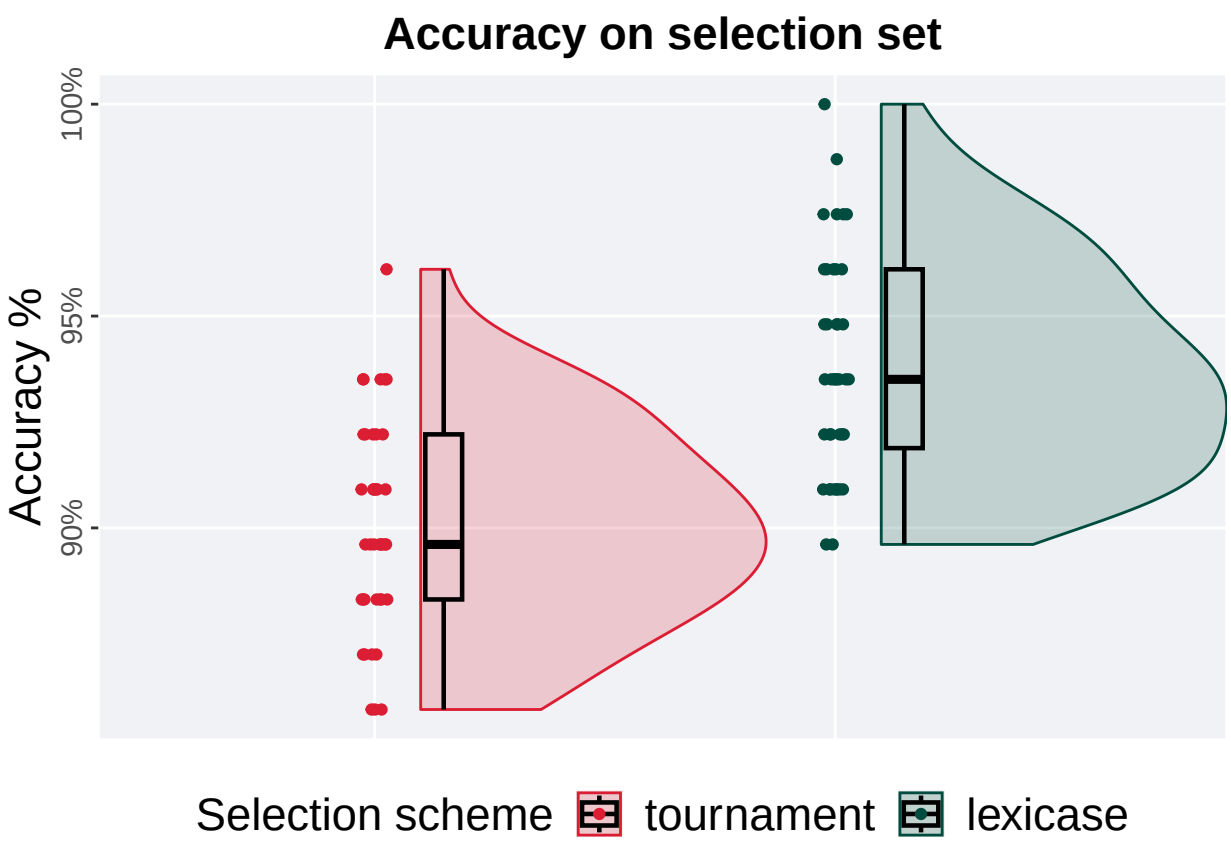
```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 43,
                 alternative = "t")
```

```
## [1] "observed_diff: -0.106802835929617"
## [1] "lower: -2.0078696403403"
## [1] "upper: 2.00786970560947"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.91468"
```



6.2.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

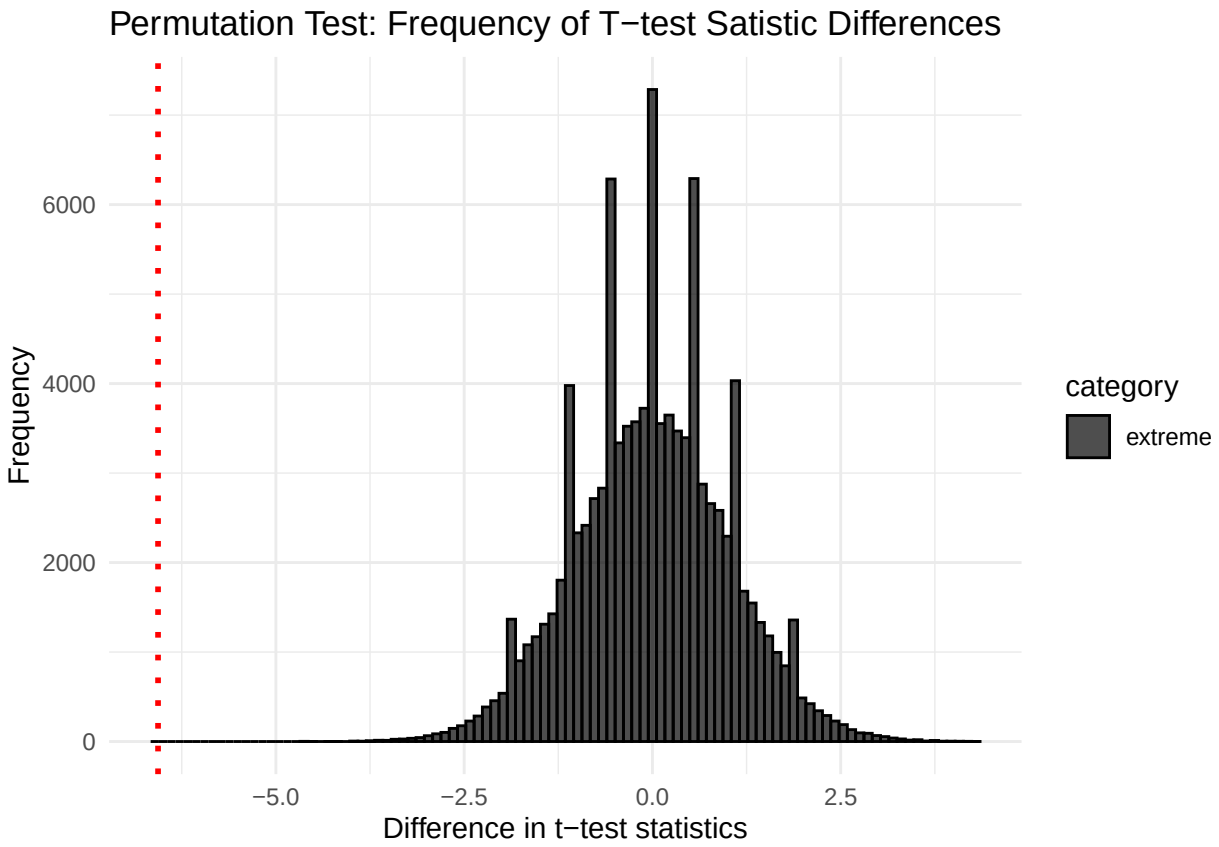
```
selection_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.857  0.896 0.900 0.961 0.0390
## 2 lexicase      40      0 0.896  0.935 0.938 1     0.0422
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 44,
                 alternative = "l")
```

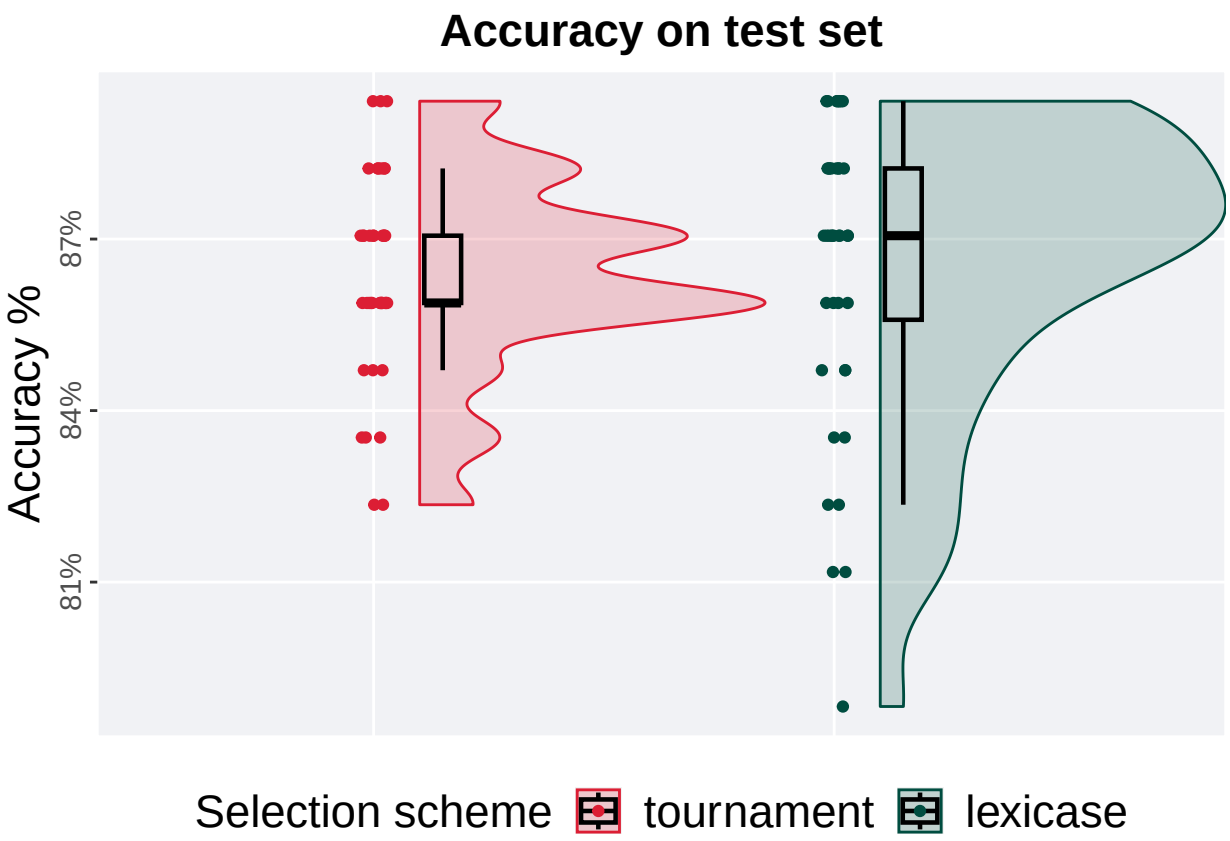
```
## [1] "observed_diff: -6.56504184677295"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.63065789057766"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```



6.3 50%

6.3.1 Testing set accuracy

```
test_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

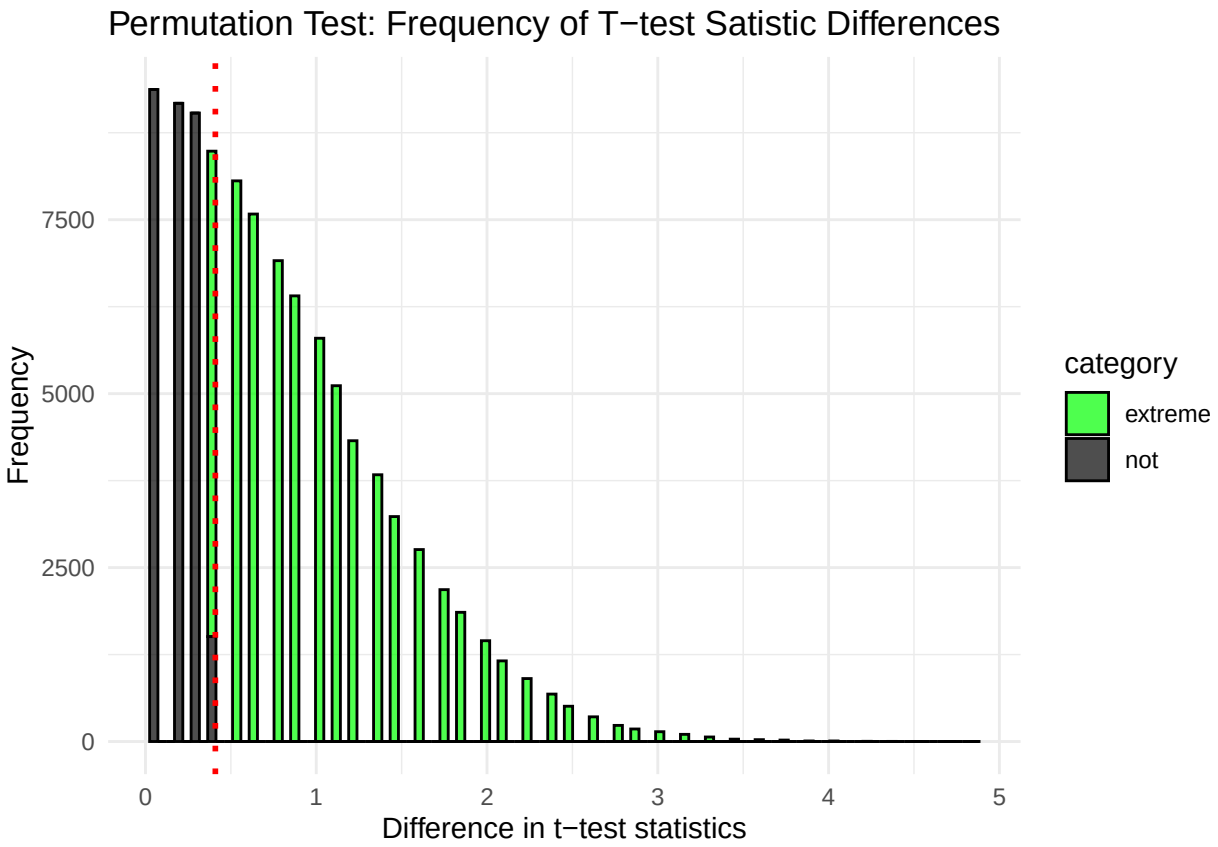
```
test_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.824  0.859 0.864 0.894 0.0118
## 2 lexicase      40      0 0.788  0.871 0.866 0.894 0.0265
```

The permutation test revealed that the results are:

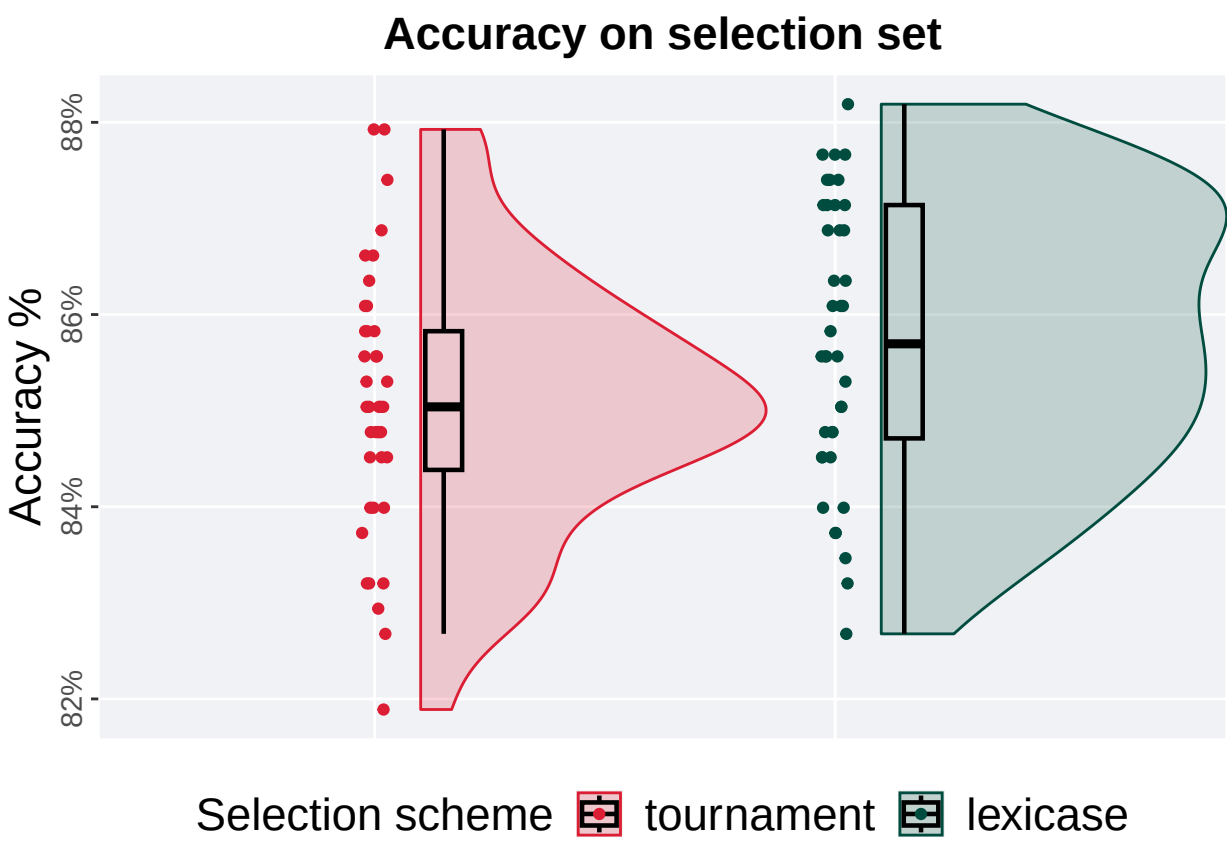
```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 45,
                 alternative = "t")
```

```
## [1] "observed_diff: -0.409158936906205"
## [1] "lower: -1.97438850833144"
## [1] "upper: 1.9743887219197"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.70915"
```



6.3.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

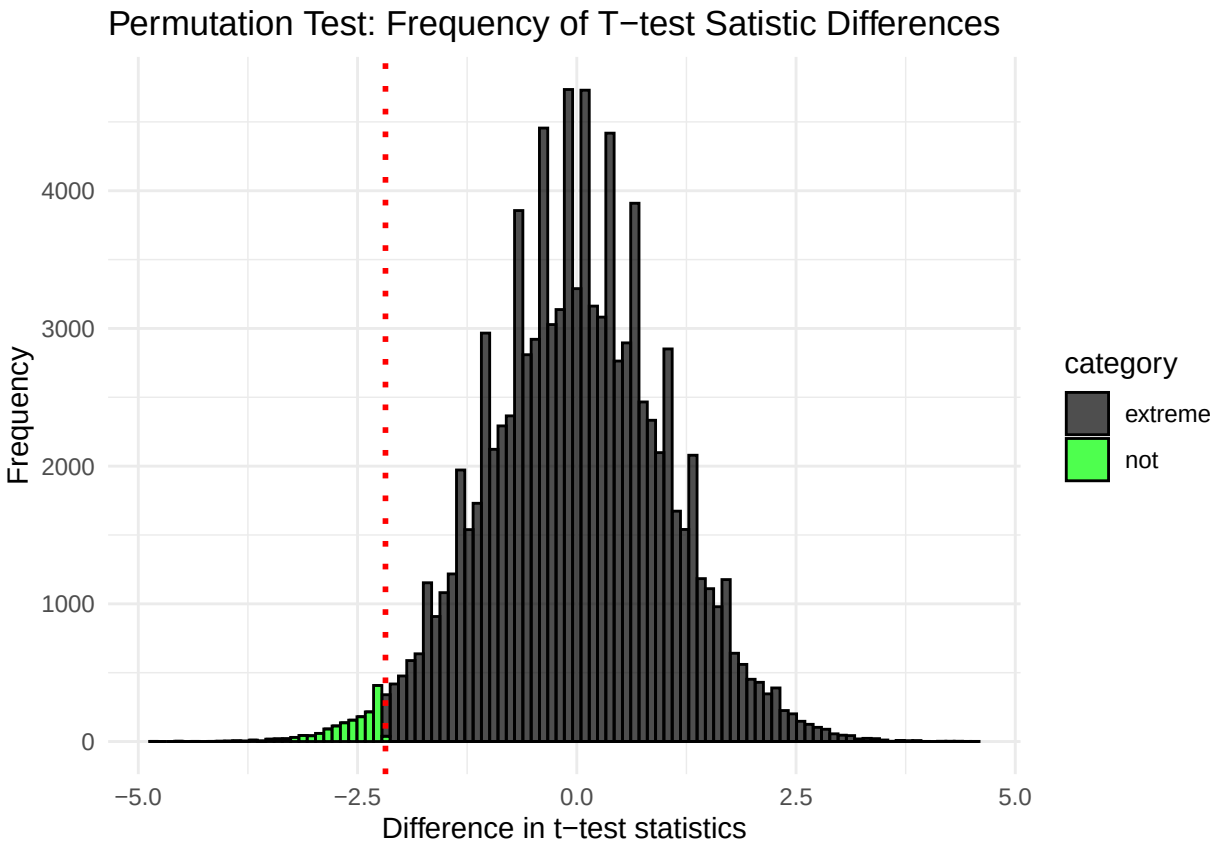
```
selection_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.819  0.850 0.851 0.879 0.0144
## 2 lexicase      40      0 0.827  0.857 0.857 0.882 0.0243
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 46,
                 alternative = "l")
```

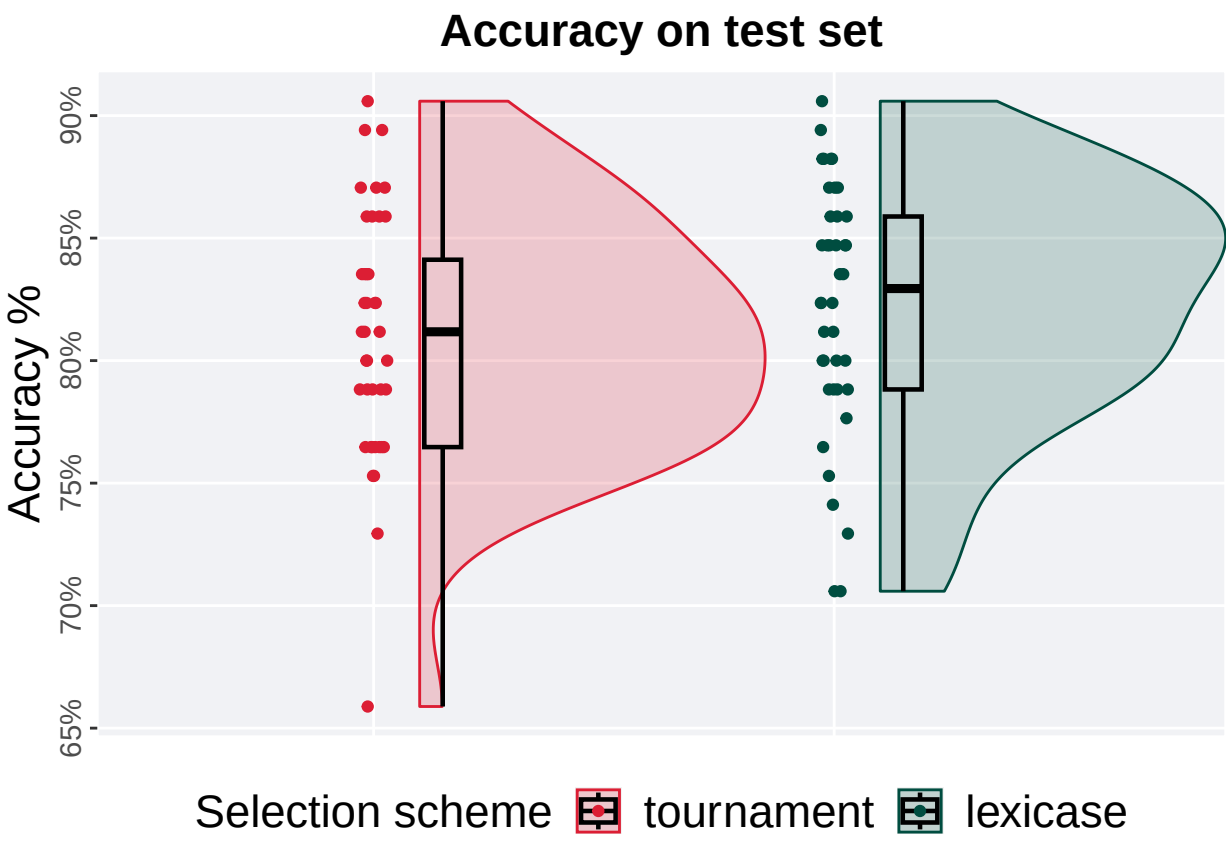
```
## [1] "observed_diff: -2.18154871539912"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.66249763126621"
## [1] "reject null hypothesis"
## [1] "p-value: 0.01598"
```



6.4 90%

6.4.1 Testing set accuracy

```
test_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

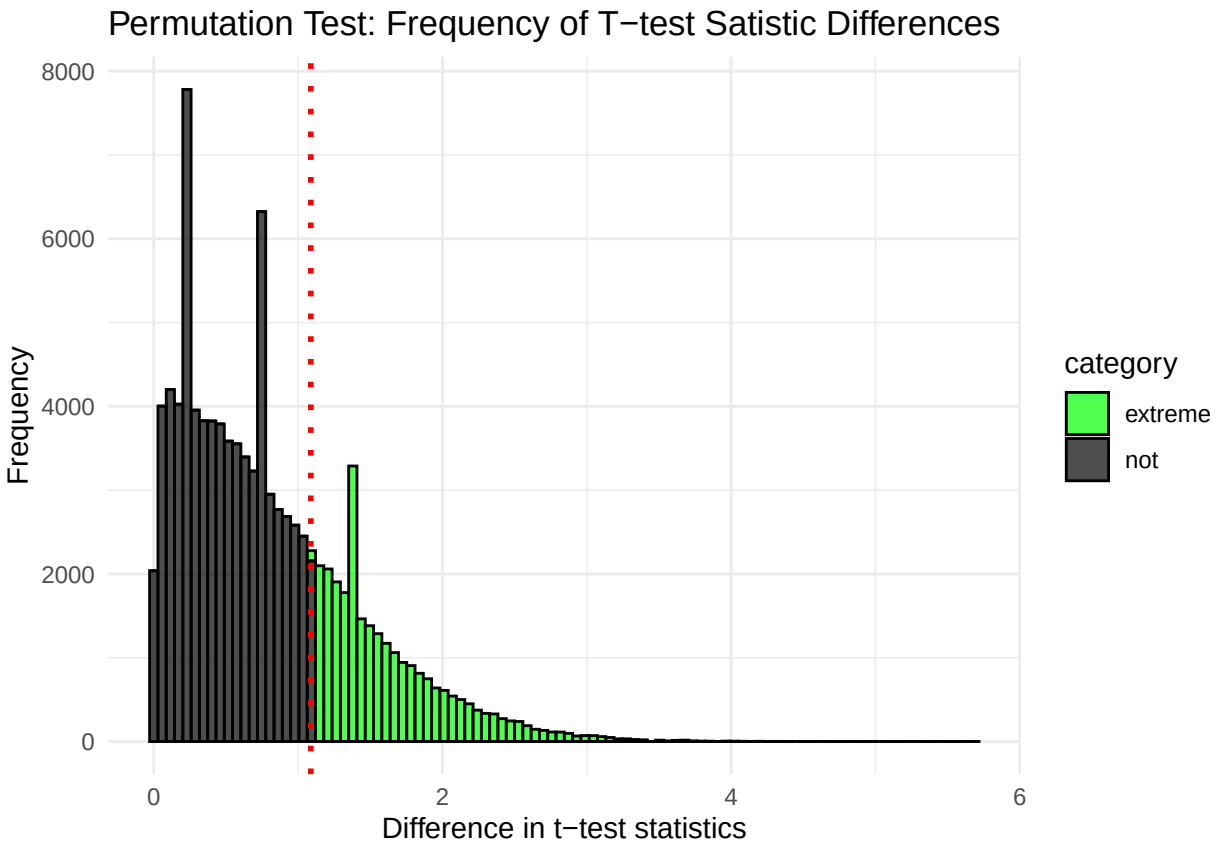
```
test_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.659  0.812 0.810 0.906 0.0765
## 2 lexicase      40      0 0.706  0.829 0.822 0.906 0.0706
```

The permutation test revealed that the results are:

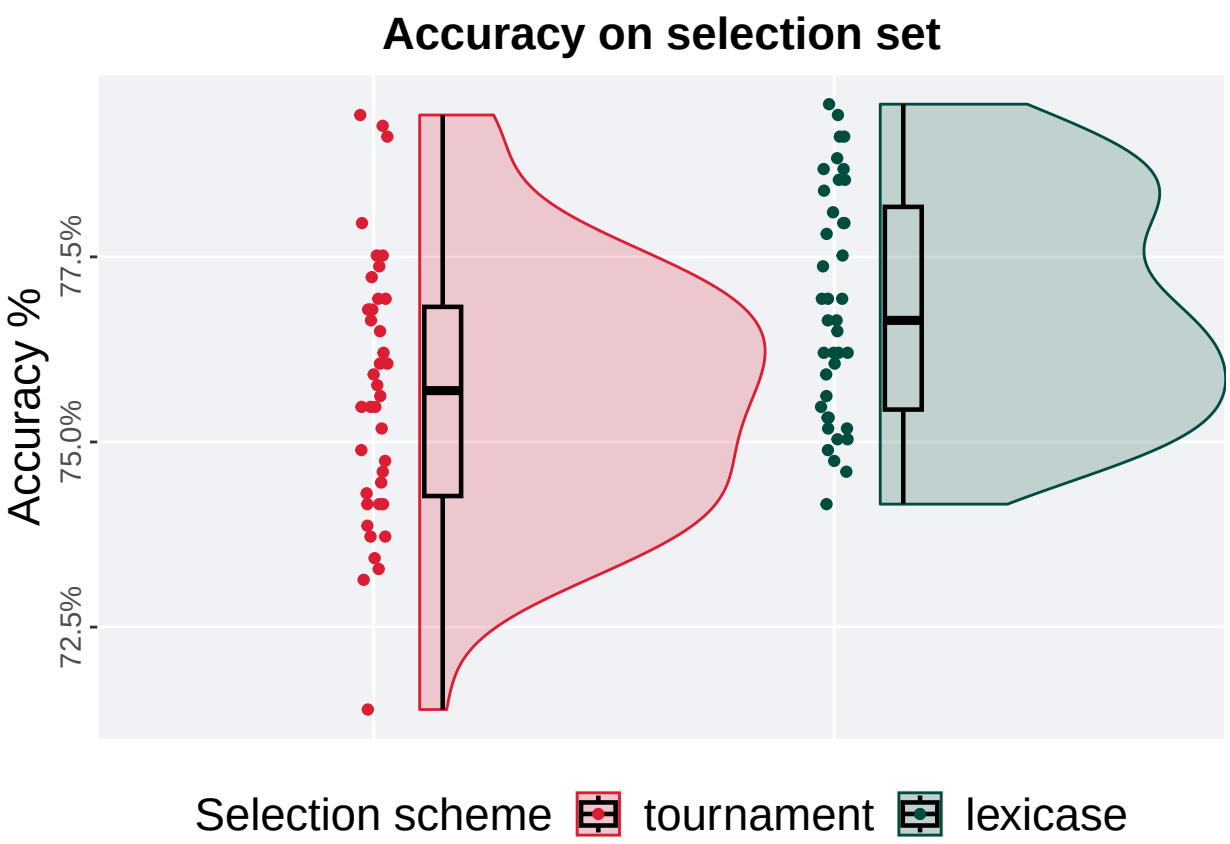
```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 47,
                 alternative = "t")
```

```
## [1] "observed_diff: -1.0880873800637"
## [1] "lower: -2.00381083912905"
## [1] "upper: 2.00381065061134"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.26874"
```



6.4.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

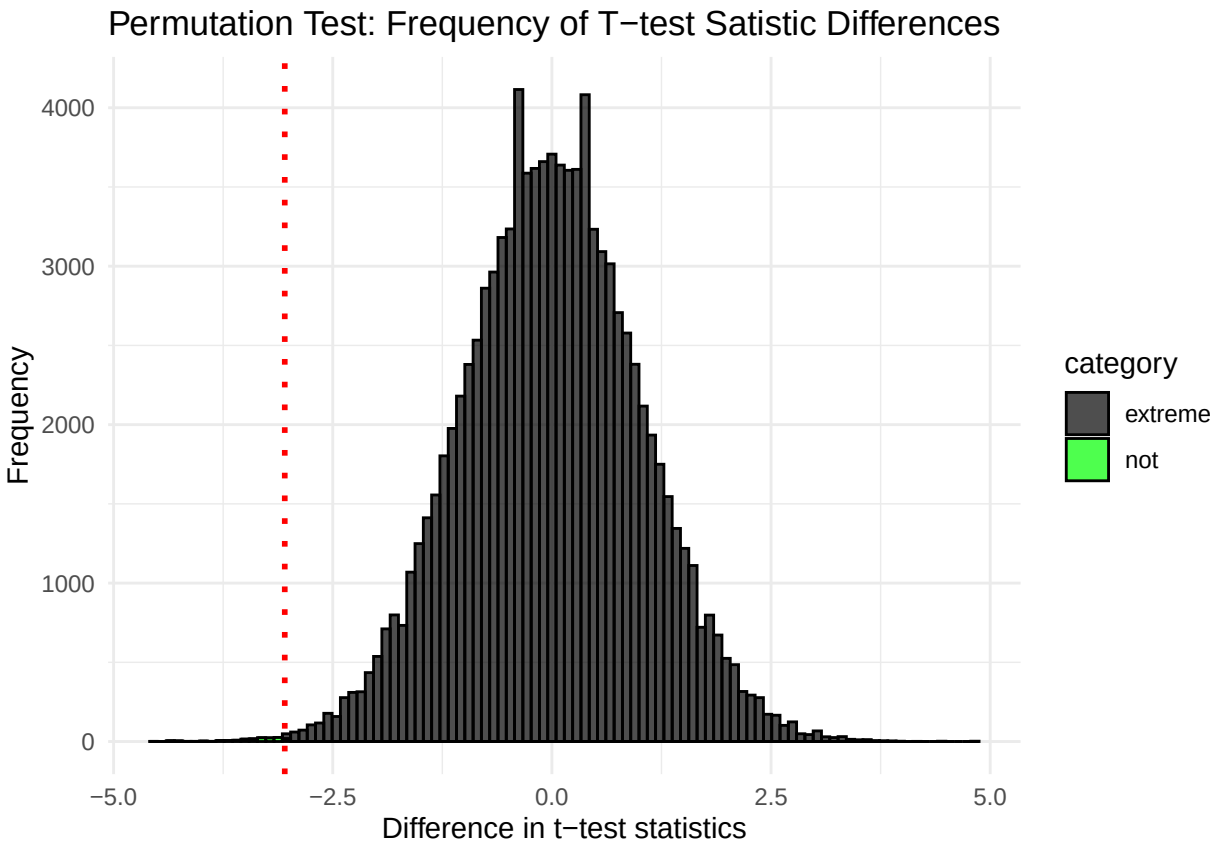
```
selection_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.714  0.757 0.757 0.794 0.0255
## 2 lexicase      40      0 0.742  0.766 0.768 0.796 0.0274
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 48,
                 alternative = "l")
```

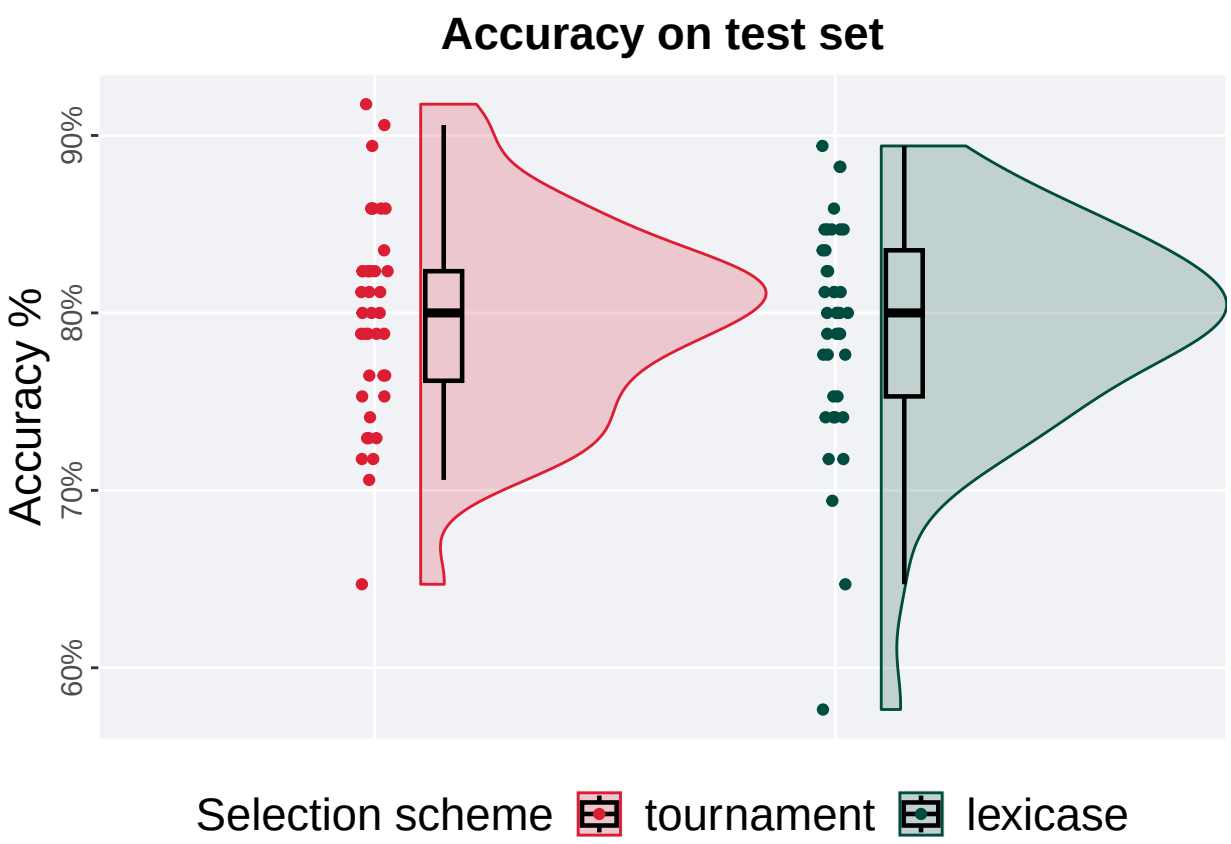
```
## [1] "observed_diff: -3.04756272712672"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.65333887825538"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00159"
```



6.5 95%

6.5.1 Testing set accuracy

```
test_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

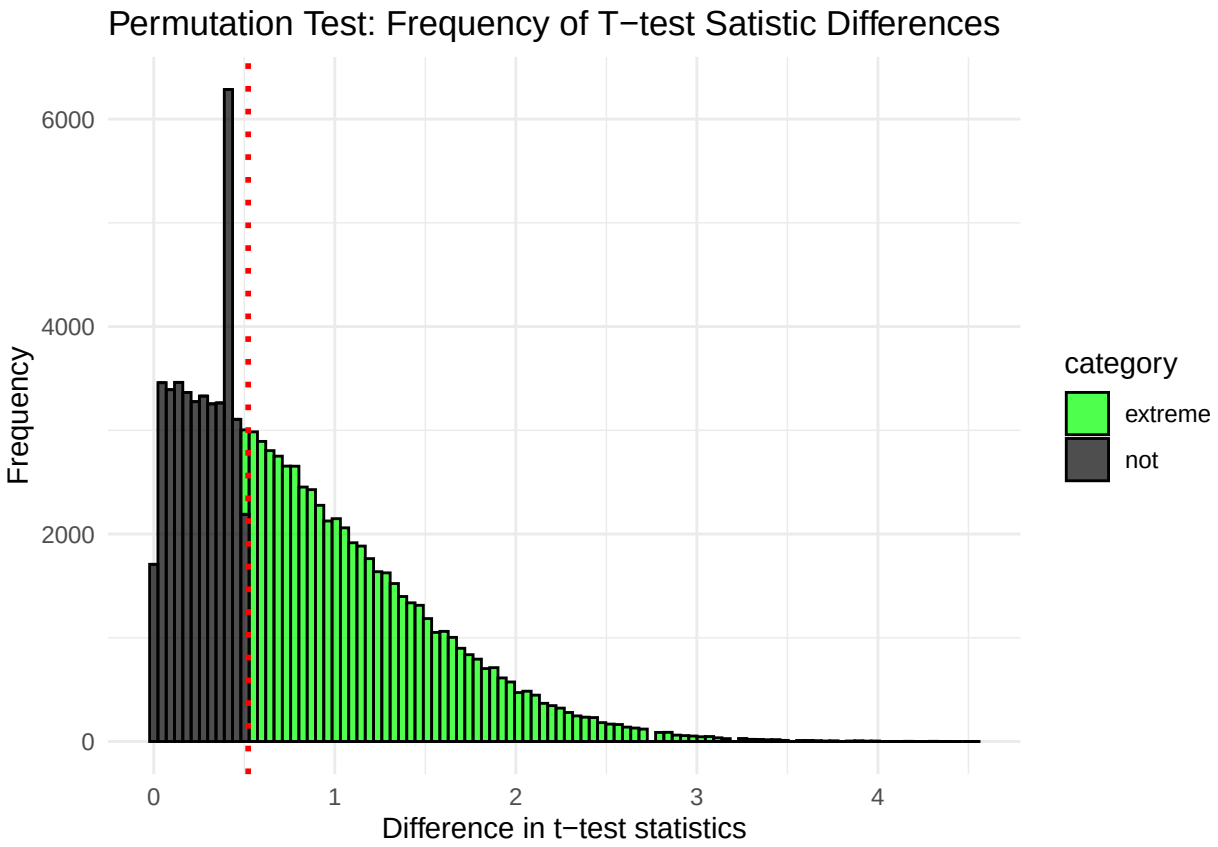
```
test_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.647    0.8 0.798 0.918 0.0618
## 2 lexicase      40      0 0.576    0.8 0.791 0.894 0.0824
```

The permutation test revealed that the results are:

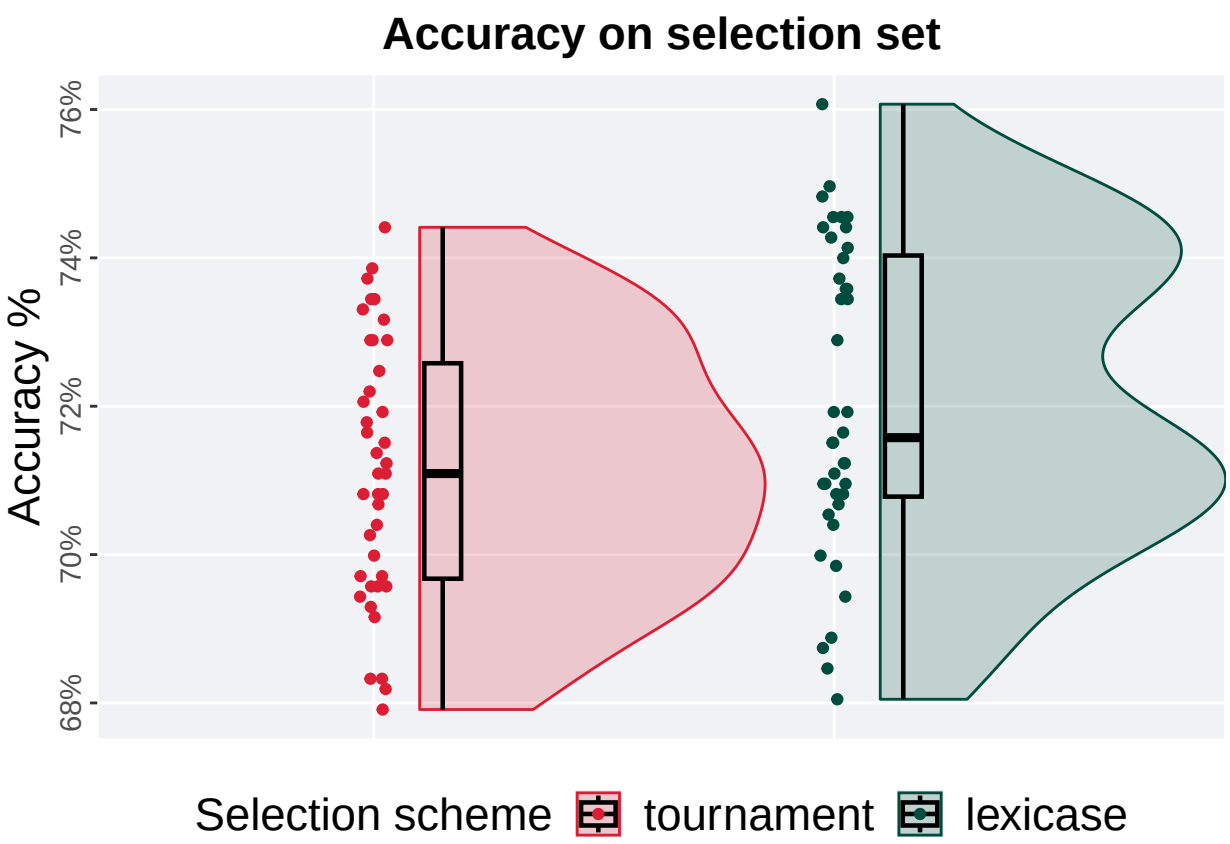
```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 49,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.521524422177645"
## [1] "lower: -1.95514751807407"
## [1] "upper: 2.00183834772485"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.59908"
```



6.5.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

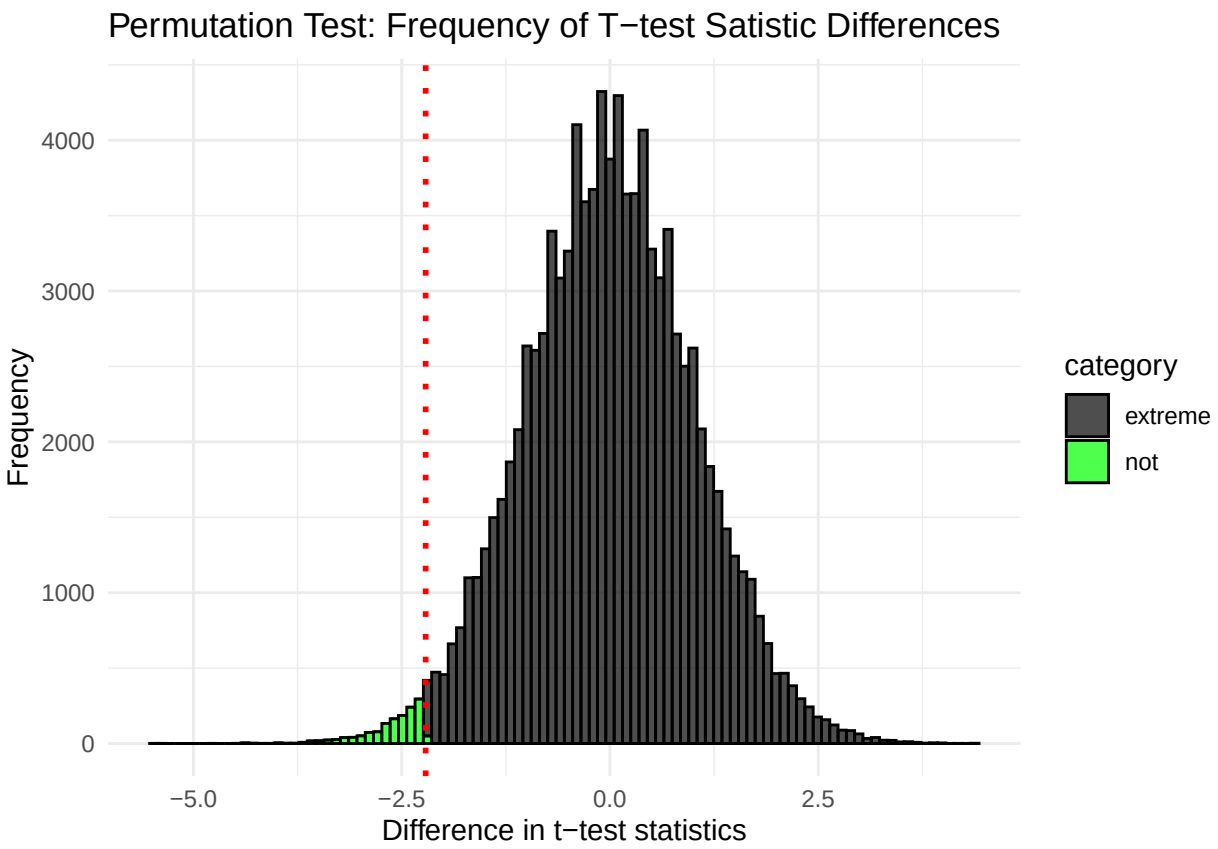
```
selection_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.679  0.711 0.711 0.744 0.0290
## 2 lexicase      40      0 0.680  0.716 0.721 0.761 0.0325
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 50,
                 alternative = "l")
```

```
## [1] "observed_diff: -2.21192504456209"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.65922504718008"
## [1] "reject null hypothesis"
## [1] "p-value: 0.01463"
```


Permutation Test: Frequency of T−test Satistic Differences
Frequency
4000
3000
2000
1000
0
−5.0
−2.5
0.0
2.5
Difference in t−test statistics
category
extreme
not

Chapter 7

Task 168757

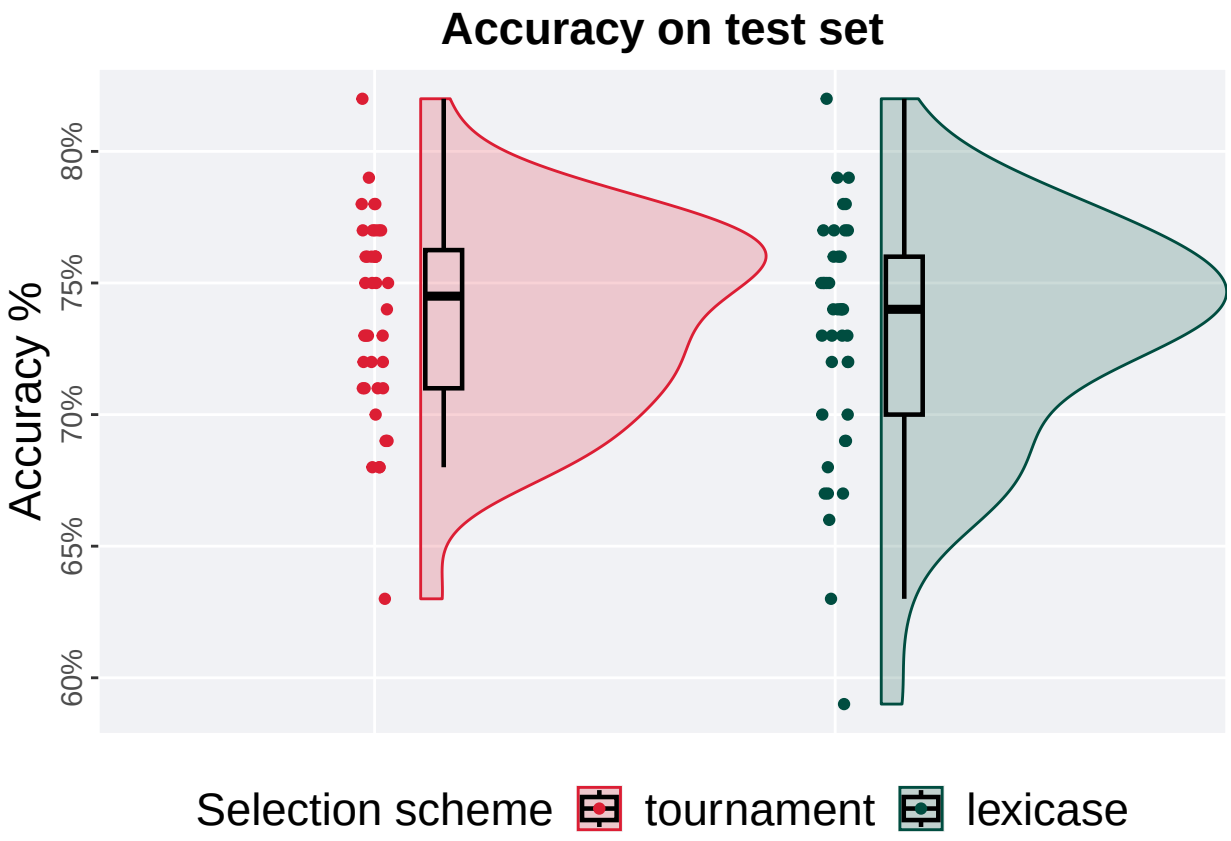
We present the results of our analysis of `task 168757` with the different selection set splits used in our study.

```
task_data <- filter(results, task_id == 168757)
```

7.1 5%

7.1.1 Testing set accuracy

```
test_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

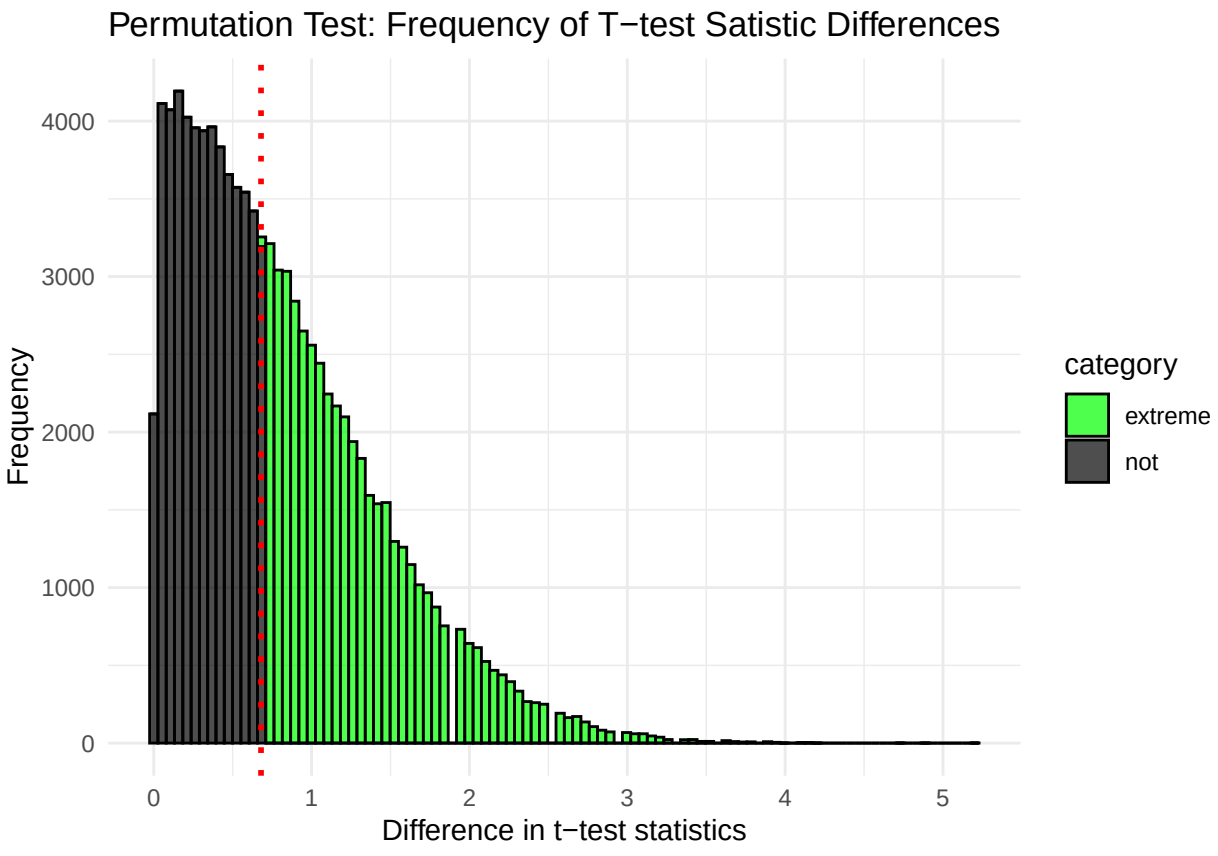
```
test_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0  0.63  0.745 0.736  0.82 0.0525
## 2 lexicase      40      0  0.59  0.74  0.73   0.82 0.0600
```

The permutation test revealed that the results are:

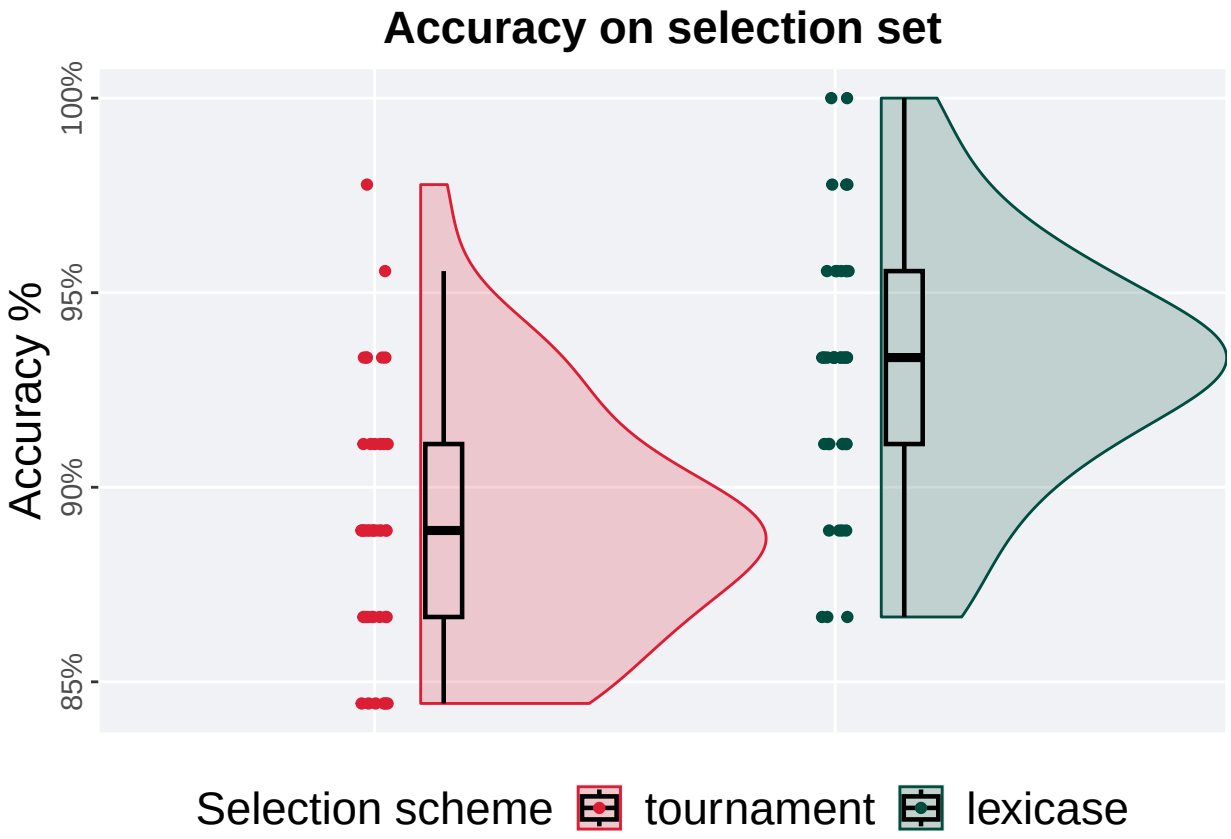
```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                    lexicase_results$testing_performance,
                    seed = 51,
                    alternative = "t")
```

```
## [1] "observed_diff: 0.679592305041863"
## [1] "lower: -1.97621361006578"
## [1] "upper: 1.97621361006577"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.48399"
```



7.1.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

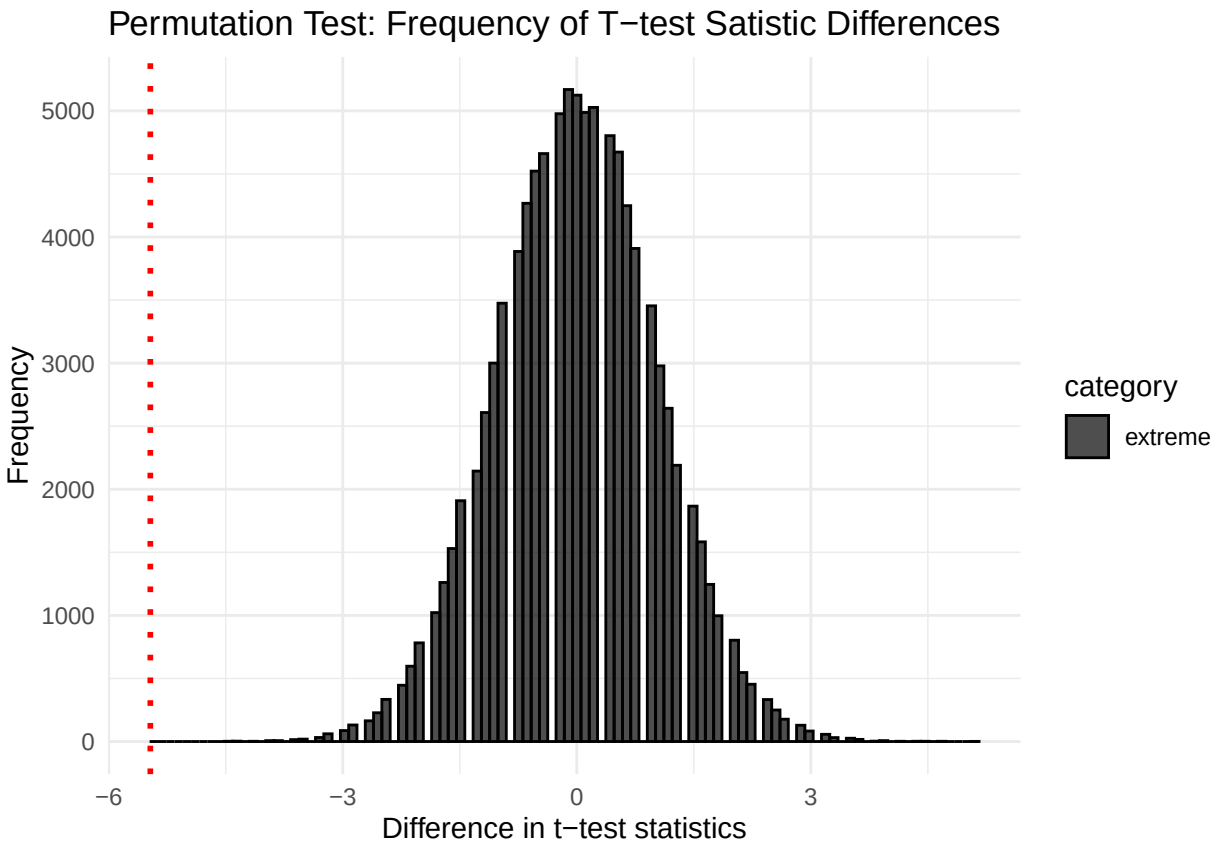
```
selection_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.844  0.889 0.891 0.978 0.0444
## 2 lexicase      40      0 0.867  0.933 0.931 1     0.0444
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 52,
                 alternative = "l")
```

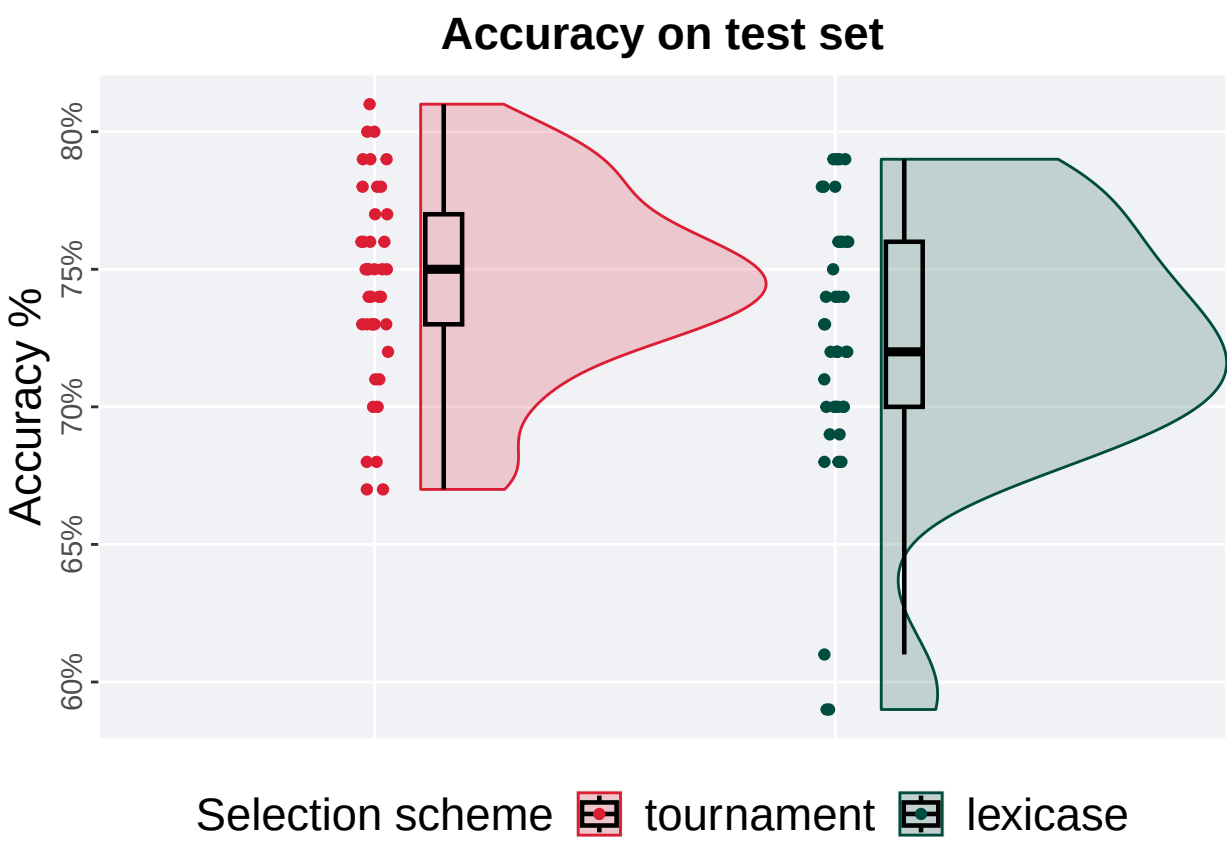
```
## [1] "observed_diff: -5.46636715299929"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.70963063314534"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```



7.2 10%

7.2.1 Testing set accuracy

```
test_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

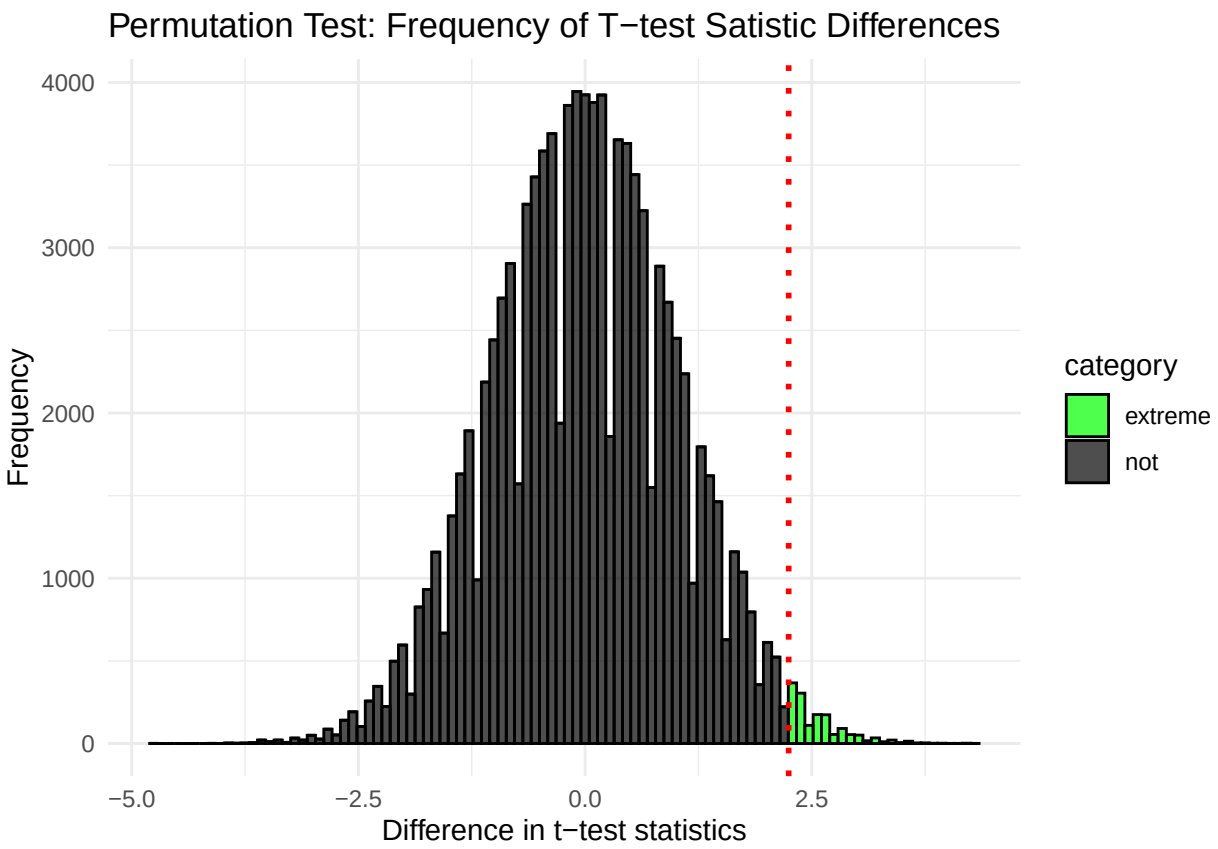
```
test_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0  0.67   0.75 0.744  0.81 0.0400
## 2 lexicase      40      0  0.59   0.72 0.723  0.79 0.0600
```

The permutation test revealed that the results are:

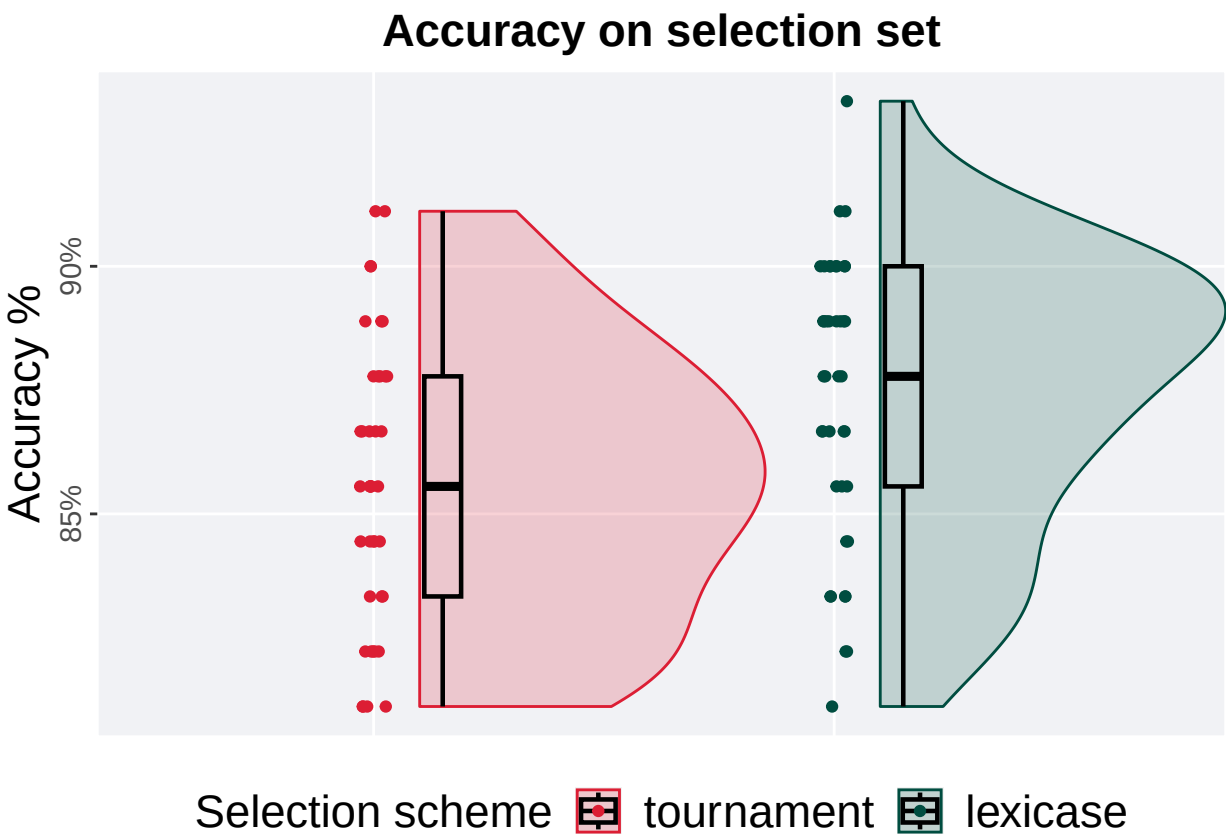
```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 53,
                 alternative = "g")
```

```
## [1] "observed_diff: 2.24527511755549"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.70682083833002"
## [1] "reject null hypothesis"
## [1] "p-value: 0.01398"
```



7.2.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

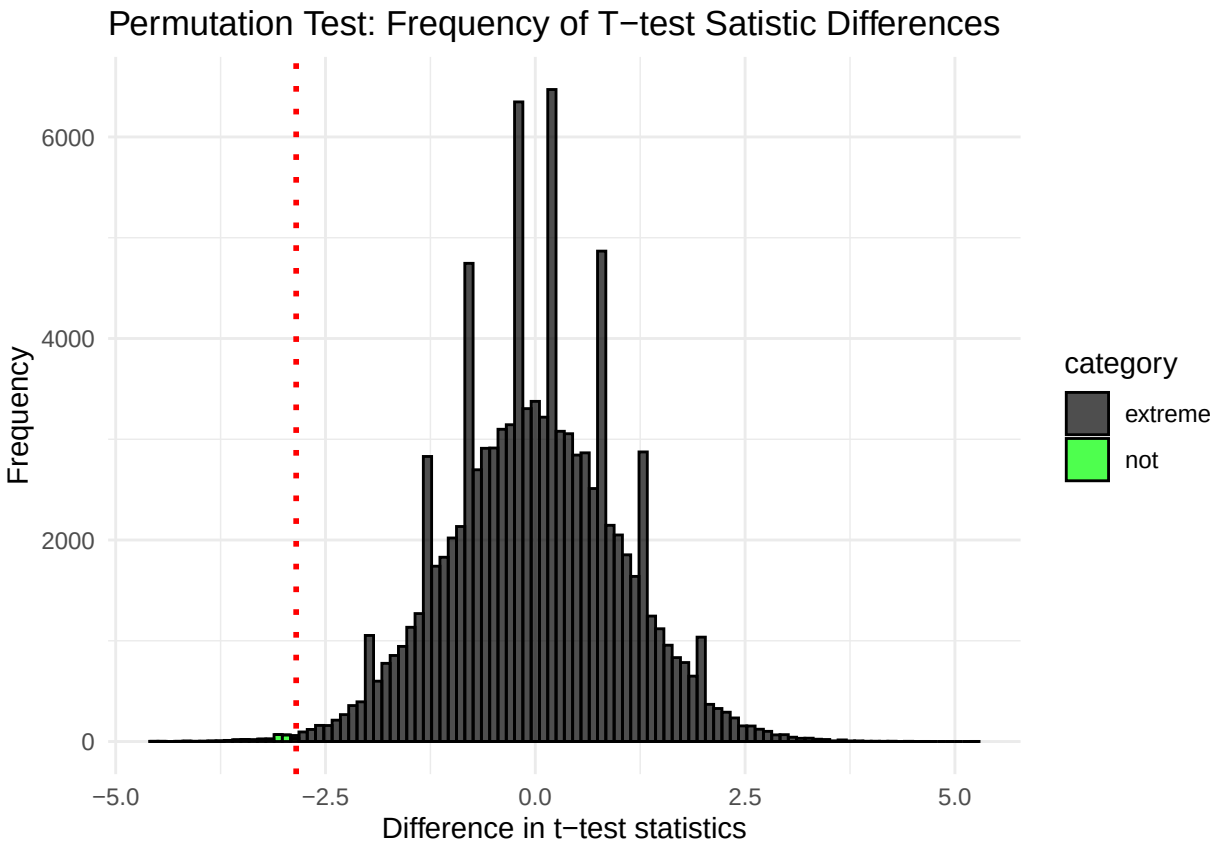
```
selection_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.811  0.856 0.856 0.911 0.0444
## 2 lexicase      40      0 0.811  0.878 0.874 0.933 0.0444
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 54,
                 alternative = "l")
```

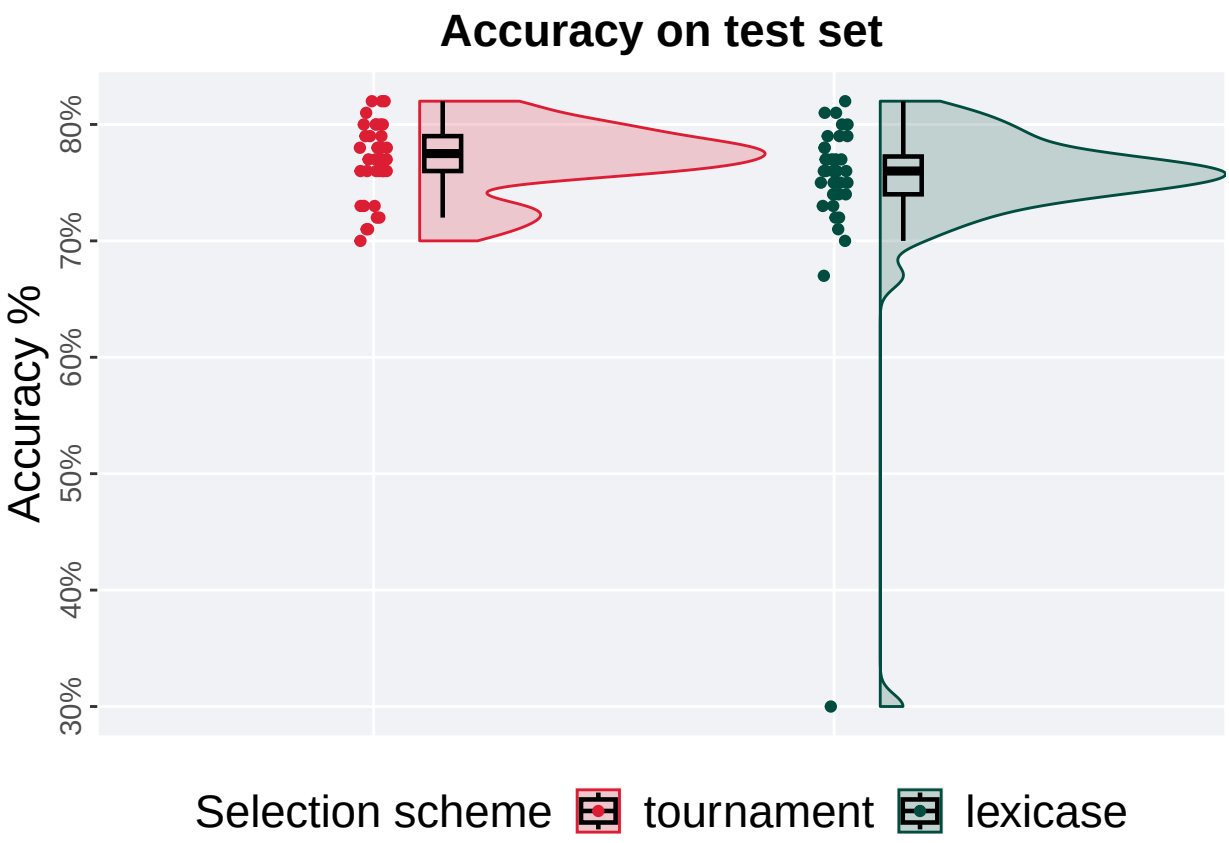
```
## [1] "observed_diff: -2.8494031342686"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.67270885820756"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00303"
```



7.3 50%

7.3.1 Testing set accuracy

```
test_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

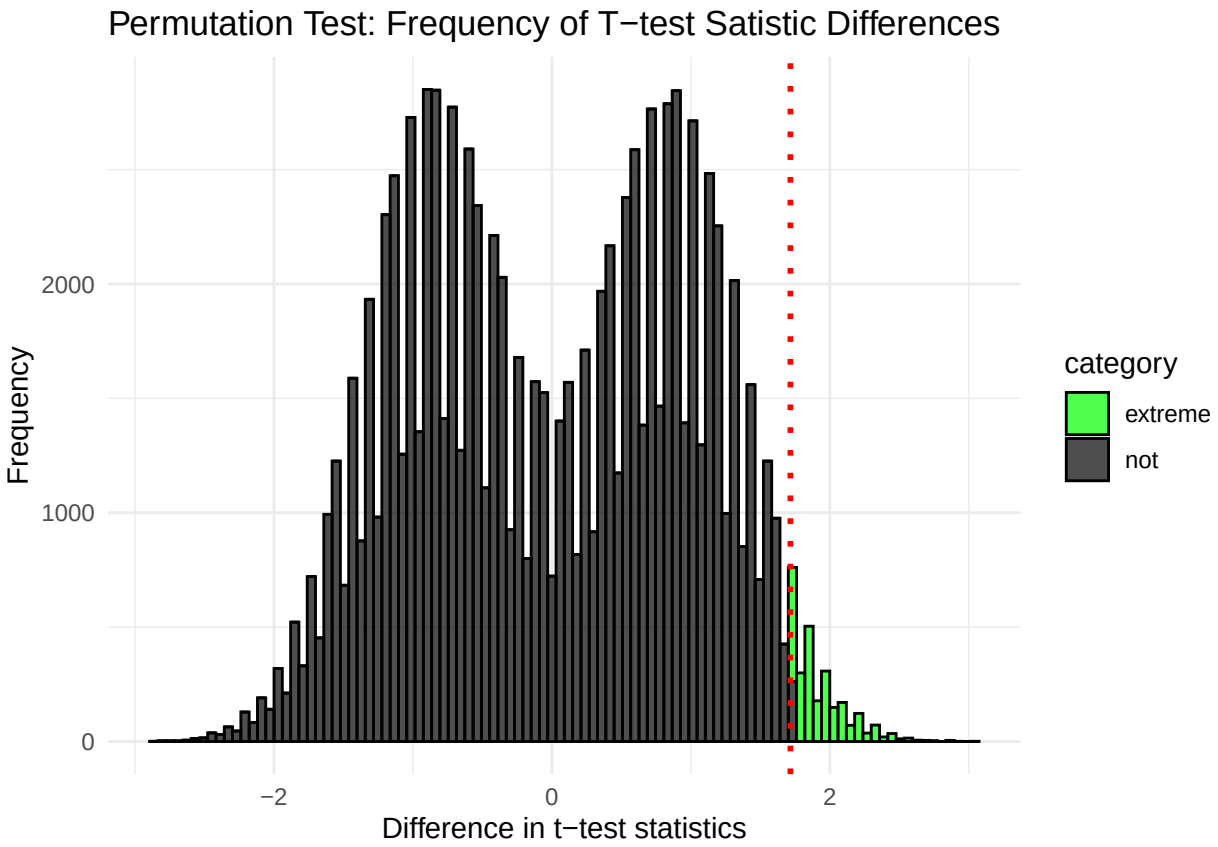
```
test_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0   0.7  0.775 0.77   0.82 0.0300
## 2 lexicase      40      0   0.3  0.76  0.747  0.82 0.0325
```

The permutation test revealed that the results are:

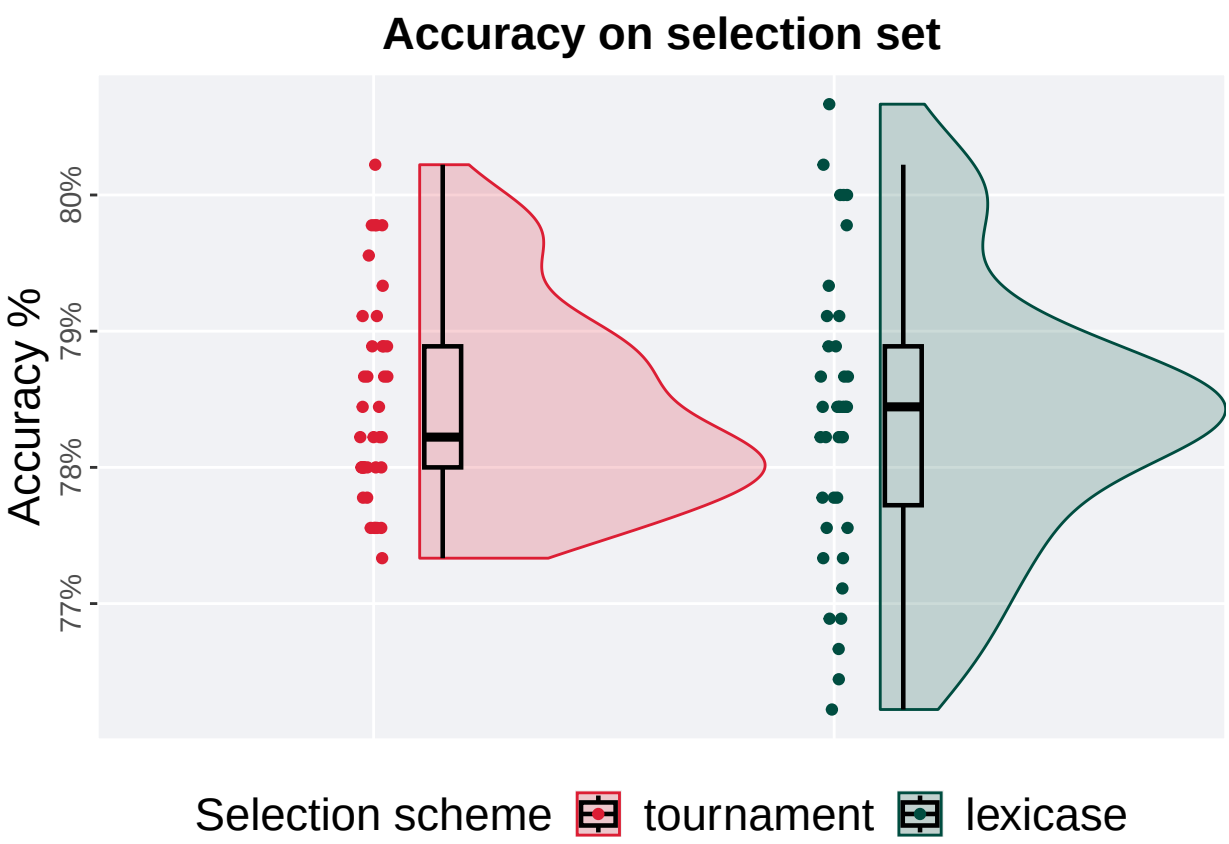
```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 55,
                 alternative = "g")
```

```
## [1] "observed_diff: 1.71603077853694"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.52360461800033"
## [1] "reject null hypothesis"
## [1] "p-value: 0.02379"
```



7.3.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

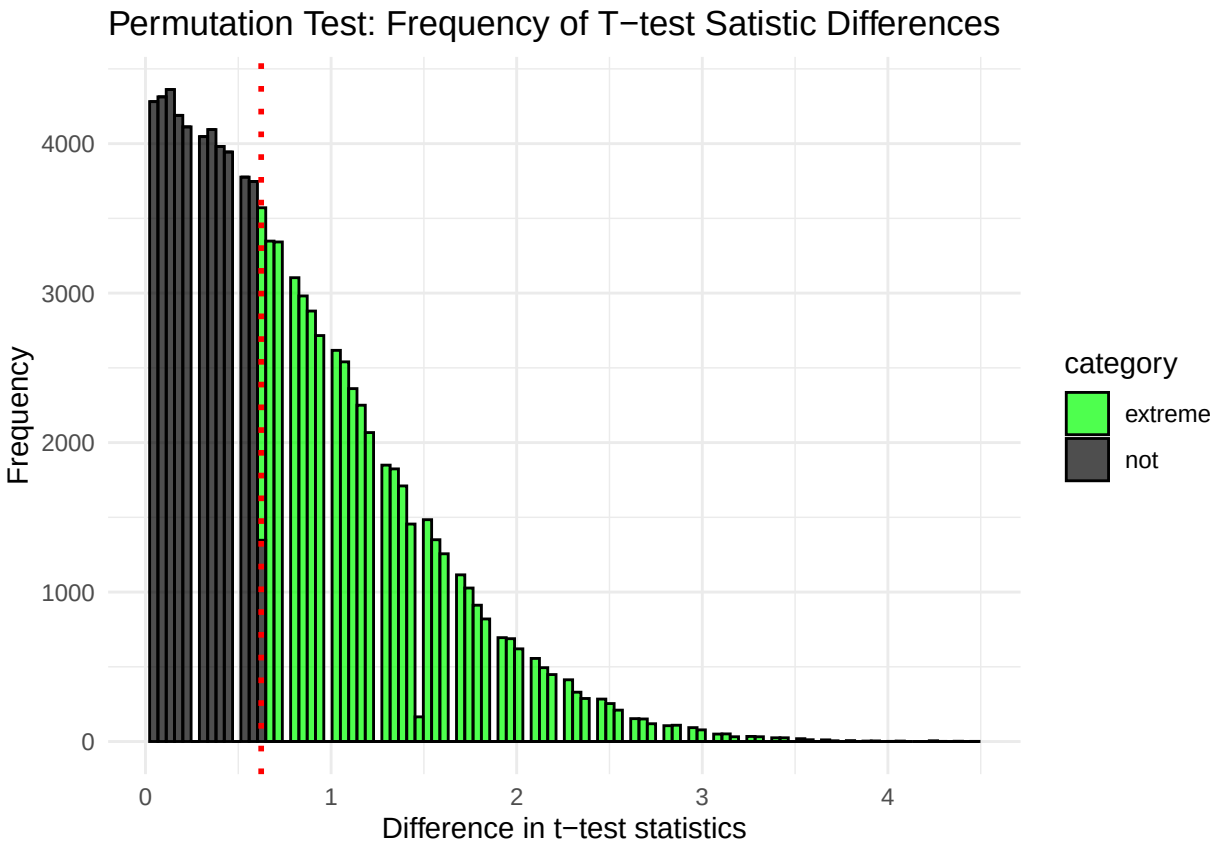
```
selection_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.773  0.782 0.785 0.802 0.00889
## 2 lexicase      40      0 0.762  0.784 0.784 0.807 0.0117
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 56,
                 alternative = "t")
```

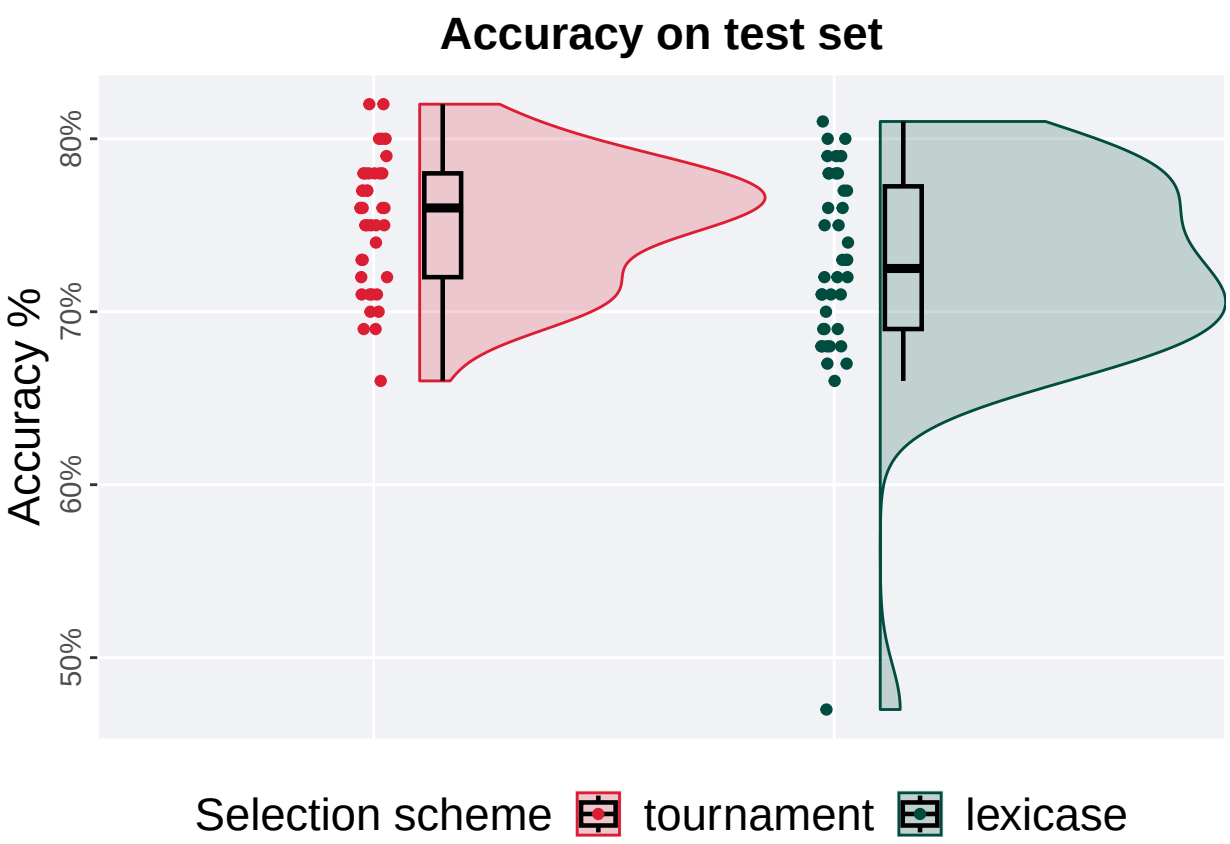
```
## [1] "observed_diff: 0.623468562343347"
## [1] "lower: -2.02515196524075"
## [1] "upper: 2.02515196524075"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.53808"
```



7.4 90%

7.4.1 Testing set accuracy

```
test_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

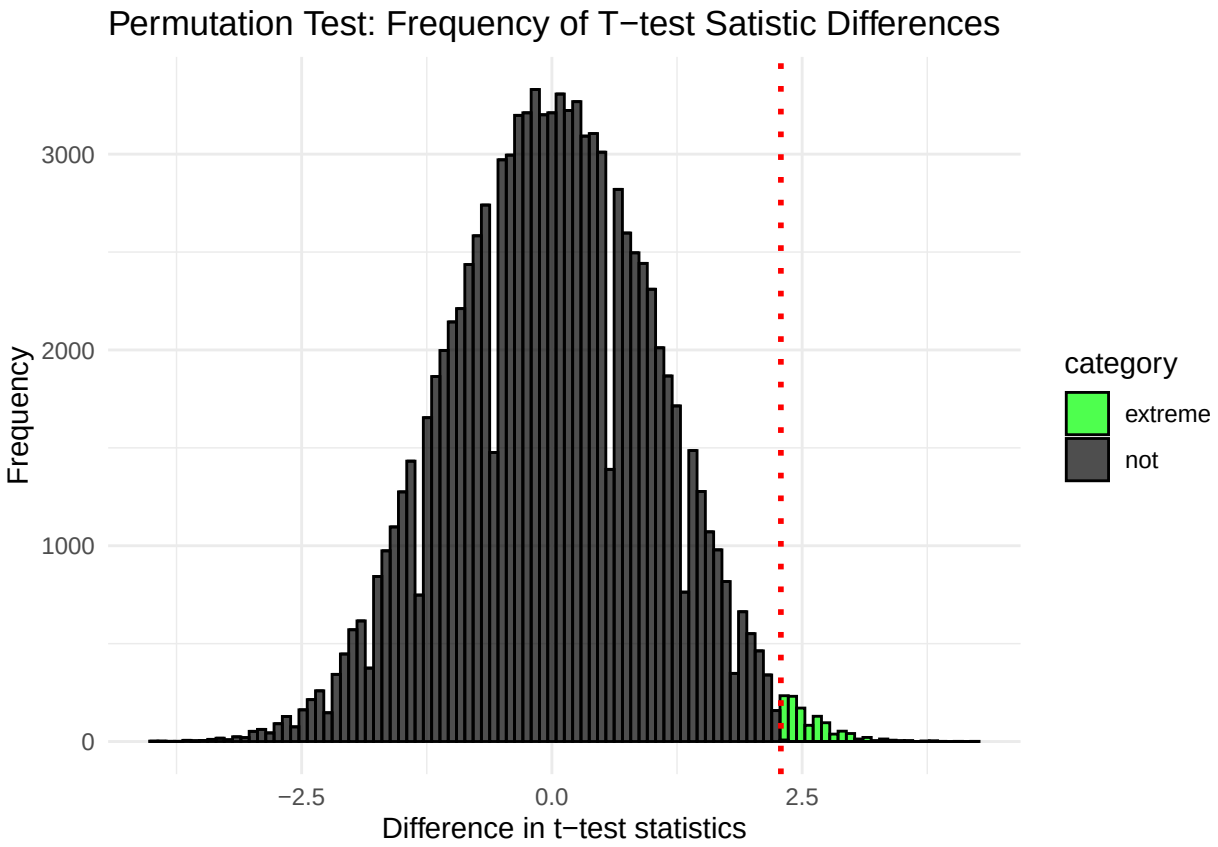
```
test_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0  0.66   0.76  0.752  0.82 0.0600
## 2 lexicase      40      0  0.47   0.725 0.726  0.81 0.0825
```

The permutation test revealed that the results are:

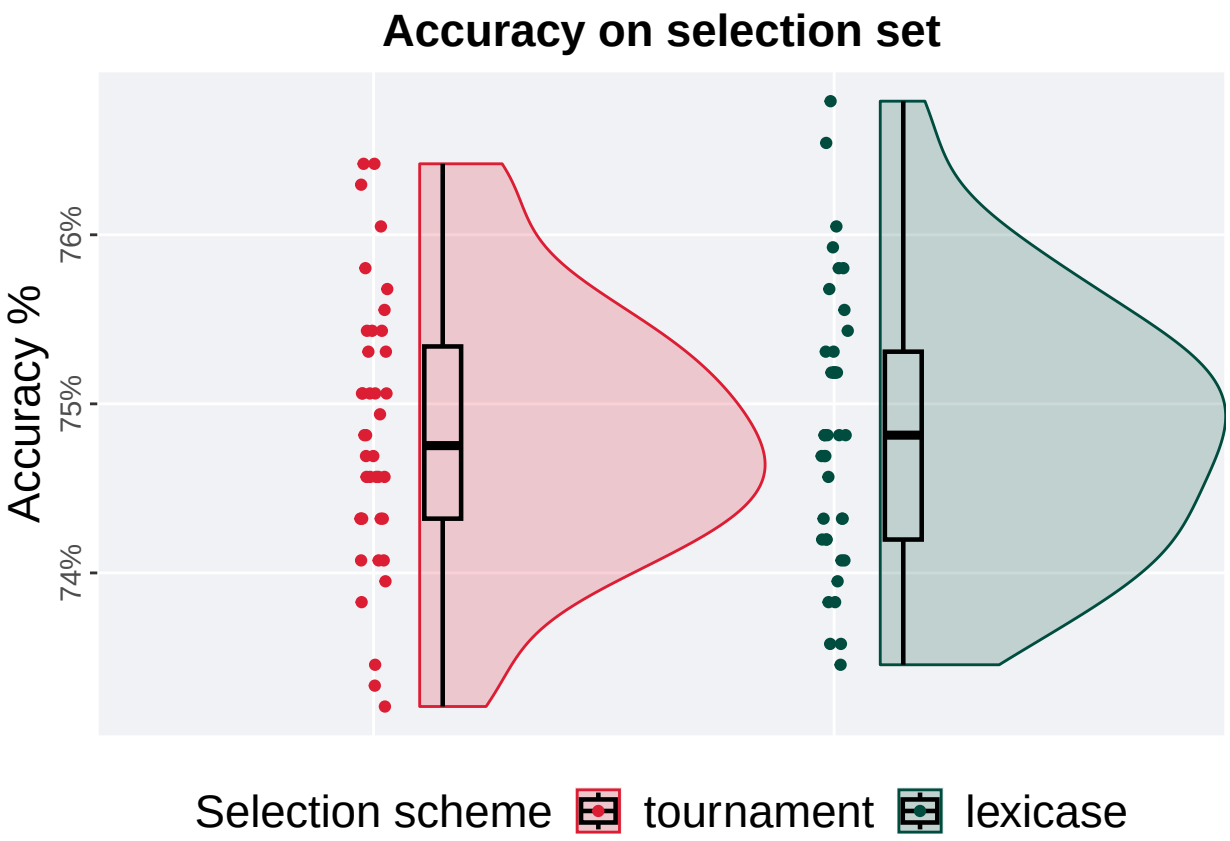
```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 57,
                 alternative = "g")
```

```
## [1] "observed_diff: 2.28744114118623"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.63997158080026"
## [1] "reject null hypothesis"
## [1] "p-value: 0.01148"
```



7.4.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

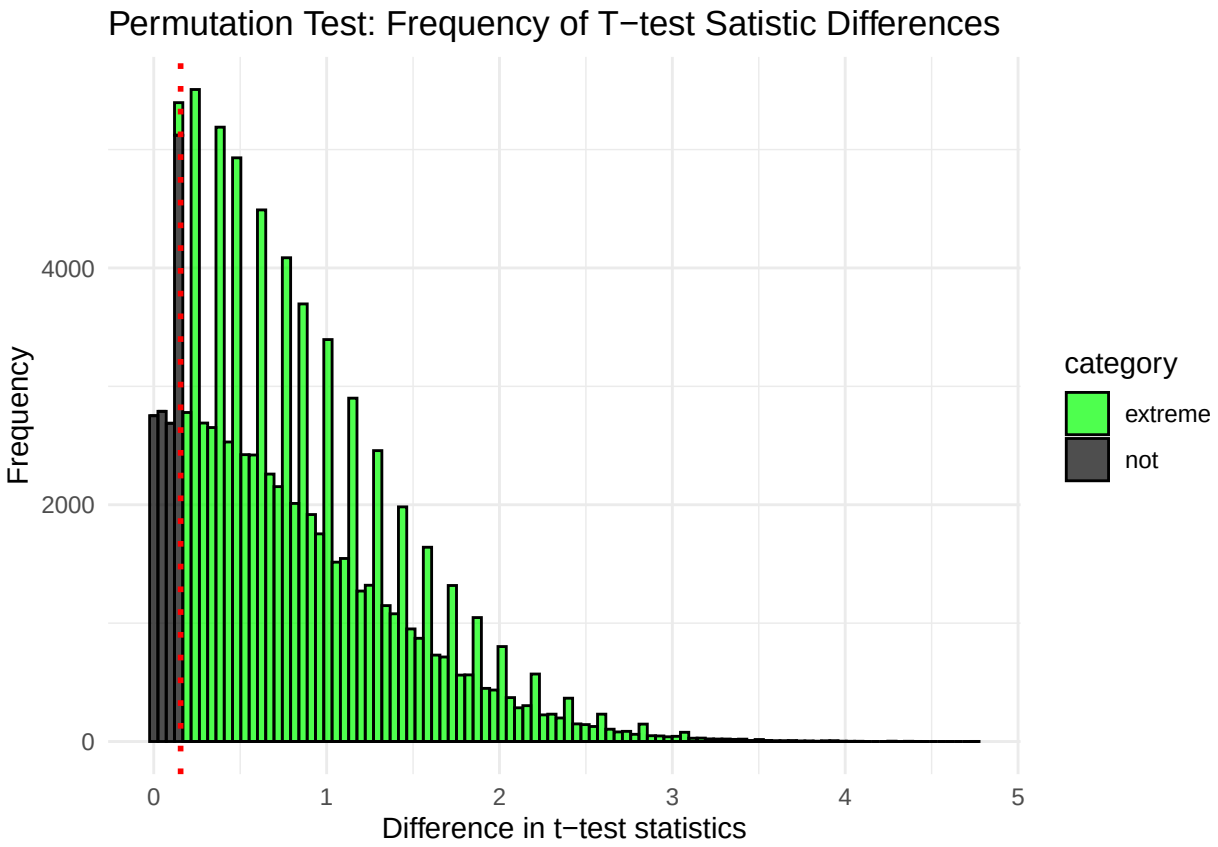
```
selection_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.732  0.748 0.748 0.764 0.0102
## 2 lexicase      40      0 0.735  0.748 0.748 0.768 0.0111
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 58,
                 alternative = "t")
```

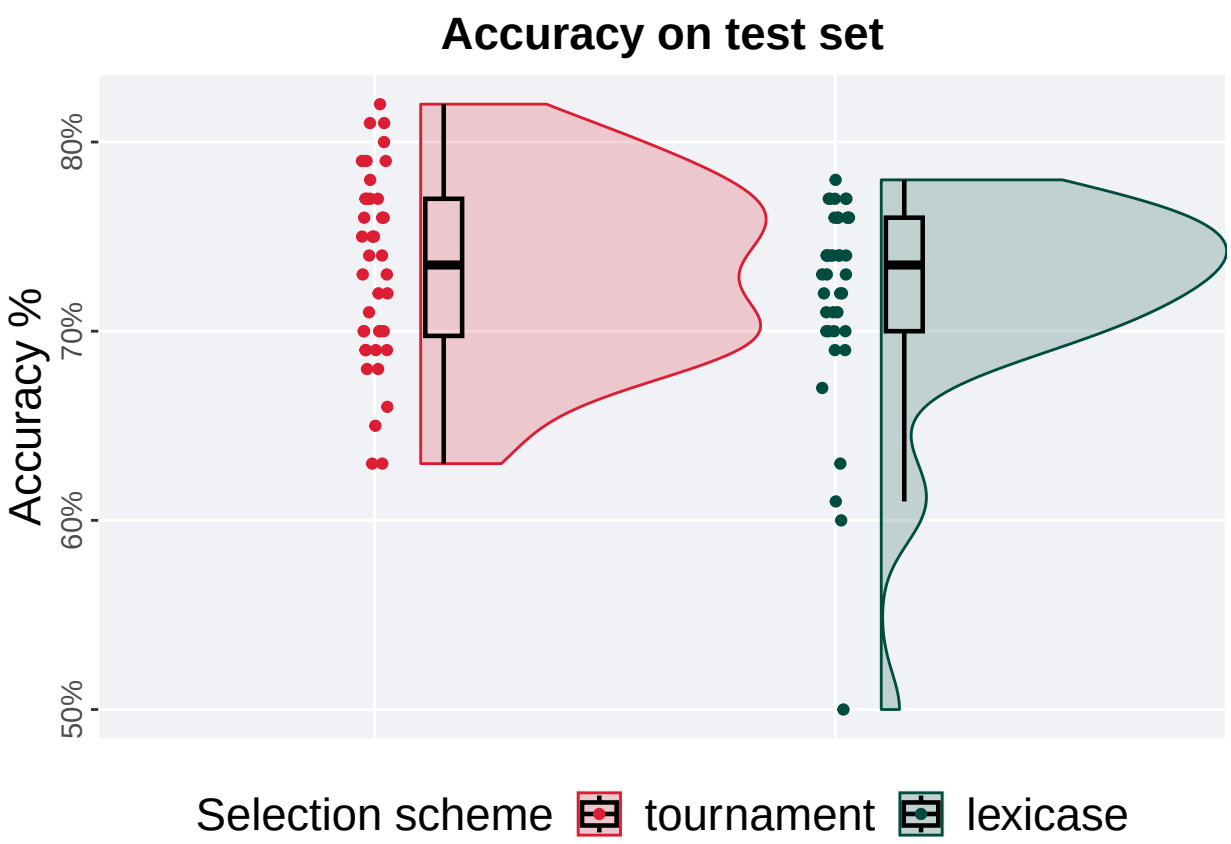
```
## [1] "observed_diff: -0.155413318723722"
## [1] "lower: -2.0003726169214"
## [1] "upper: 1.96320799741225"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.8665"
```



7.5 95%

7.5.1 Testing set accuracy

```
test_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

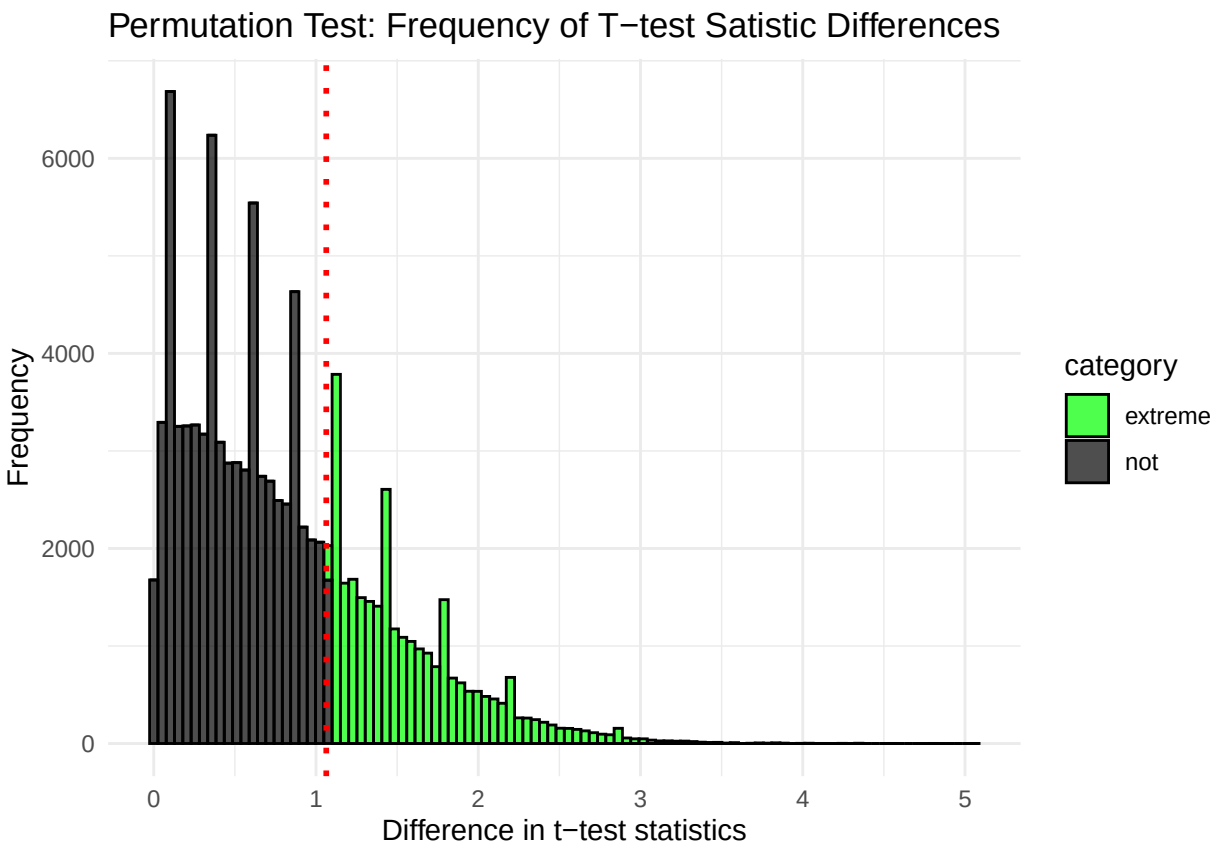
```
test_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0  0.63  0.735 0.732  0.82 0.0725
## 2 lexicase      40      0  0.5   0.735 0.720  0.78 0.0600
```

The permutation test revealed that the results are:

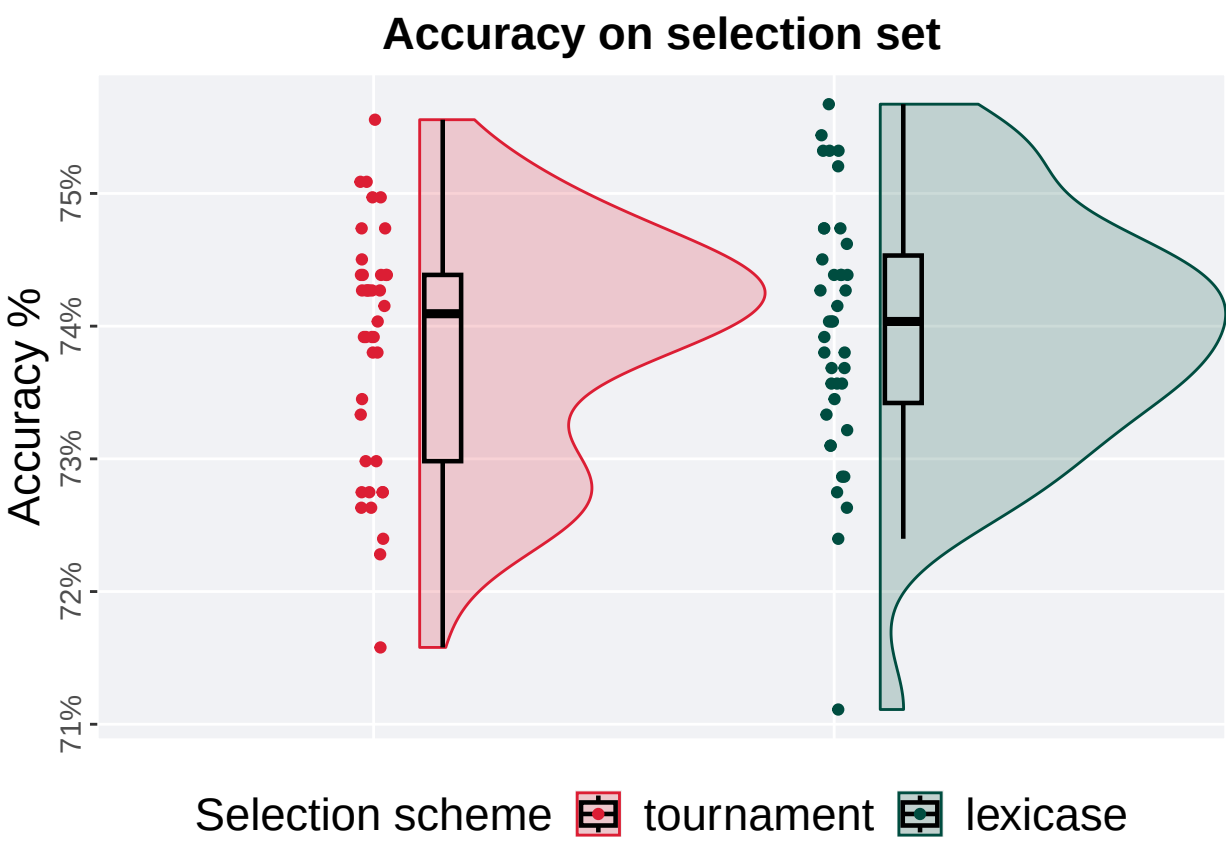
```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 59,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.06320673917919"
## [1] "lower: -1.99102103585612"
## [1] "upper: 1.99102103585612"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.28918"
```



7.5.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

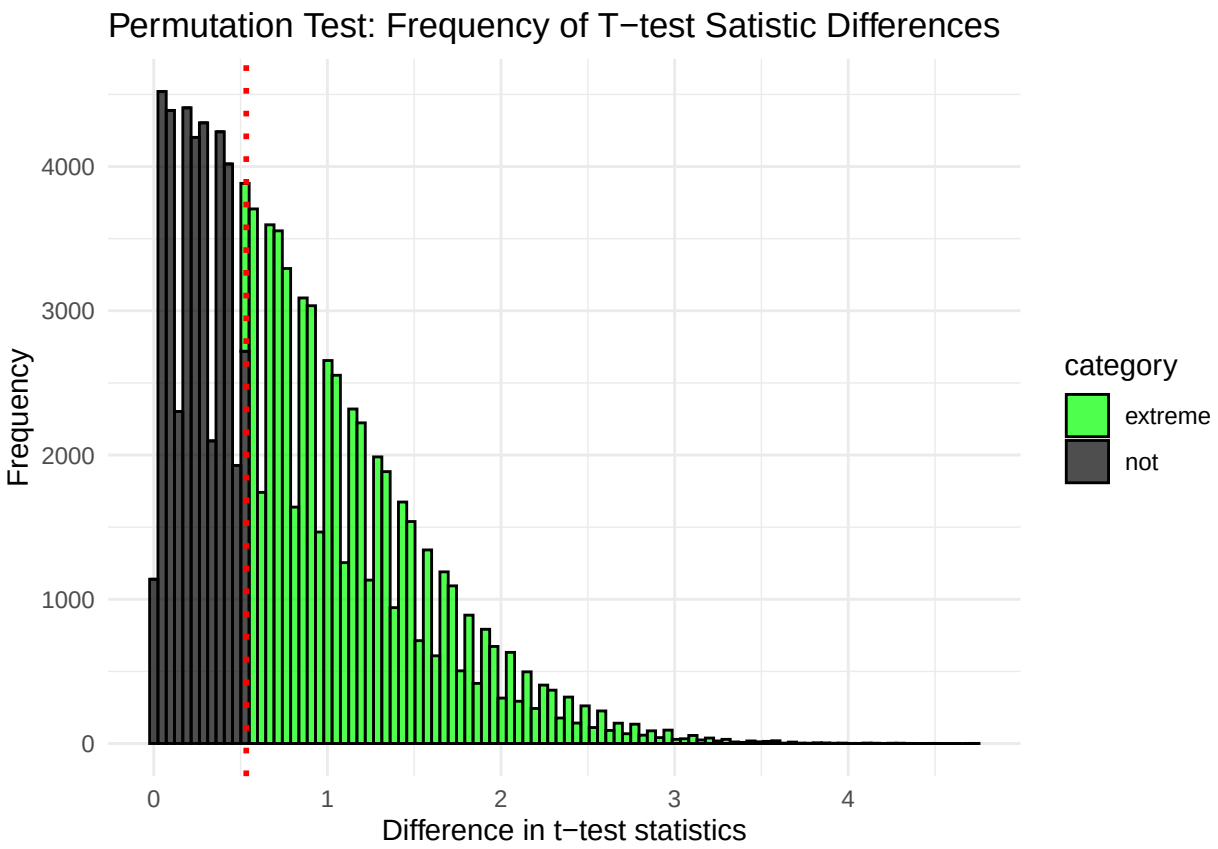
```
selection_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.716  0.741 0.738 0.756 0.0140
## 2 lexicase      40      0 0.711  0.740 0.740 0.757 0.0111
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 60,
                 alternative = "t")
```

```
## [1] "observed_diff: -0.532630909404782"
## [1] "lower: -2.00879367960193"
## [1] "upper: 2.00879574403038"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.59734"
```


Permutation Test: Frequency of T−test Satistic Differences
Frequency
4000
3000
2000
1000
0
0
1
2
3
4
Difference in t−test statistics
category
extreme
not

Chapter 8

Task 359956

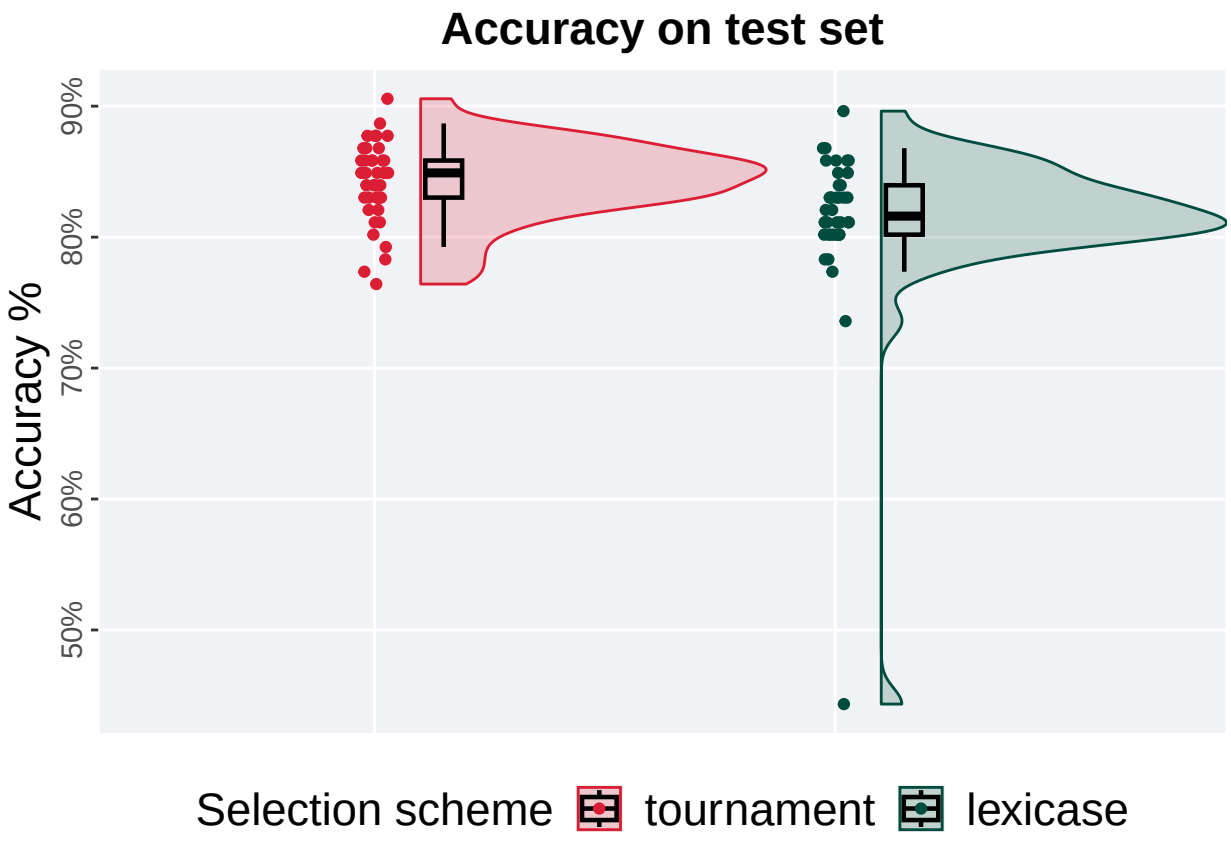
We present the results of our analysis of `task 359956` with the different selection set splits used in our study.

```
task_data <- filter(results, task_id == 359956)
```

8.1 5%

8.1.1 Testing set accuracy

```
test_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

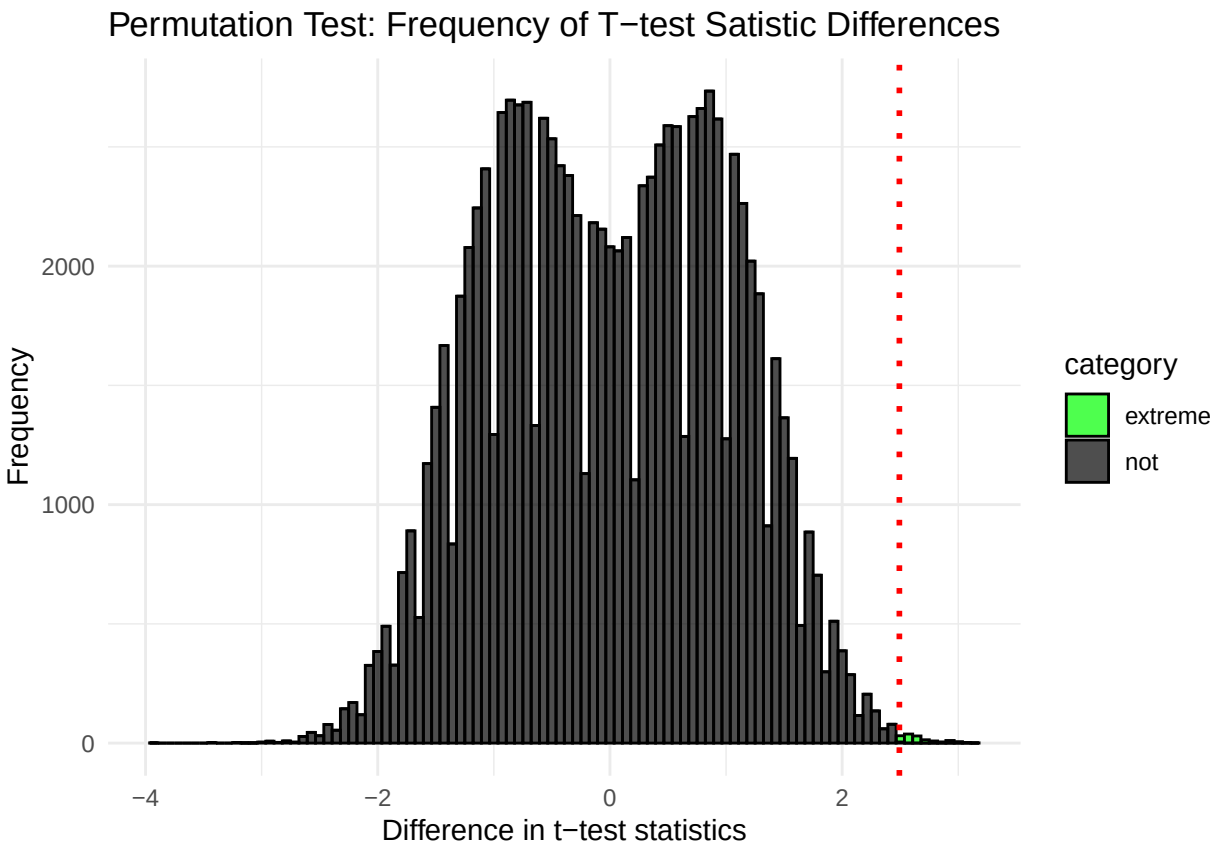
```
test_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.764  0.849 0.842 0.906 0.0283
## 2 lexicase      40      0 0.443  0.816 0.813 0.896 0.0377
```

The permutation test revealed that the results are:

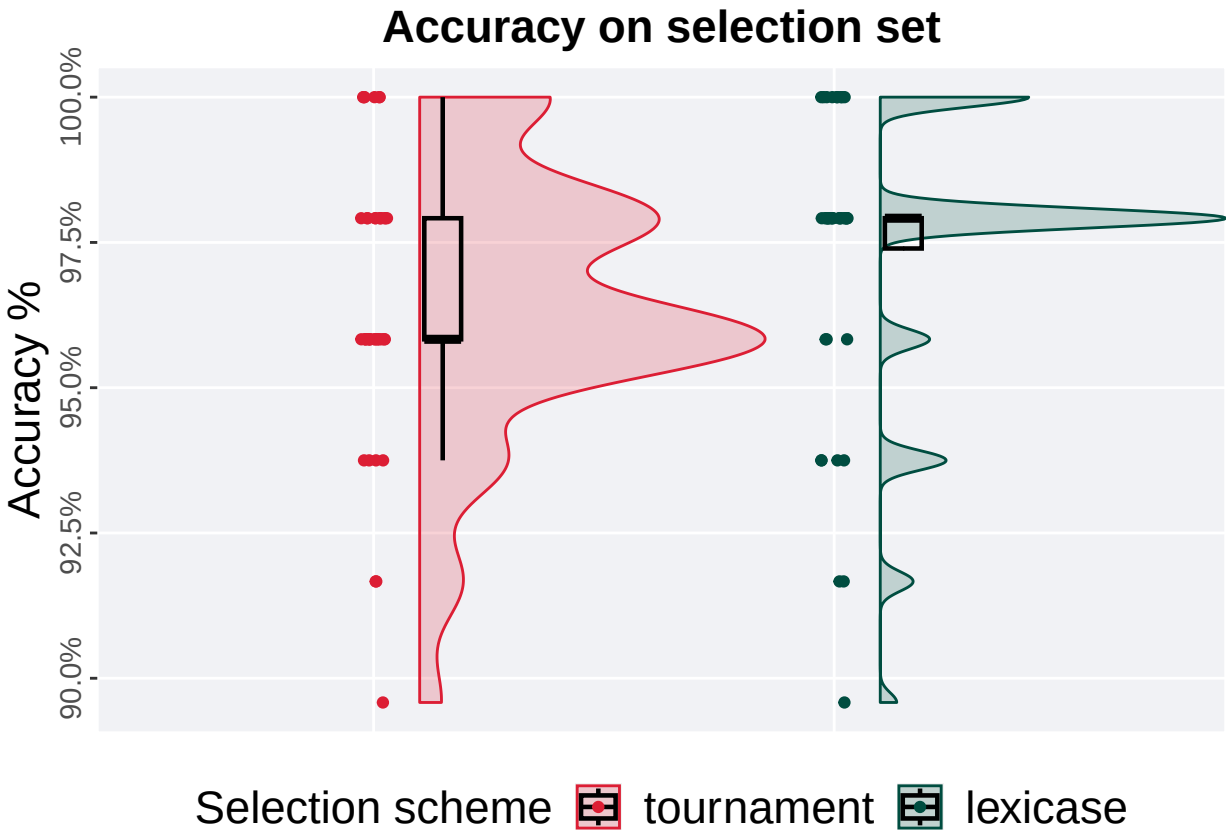
```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 61,
                 alternative = "g")
```

```
## [1] "observed_diff: 2.49264287194845"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.5647718135028"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00143"
```



8.1.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

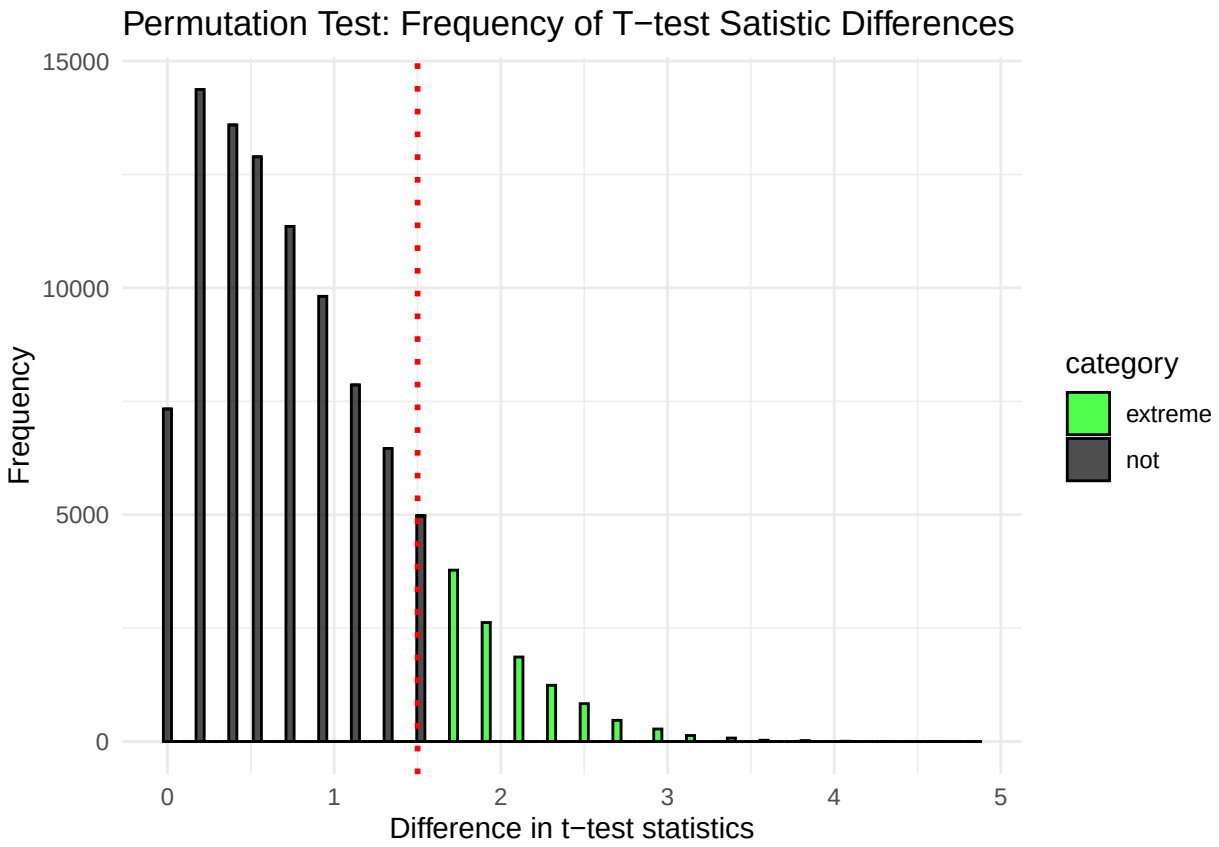
```
selection_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.896  0.958 0.965     1 0.0208
## 2 lexicase      40      0 0.896  0.979 0.973     1 0.00521
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 62,
                 alternative = "t")
```

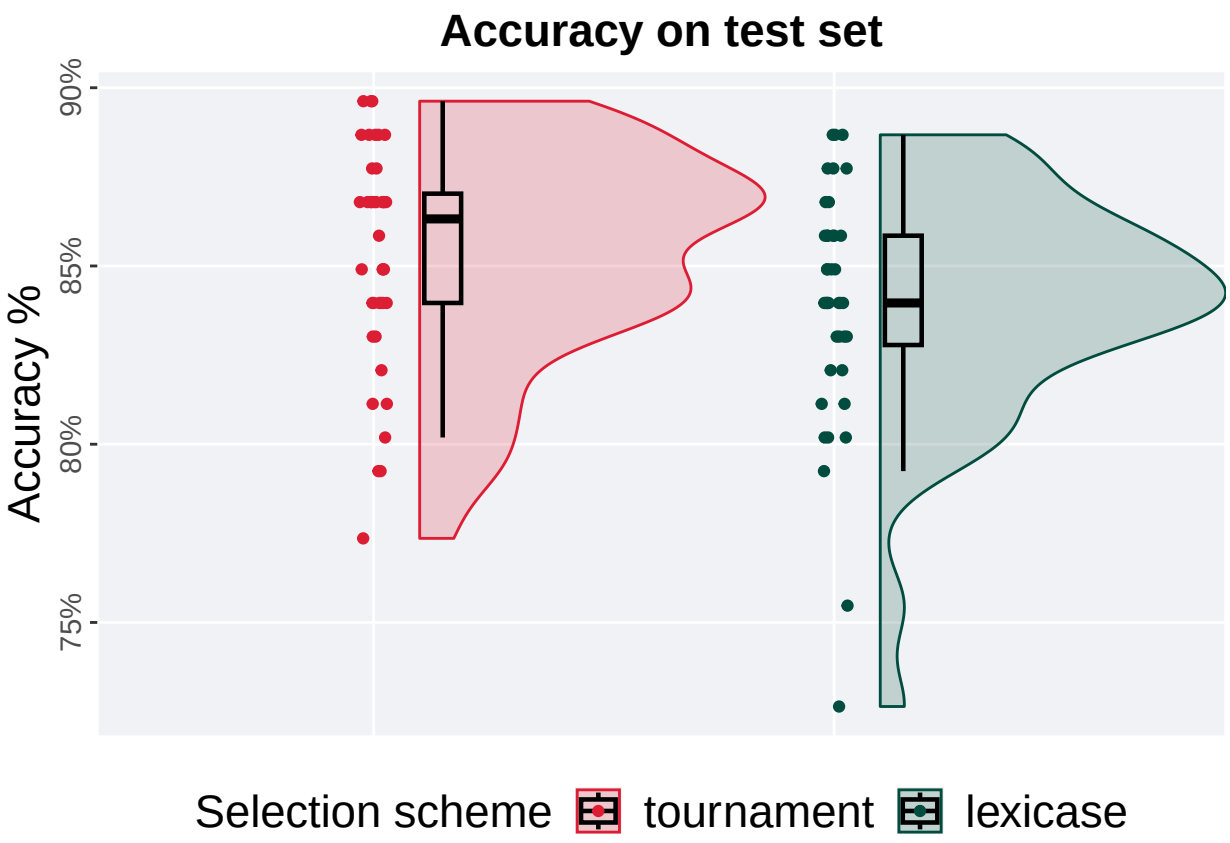
```
## [1] "observed_diff: -1.50090531983546"
## [1] "lower: -2.09080286669461"
## [1] "upper: 1.89155678516992"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.11353"
```



8.2 10%

8.2.1 Testing set accuracy

```
test_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

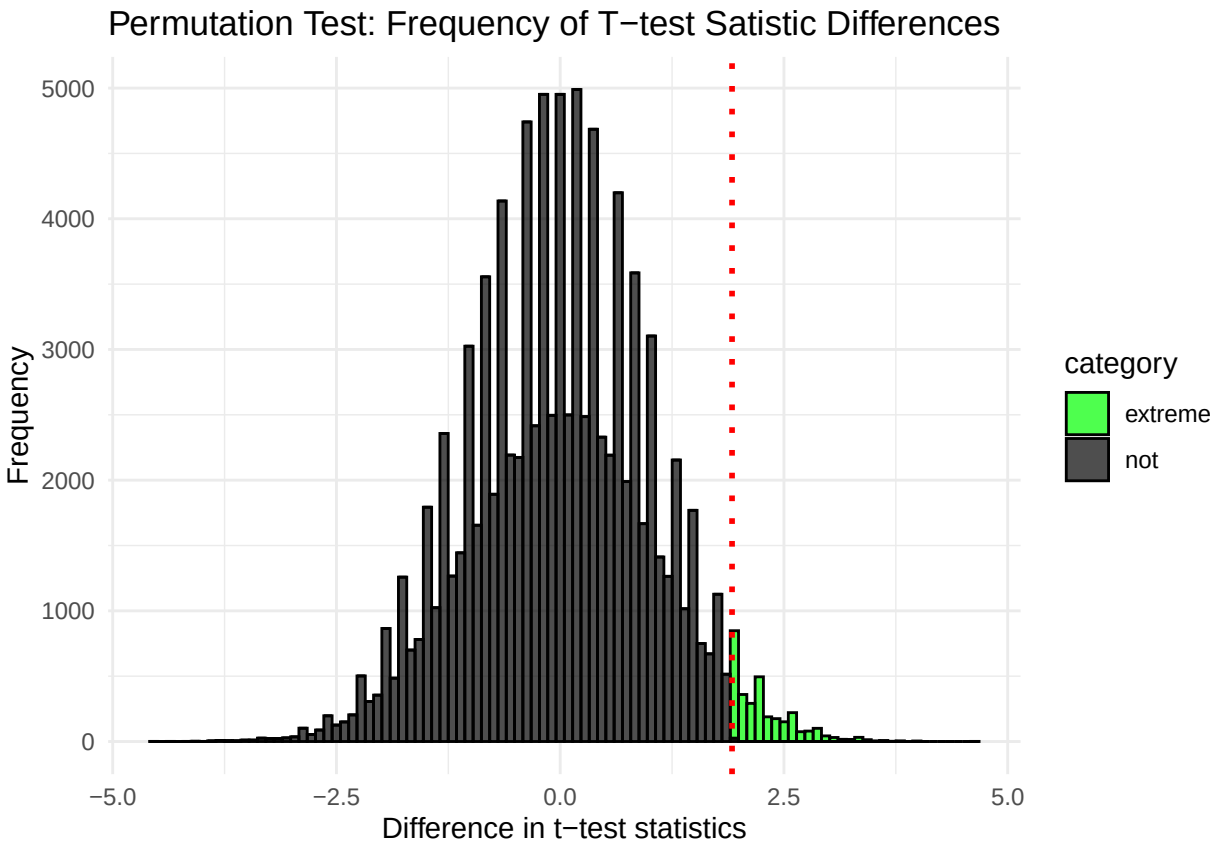
```
test_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.774  0.863 0.853 0.896 0.0307
## 2 lexicase      40      0 0.726  0.840 0.839 0.887 0.0307
```

The permutation test revealed that the results are:

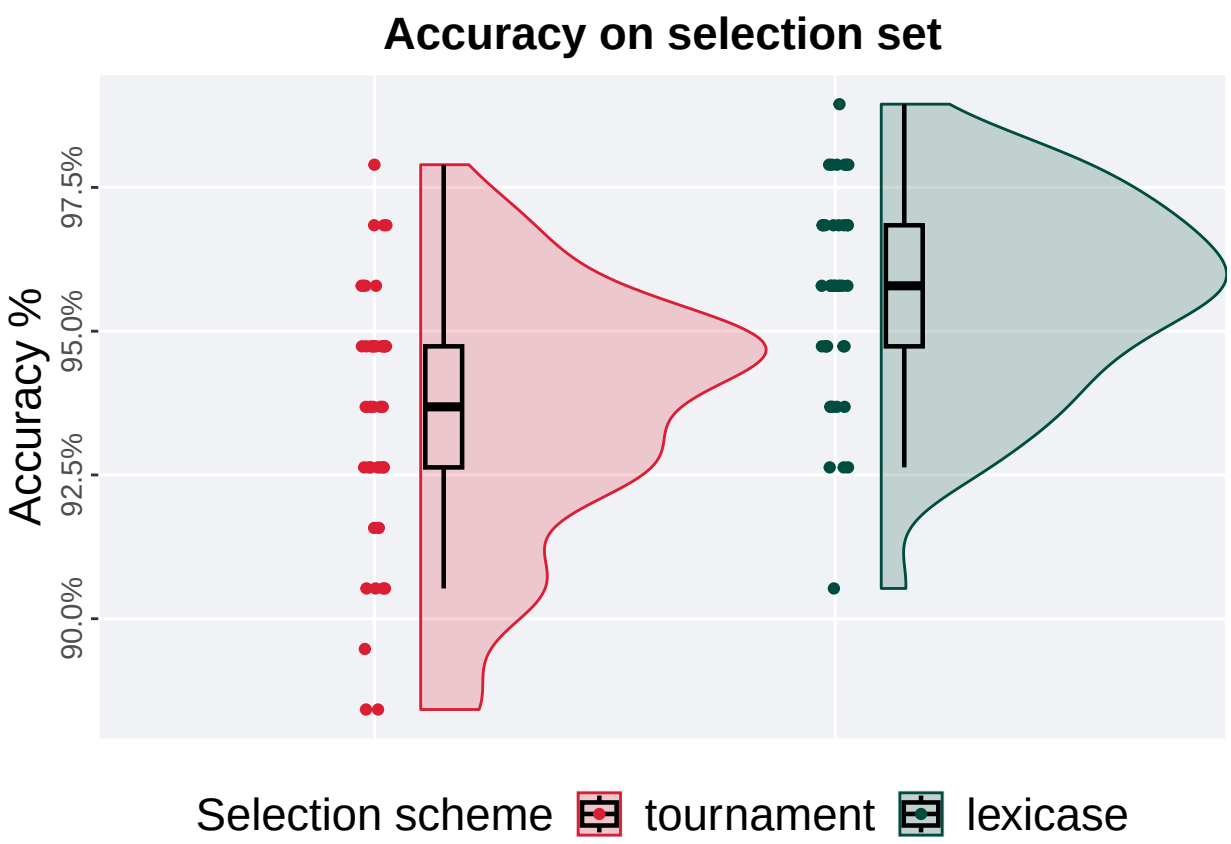
```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 63,
                 alternative = "g")
```

```
## [1] "observed_diff: 1.92031097297846"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.65010001663041"
## [1] "reject null hypothesis"
## [1] "p-value: 0.03129"
```



8.2.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

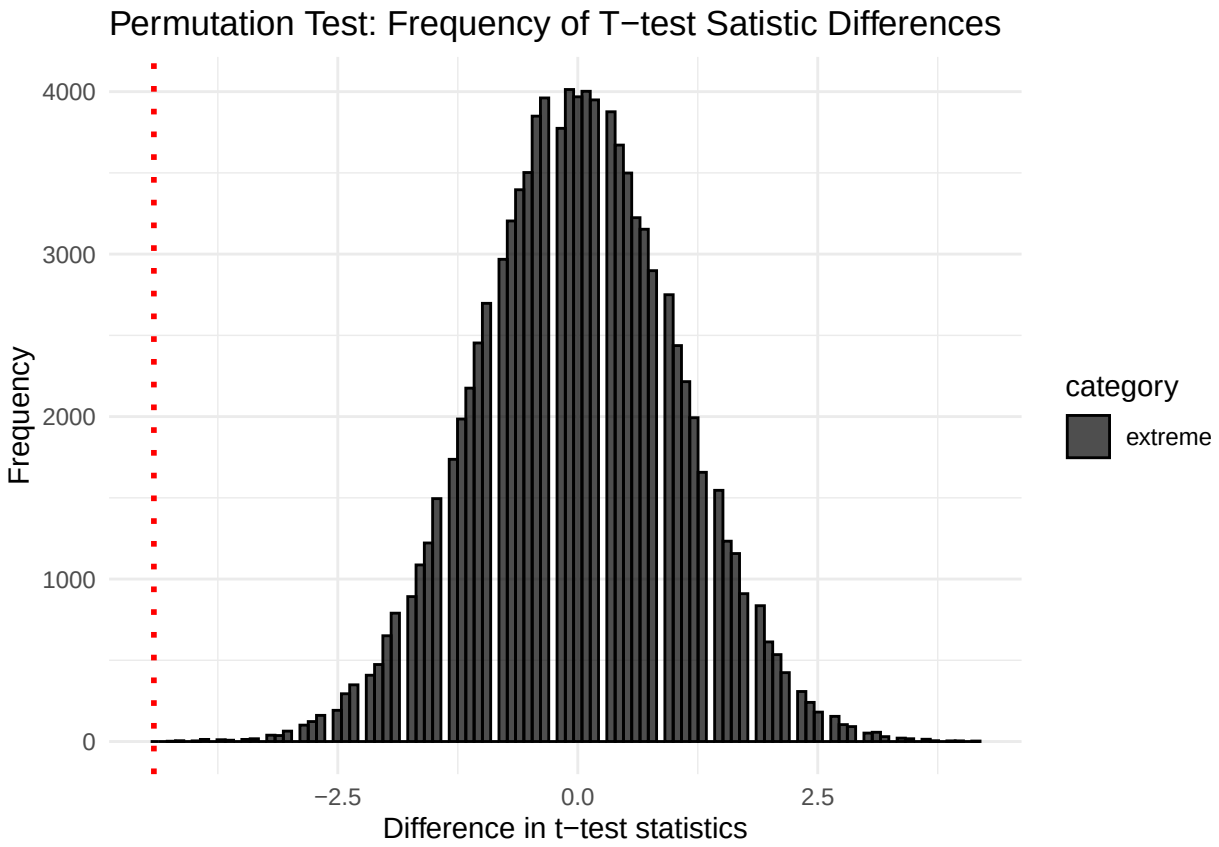
```
selection_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.884  0.937 0.936 0.979 0.0211
## 2 lexicase      40      0 0.905  0.958 0.956 0.989 0.0211
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 64,
                 alternative = "l")
```

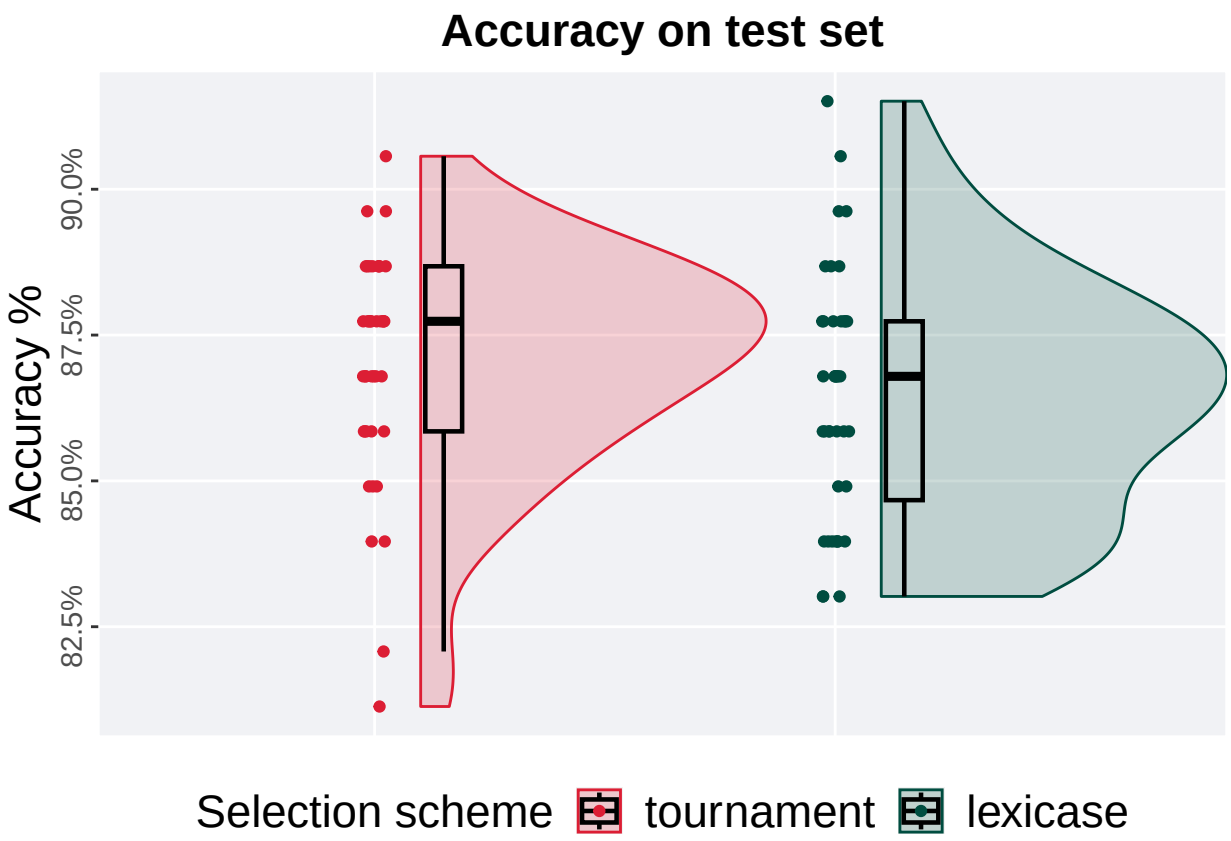
```
## [1] "observed_diff: -4.41624262918063"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.64847676079247"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```



8.3 50%

8.3.1 Testing set accuracy

```
test_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

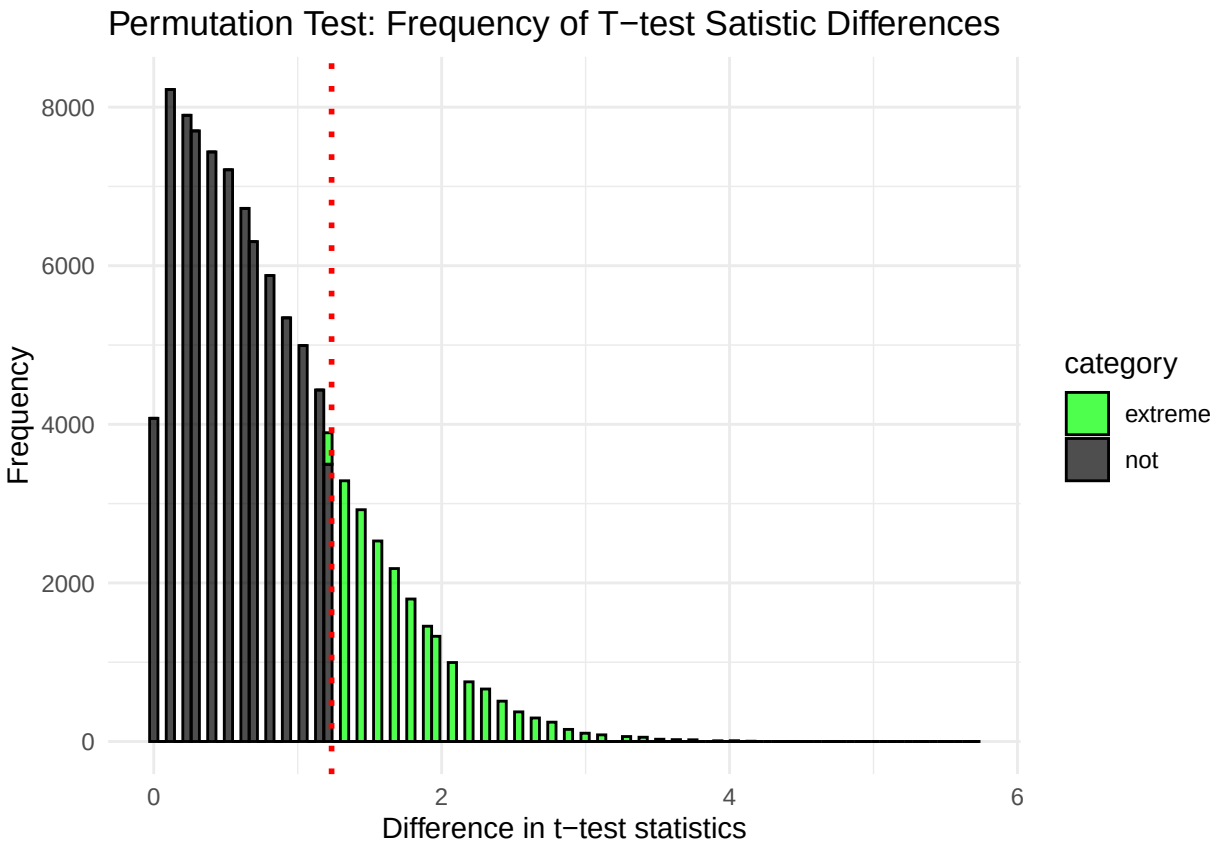
```
test_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.811  0.877 0.870 0.906 0.0283
## 2 lexicase      40      0 0.830  0.868 0.864 0.915 0.0307
```

The permutation test revealed that the results are:

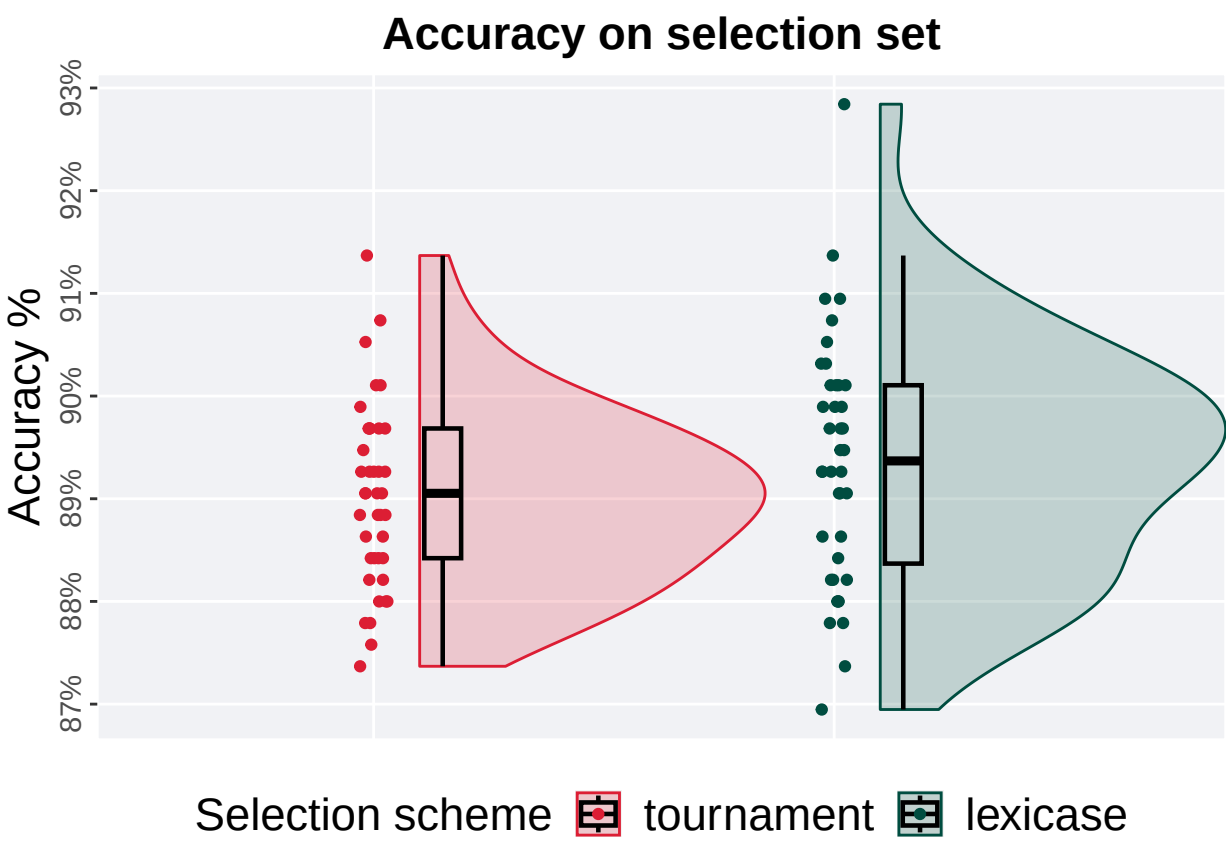
```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 65,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.23535069775879"
## [1] "lower: -1.98545740292316"
## [1] "upper: 1.98545740292316"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.20292"
```



8.3.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

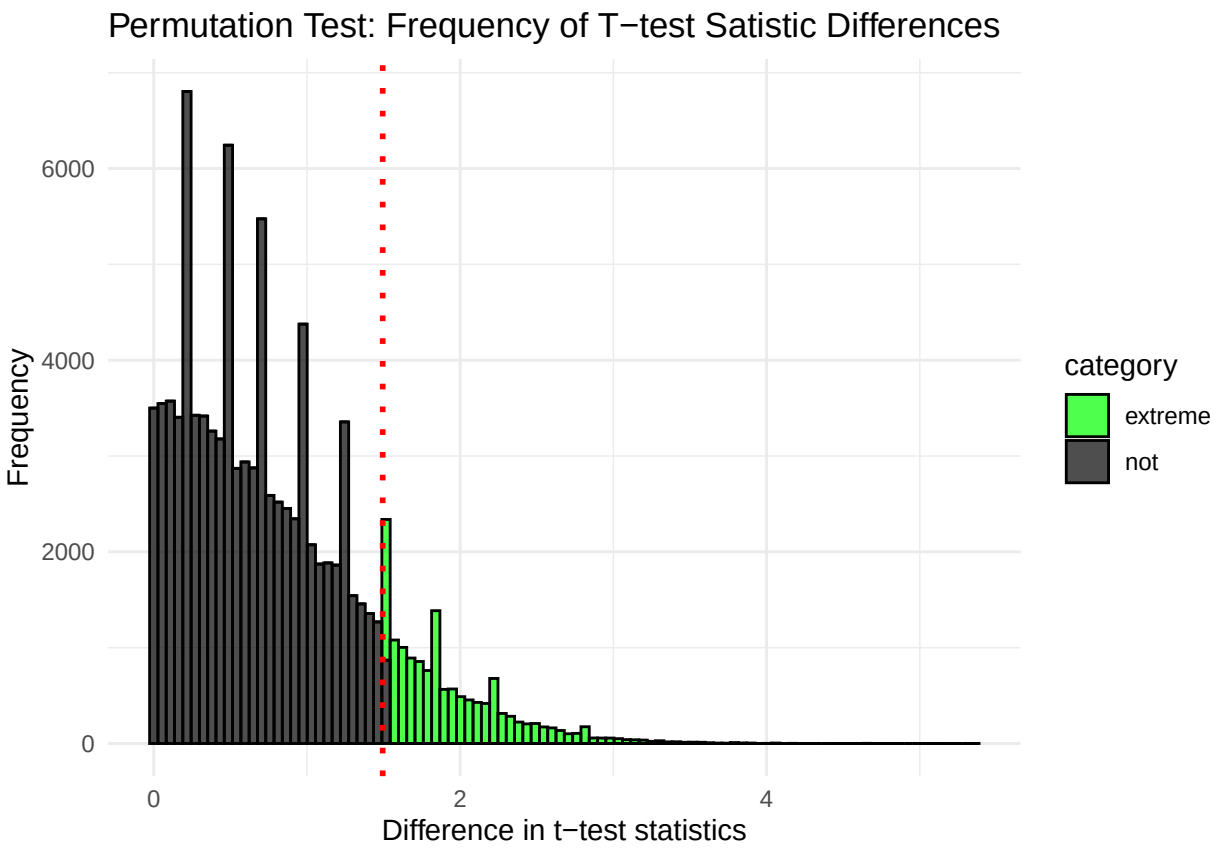
```
selection_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.874  0.891 0.890 0.914 0.0126
## 2 lexicase      40      0 0.869  0.894 0.894 0.928 0.0174
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 66,
                 alternative = "t")
```

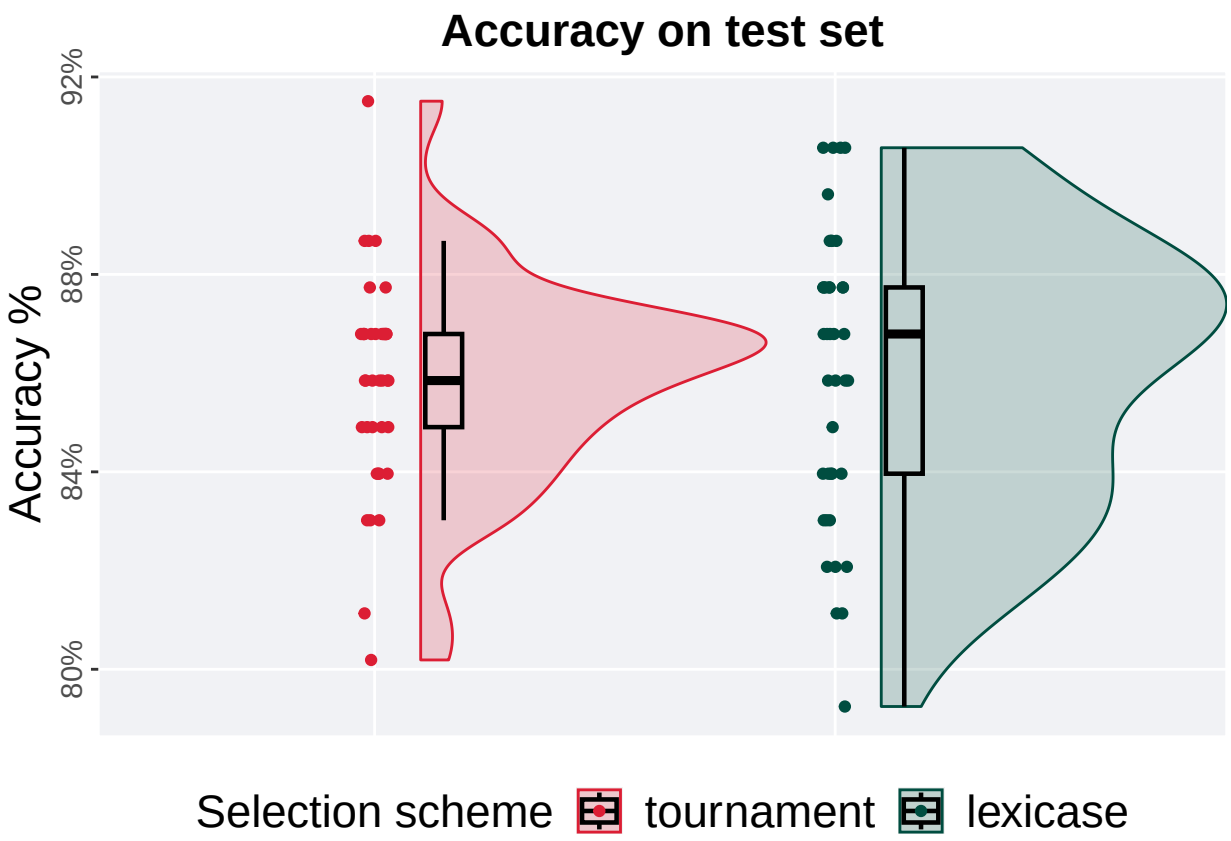
```
## [1] "observed_diff: -1.49419701600044"
## [1] "lower: -2.00690565895584"
## [1] "upper: 2.00690565895579"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.13664"
```



8.4 90%

8.4.1 Testing set accuracy

```
test_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

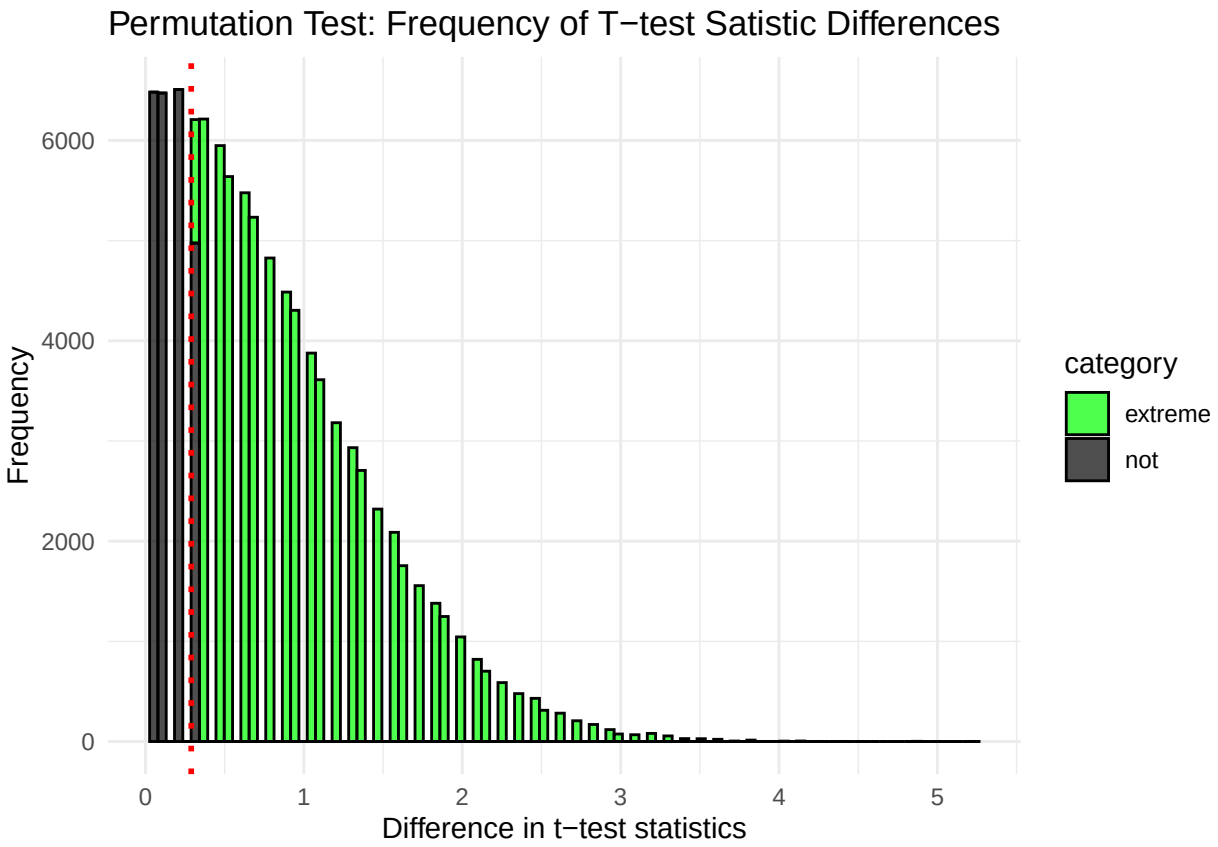
```
test_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.802  0.858 0.858 0.915 0.0189
## 2 lexicase      40      0 0.792  0.868 0.860 0.906 0.0377
```

The permutation test revealed that the results are:

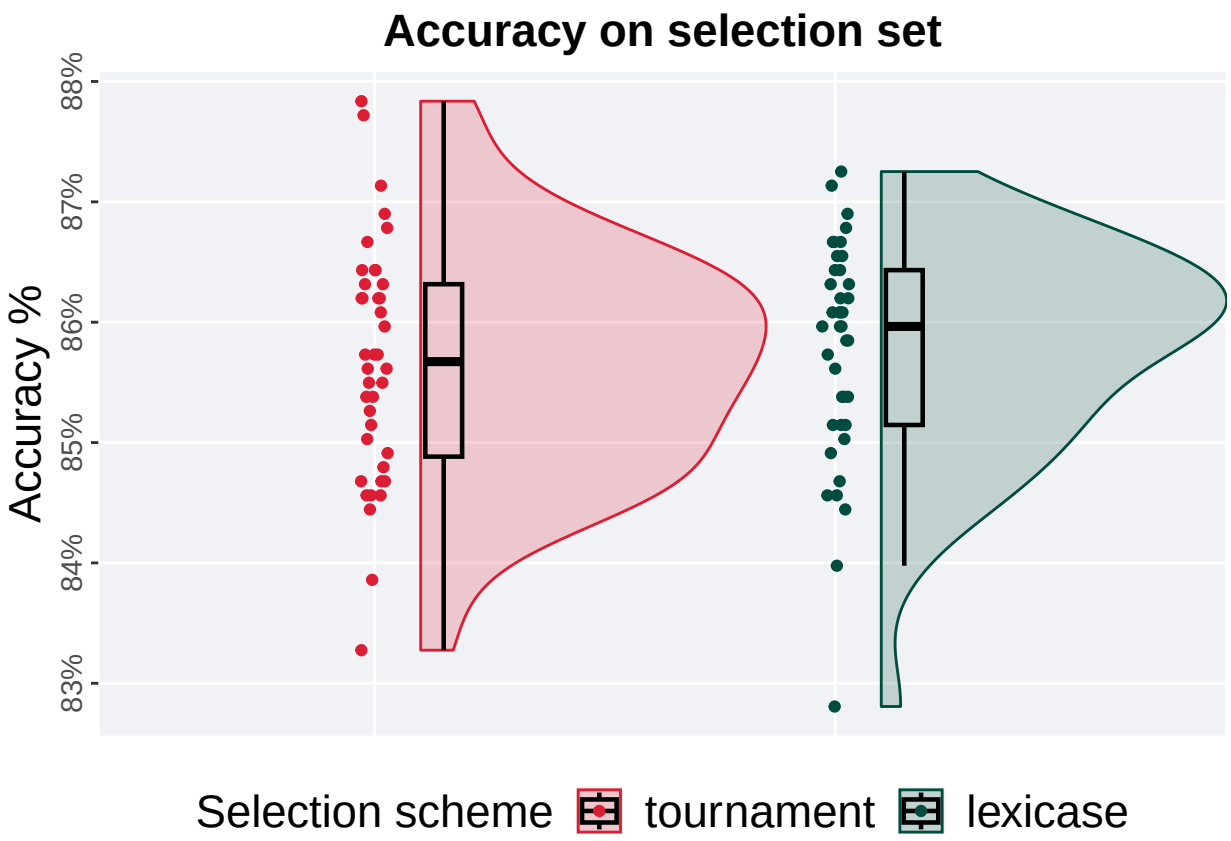
```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 67,
                 alternative = "t")
```

```
## [1] "observed_diff: -0.288985153074226"
## [1] "lower: -1.98779654792212"
## [1] "upper: 1.98779748996659"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.75562"
```



8.4.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

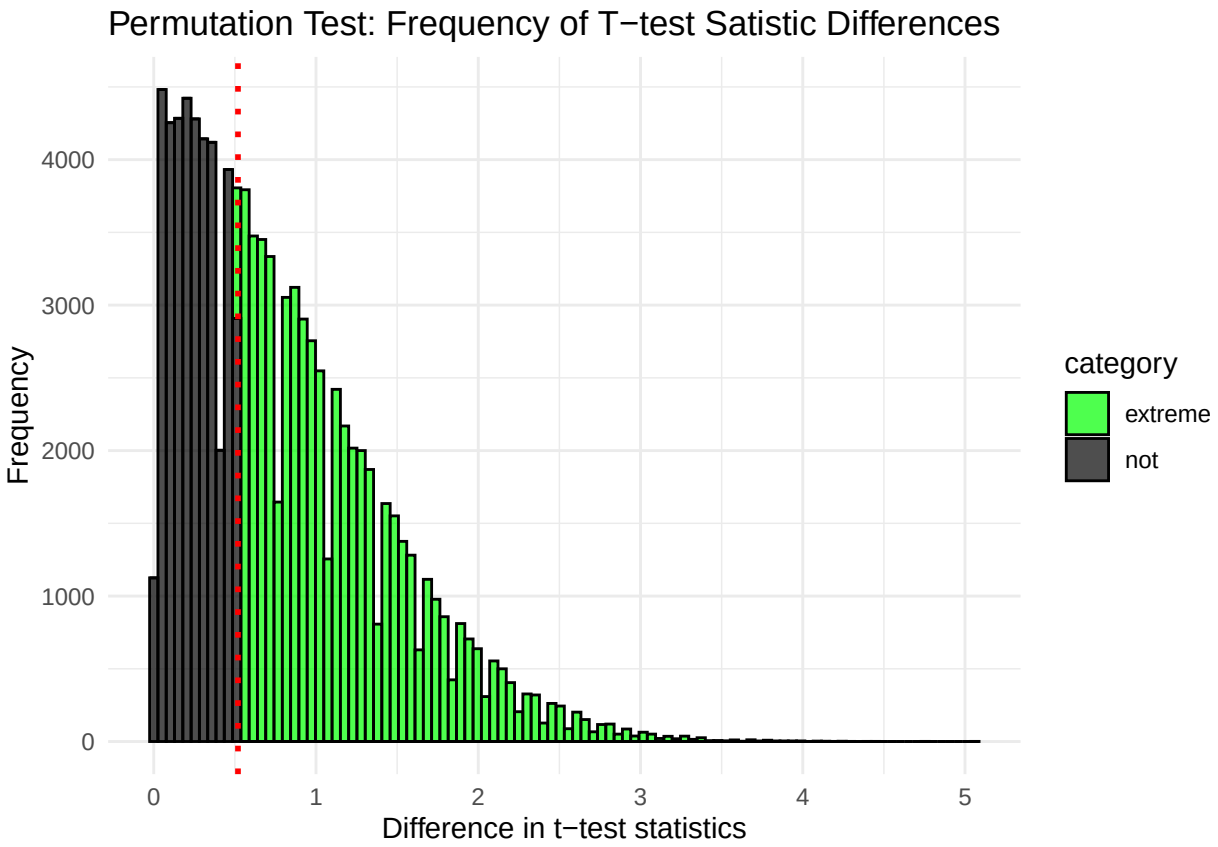
```
selection_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.833  0.857 0.857 0.878 0.0143
## 2 lexicase      40      0 0.828  0.860 0.858 0.873 0.0129
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 68,
                 alternative = "t")
```

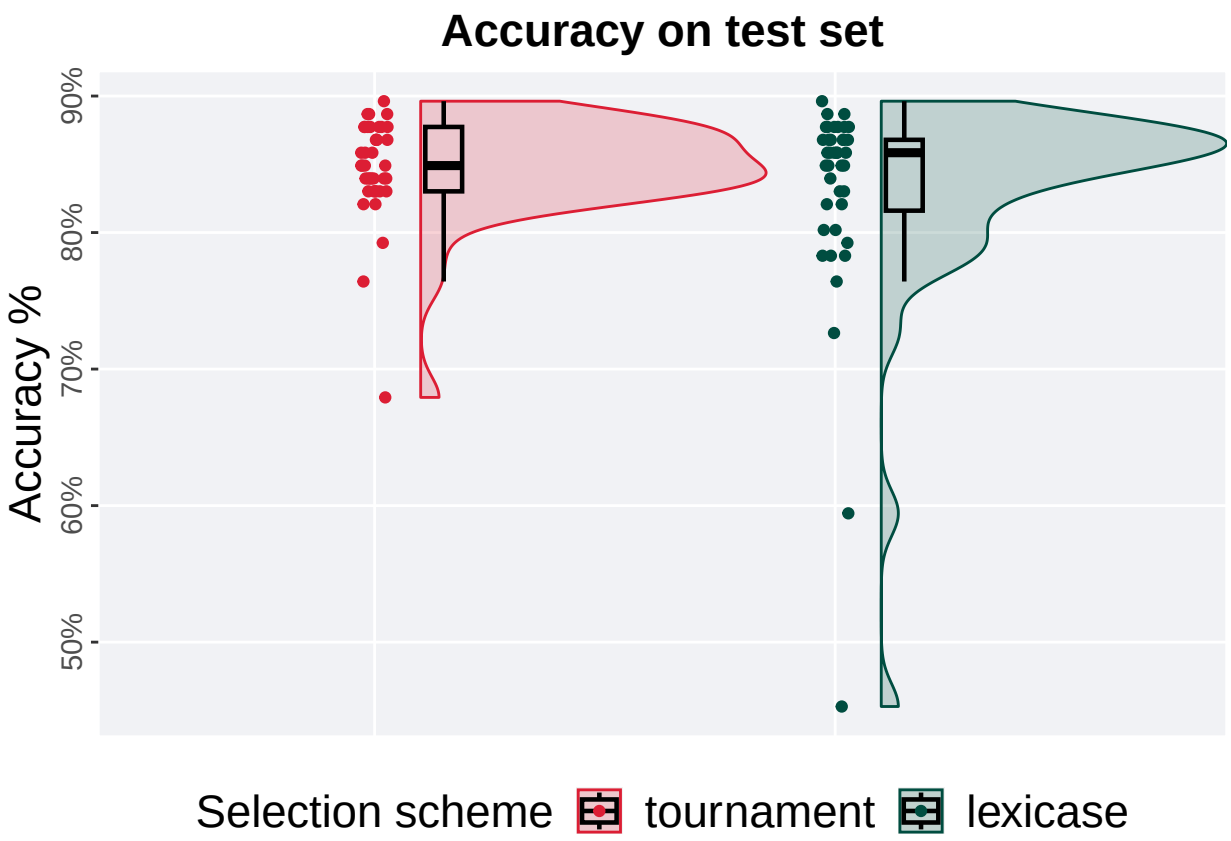
```
## [1] "observed_diff: -0.519105003995363"
## [1] "lower: -1.98476786090786"
## [1] "upper: 1.98476961848034"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.60049"
```



8.5 95%

8.5.1 Testing set accuracy

```
test_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

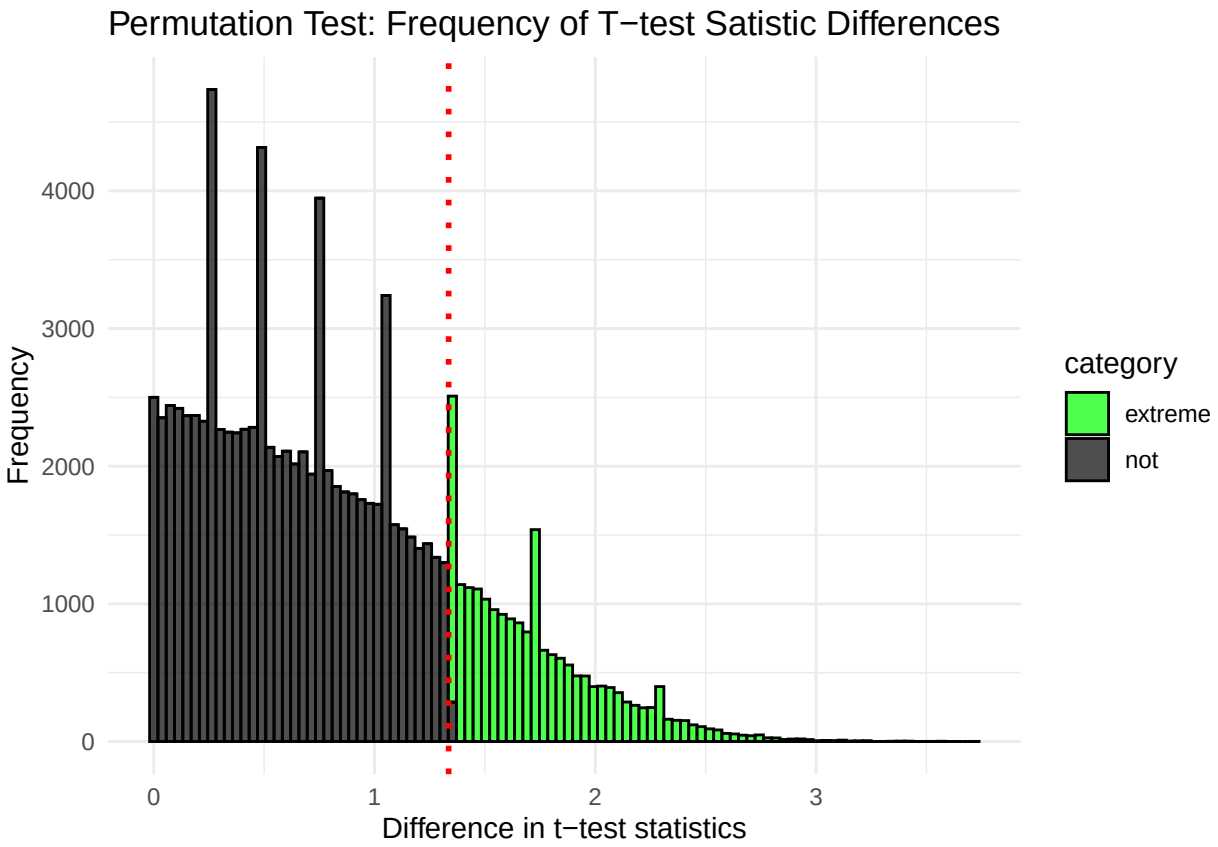
```
test_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.679  0.849 0.847 0.896 0.0472
## 2 lexicase      40      0 0.453  0.858 0.828 0.896 0.0519
```

The permutation test revealed that the results are:

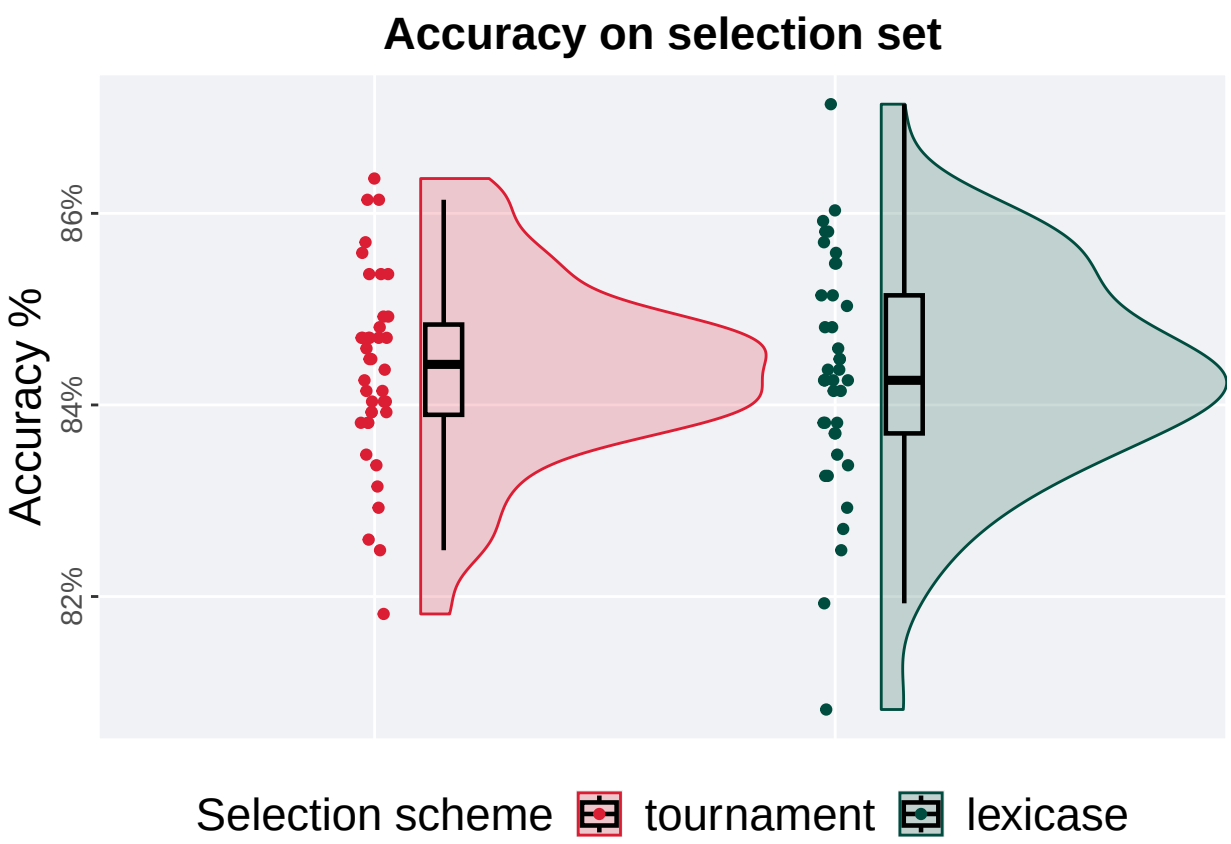
```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 69,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.33590135470976"
## [1] "lower: -1.91908070055885"
## [1] "upper: 1.91908070055885"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.20293"
```



8.5.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

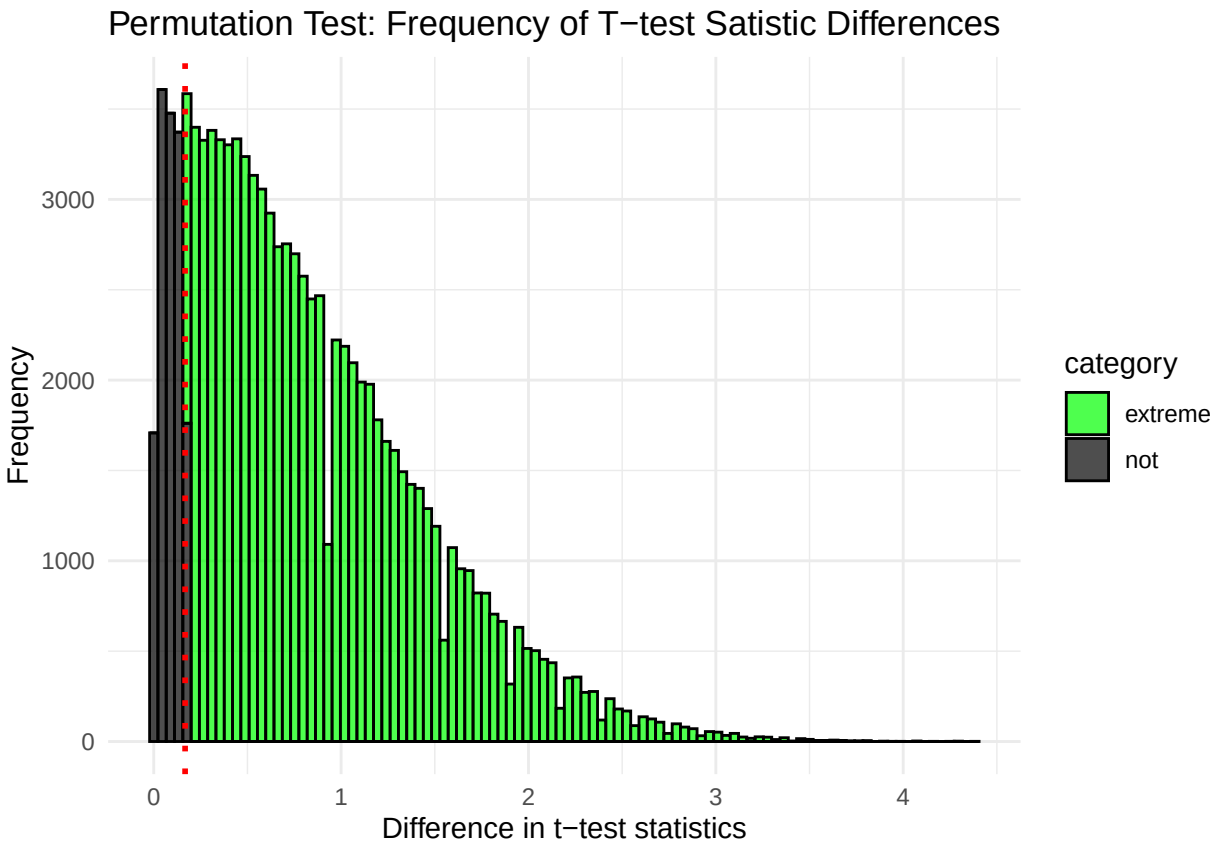
```
selection_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.818  0.844 0.844 0.864 0.00942
## 2 lexicase      40      0 0.808  0.843 0.843 0.871 0.0144
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 70,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.167199522669578"
## [1] "lower: -1.9996181495468"
## [1] "upper: 1.97561829637897"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.86074"
```


Permutation Test: Frequency of T−test Satistic Differences
Frequency
3000
2000
1000
0
0
1
2
3
4
Difference in t−test statistics
category
extreme
not

Chapter 9

Task 359958

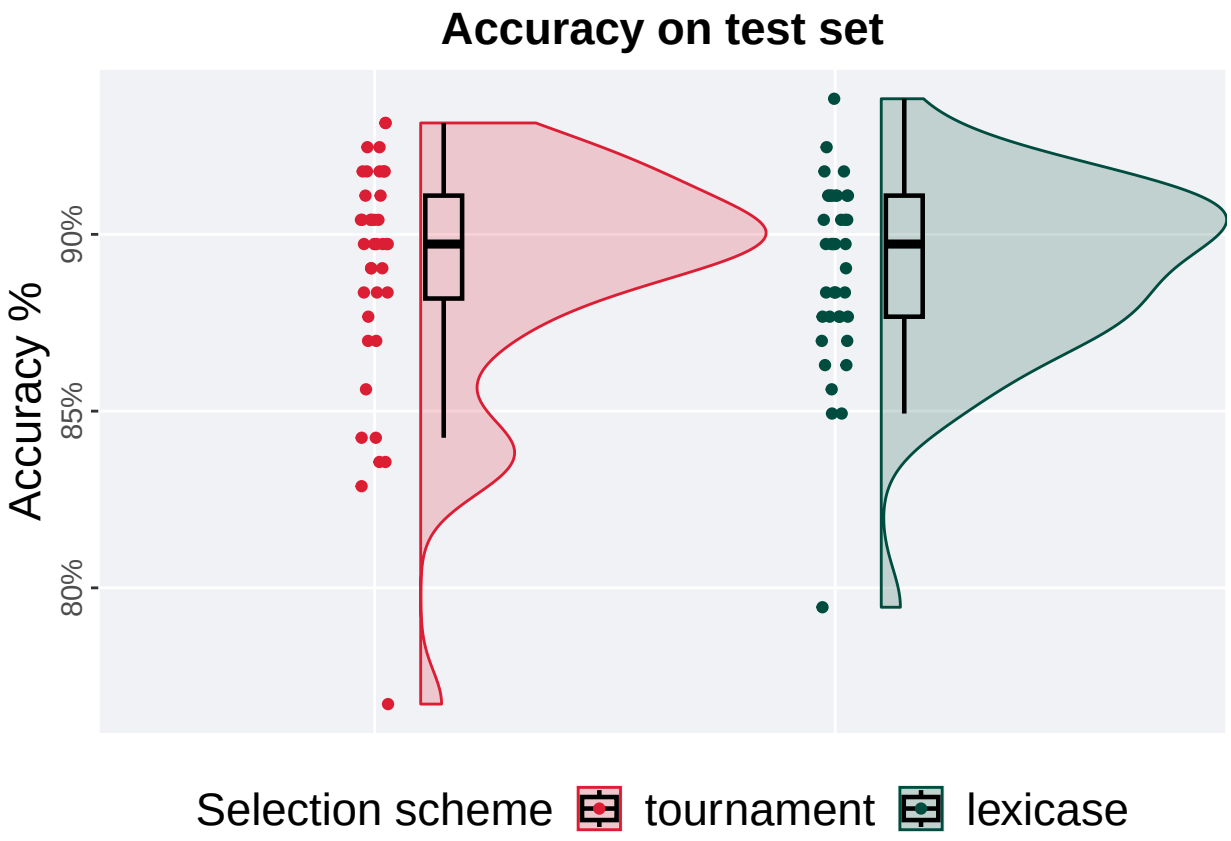
We present the results of our analysis of `task 359958` with the different selection set splits used in our study.

```
task_data <- filter(results, task_id == 359958)
```

9.1 5%

9.1.1 Testing set accuracy

```
test_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

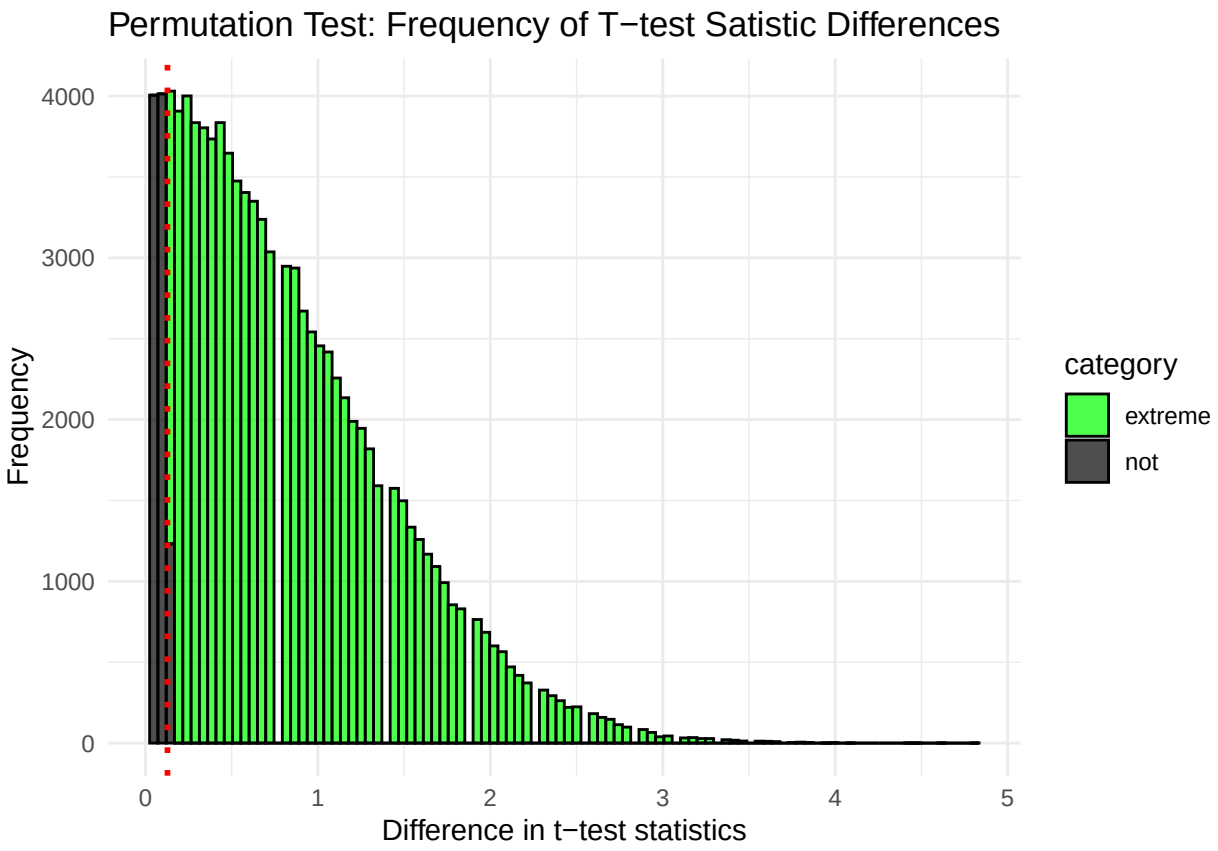
```
test_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.767  0.897 0.889 0.932 0.0291
## 2 lexicase      40      0 0.795  0.897 0.890 0.938 0.0342
```

The permutation test revealed that the results are:

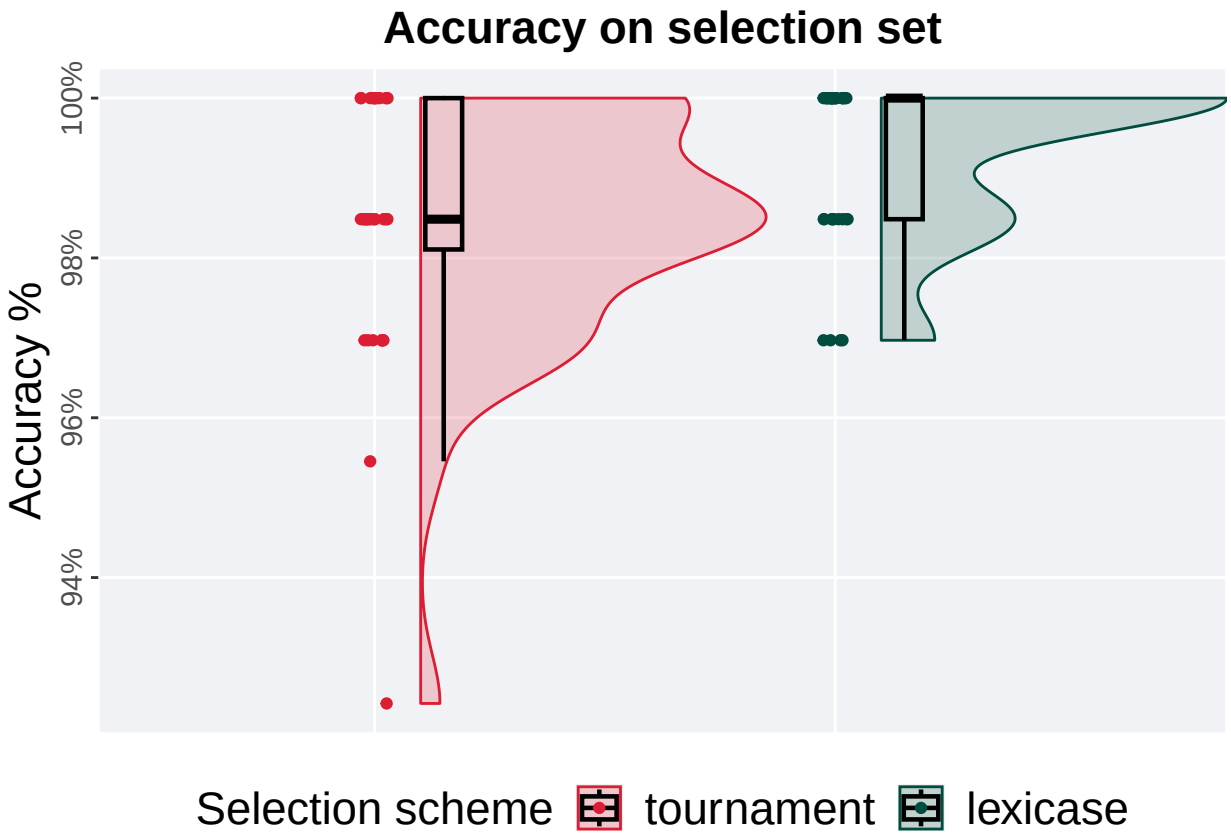
```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 71,
                 alternative = "t")
```

```
## [1] "observed_diff: -0.127556855492129"
## [1] "lower: -1.95969411811632"
## [1] "upper: 1.95969419817028"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.90748"
```



9.1.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

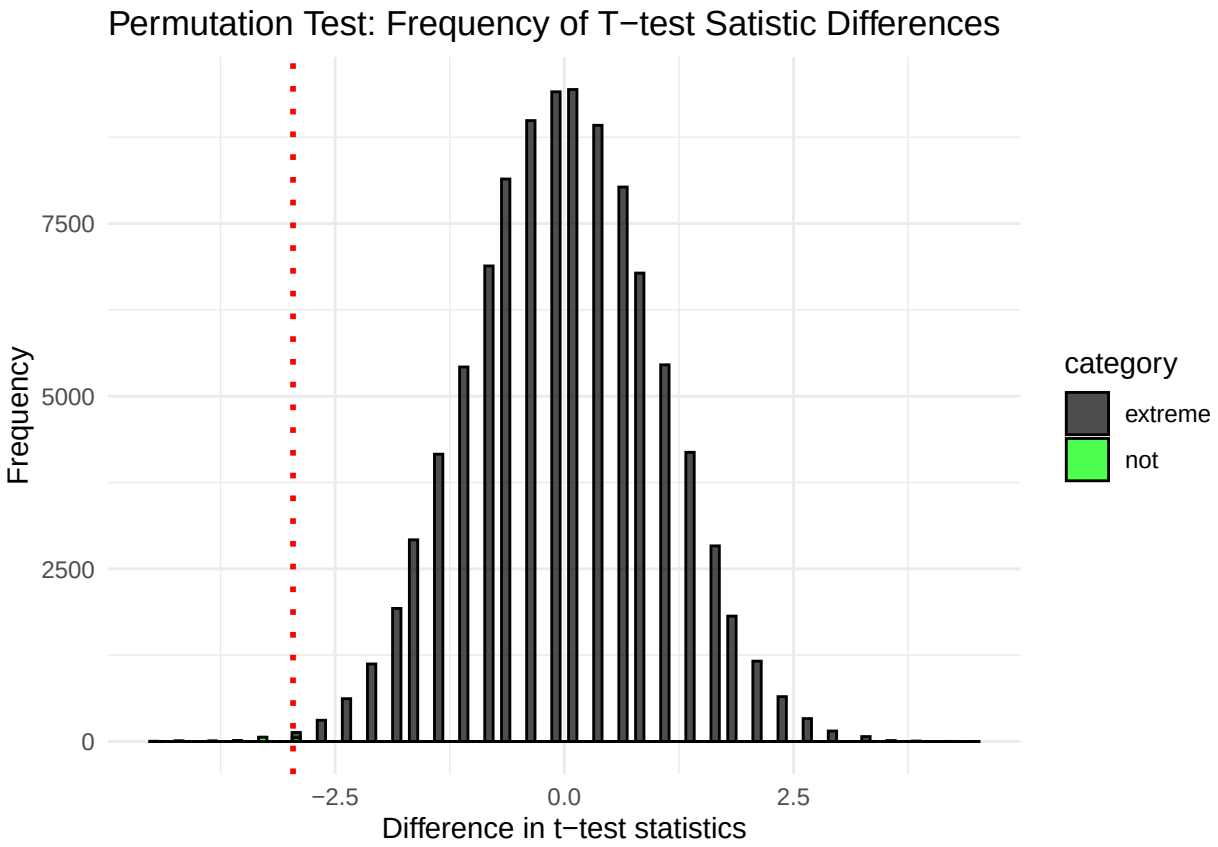
```
selection_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.924  0.985 0.984     1 0.0189
## 2 lexicase      40      0 0.970  1     0.993     1 0.0152
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 72,
                 alternative = "l")
```

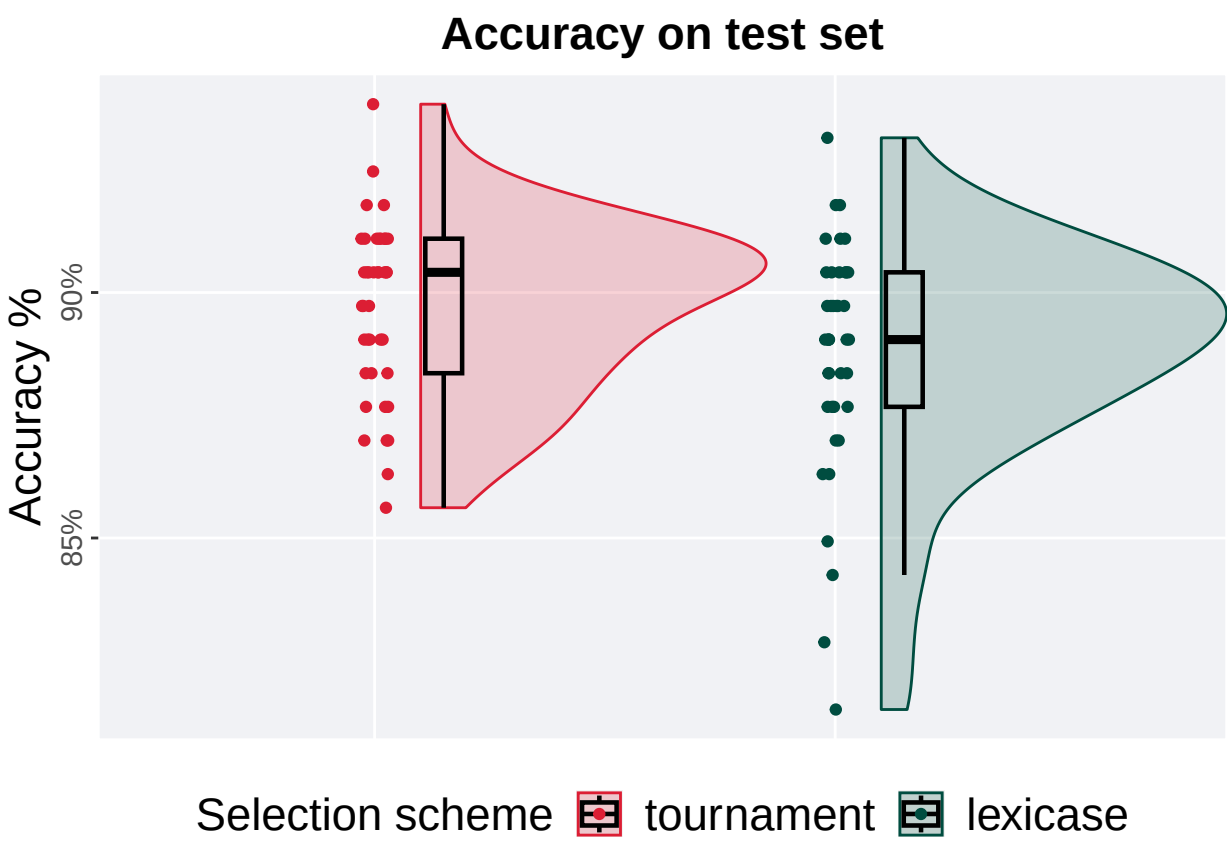
```
## [1] "observed_diff: -2.9598156320086"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.61245190733767"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00147"
```



9.2 10%

9.2.1 Testing set accuracy

```
test_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

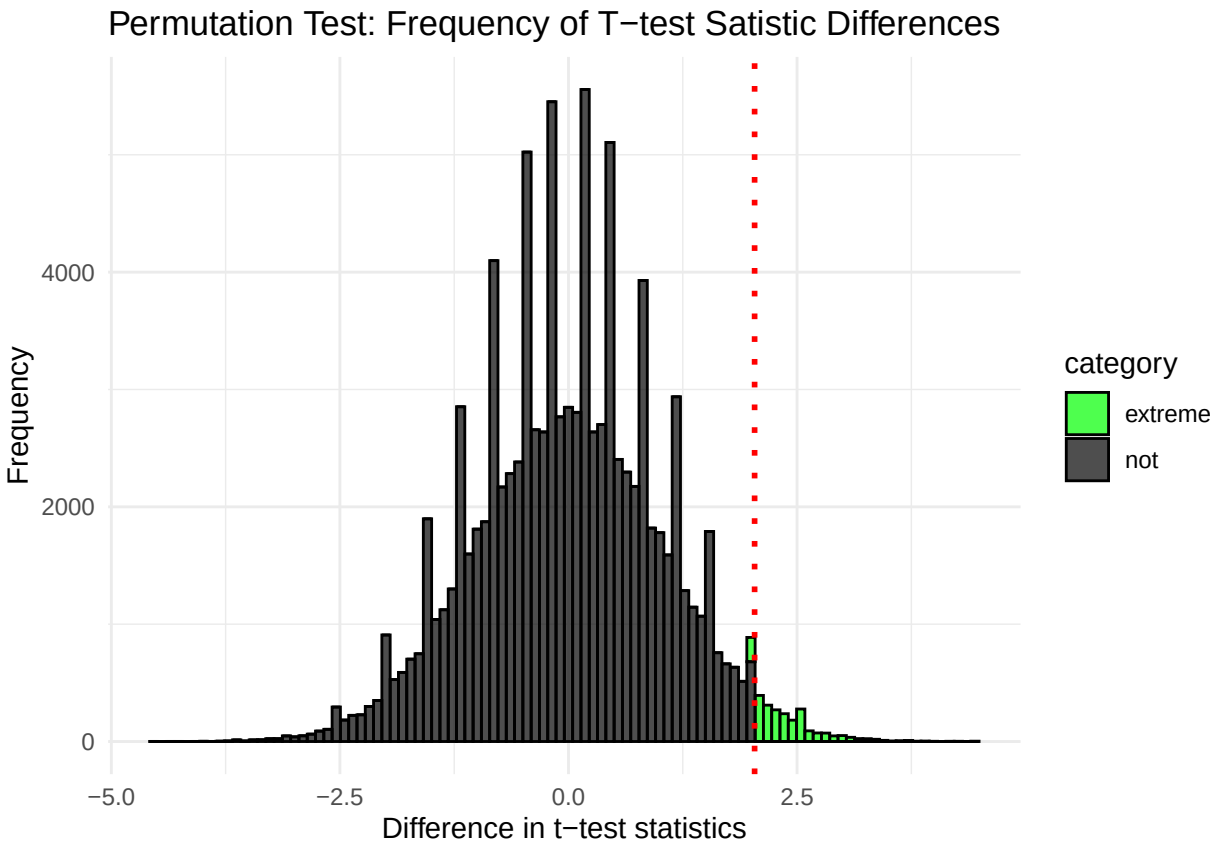
```
test_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.856  0.904 0.897 0.938 0.0274
## 2 lexicase      40      0 0.815  0.890 0.887 0.932 0.0274
```

The permutation test revealed that the results are:

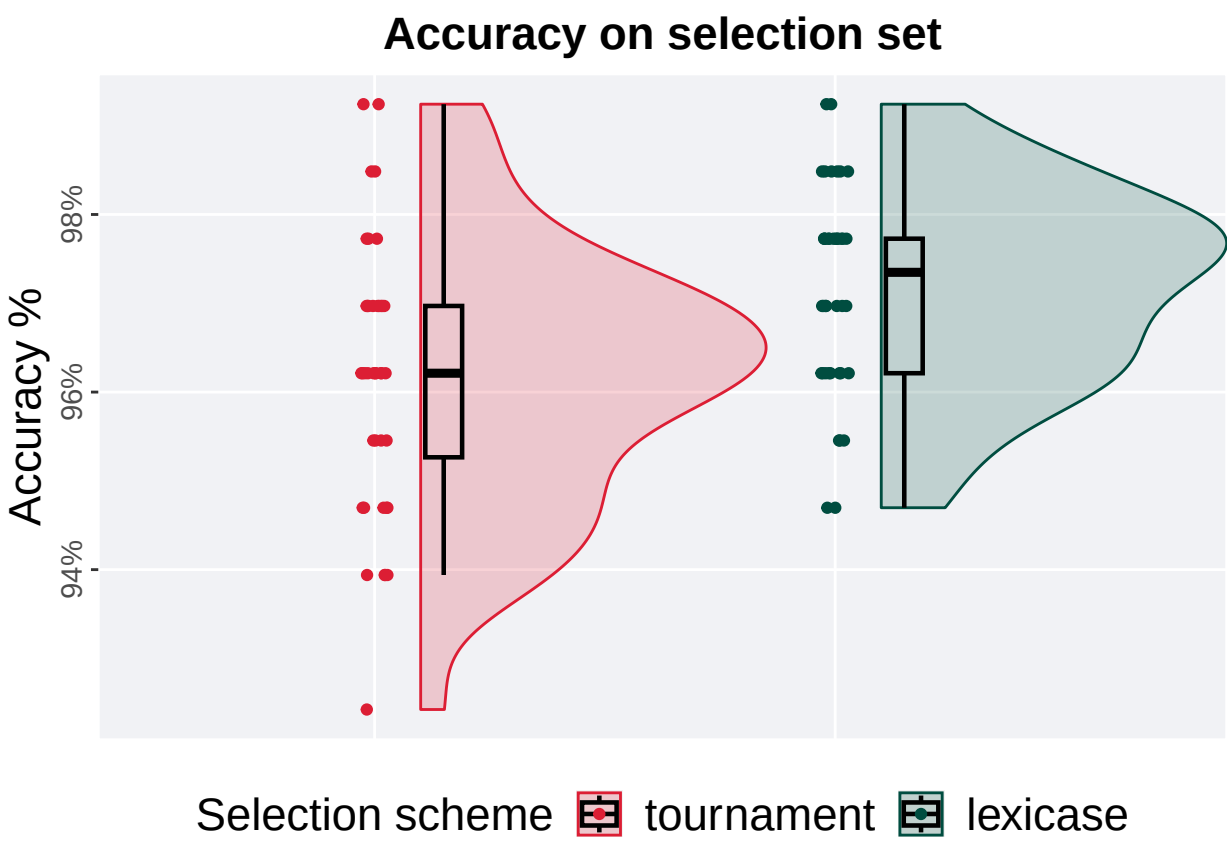
```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 73,
                 alternative = "g")
```

```
## [1] "observed_diff: 2.03573402533652"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.6579467289571"
## [1] "reject null hypothesis"
## [1] "p-value: 0.0235"
```



9.2.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

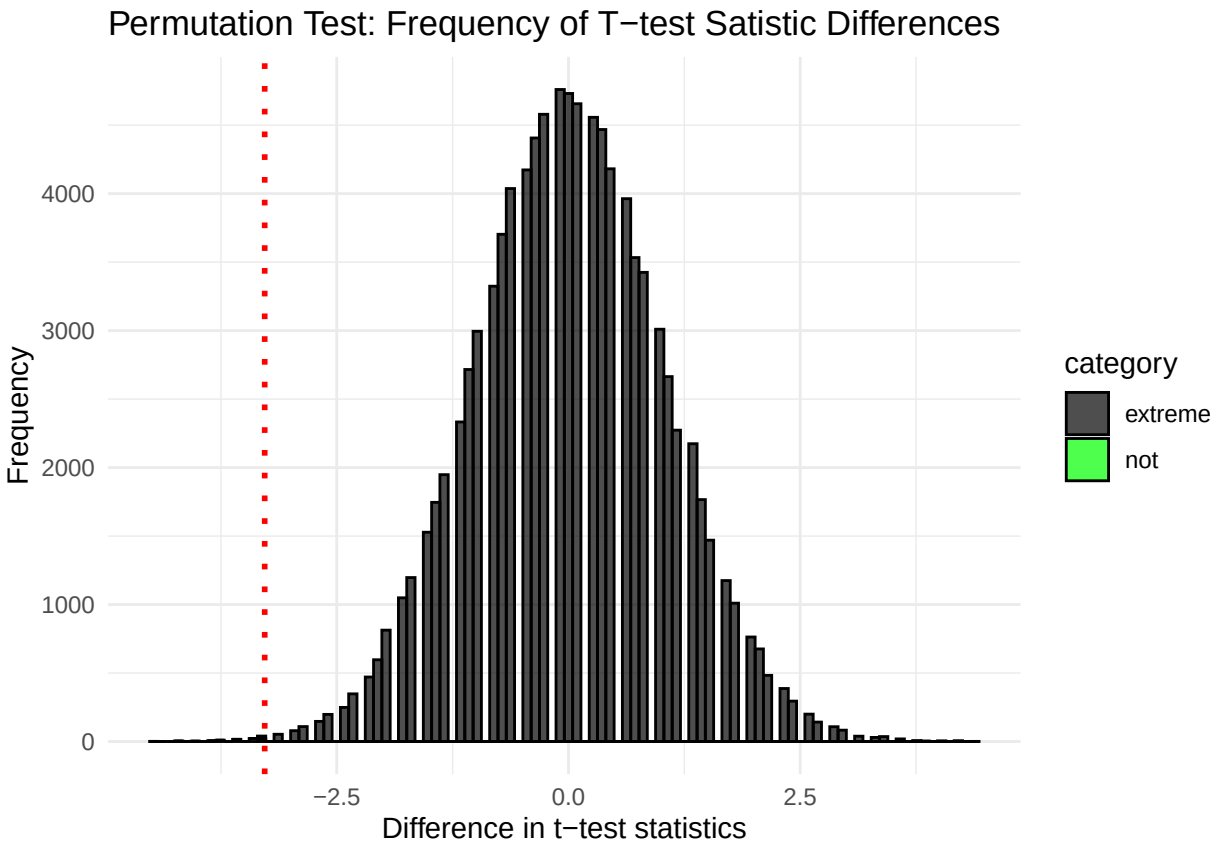
```
selection_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.924  0.962 0.962 0.992 0.0170
## 2 lexicase      40      0 0.947  0.973 0.972 0.992 0.0152
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 74,
                 alternative = "l")
```

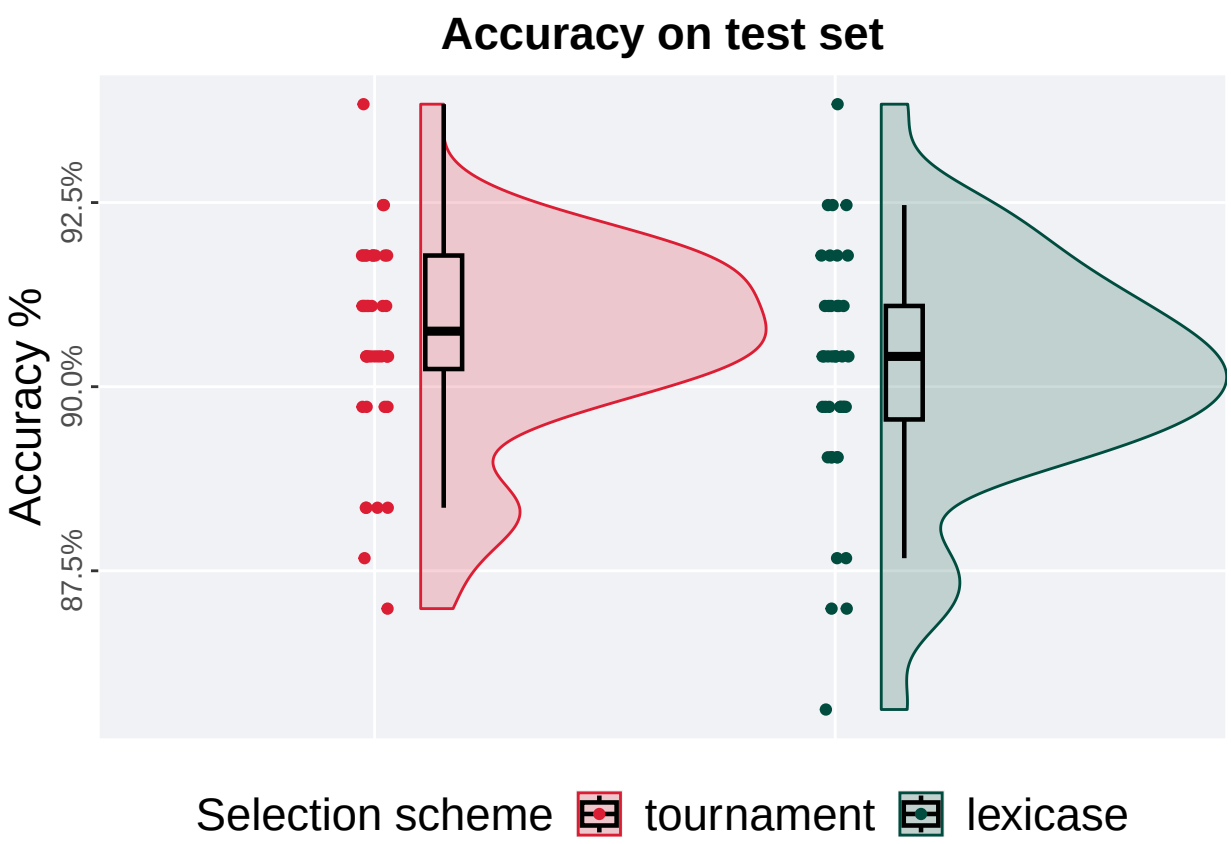
```
## [1] "observed_diff: -3.27769366217578"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.68446274227723"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00083"
```



9.3 50%

9.3.1 Testing set accuracy

```
test_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

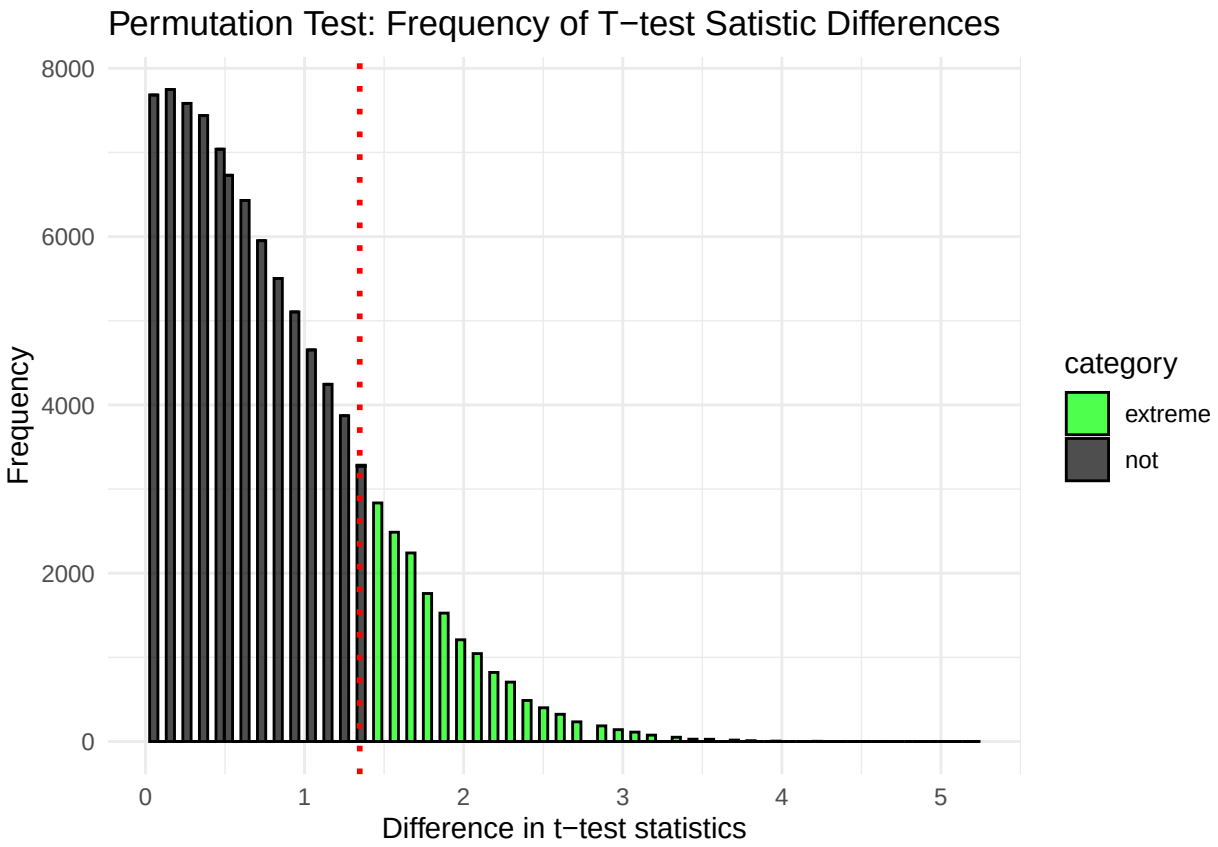
```
test_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.870  0.908 0.906 0.938 0.0154
## 2 lexicase      40      0 0.856  0.904 0.902 0.938 0.0154
```

The permutation test revealed that the results are:

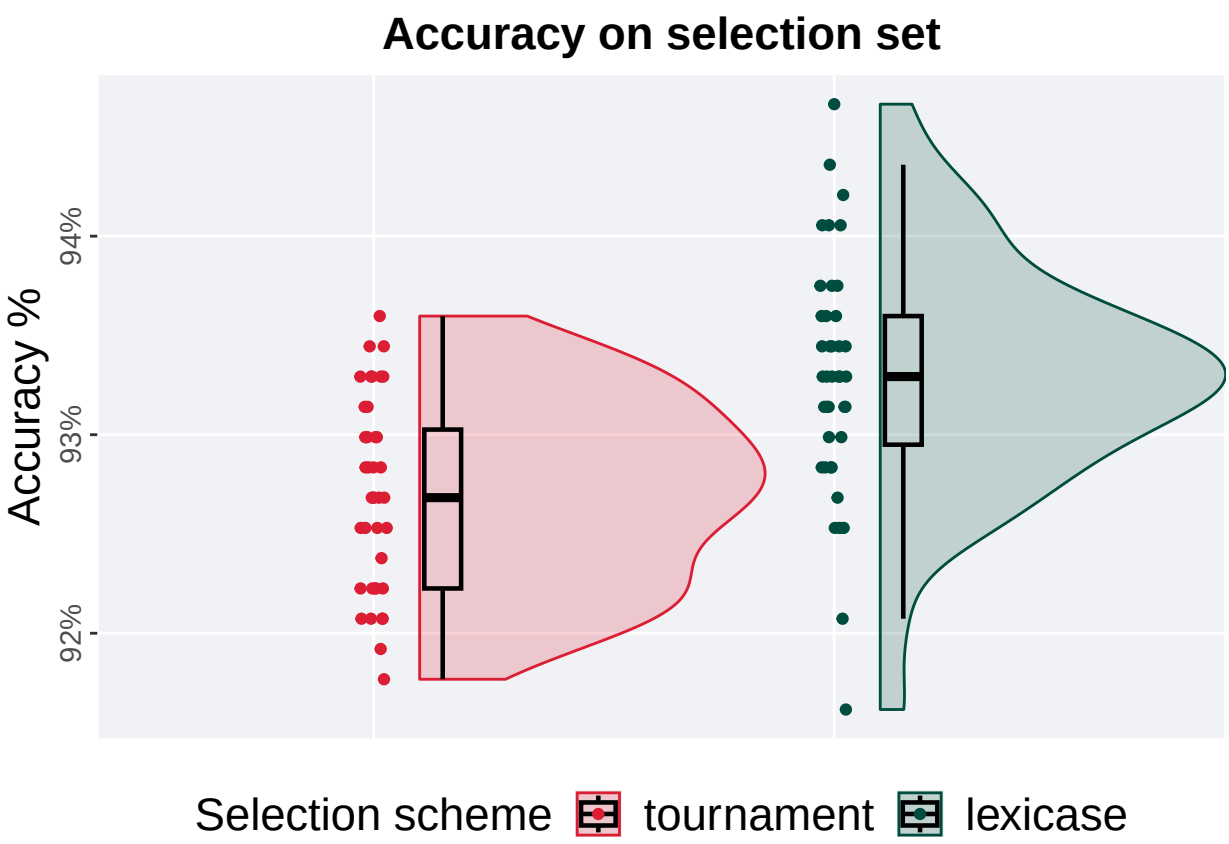
```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 75,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.34694178441485"
## [1] "lower: -1.97063646149436"
## [1] "upper: 1.97063630660342"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.16746"
```



9.3.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

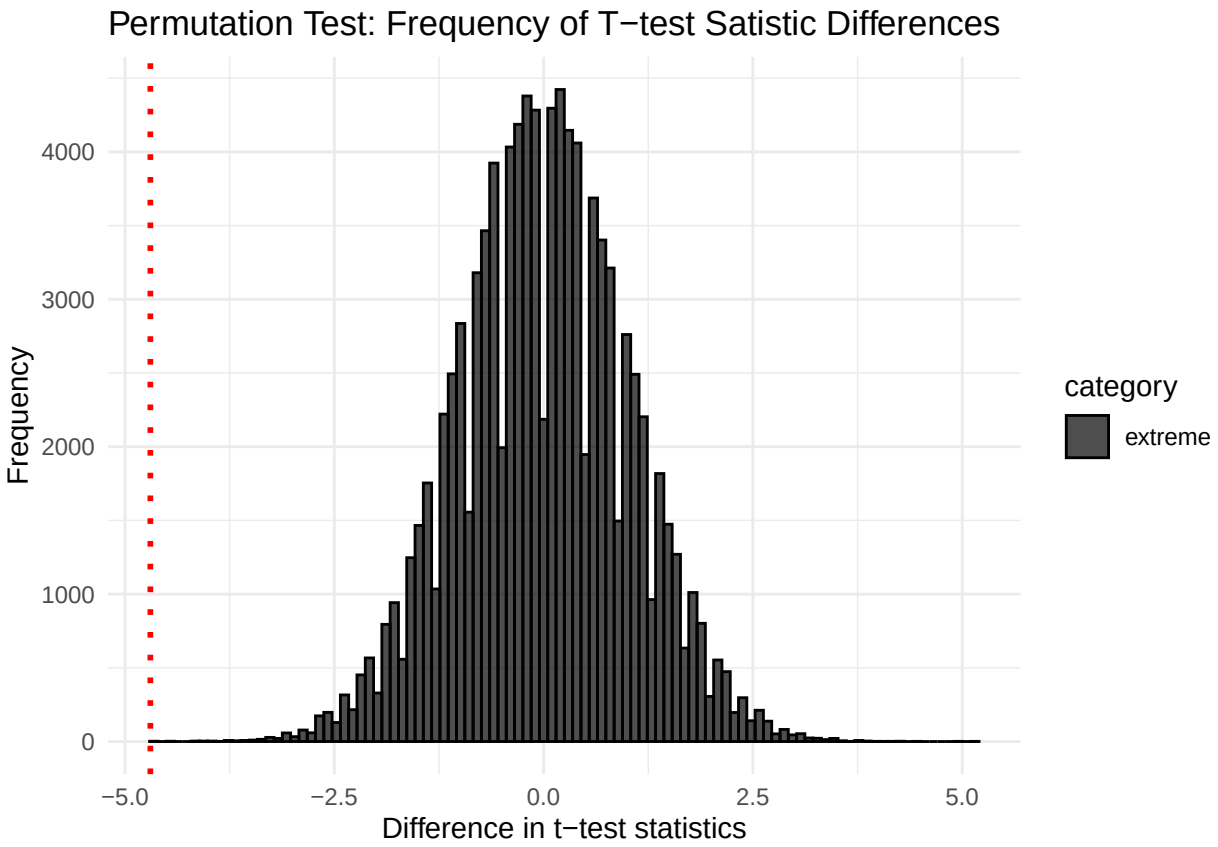
```
selection_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.918  0.927 0.927 0.936 0.00800
## 2 lexicase      40      0 0.916  0.933 0.933 0.947 0.00648
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 76,
                 alternative = "l")
```

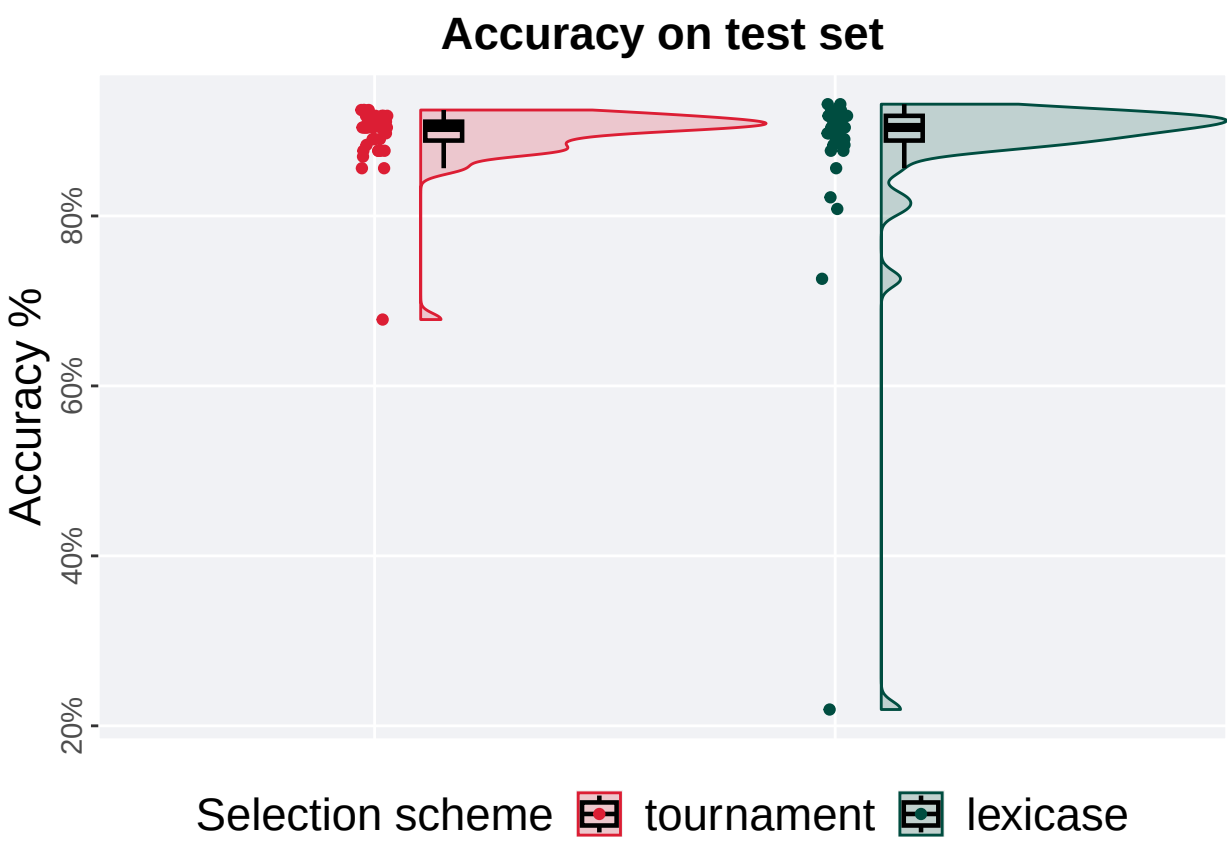
```
## [1] "observed_diff: -4.69715356107344"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.6888955870353"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```



9.4 90%

9.4.1 Testing set accuracy

```
test_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

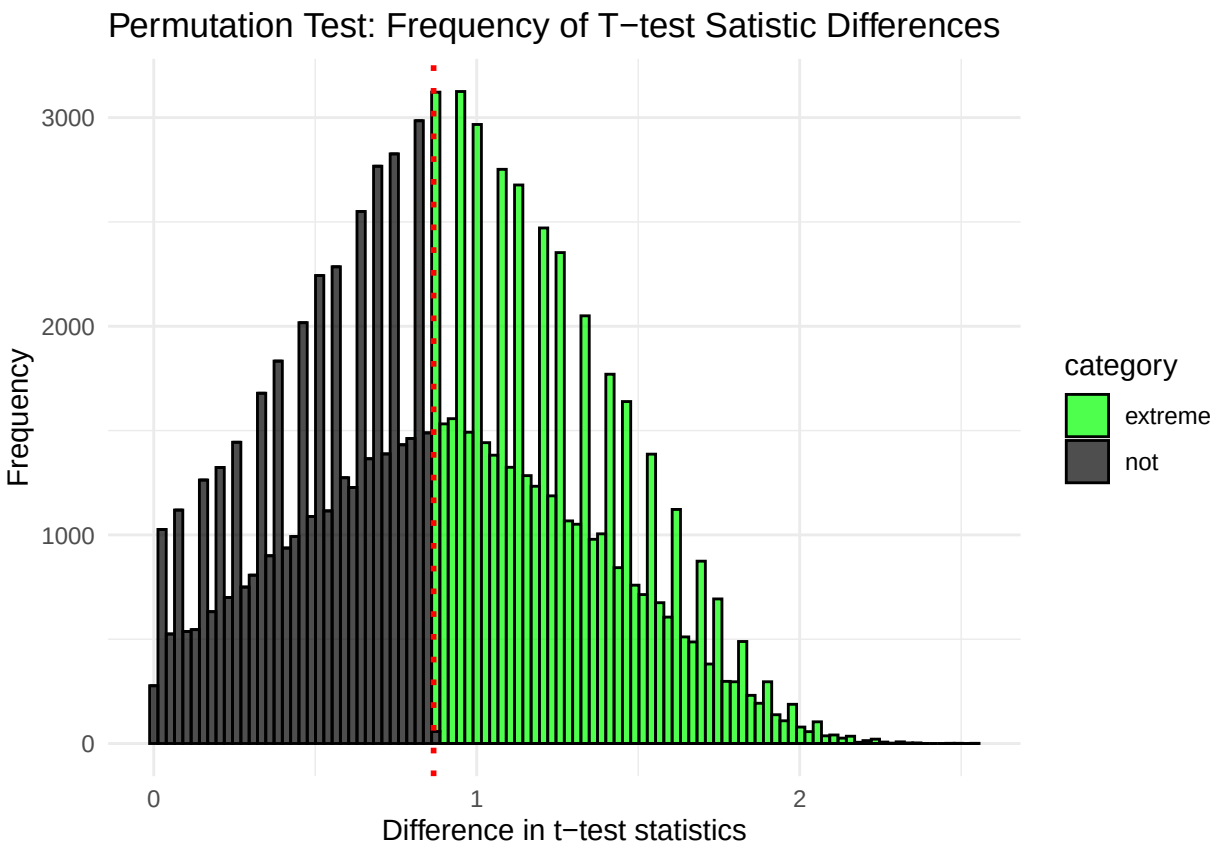
```
test_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.678  0.904 0.895 0.925 0.0223
## 2 lexicase      40      0 0.219  0.904 0.878 0.932 0.0291
```

The permutation test revealed that the results are:

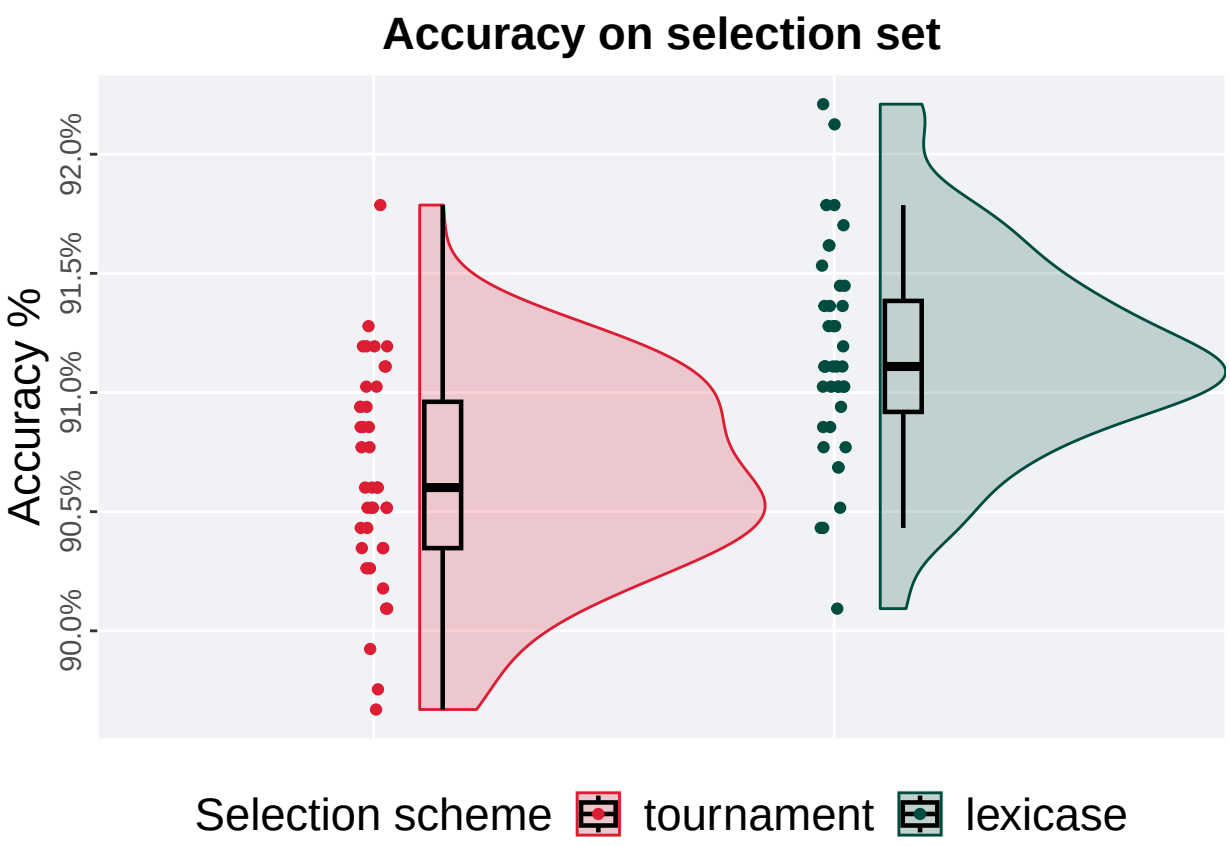
```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 77,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.866475250333264"
## [1] "lower: -1.66359475306712"
## [1] "upper: 1.66359458724114"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.53139"
```



9.4.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

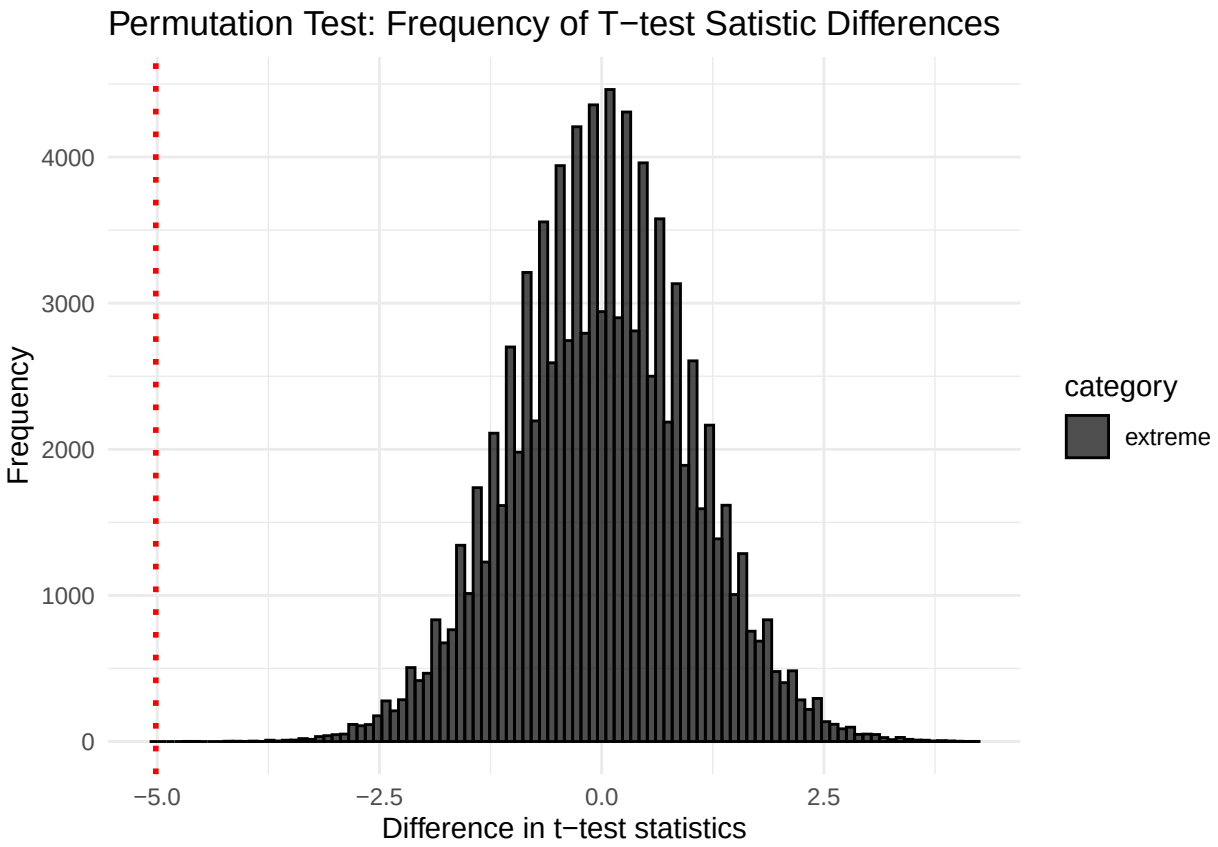
```
selection_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.897  0.906 0.907 0.918 0.00614
## 2 lexicase      40      0 0.901  0.911 0.912 0.922 0.00466
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 78,
                 alternative = "l")
```

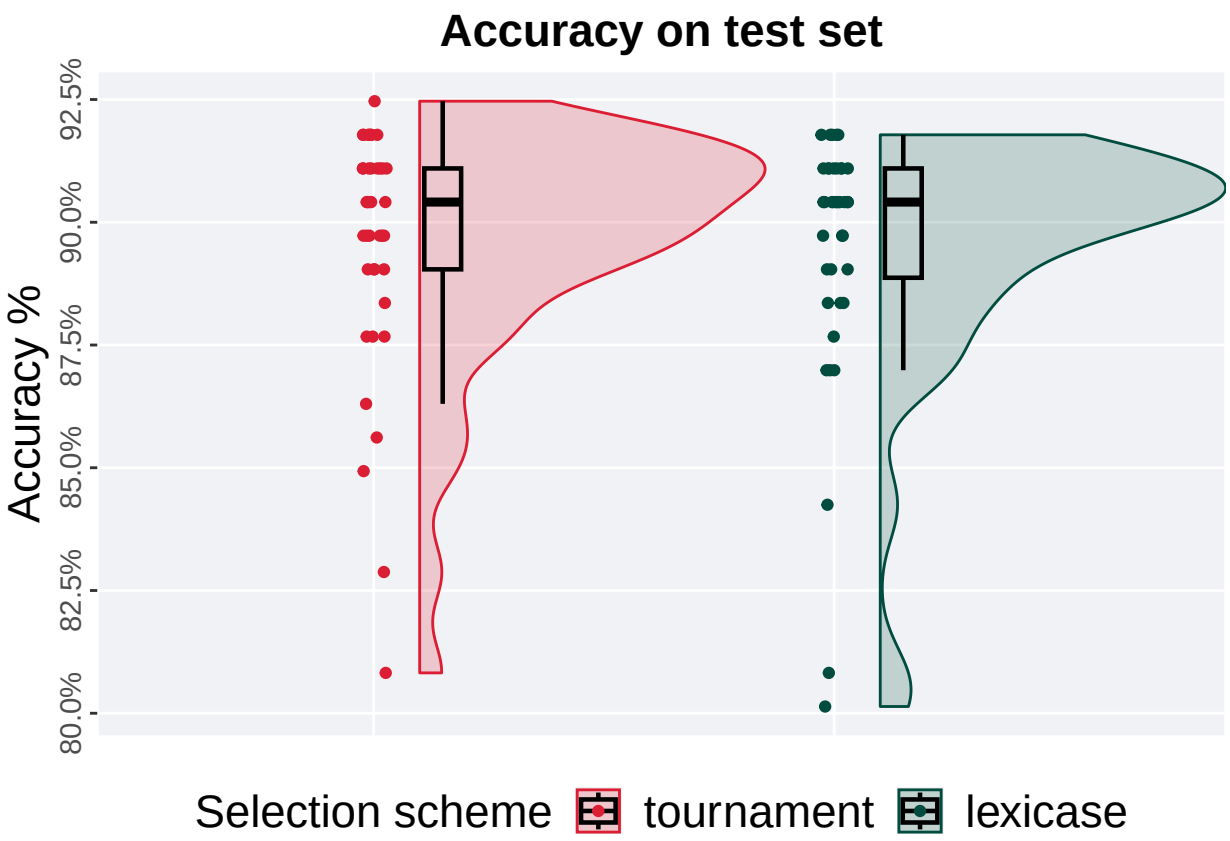
```
## [1] "observed_diff: -5.01526490705556"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.66663584058073"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```



9.5 95%

9.5.1 Testing set accuracy

```
test_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

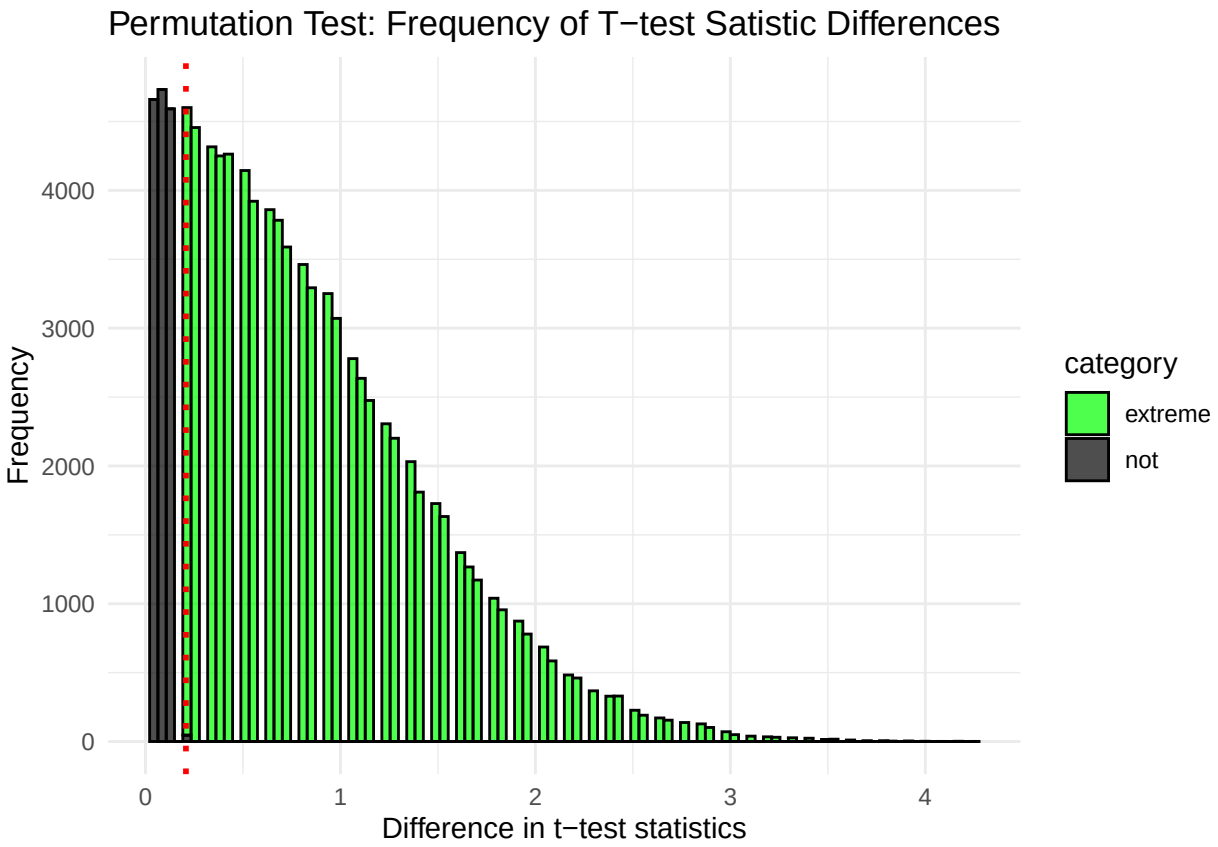
```
test_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.808  0.904 0.896 0.925 0.0205
## 2 lexicase      40      0 0.801  0.904 0.894 0.918 0.0223
```

The permutation test revealed that the results are:

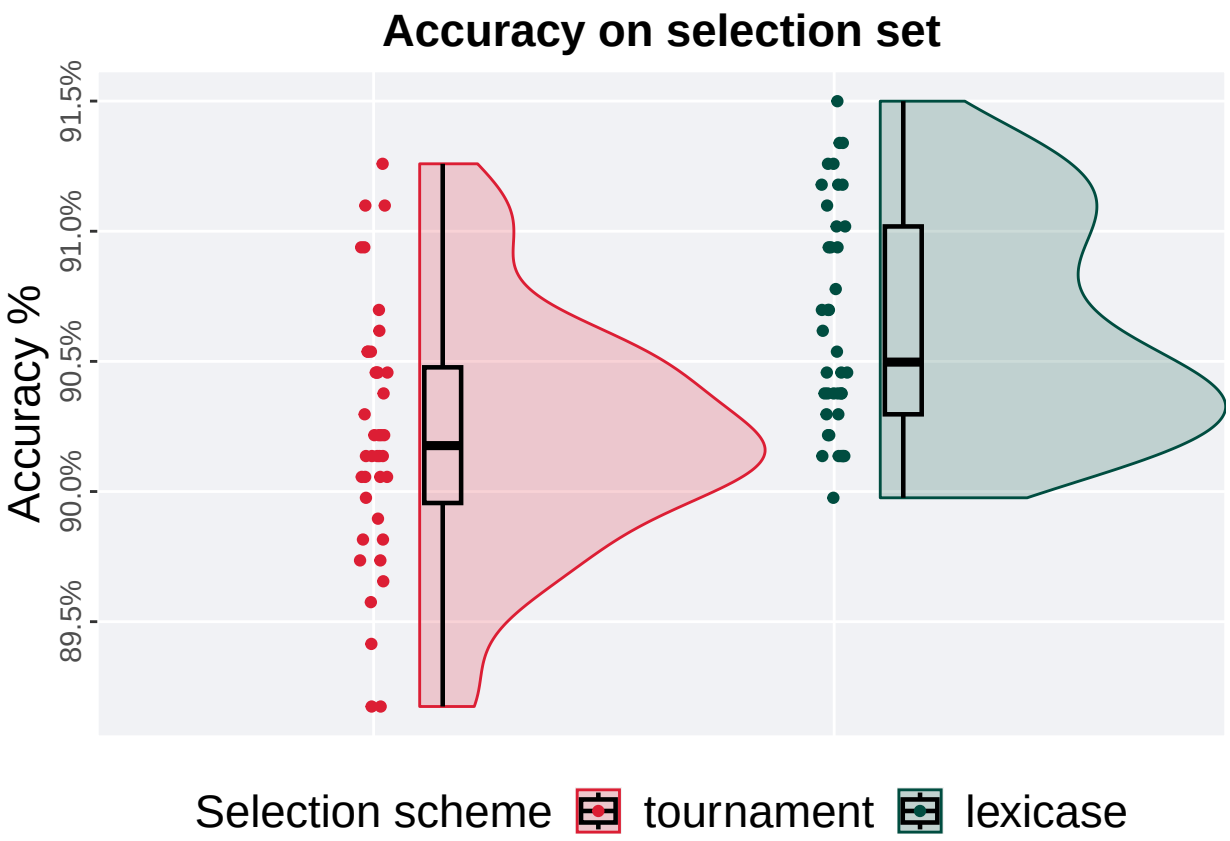
```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 79,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.207528262200296"
## [1] "lower: -1.97407111043758"
## [1] "upper: 1.97407120354954"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.8597"
```



9.5.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

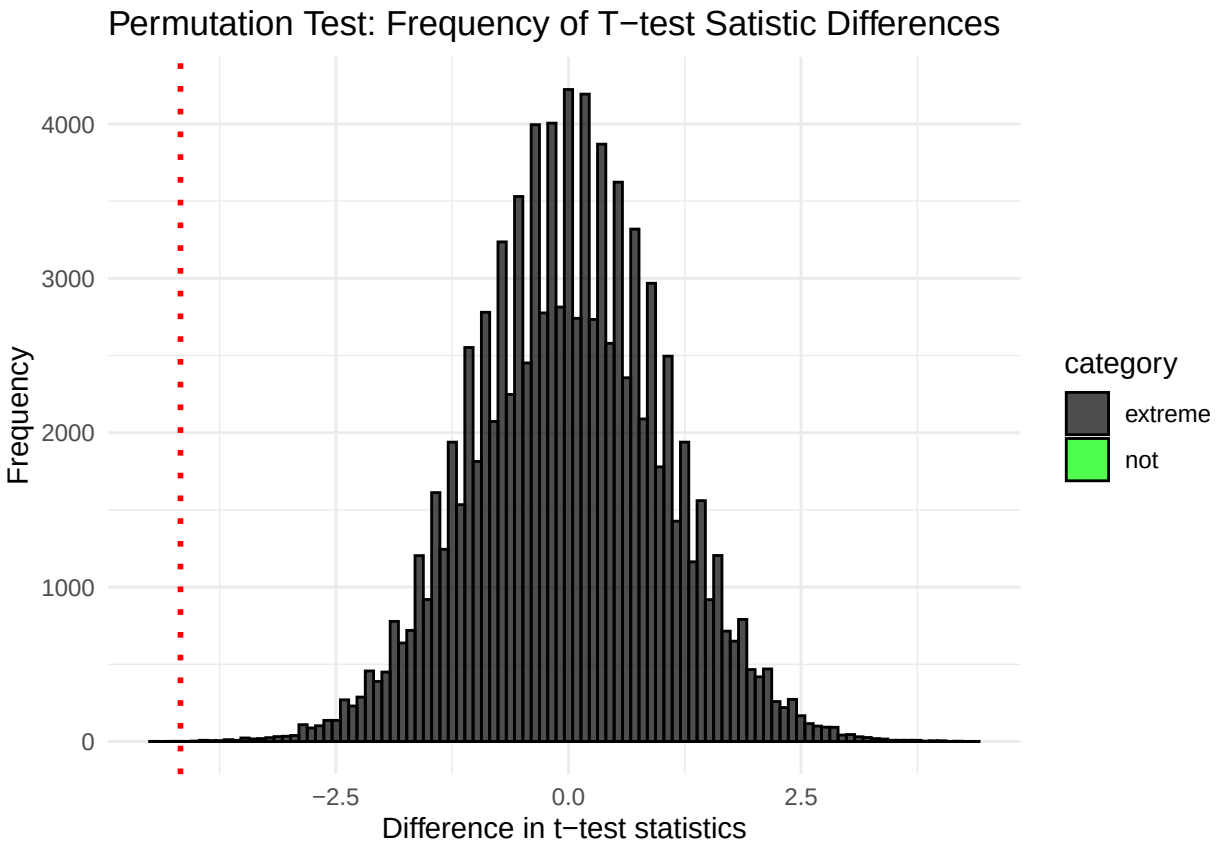
```
selection_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.892  0.902 0.902 0.913 0.00521
## 2 lexicase      40      0 0.900  0.905 0.906 0.915 0.00722
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 80,
                 alternative = "l")
```

```
## [1] "observed_diff: -4.17120455552955"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.68666533186232"
## [1] "reject null hypothesis"
## [1] "p-value: 3e-05"
```


Permutation Test: Frequency of T−test Satistic Differences
Frequency
4000
3000
2000
1000
0
−2.5
0.0
2.5
Difference in t−test statistics
category
extreme
not

Chapter 10

Task 359959

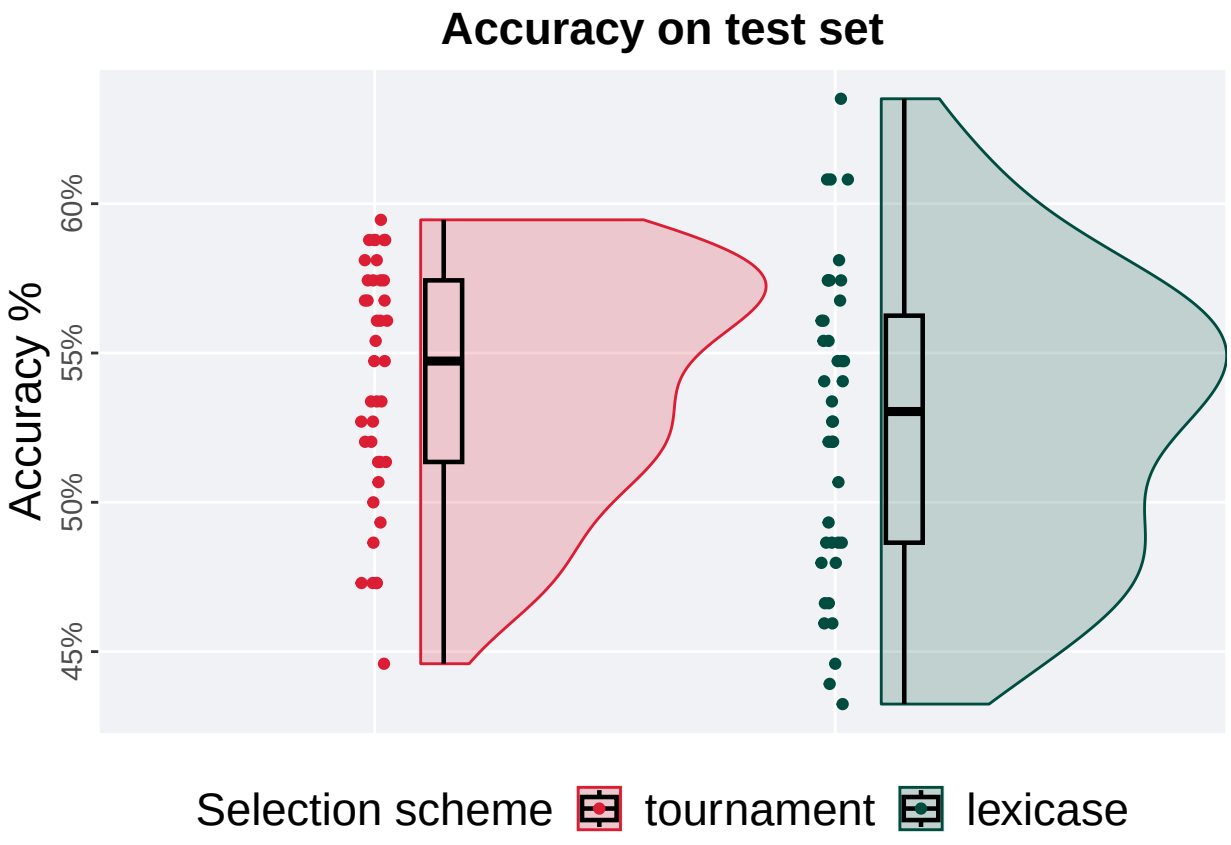
We present the results of our analysis of `task 359959` with the different selection set splits used in our study.

```
task_data <- filter(results, task_id == 359959)
```

10.1 5%

10.1.1 Testing set accuracy

```
test_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

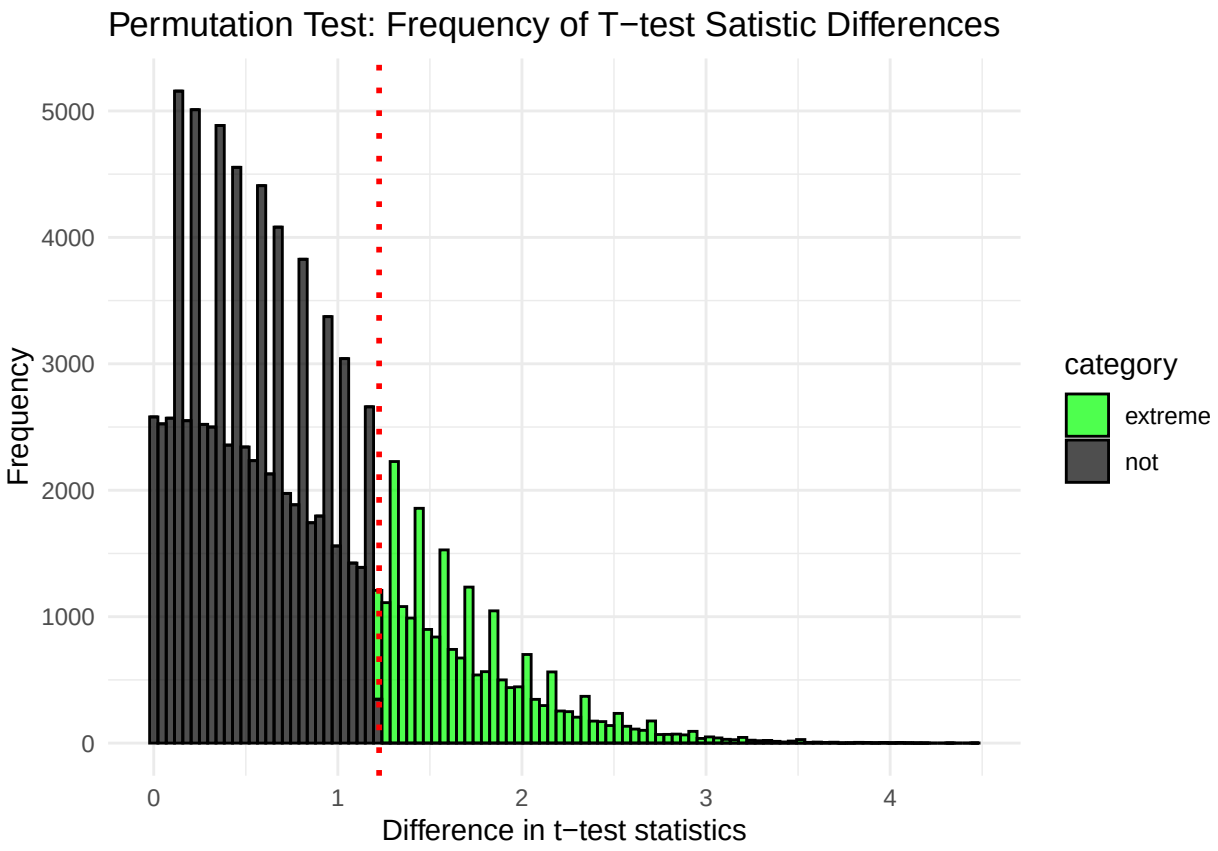
```
test_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.446  0.547 0.540 0.595 0.0608
## 2 lexicase      40      0 0.432  0.530 0.527 0.635 0.0760
```

The permutation test revealed that the results are:

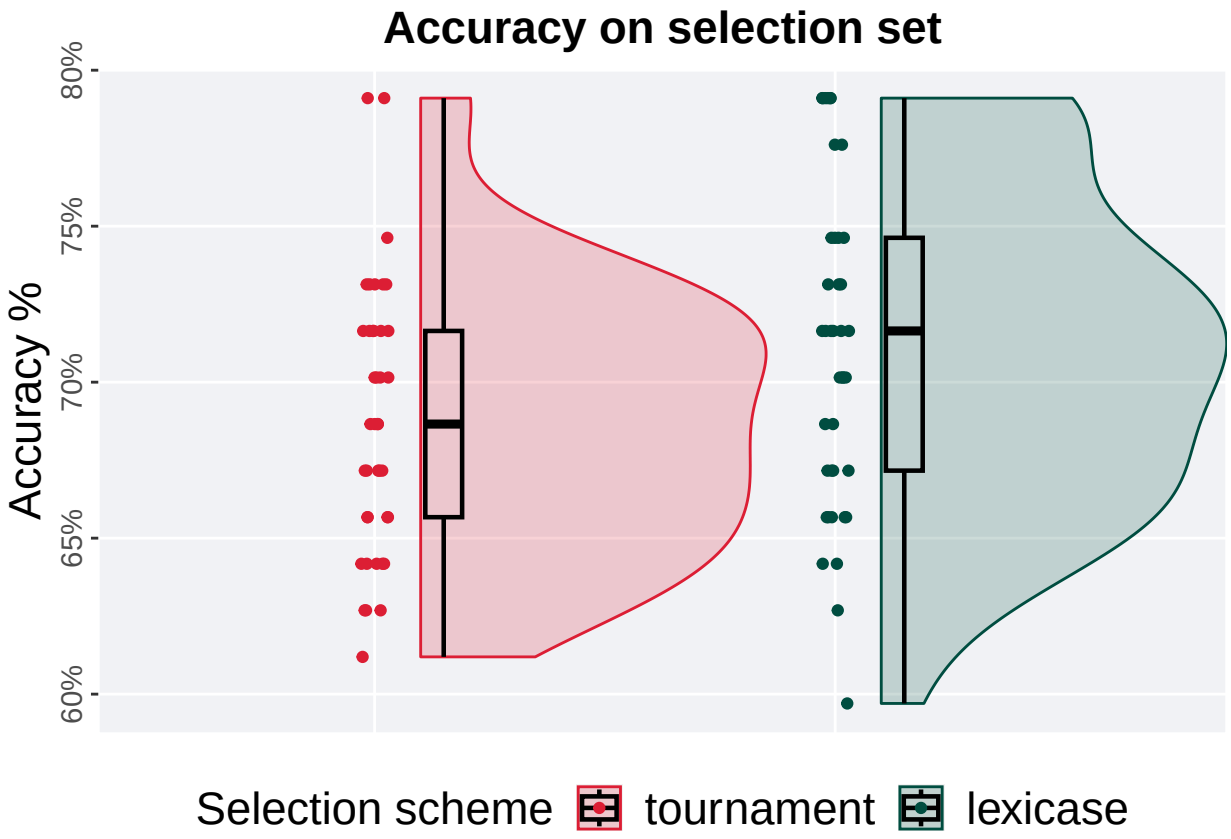
```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 81,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.22405437285302"
## [1] "lower: -1.97110919644234"
## [1] "upper: 2.00592908399195"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.22576"
```



10.1.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

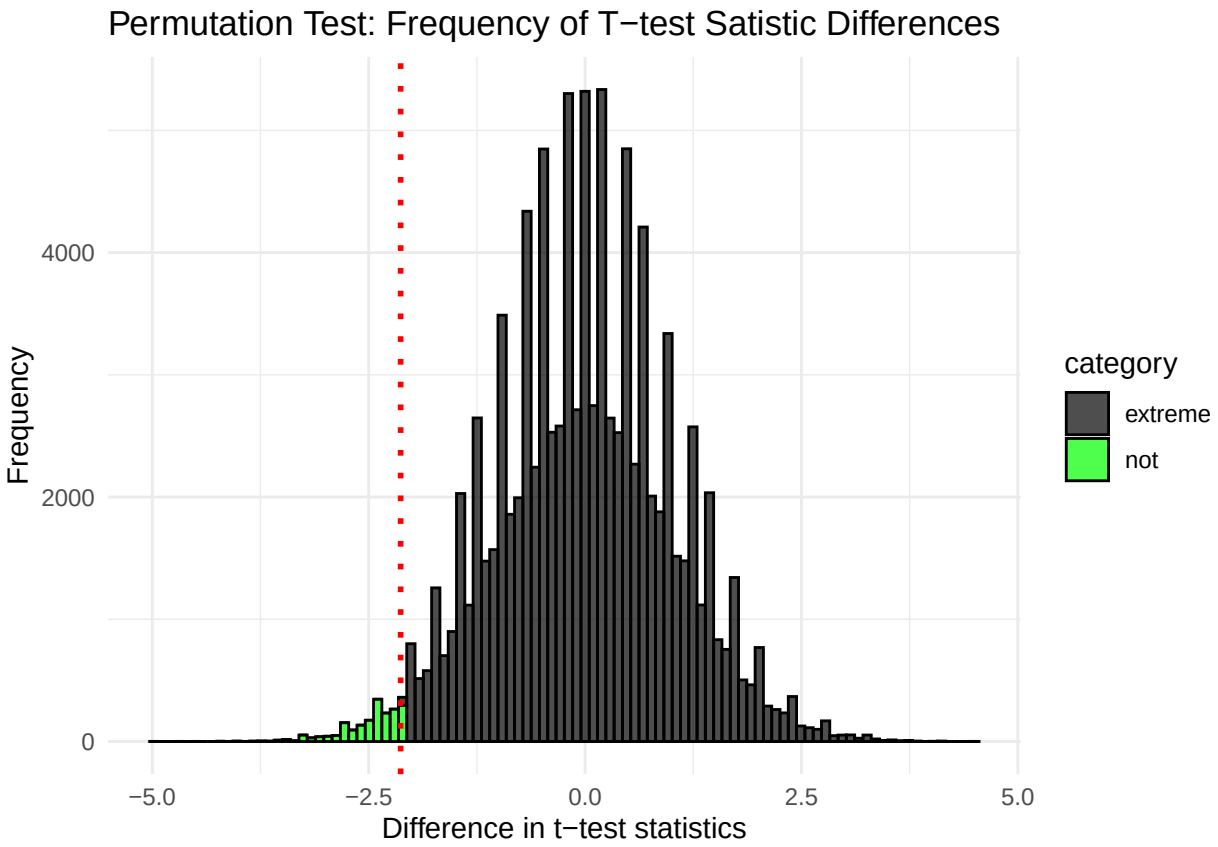
```
selection_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.612  0.687 0.688 0.791 0.0597
## 2 lexicase      40      0 0.597  0.716 0.711 0.791 0.0746
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 82,
                 alternative = "l")
```

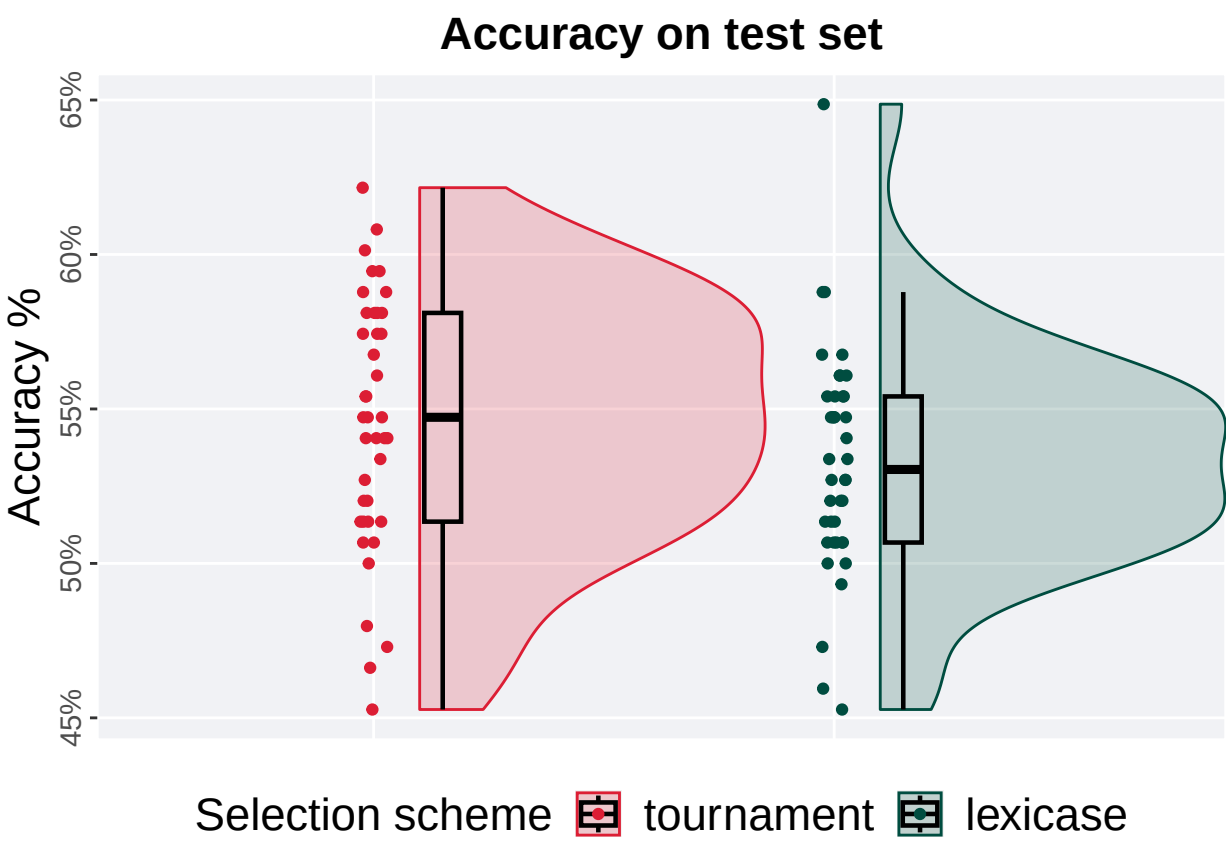
```
## [1] "observed_diff: -2.13091175211124"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.69431049247206"
## [1] "reject null hypothesis"
## [1] "p-value: 0.01963"
```



10.2 10%

10.2.1 Testing set accuracy

```
test_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

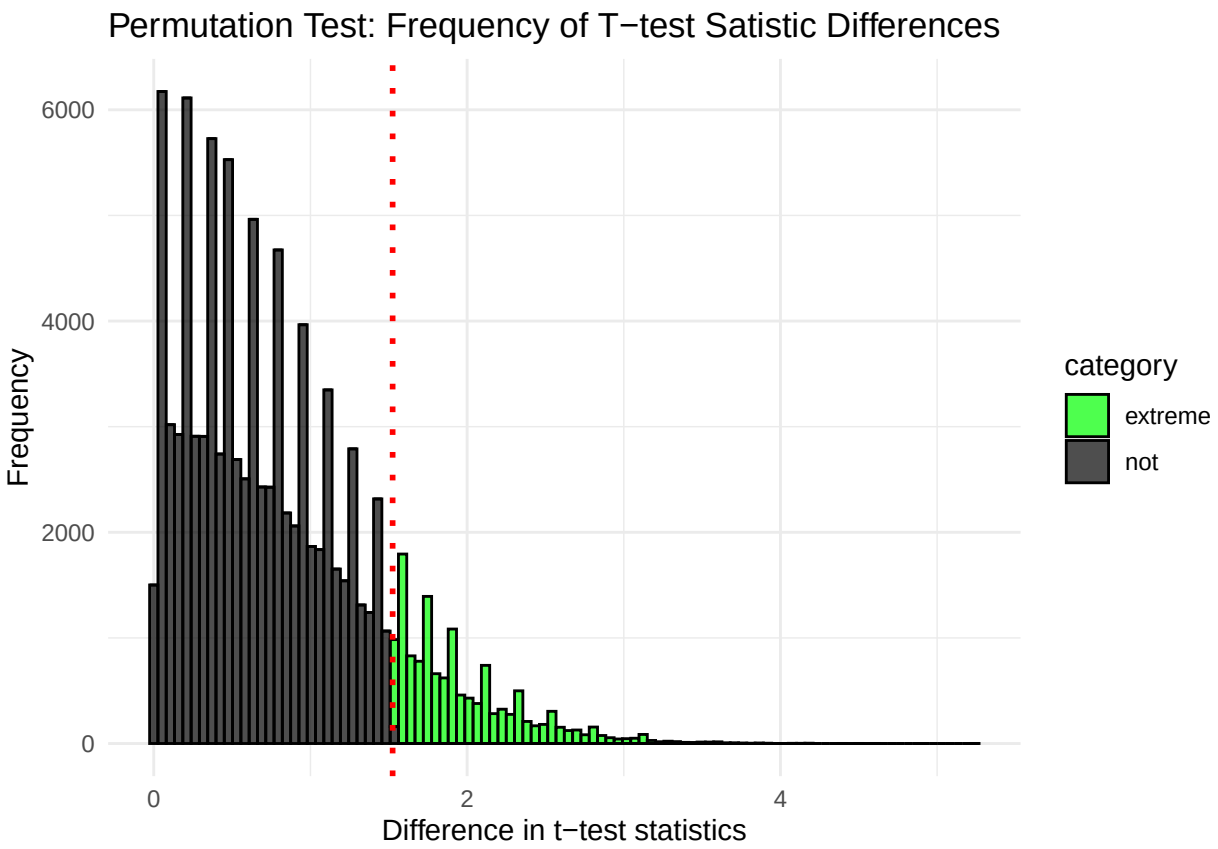
```
test_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.453  0.547 0.546 0.622 0.0676
## 2 lexicase      40      0 0.453  0.530 0.532 0.649 0.0473
```

The permutation test revealed that the results are:

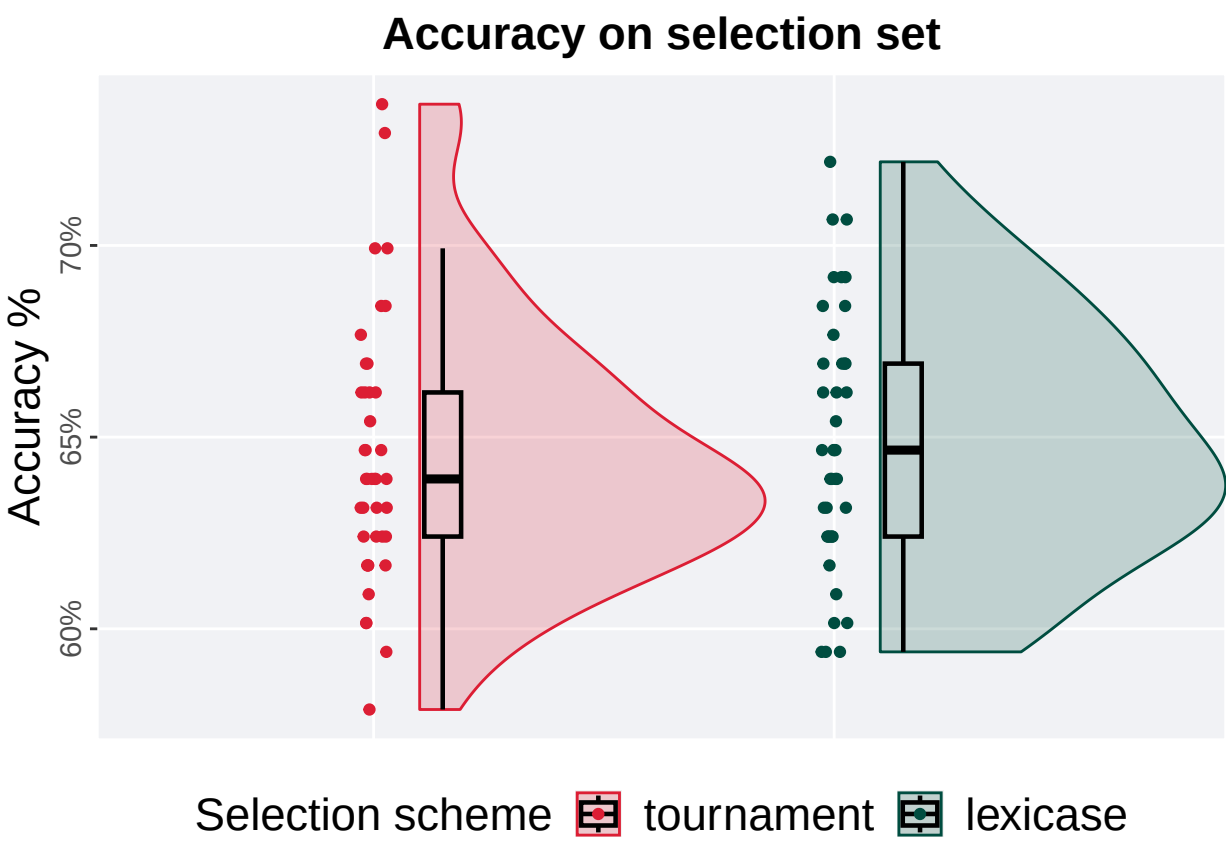
```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 83,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.52463147615729"
## [1] "lower: -2.01518489005153"
## [1] "upper: 1.97367777918776"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.13434"
```



10.2.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

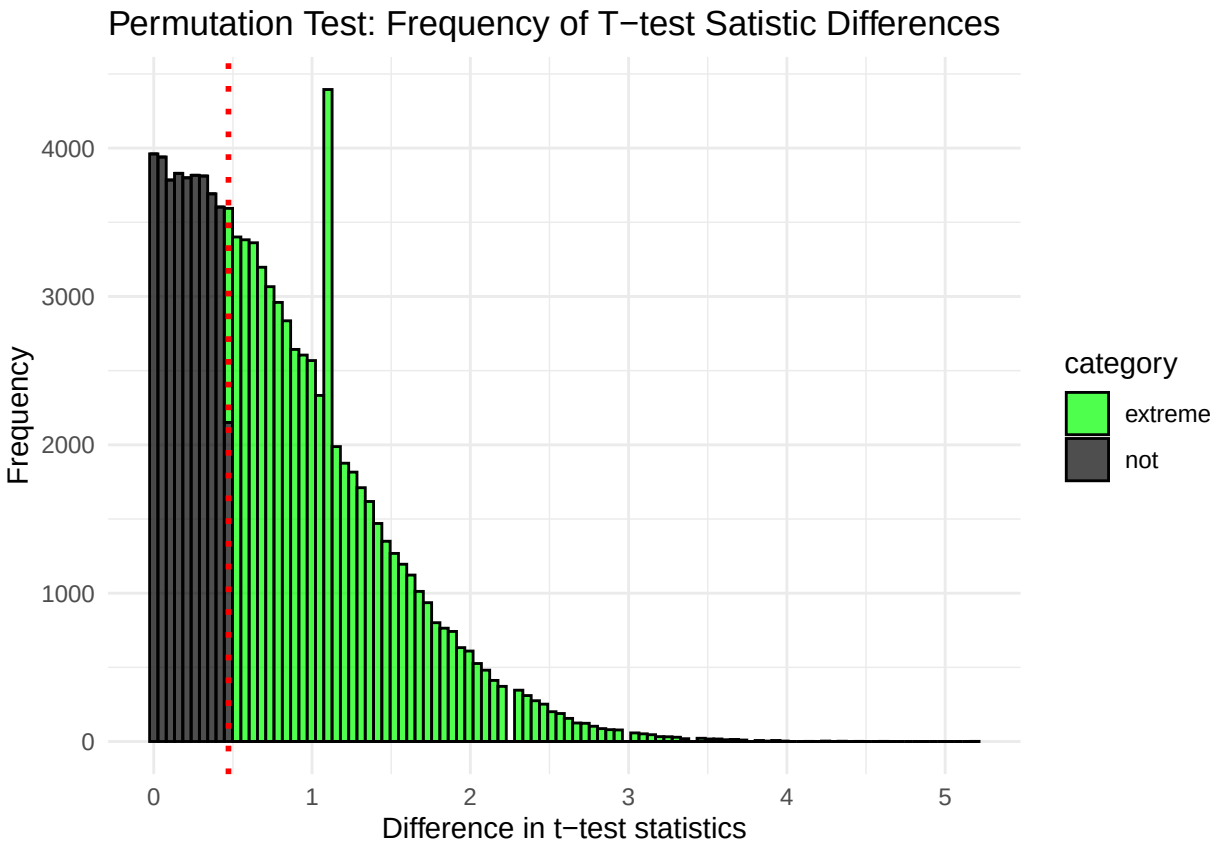
```
selection_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.579  0.639 0.645 0.737 0.0376
## 2 lexicase      40      0 0.594  0.647 0.648 0.722 0.0451
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 84,
                 alternative = "t")
```

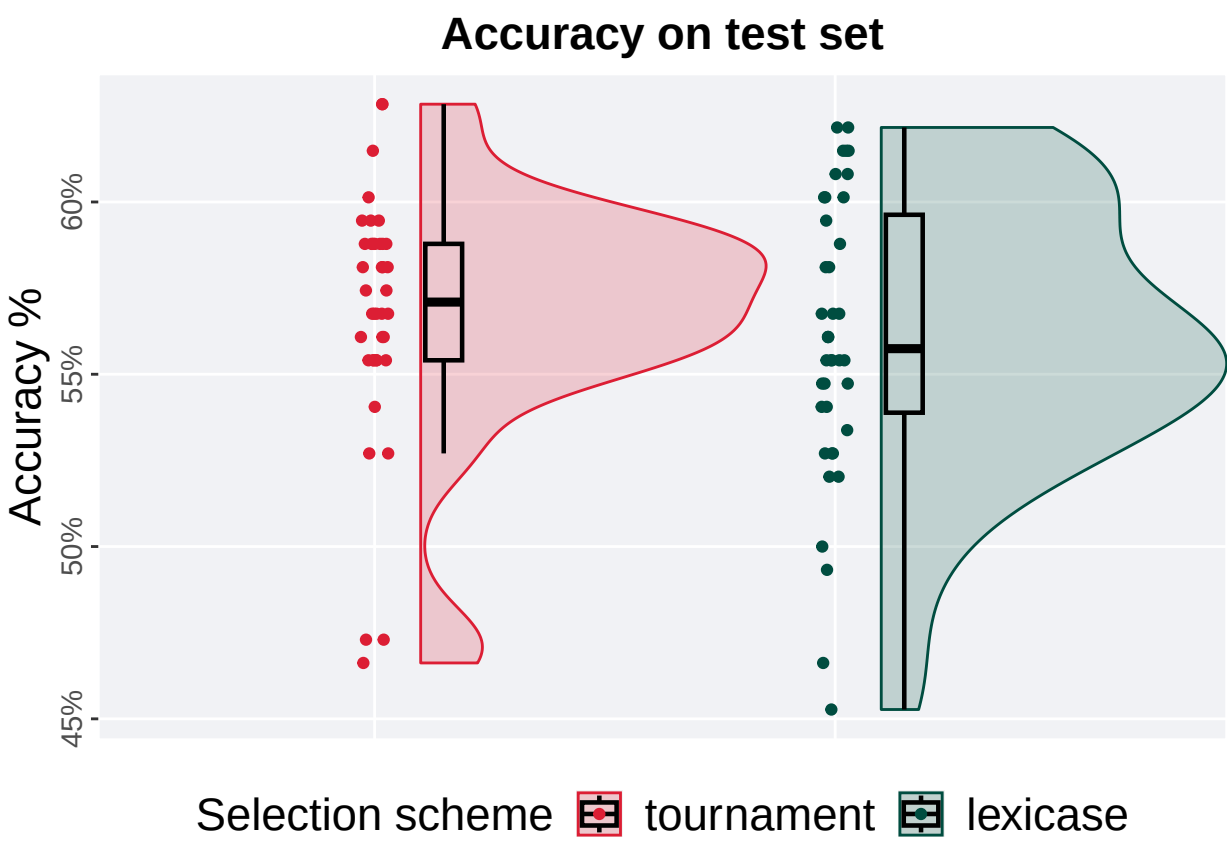
```
## [1] "observed_diff: -0.471913297591953"
## [1] "lower: -2.0094448325709"
## [1] "upper: 2.00944582884462"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.63609"
```



10.3 50%

10.3.1 Testing set accuracy

```
test_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

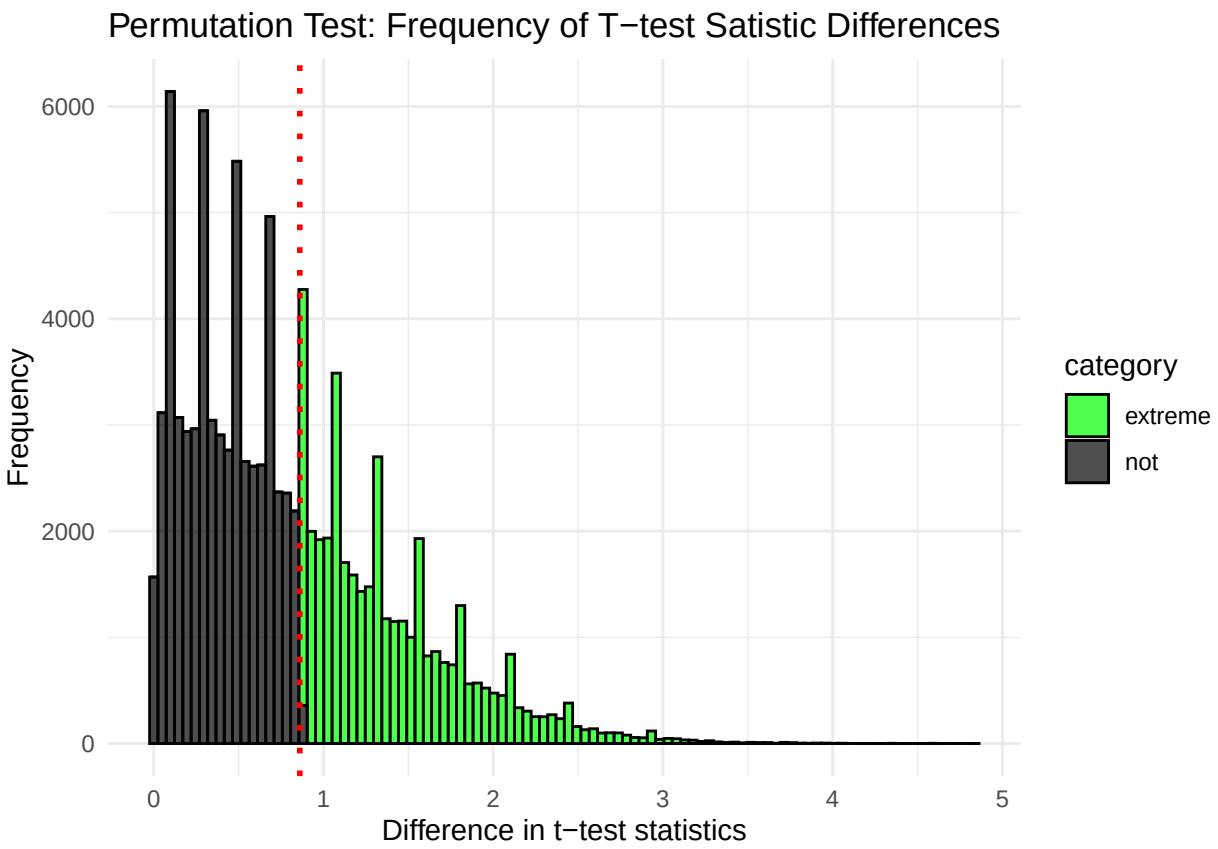
```
test_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.466  0.571 0.567 0.628 0.0338
## 2 lexicase      40      0 0.453  0.557 0.560 0.622 0.0574
```

The permutation test revealed that the results are:

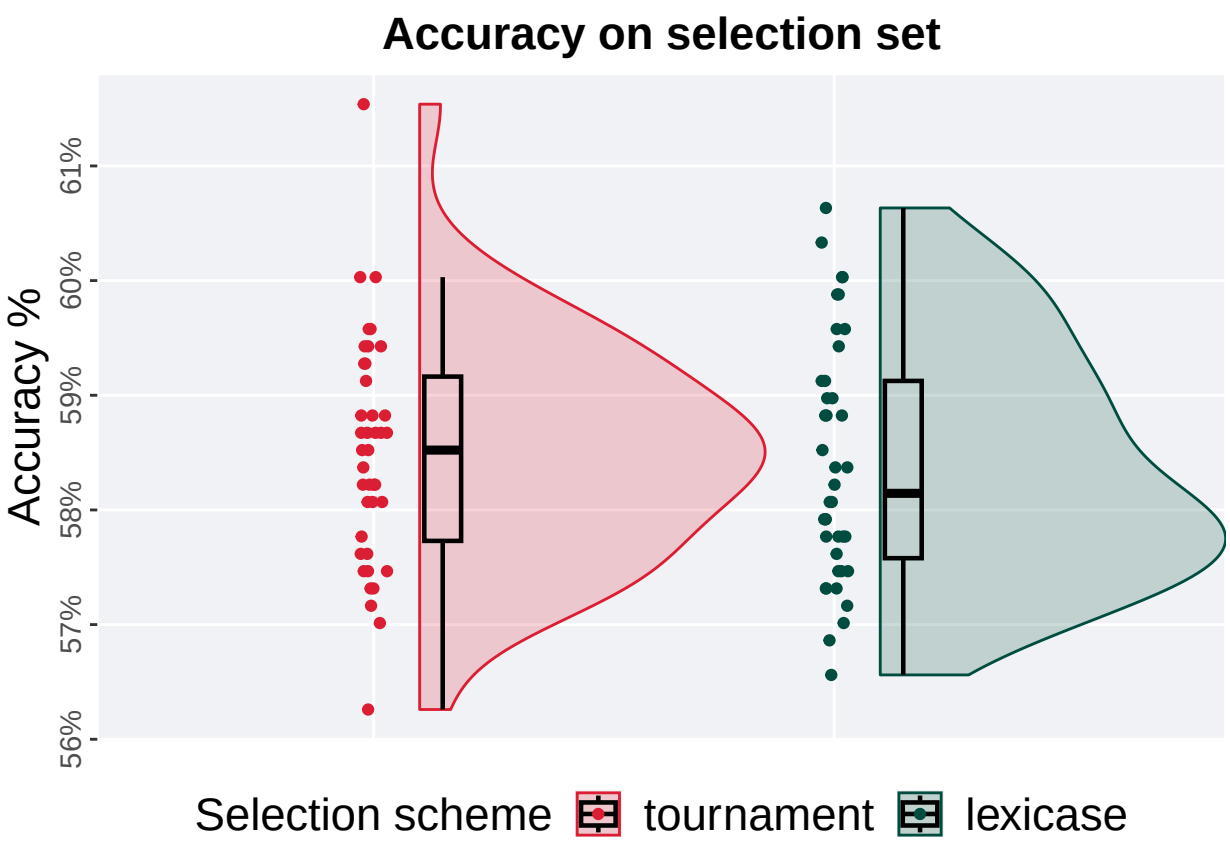
```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 85,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.86047817755061"
## [1] "lower: -1.99548160987446"
## [1] "upper: 1.99548229277239"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.39919"
```



10.3.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

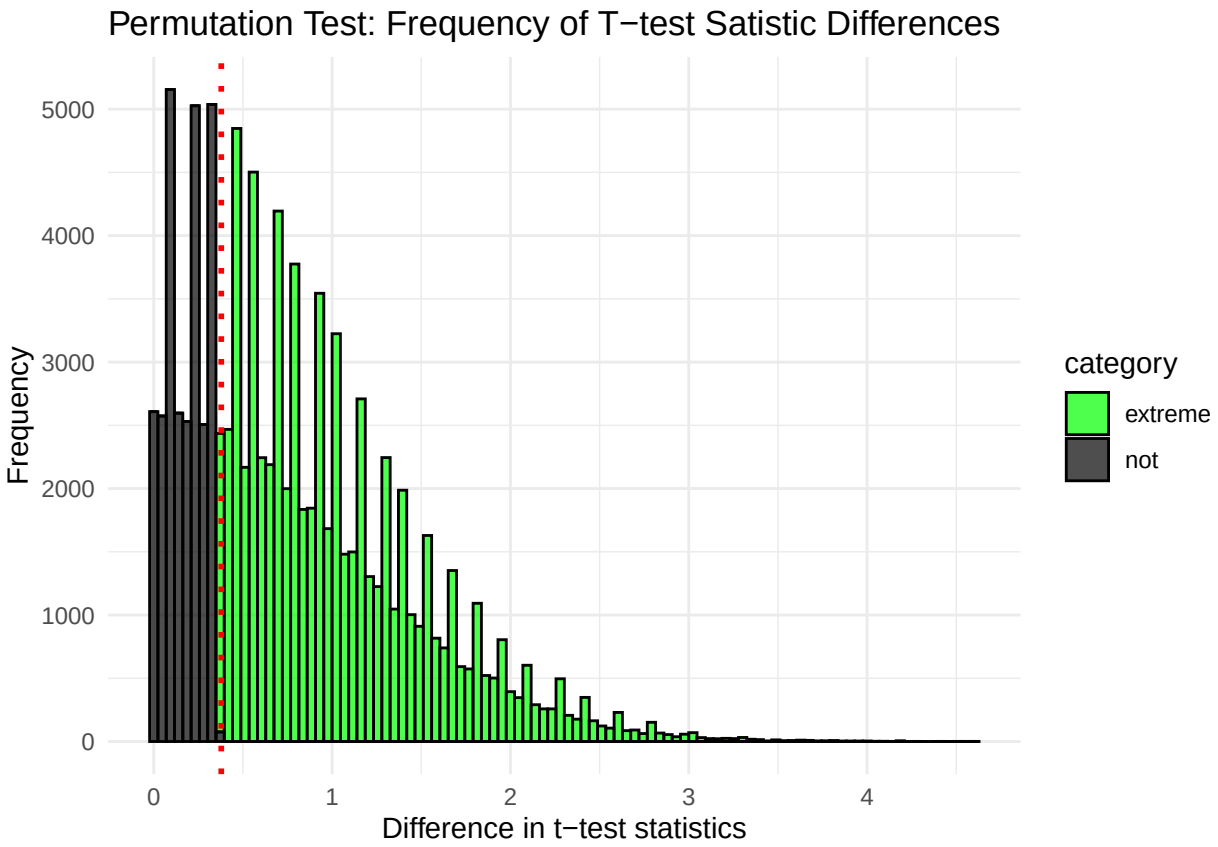
```
selection_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.563  0.585 0.585 0.615 0.0143
## 2 lexicase      40      0 0.566  0.581 0.584 0.606 0.0155
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 86,
                 alternative = "t")
```

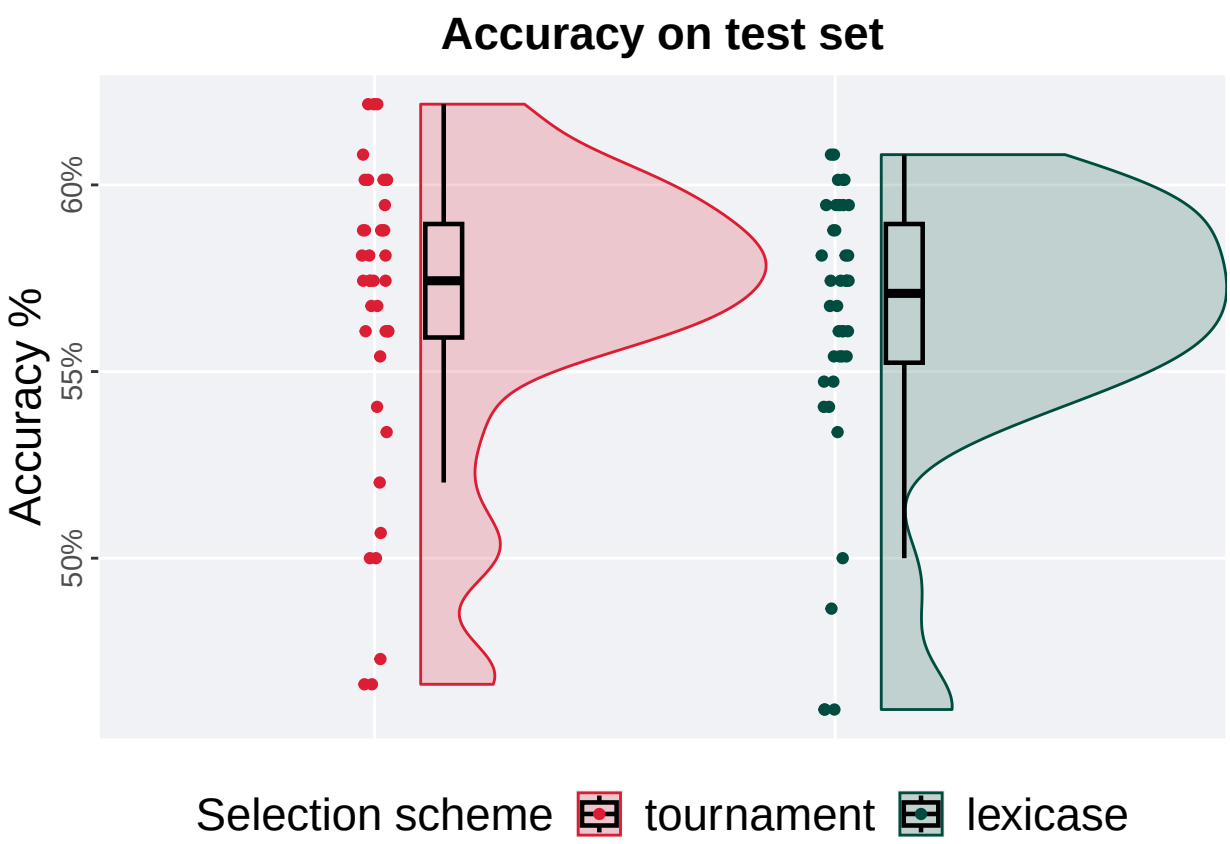
```
## [1] "observed_diff: 0.378541953307579"
## [1] "lower: -2.00662736312658"
## [1] "upper: 1.97121031816678"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.7189"
```



10.4 90%

10.4.1 Testing set accuracy

```
test_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

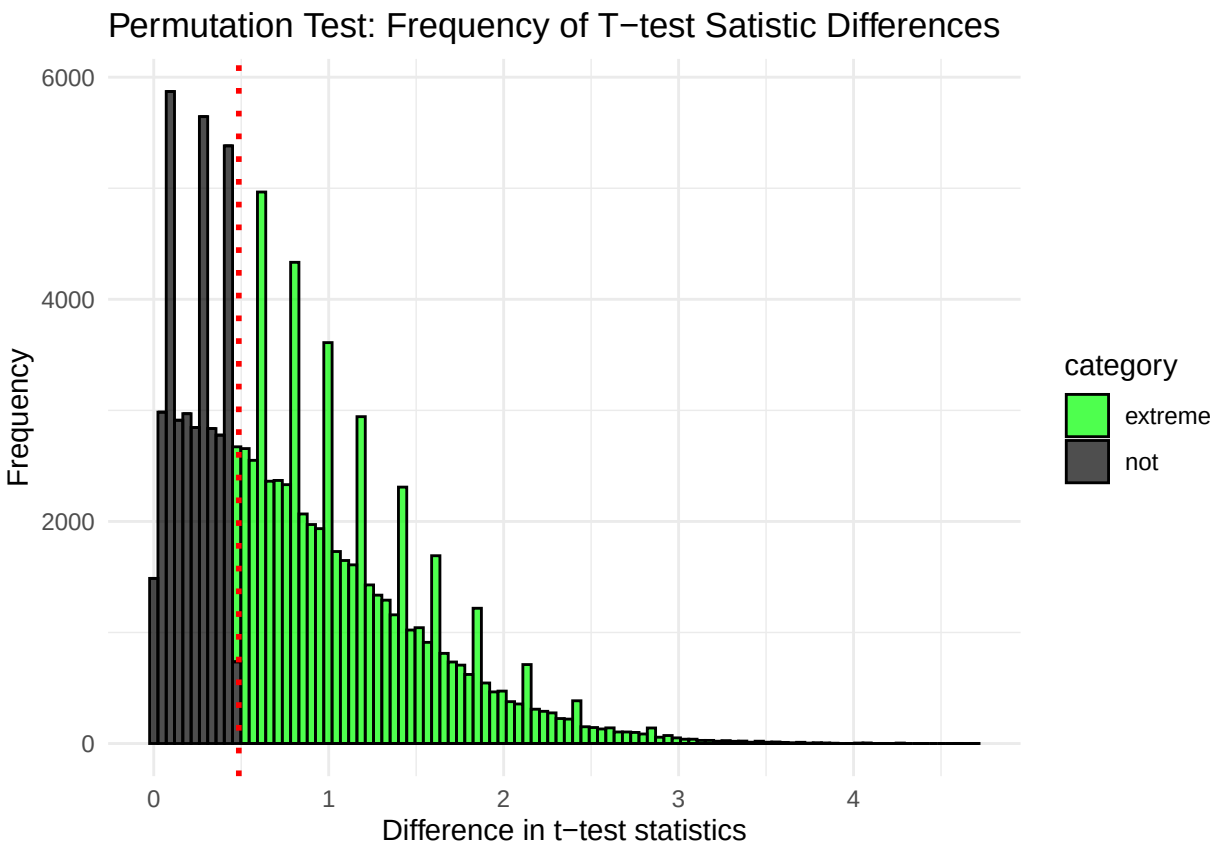
```
test_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.466  0.574 0.566 0.622 0.0304
## 2 lexicase      40      0 0.459  0.571 0.561 0.608 0.0372
```

The permutation test revealed that the results are:

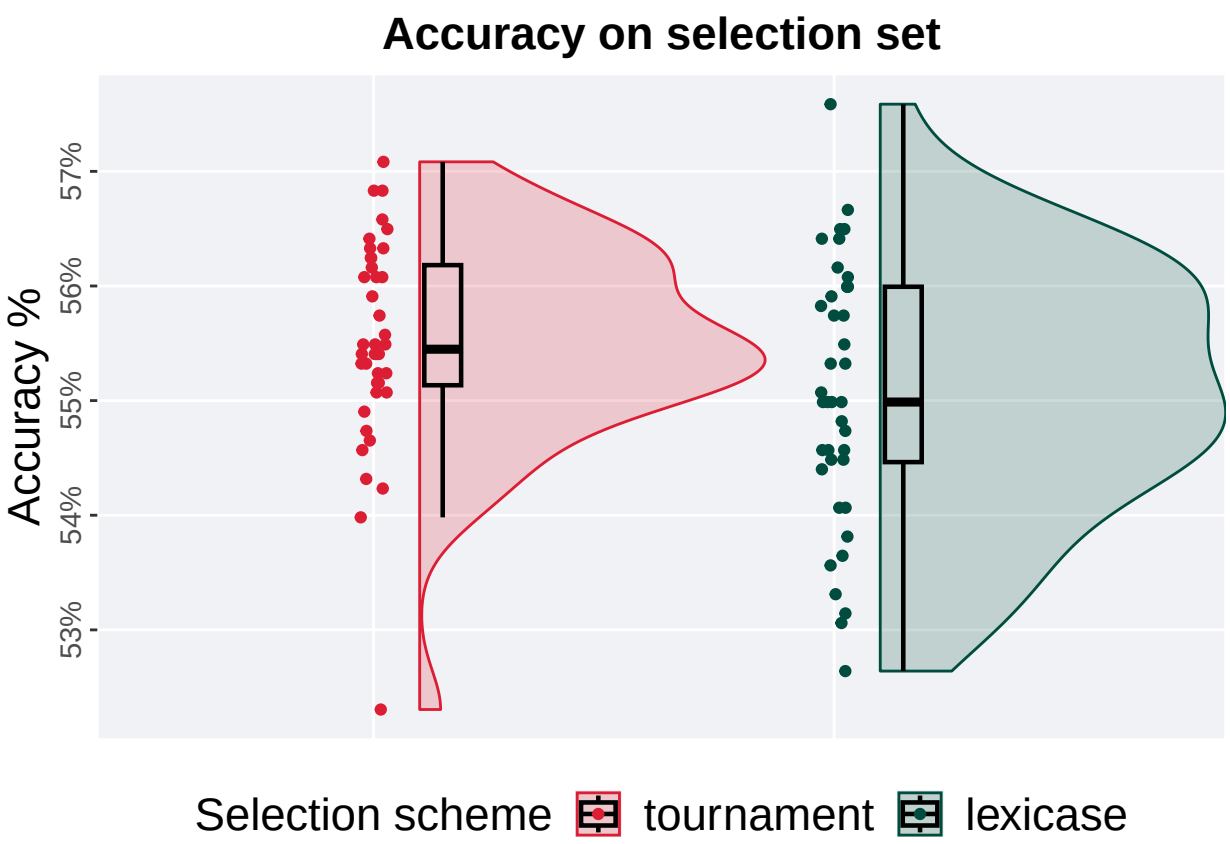
```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 87,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.486150157327831"
## [1] "lower: -1.99036008856116"
## [1] "upper: 1.99036008856116"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.63556"
```



10.4.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

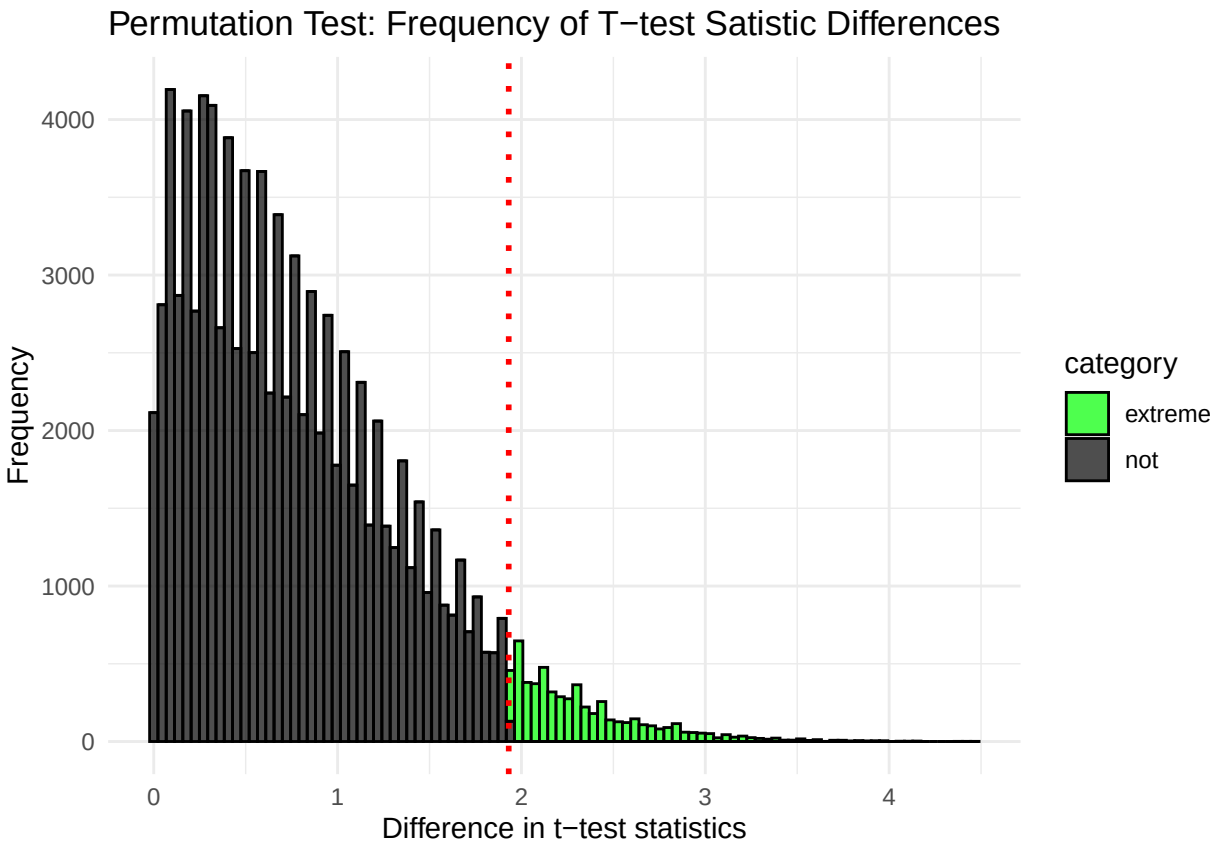
```
selection_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.523  0.554 0.555 0.571 0.0105
## 2 lexicase      40      0 0.526  0.550 0.551 0.576 0.0153
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 88,
                 alternative = "t")
```

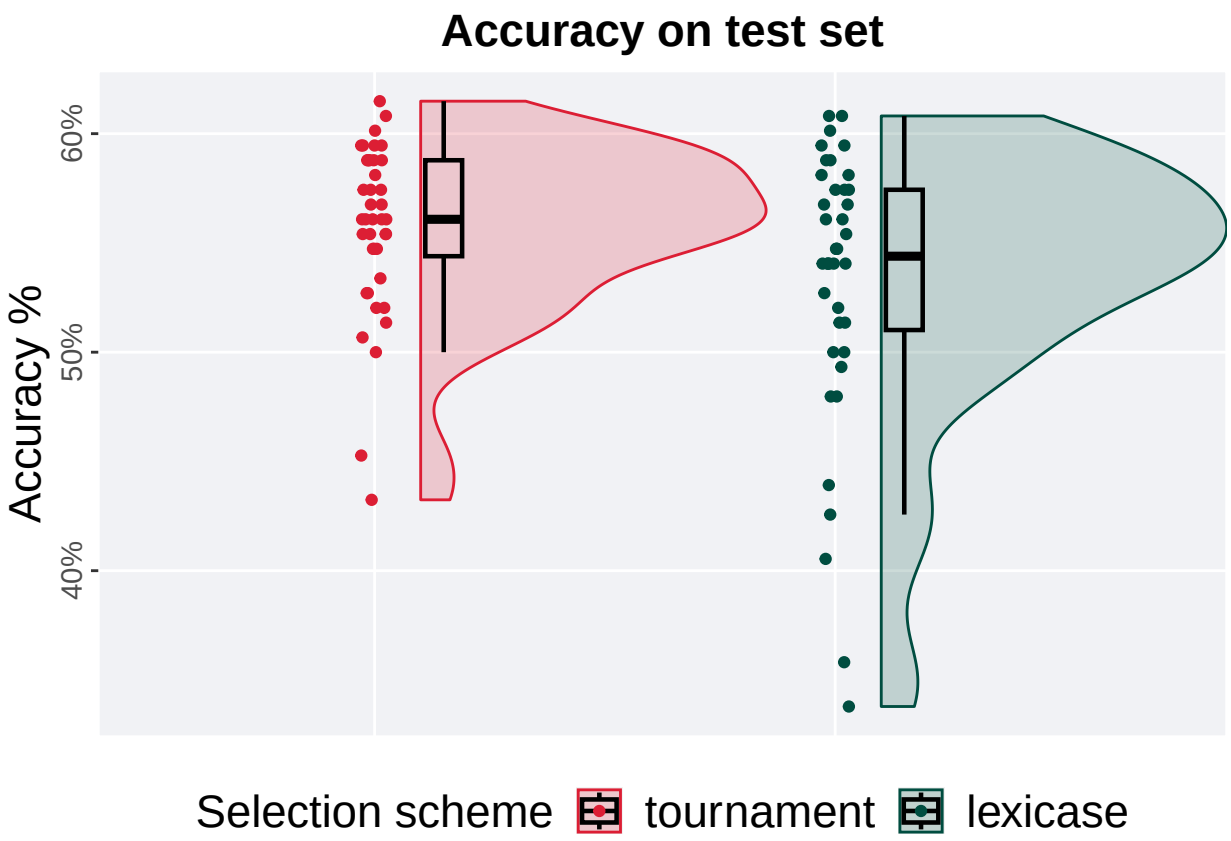
```
## [1] "observed_diff: 1.93069243094997"
## [1] "lower: -2.00723673836918"
## [1] "upper: 1.98806145362816"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.05679"
```



10.5 95%

10.5.1 Testing set accuracy

```
test_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

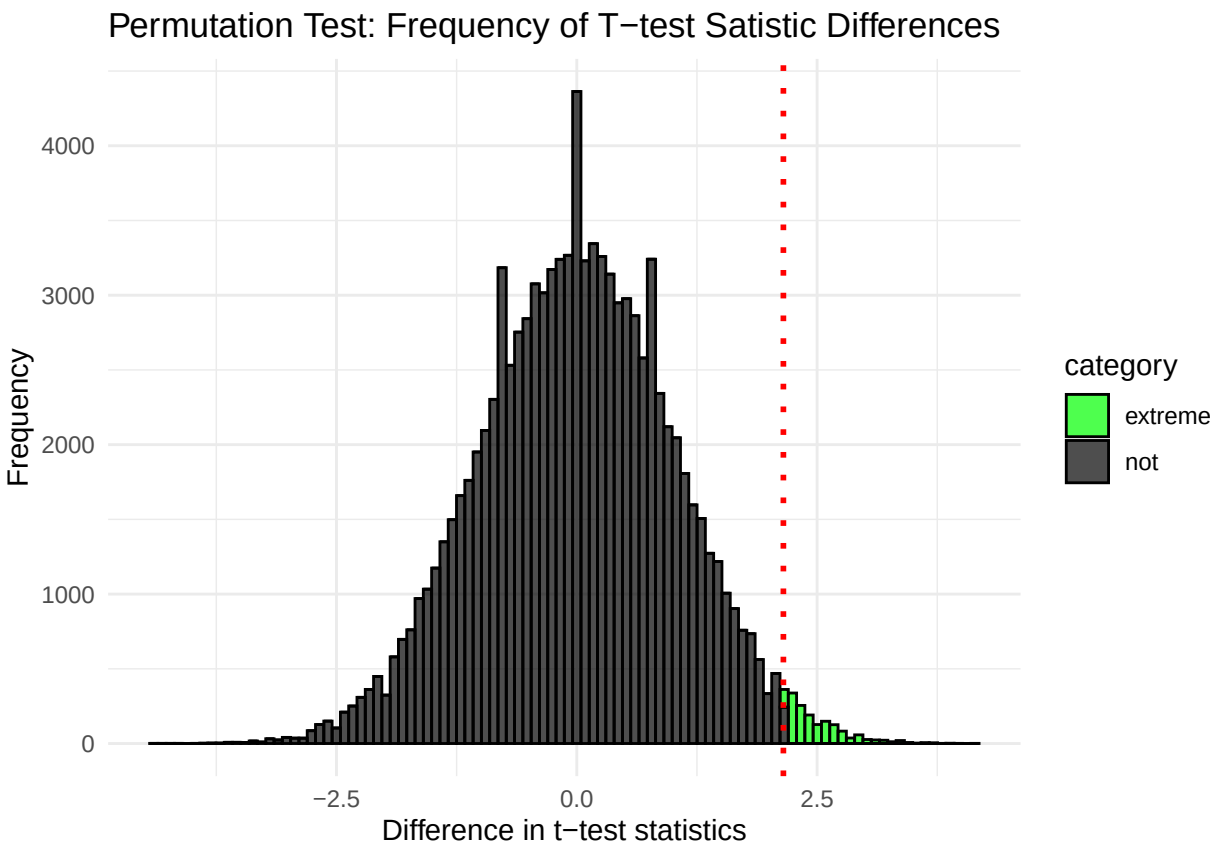
```
test_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.432  0.561 0.557 0.615 0.0439
## 2 lexicase      40      0 0.338  0.544 0.531 0.608 0.0642
```

The permutation test revealed that the results are:

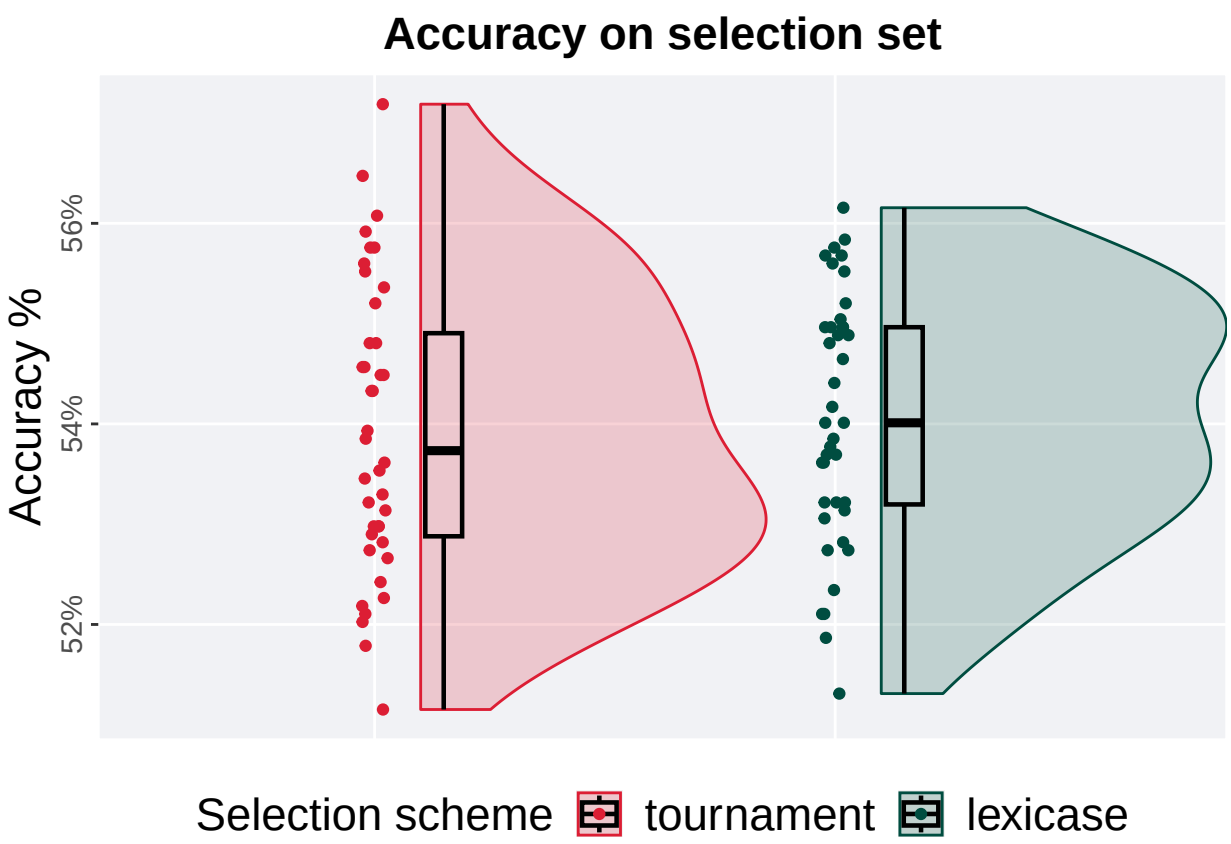
```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 89,
                 alternative = "g")
```

```
## [1] "observed_diff: 2.14920138405129"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.64591413063659"
## [1] "reject null hypothesis"
## [1] "p-value: 0.01608"
```



10.5.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

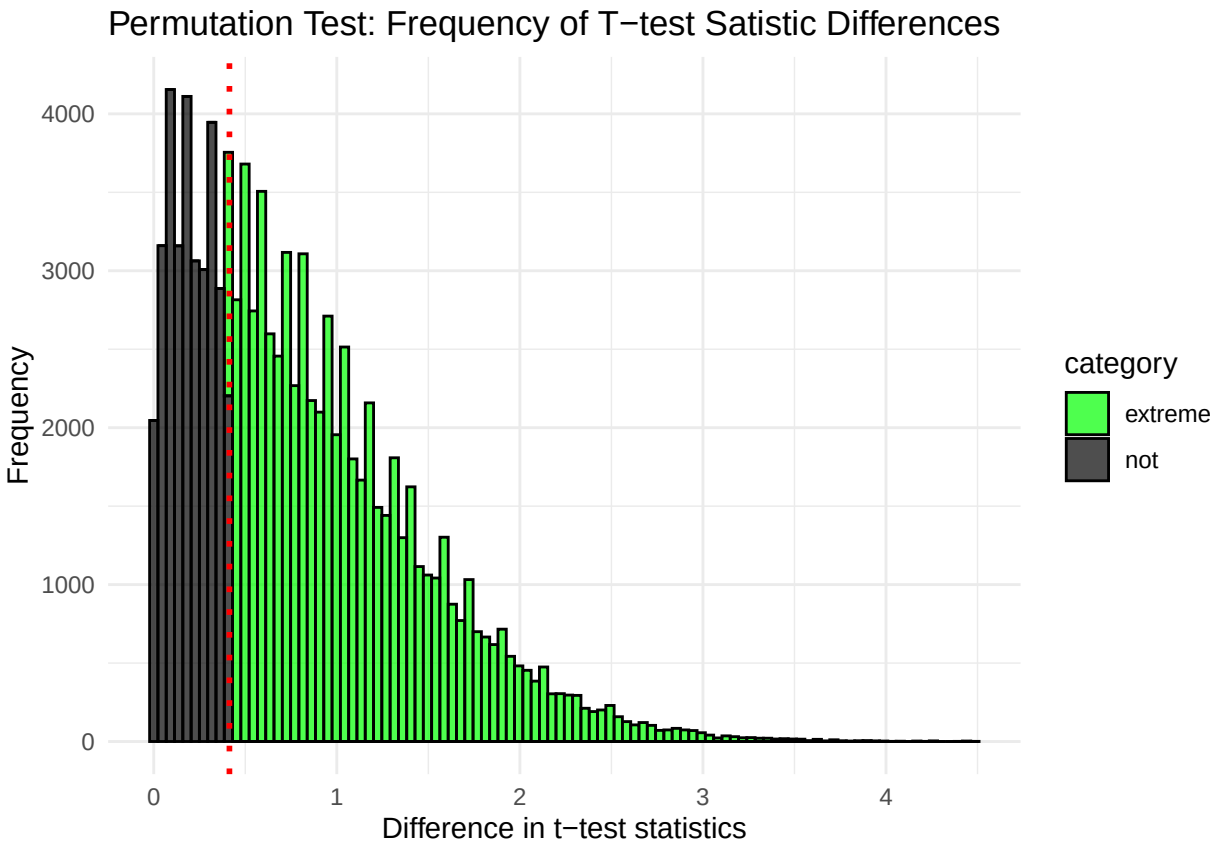
```
selection_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.512  0.537 0.539 0.572 0.0203
## 2 lexicase      40      0 0.513  0.540 0.541 0.562 0.0177
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 90,
                 alternative = "t")
```

```
## [1] "observed_diff: -0.413305888924775"
## [1] "lower: -1.9953719420889"
## [1] "upper: 1.99537354233663"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.68262"
```


Permutation Test: Frequency of T−test Satistic Differences
Frequency
4000
3000
2000
1000
0
0
1
2
3
4
Difference in t−test statistics
category
extreme
not

Chapter 11

Task 2073

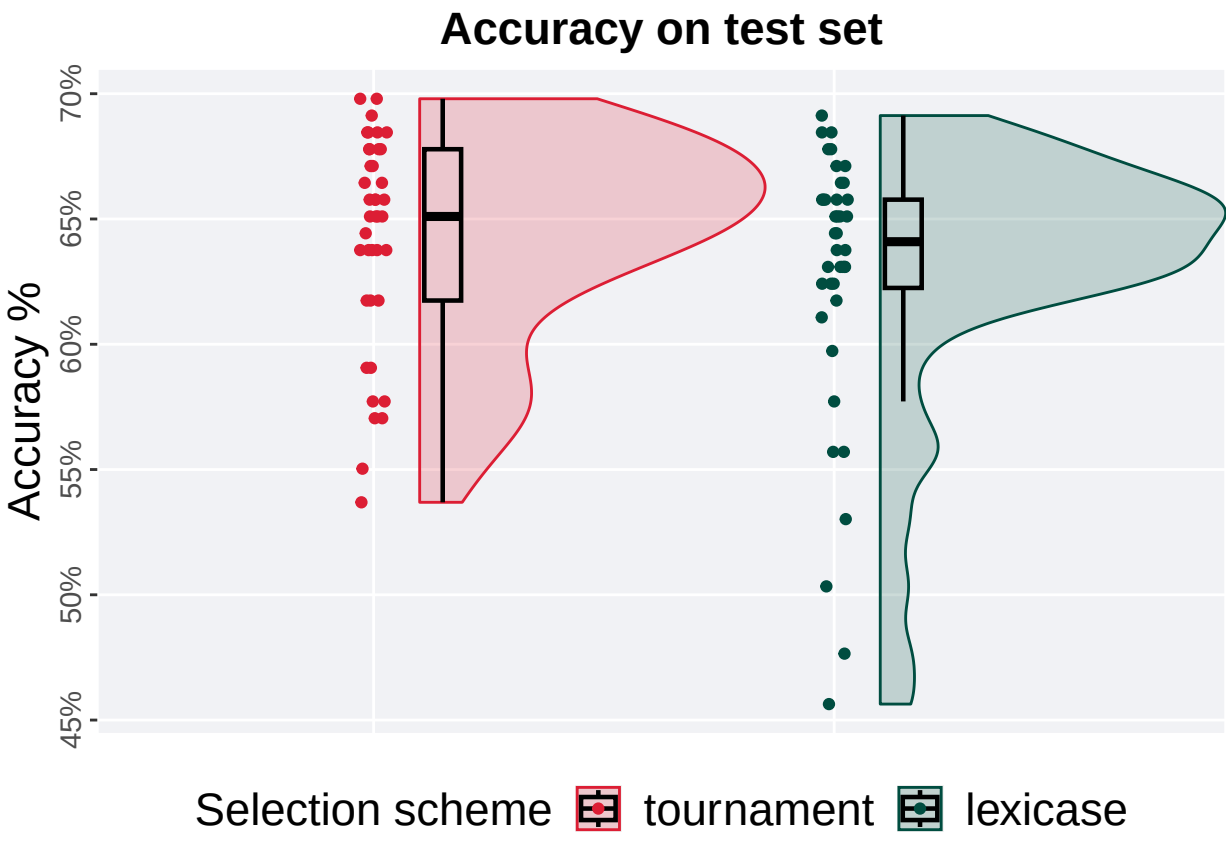
We present the results of our analysis of `task 2073` with the different selection set splits used in our study.

```
task_data <- filter(results, task_id == 2073)
```

11.1 5%

11.1.1 Testing set accuracy

```
test_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

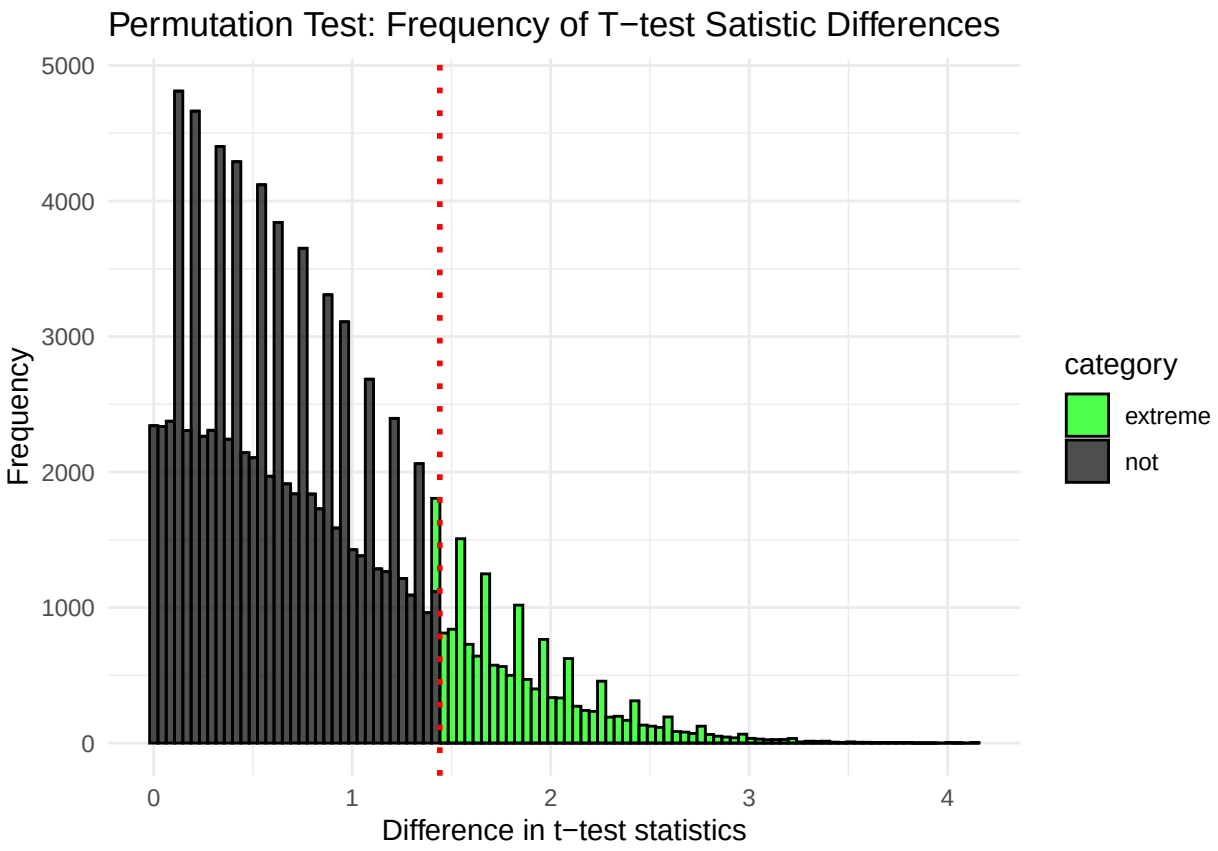
```
test_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.537  0.651 0.642 0.698 0.0604
## 2 lexicase      40      0 0.456  0.641 0.626 0.691 0.0352
```

The permutation test revealed that the results are:

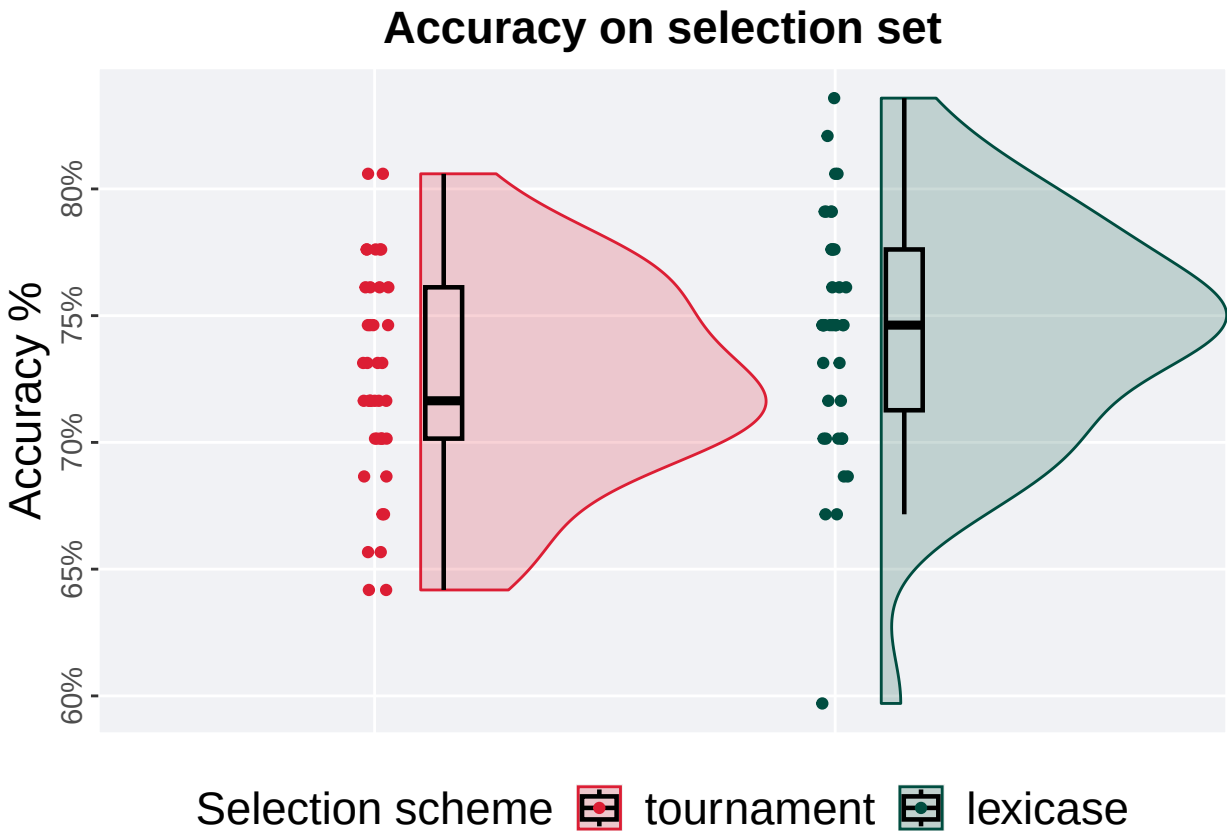
```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 91,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.44107841467357"
## [1] "lower: -1.97919349953109"
## [1] "upper: 1.97919397970146"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.15617"
```



11.1.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

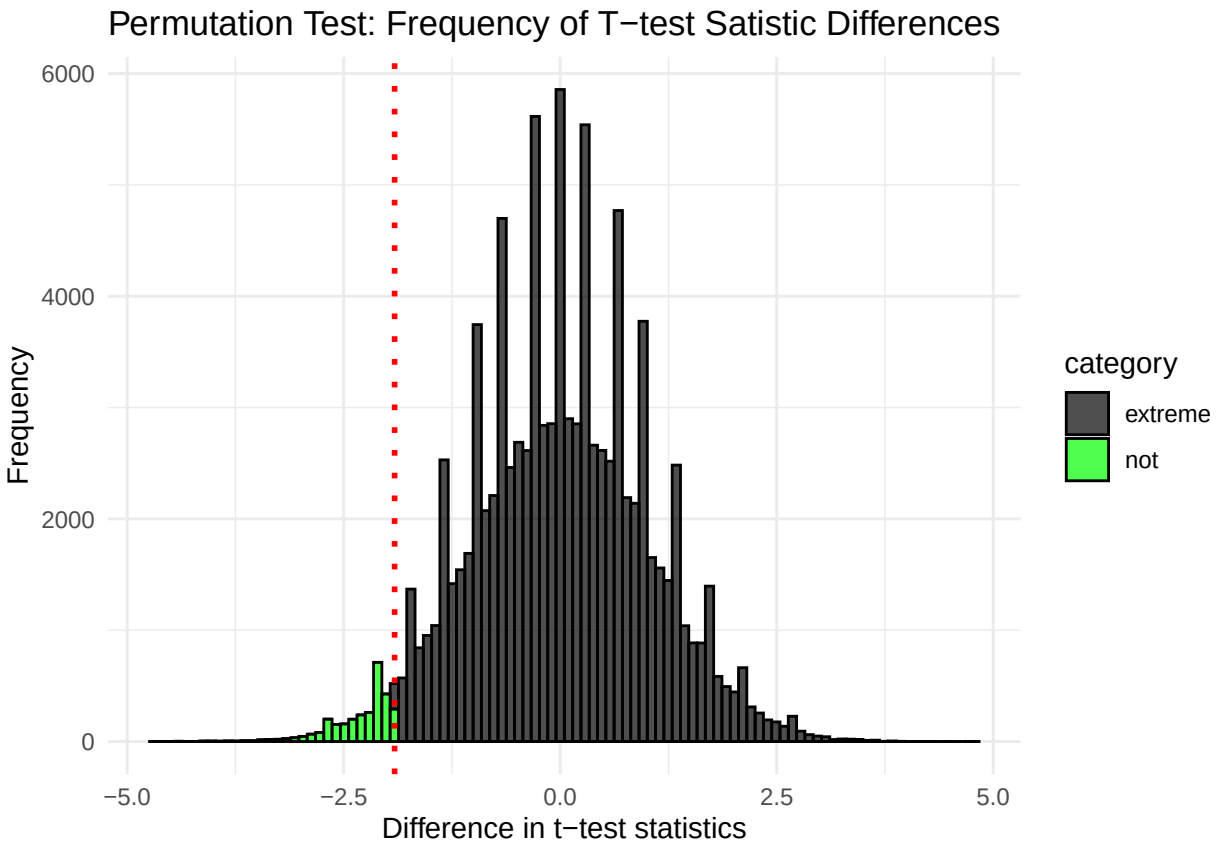
```
selection_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.642  0.716 0.725 0.806 0.0597
## 2 lexicase      40      0 0.597  0.746 0.744 0.836 0.0634
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 92,
                 alternative = "l")
```

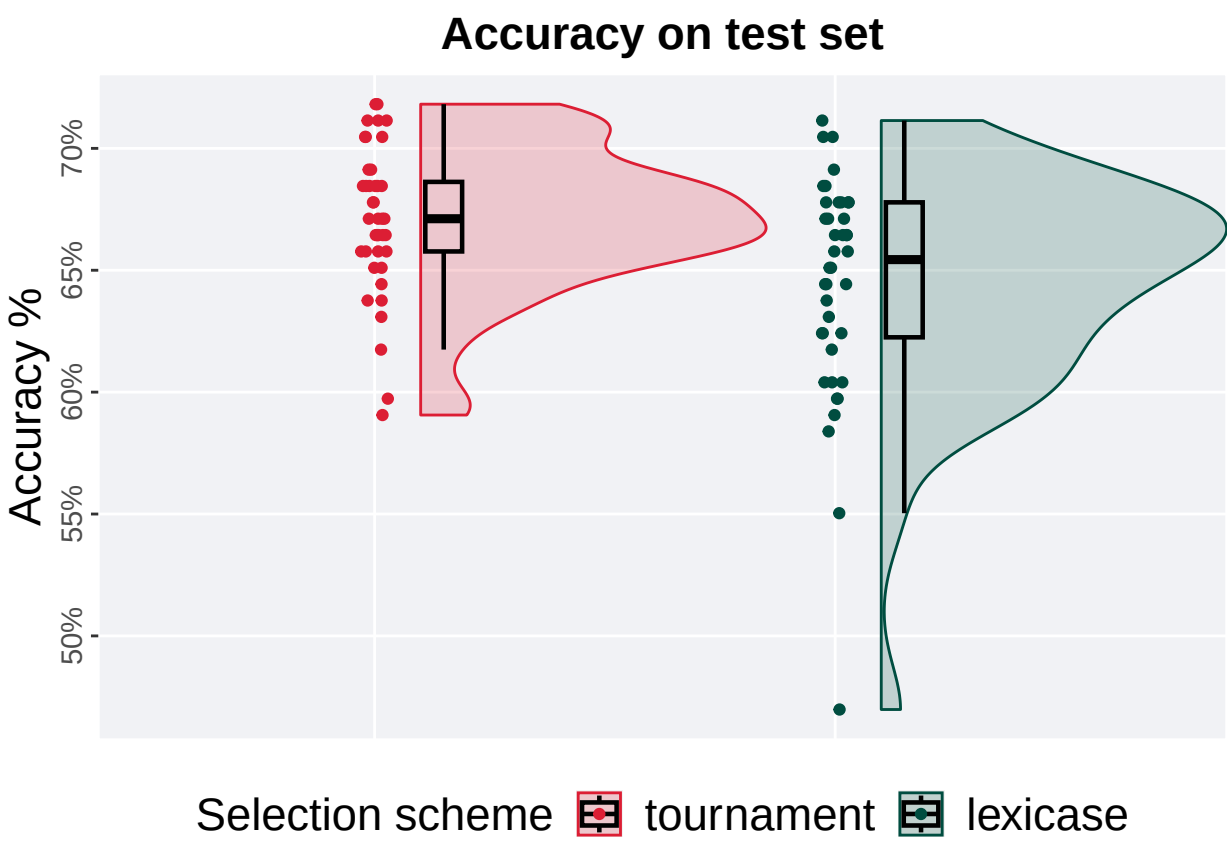
```
## [1] "observed_diff: -1.9120288209559"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.67839605493495"
## [1] "reject null hypothesis"
## [1] "p-value: 0.02986"
```



11.2 10%

11.2.1 Testing set accuracy

```
test_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

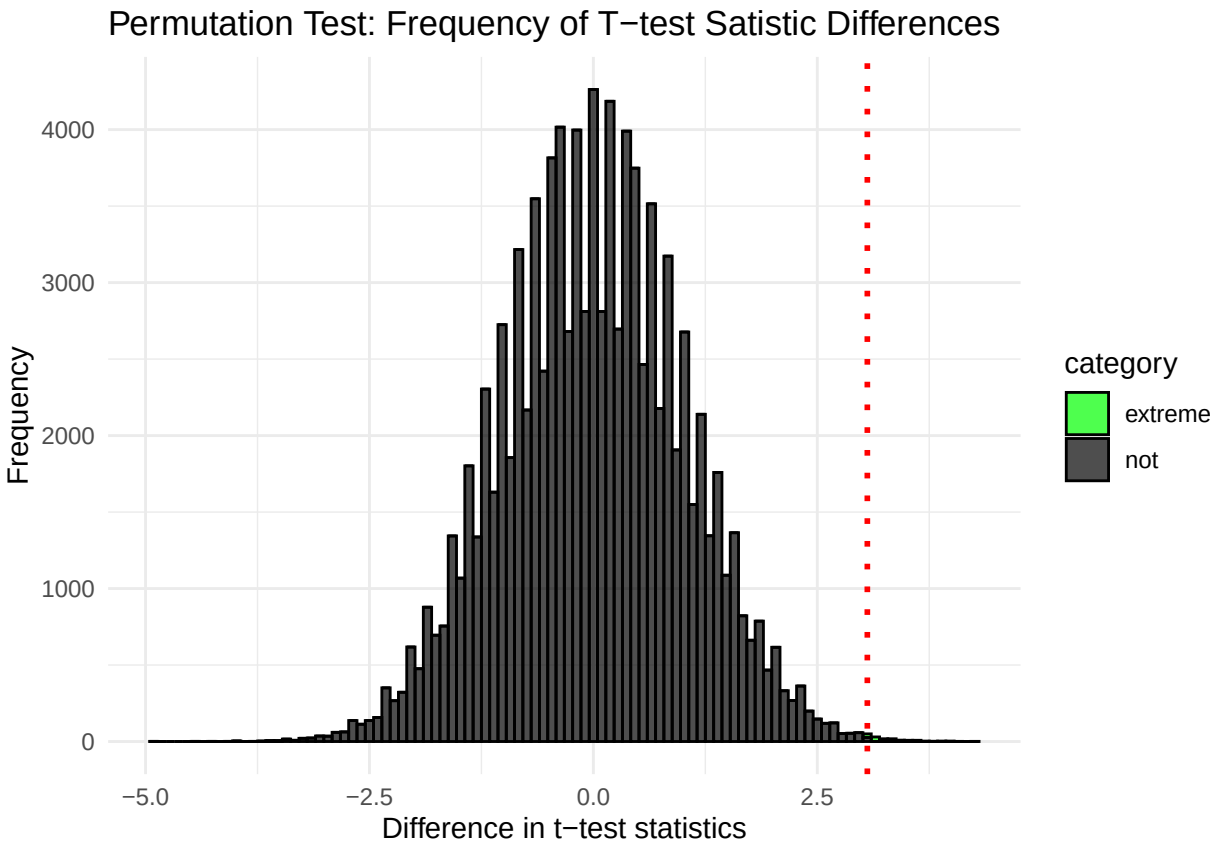
```
test_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.591  0.671 0.671 0.718 0.0285
## 2 lexicase      40      0 0.470  0.654 0.644 0.711 0.0554
```

The permutation test revealed that the results are:

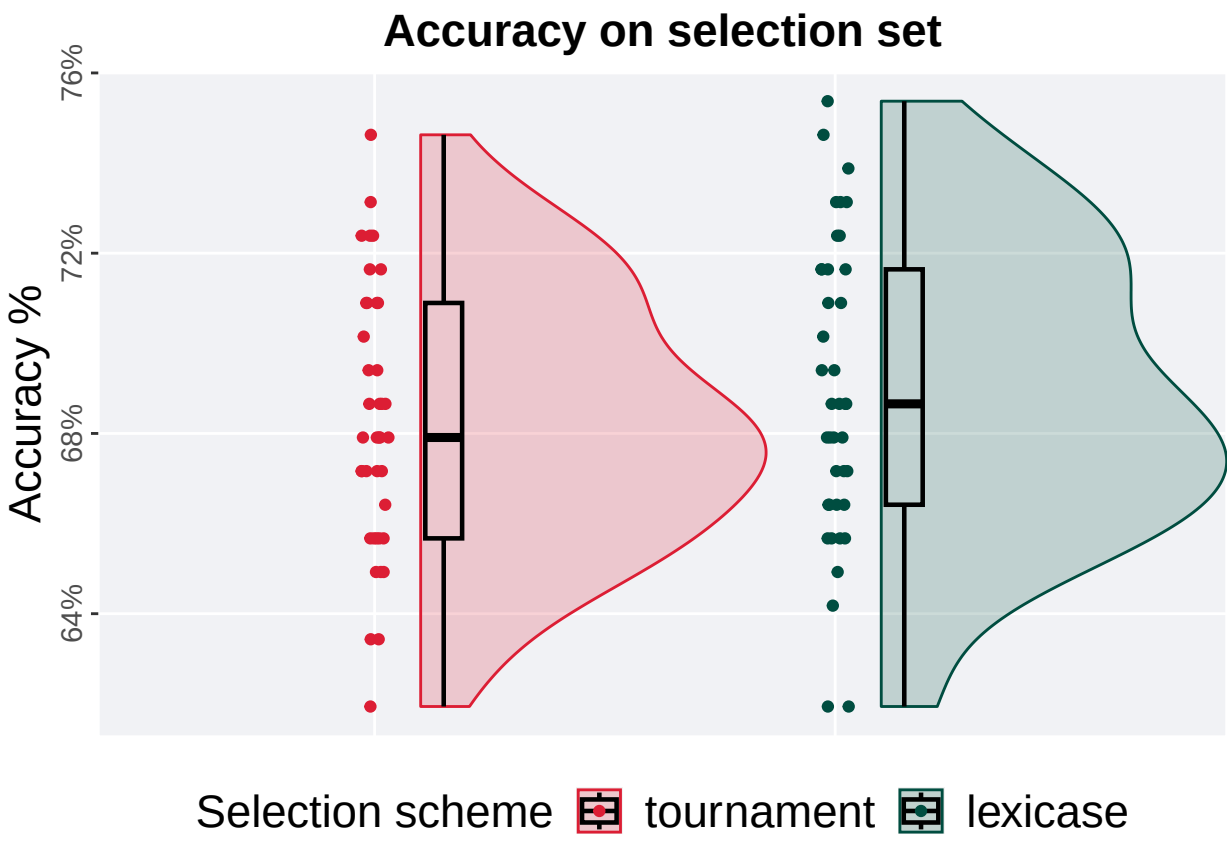
```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 93,
                 alternative = "g")
```

```
## [1] "observed_diff: 3.05890528357161"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.6541469407571"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00128"
```



11.2.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

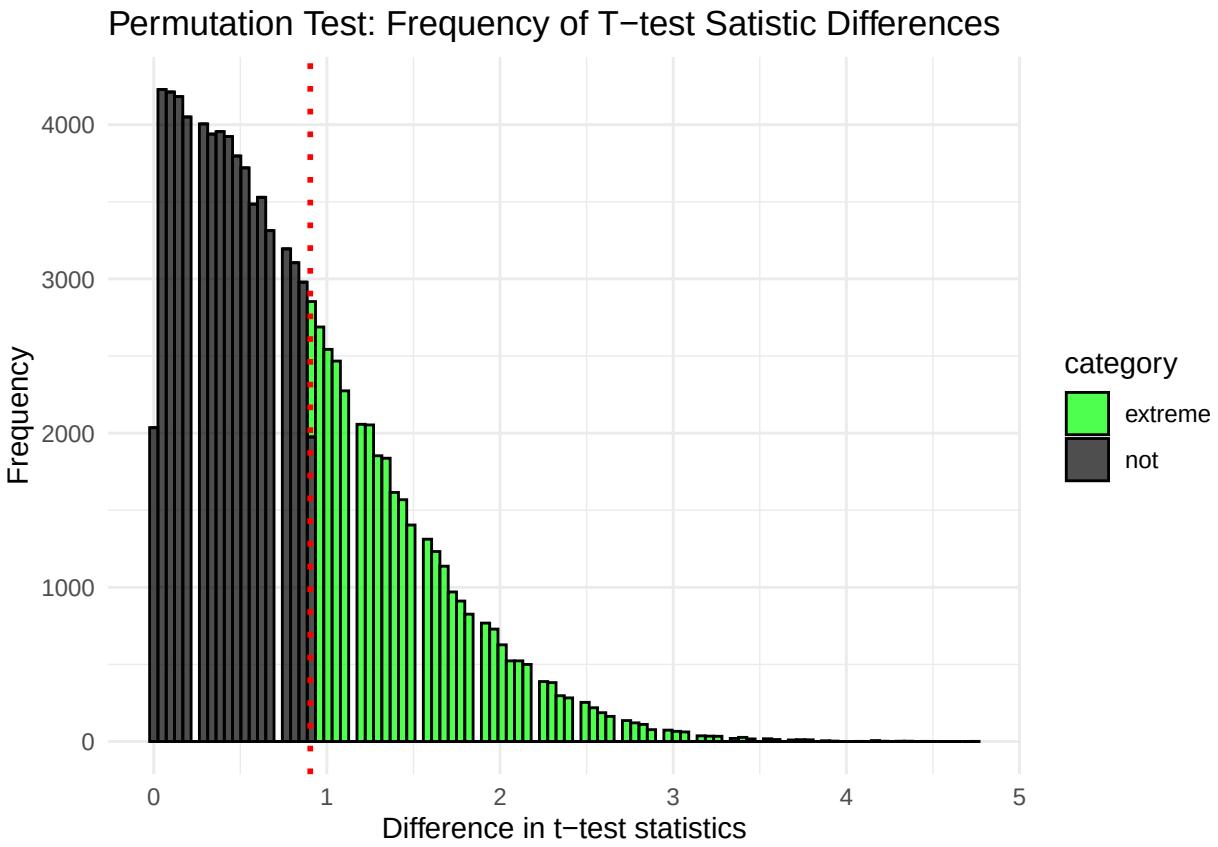
```
selection_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.619  0.679 0.682 0.746 0.0522
## 2 lexicase      40      0 0.619  0.687 0.689 0.754 0.0522
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 94,
                 alternative = "t")
```

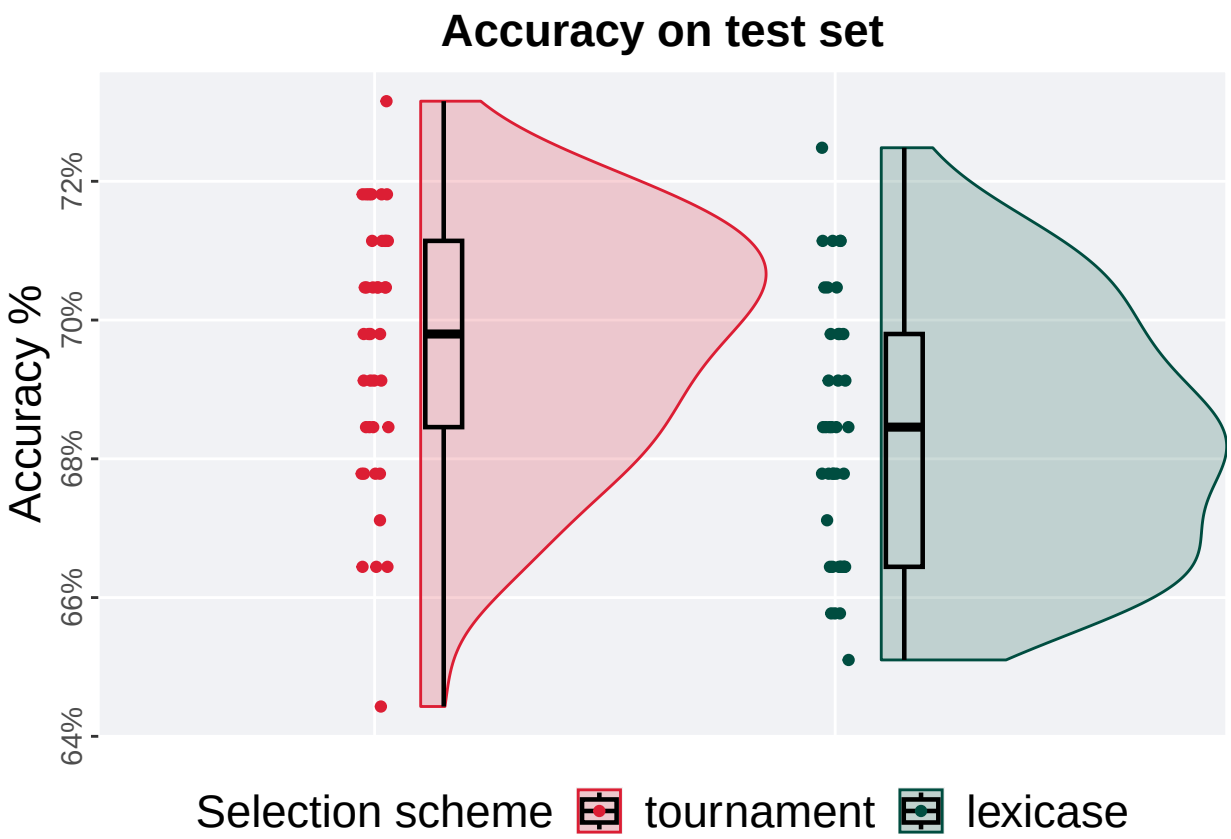
```
## [1] "observed_diff: -0.903818413638582"
## [1] "lower: -2.00679568647391"
## [1] "upper: 2.00679576290495"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.36373"
```



11.3 50%

11.3.1 Testing set accuracy

```
test_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

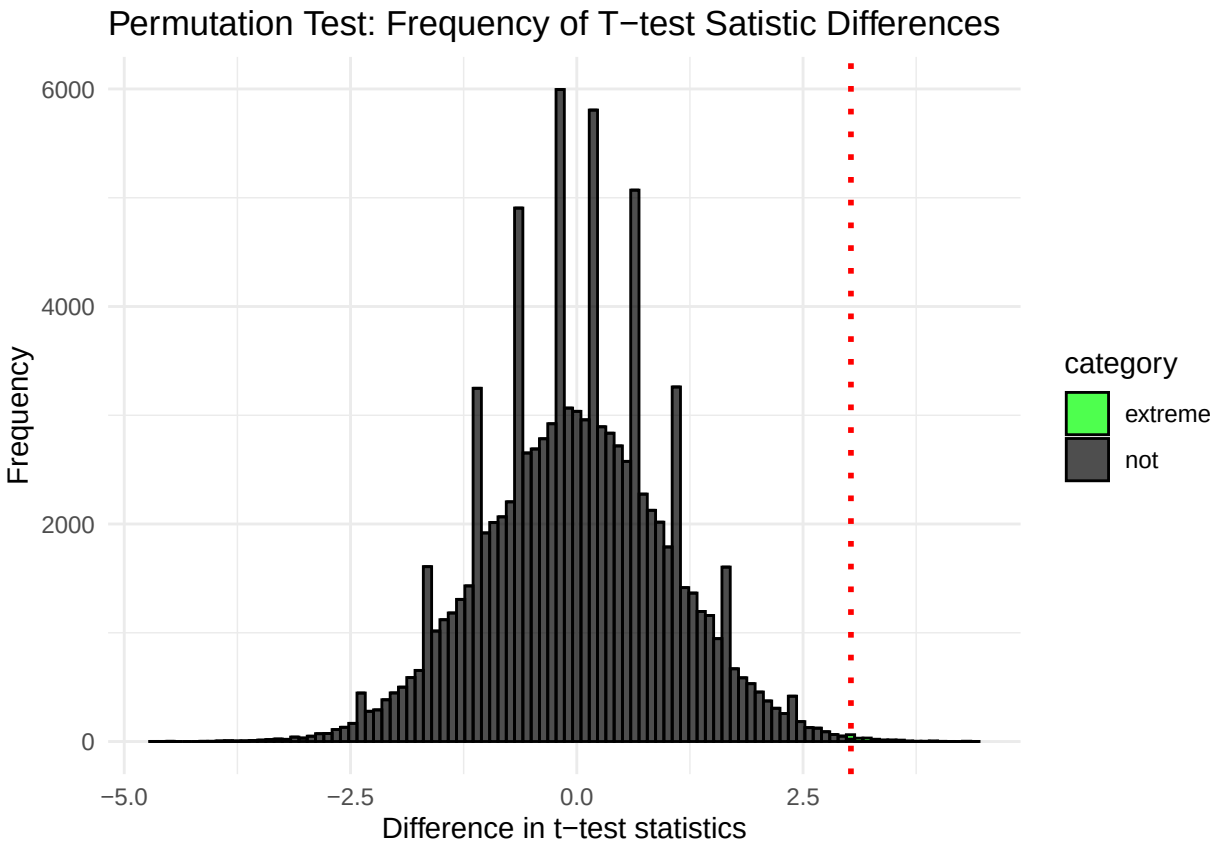
```
test_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.644  0.698 0.696 0.732 0.0268
## 2 lexicase      40      0 0.651  0.685 0.683 0.725 0.0336
```

The permutation test revealed that the results are:

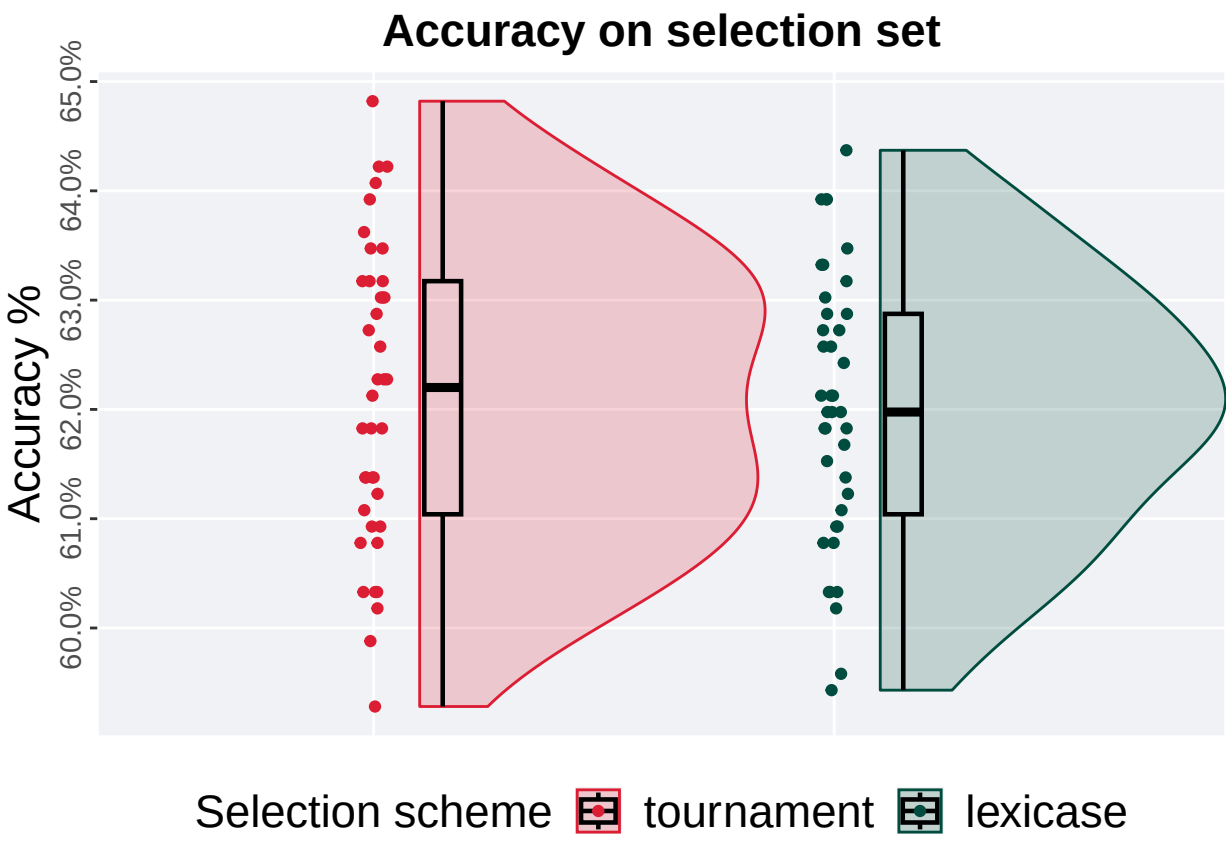
```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 95,
                 alternative = "g")
```

```
## [1] "observed_diff: 3.02914521008793"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.68891527019981"
## [1] "reject null hypothesis"
## [1] "p-value: 0.0019"
```



11.3.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

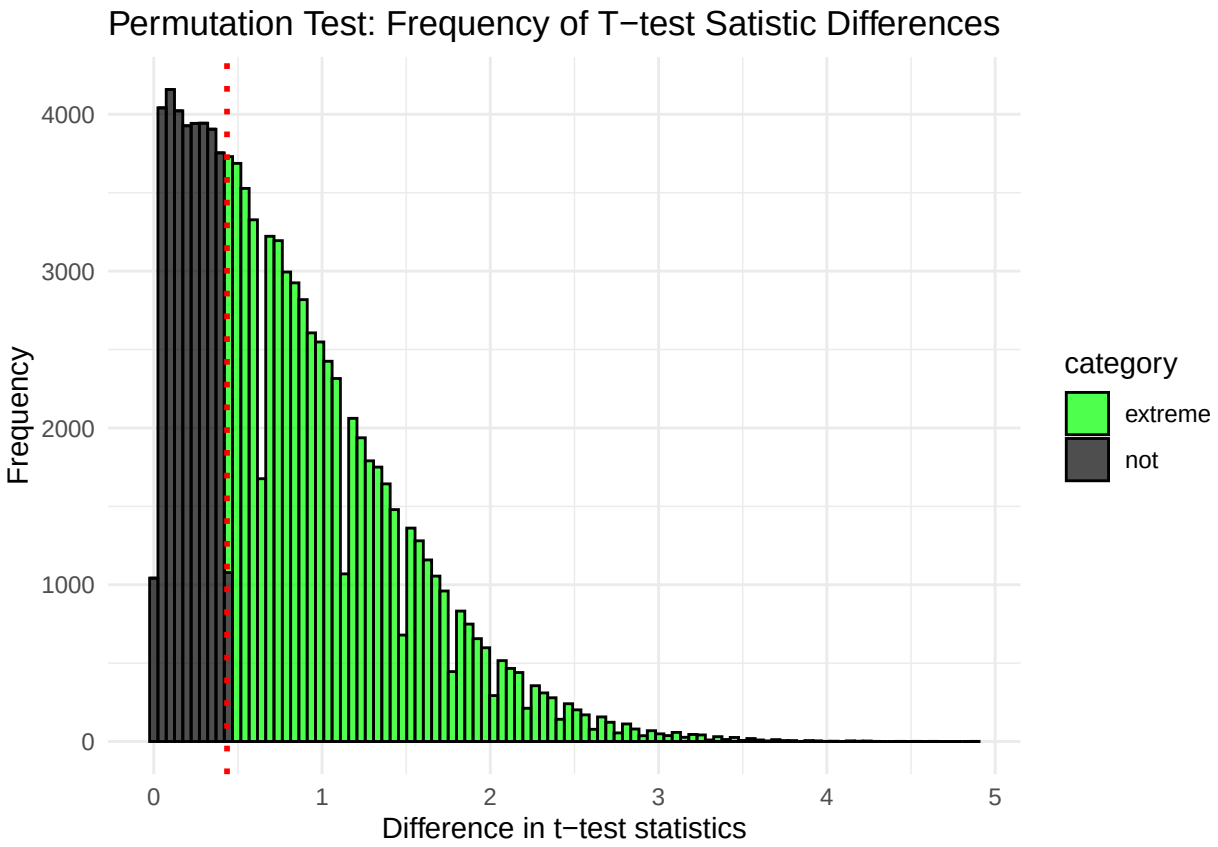
```
selection_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.593  0.622 0.621 0.648 0.0213
## 2 lexicase      40      0 0.594  0.620 0.620 0.644 0.0183
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 96,
                 alternative = "t")
```

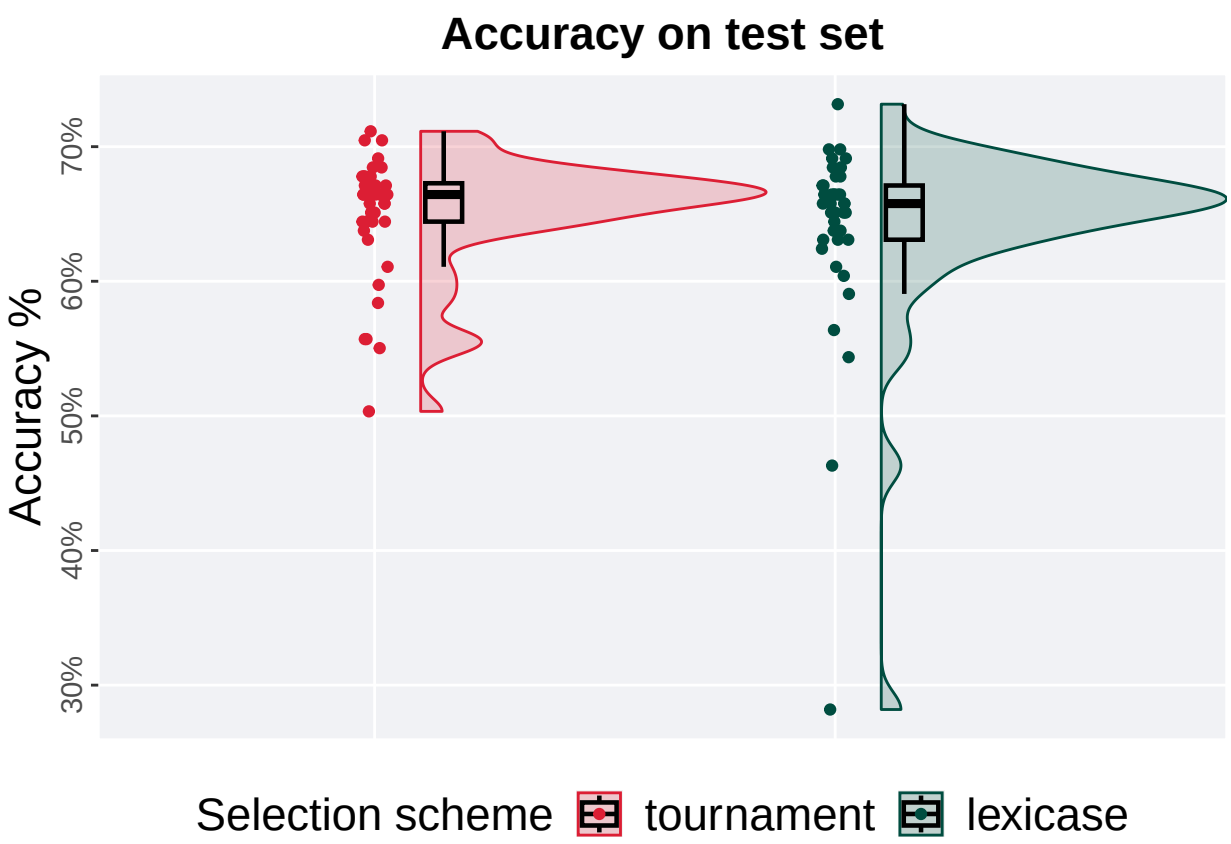
```
## [1] "observed_diff: 0.435323861862444"
## [1] "lower: -1.99265142509362"
## [1] "upper: 1.99265308163027"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.66188"
```



11.4 90%

11.4.1 Testing set accuracy

```
test_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

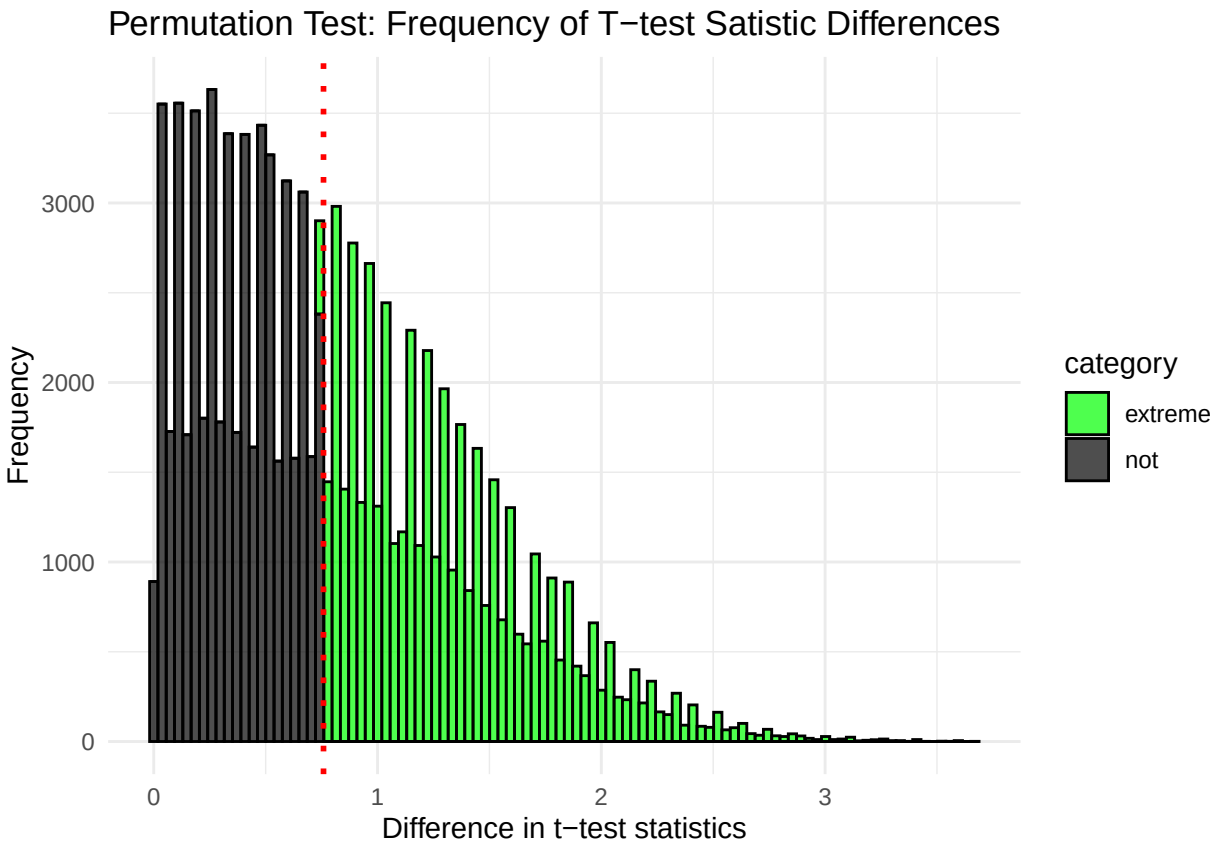
```
test_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.503  0.664 0.649 0.711 0.0285
## 2 lexicase      40      0 0.282  0.658 0.639 0.732 0.0403
```

The permutation test revealed that the results are:

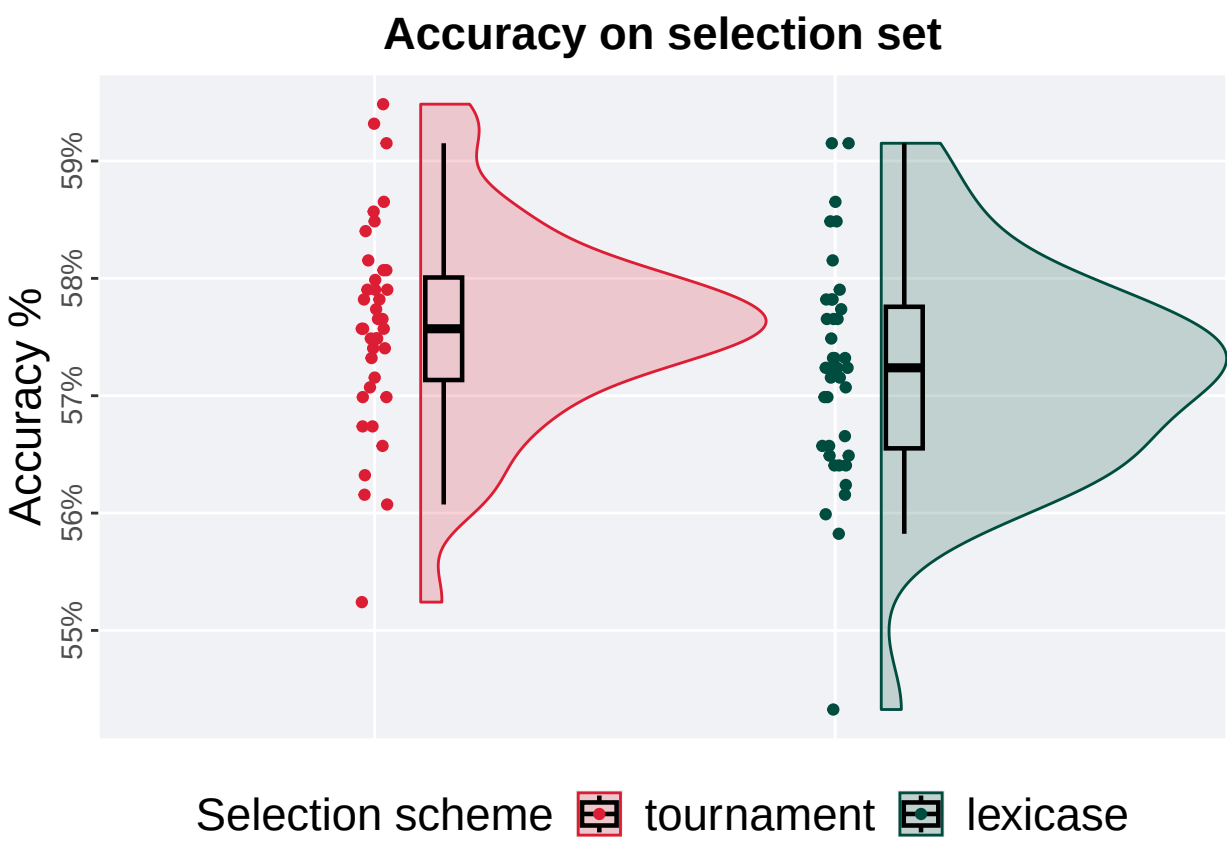
```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 97,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.758531310895758"
## [1] "lower: -1.92107872814561"
## [1] "upper: 1.92107872814561"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.47717"
```



11.4.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

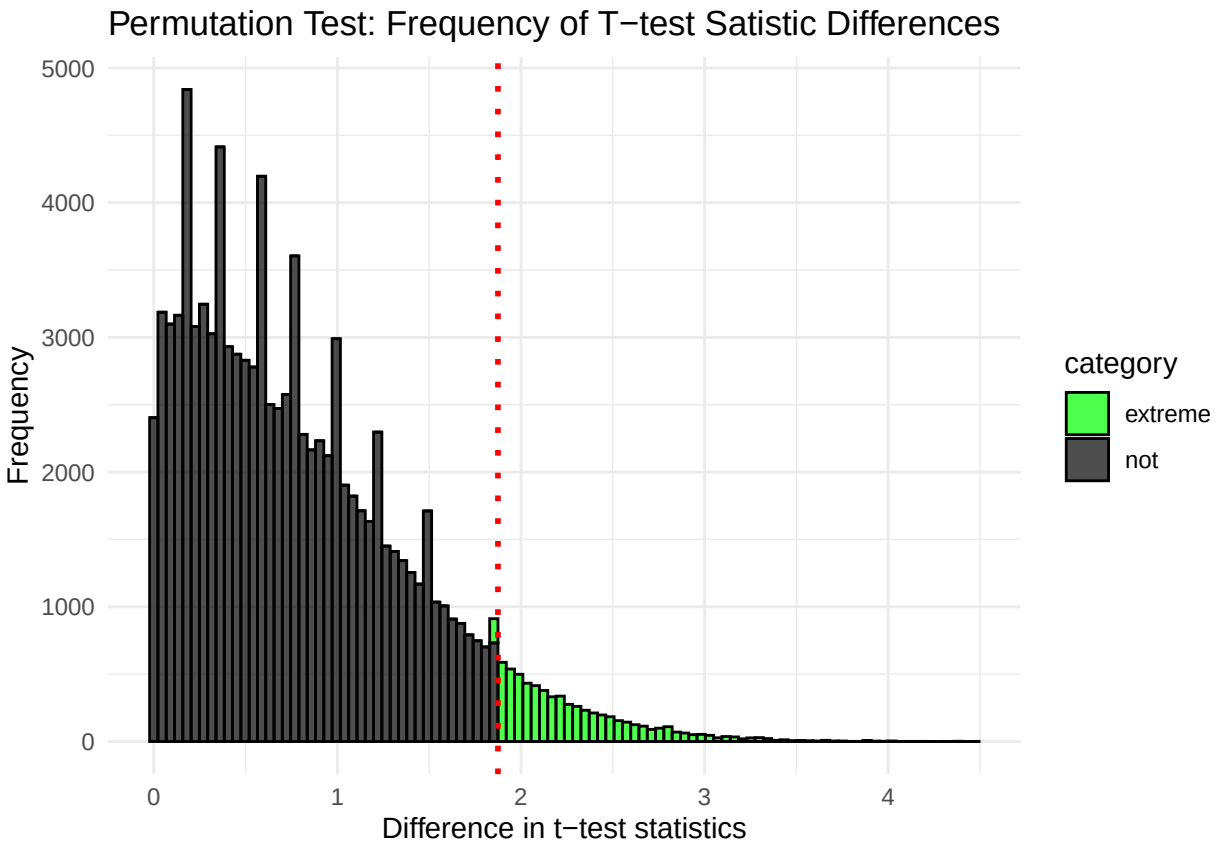
```
selection_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.552  0.576 0.576 0.595 0.00874
## 2 lexicase      40      0 0.543  0.572 0.572 0.592 0.0121
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 98,
                 alternative = "t")
```

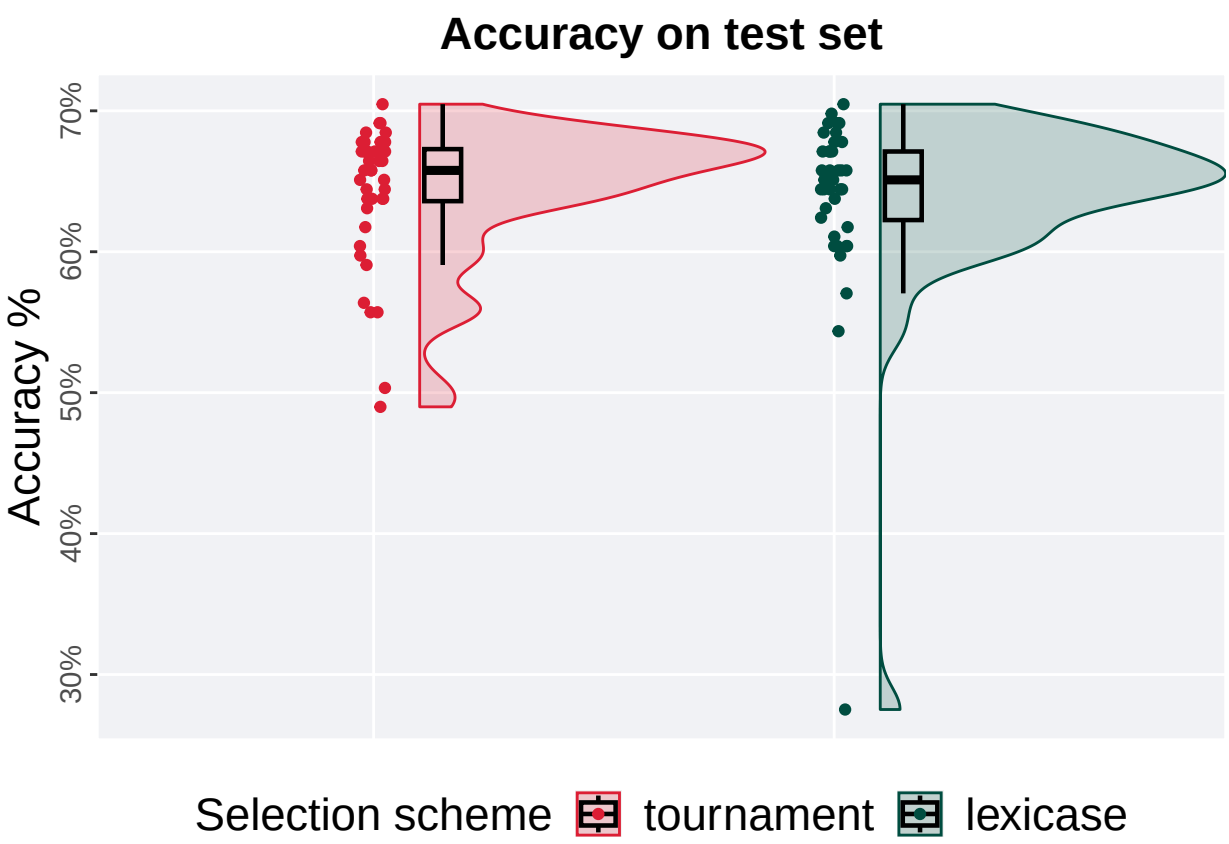
```
## [1] "observed_diff: 1.87465601726122"
## [1] "lower: -1.98271127158185"
## [1] "upper: 1.98270996776461"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.0647"
```



11.5 95%

11.5.1 Testing set accuracy

```
test_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

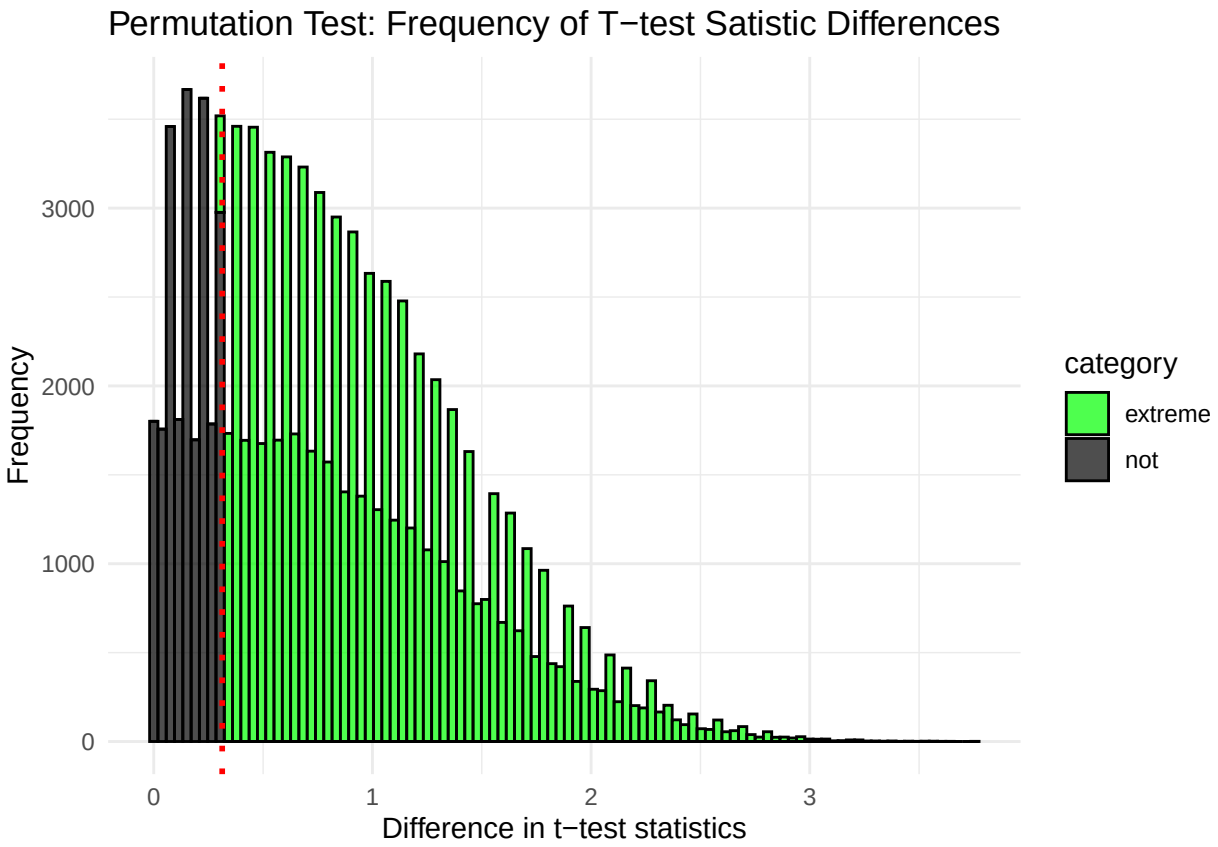
```
test_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.490  0.658 0.642 0.705 0.0369
## 2 lexicase      40      0 0.275  0.651 0.638 0.705 0.0487
```

The permutation test revealed that the results are:

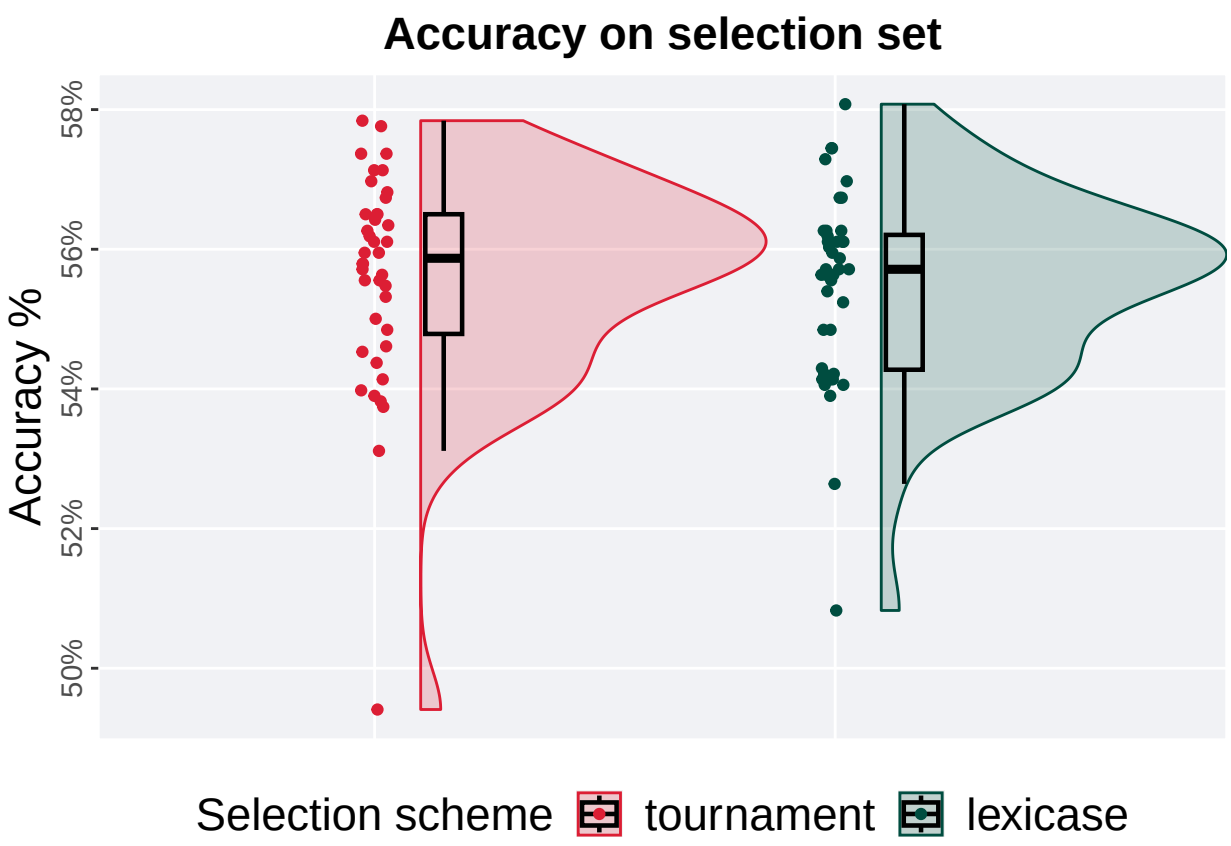
```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 99,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.312972589294503"
## [1] "lower: -1.90711257326836"
## [1] "upper: 1.90711273295152"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.77428"
```



11.5.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

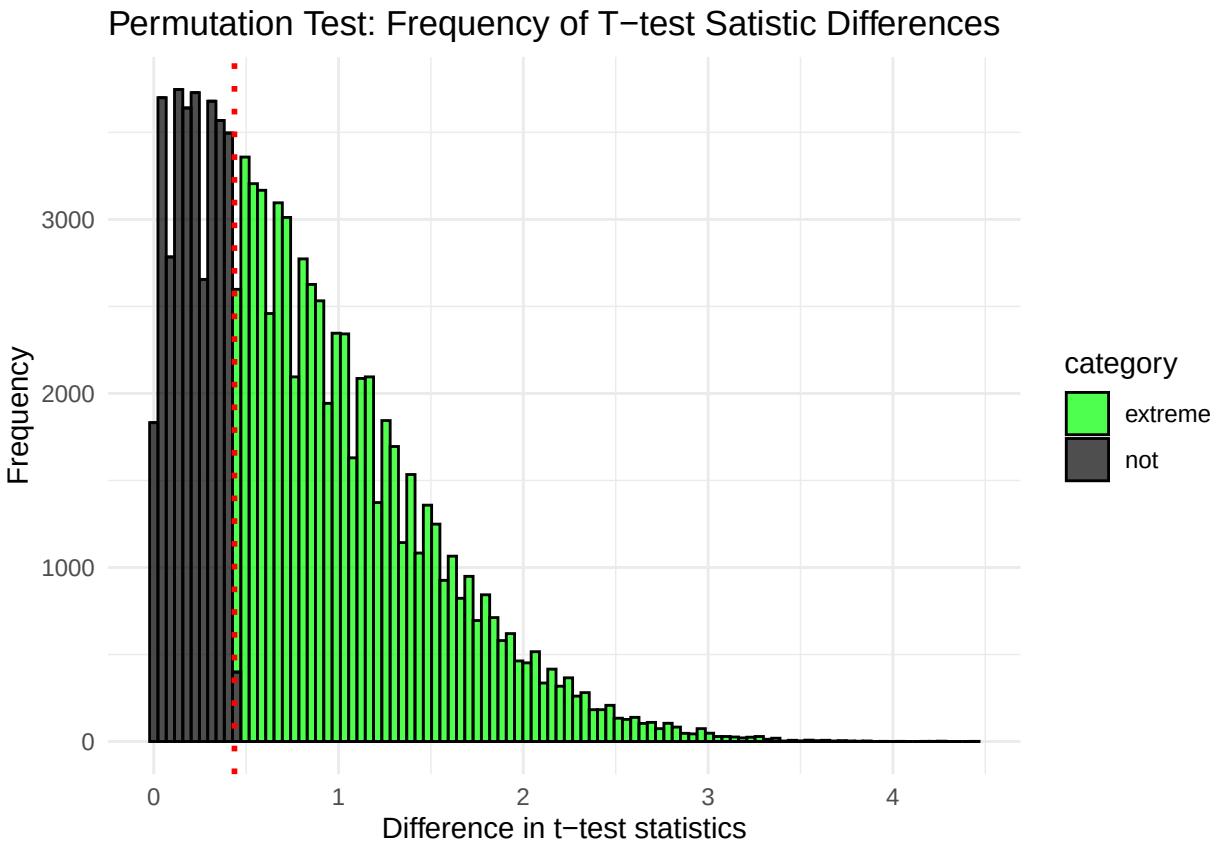
```
selection_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.494  0.559 0.556 0.578 0.0171
## 2 lexicase      40      0 0.508  0.557 0.555 0.581 0.0193
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 100,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.436779653664196"
## [1] "lower: -1.97806377537585"
## [1] "upper: 1.9909305869247"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.66774"
```


Permutation Test: Frequency of T−test Satistic Differences
Frequency
3000
2000
1000
0
0
1
2
3
4
Difference in t−test statistics
category
extreme
not

Chapter 12

Task 359960

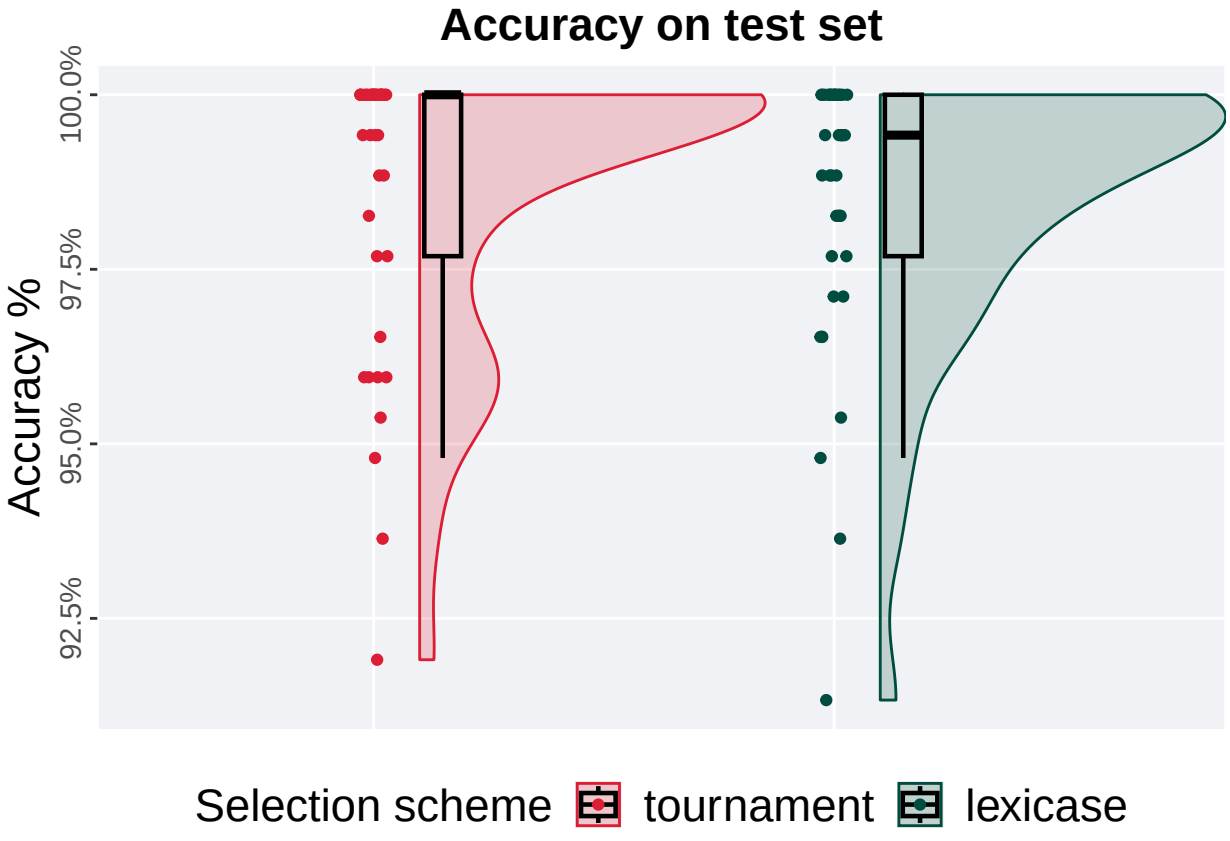
We present the results of our analysis of `task 359960` with the different selection set splits used in our study.

```
task_data <- filter(results, task_id == 359960)
```

12.1 5%

12.1.1 Testing set accuracy

```
test_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

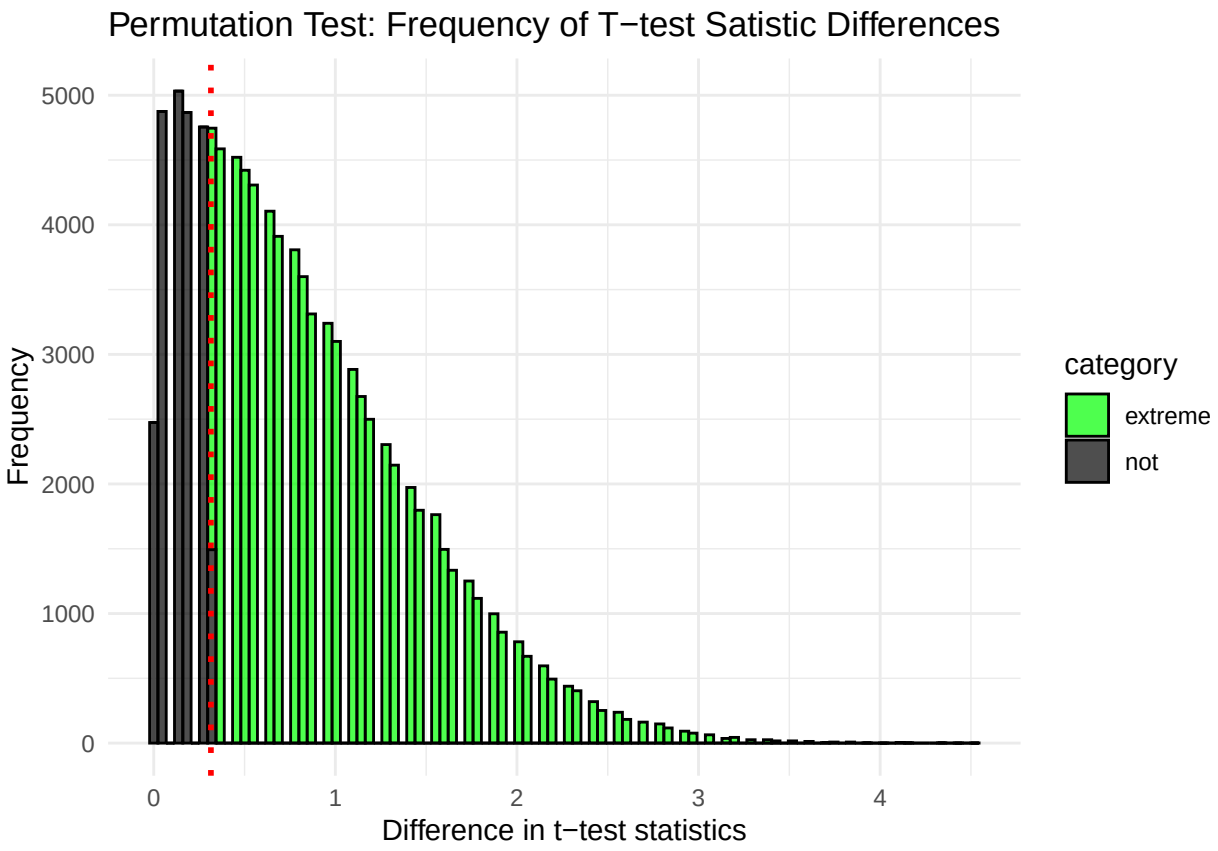
```
test_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.919  1     0.986     1 0.0231
## 2 lexicase      40      0 0.913  0.994 0.985     1 0.0231
```

The permutation test revealed that the results are:

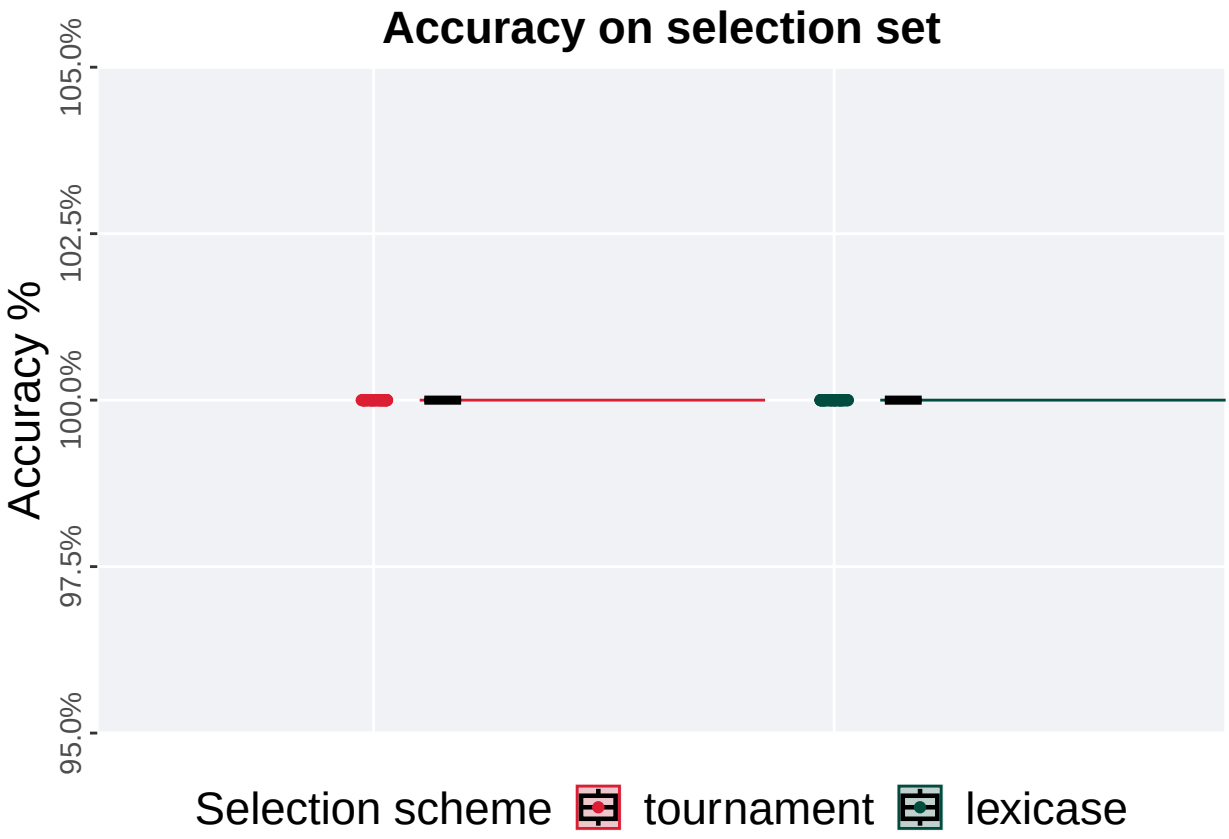
```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                    lexicase_results$testing_performance,
                    seed = 101,
                    alternative = "t")
```

```
## [1] "observed_diff: 0.314658049512107"
## [1] "lower: -1.99895989583997"
## [1] "upper: 1.99895977857028"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.76504"
```



12.1.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

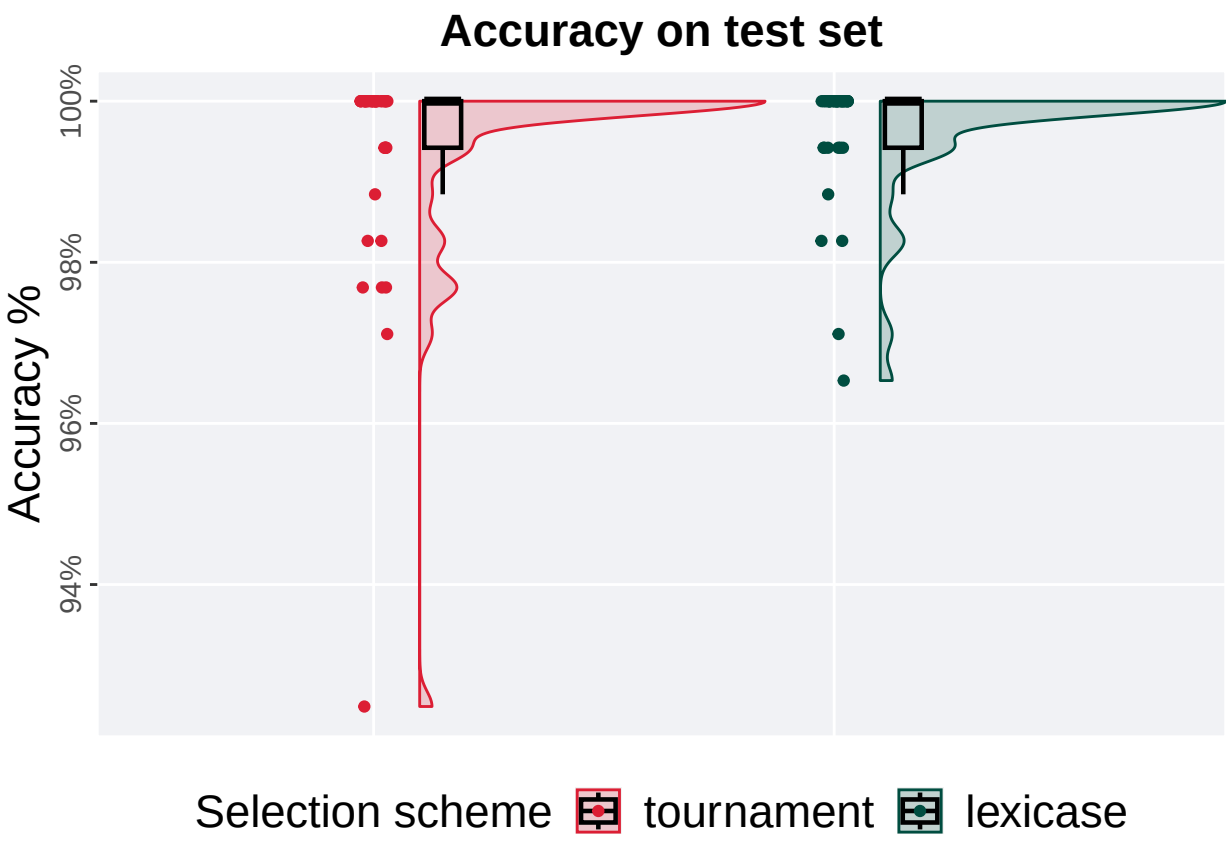
```
selection_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max   IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl> <dbl>
## 1 tournament    40      0     1      1     1     1     0
## 2 lexicase      40      0     1      1     1     1     0
```

12.2 10%

12.2.1 Testing set accuracy

```
test_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

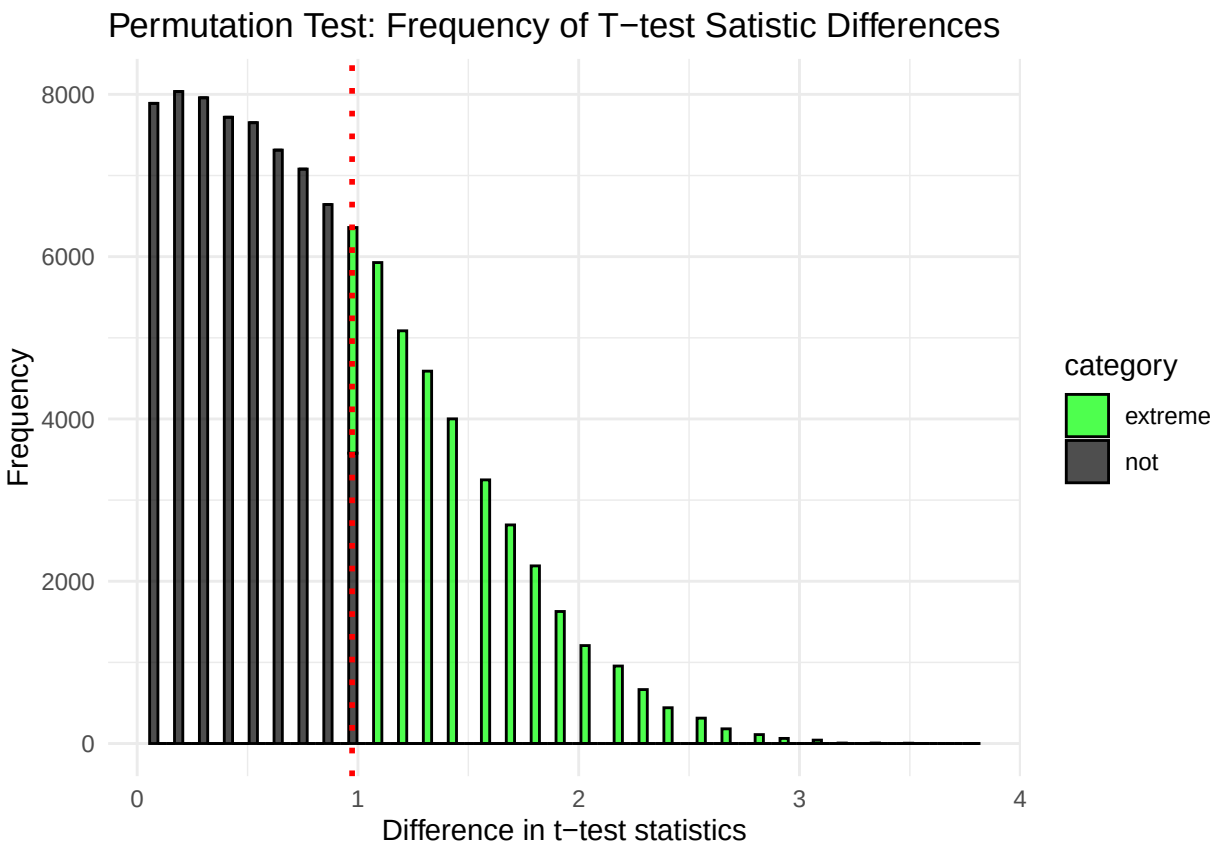
```
test_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.925      1 0.994     1 0.00578
## 2 lexicase      40      0 0.965      1 0.996     1 0.00578
```

The permutation test revealed that the results are:

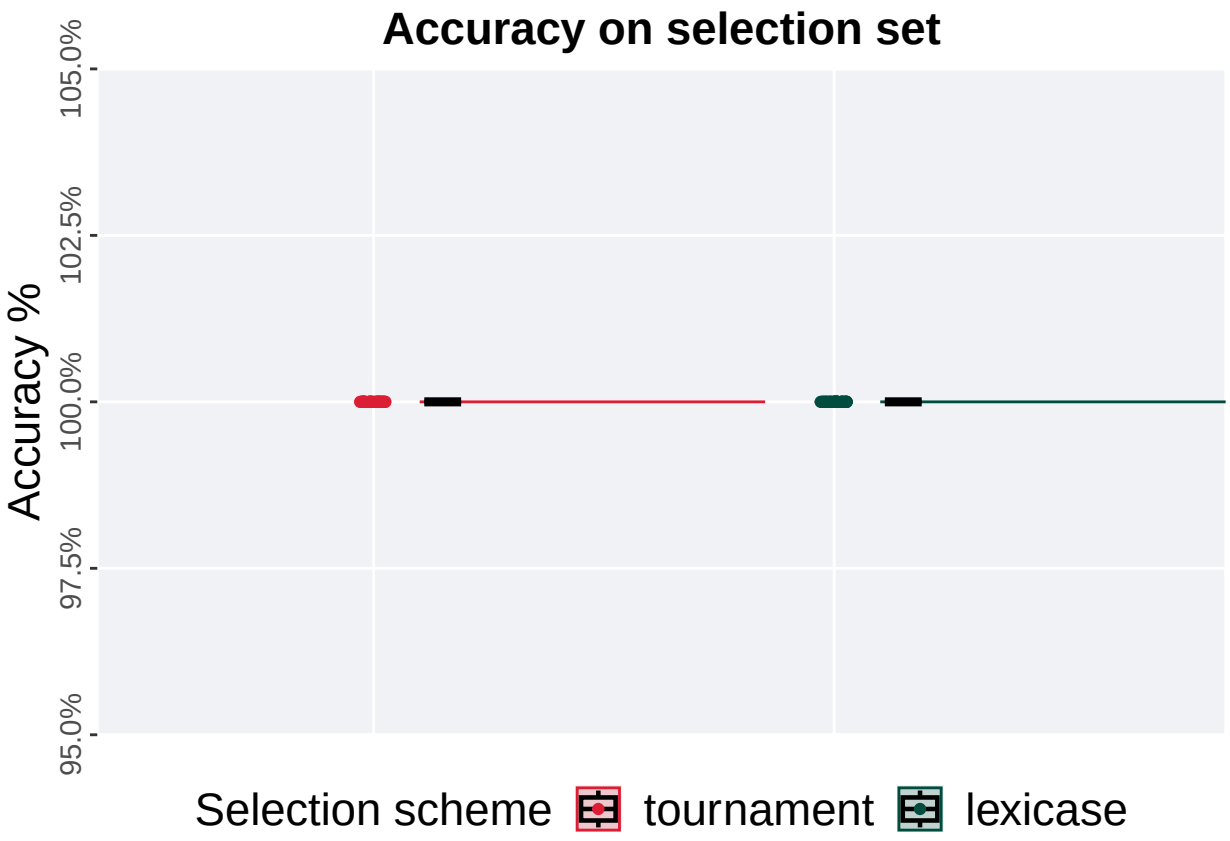
```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 103,
                 alternative = "t")
```

```
## [1] "observed_diff: -0.97358112870935"
## [1] "lower: -1.92250389346255"
## [1] "upper: 1.92250389346255"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.36137"
```



12.2.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

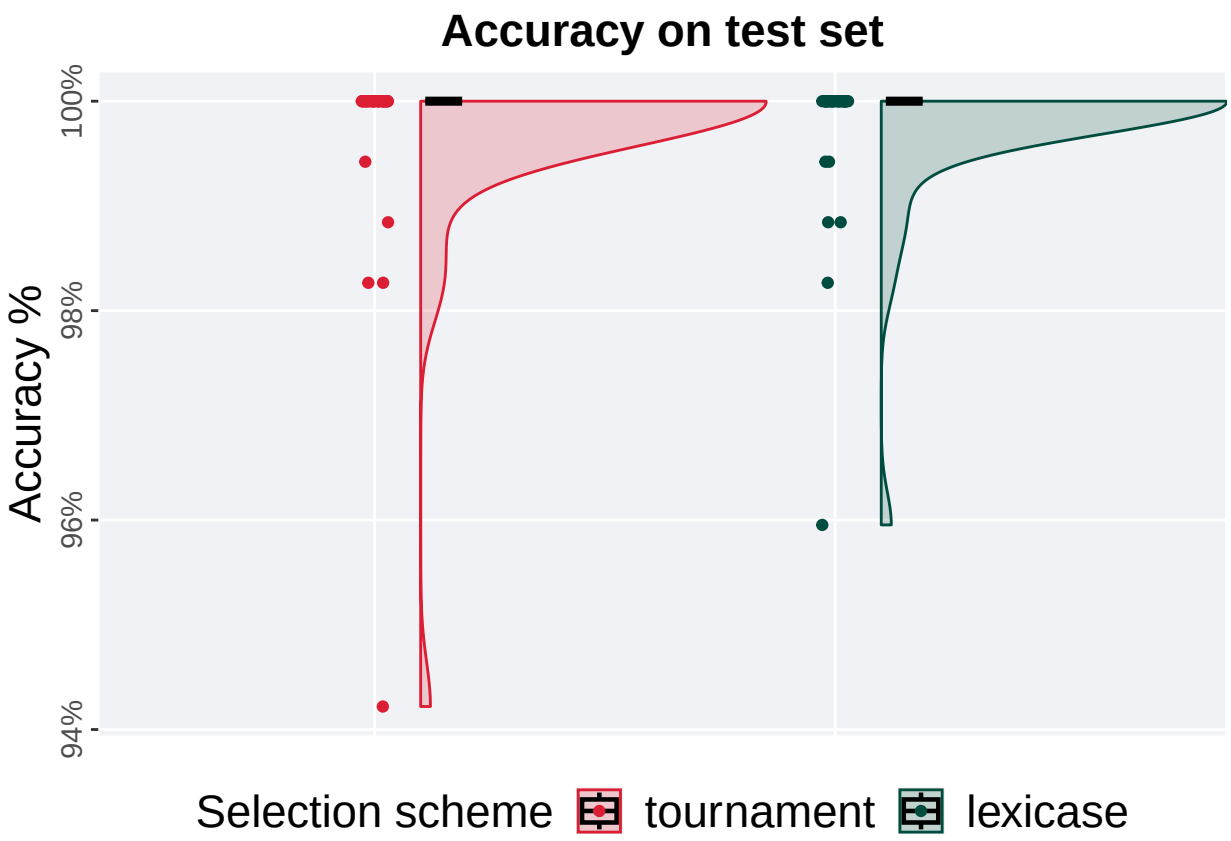
```
selection_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max   IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl> <dbl>
## 1 tournament    40      0     1      1     1     1     0
## 2 lexicase      40      0     1      1     1     1     0
```

12.3 50%

12.3.1 Testing set accuracy

```
test_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

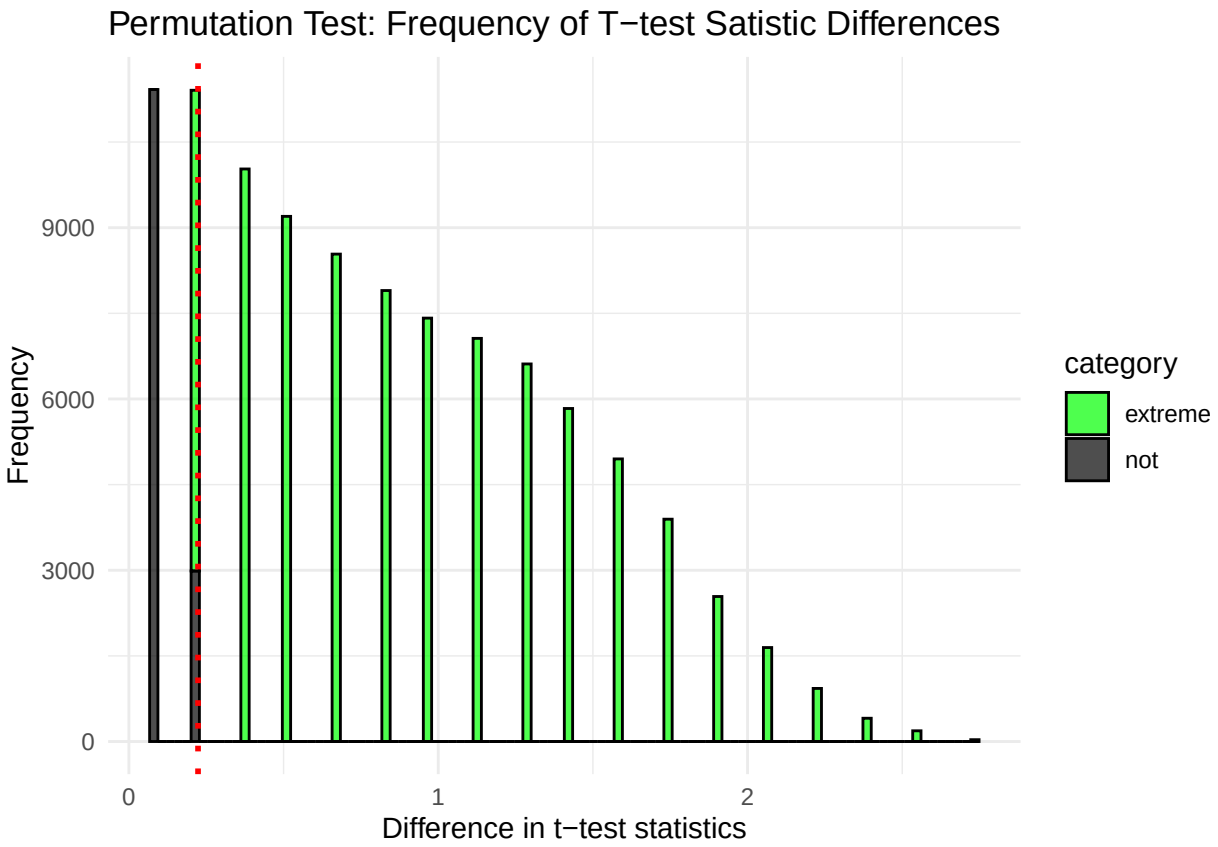
```
test_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max   IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl> <dbl>
## 1 tournament    40      0 0.942      1 0.997     1     0
## 2 lexicase      40      0 0.960      1 0.998     1     0
```

The permutation test revealed that the results are:

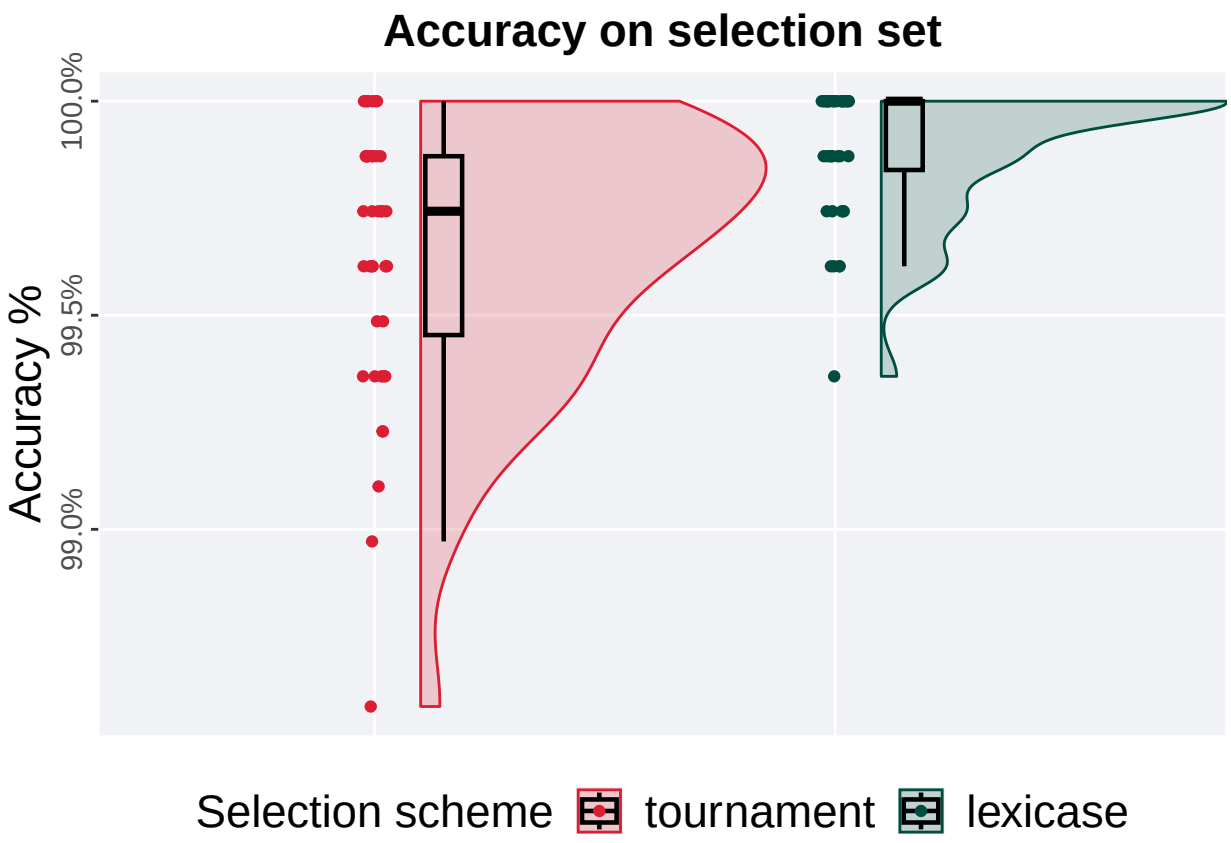
```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 105,
                 alternative = "t")
```

```
## [1] "observed_diff: -0.223558353436898"
## [1] "lower: -1.90523711235765"
## [1] "upper: 1.90523711235765"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.85593"
```



12.3.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

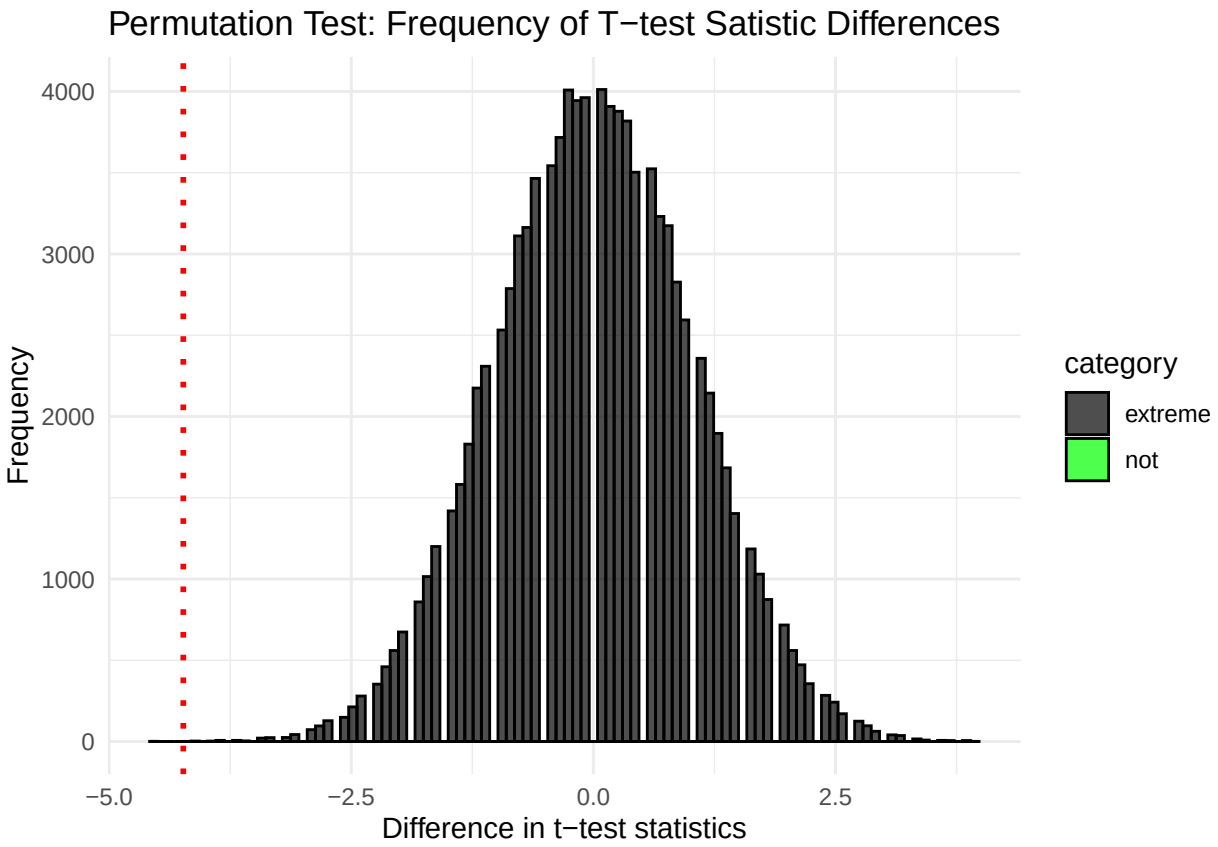
```
selection_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.986  0.997 0.996     1 0.00418
## 2 lexicase      40      0 0.994  1     0.999     1 0.00161
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 106,
                 alternative = "l")
```

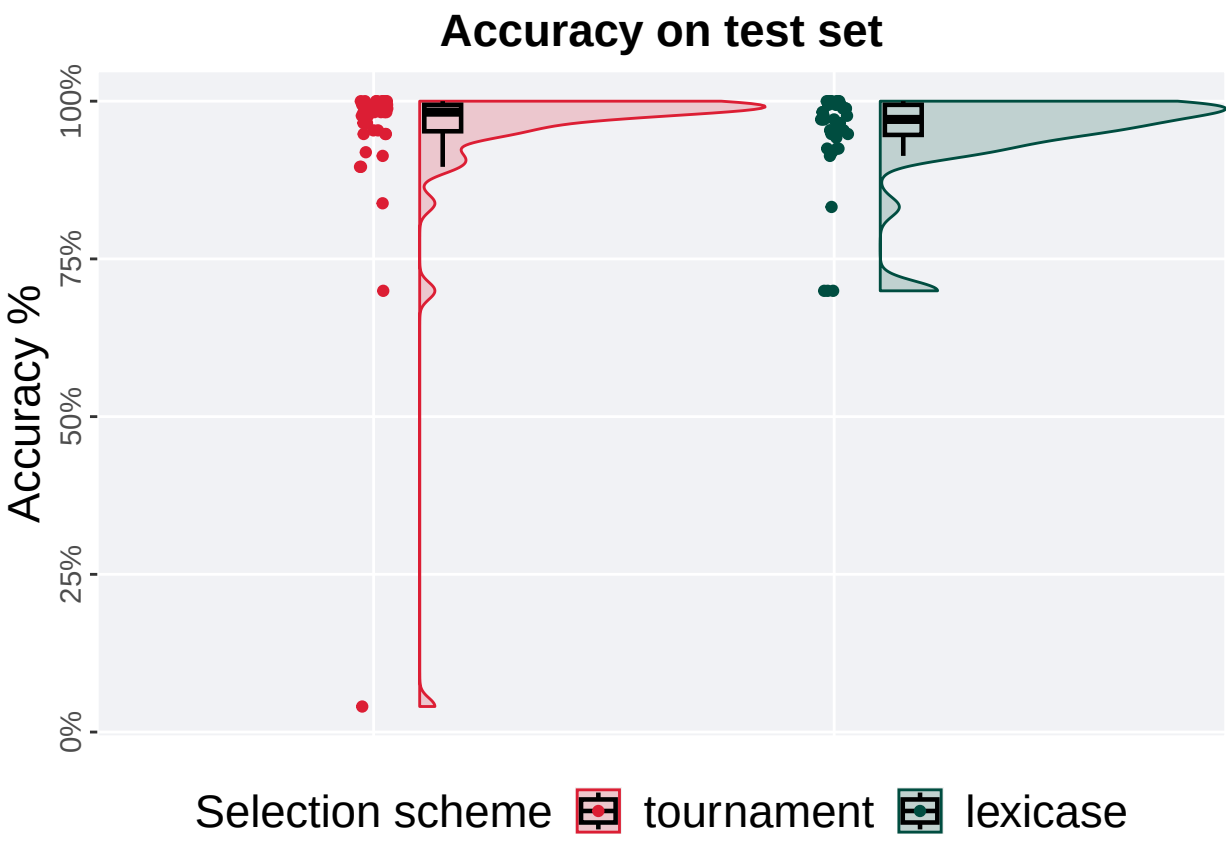
```
## [1] "observed_diff: -4.23440936732469"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.60404248357023"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```



12.4 90%

12.4.1 Testing set accuracy

```
test_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

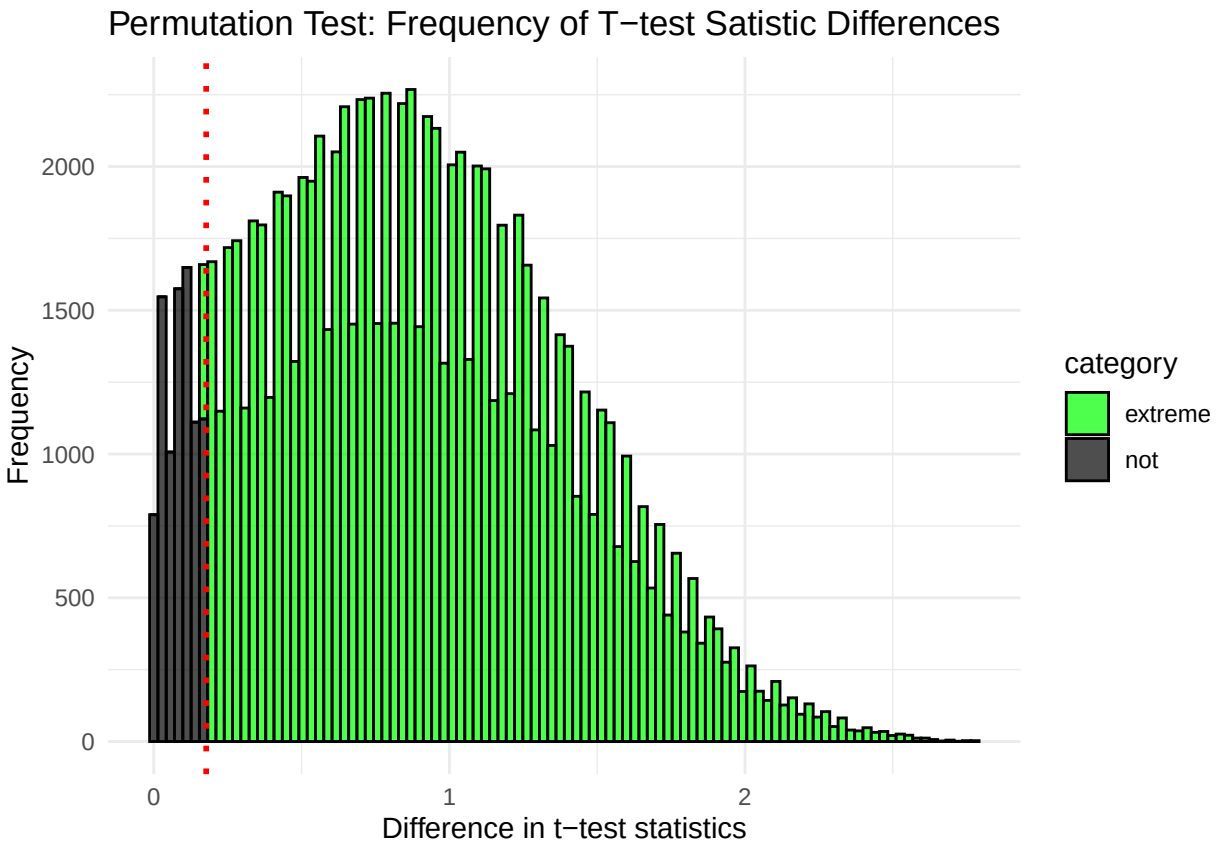
```
test_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt    min median  mean   max    IQR
##   <fct>      <int>  <int>  <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.0405  0.983 0.942     1 0.0419
## 2 lexicase      40      0 0.699   0.971 0.947     1 0.0477
```

The permutation test revealed that the results are:

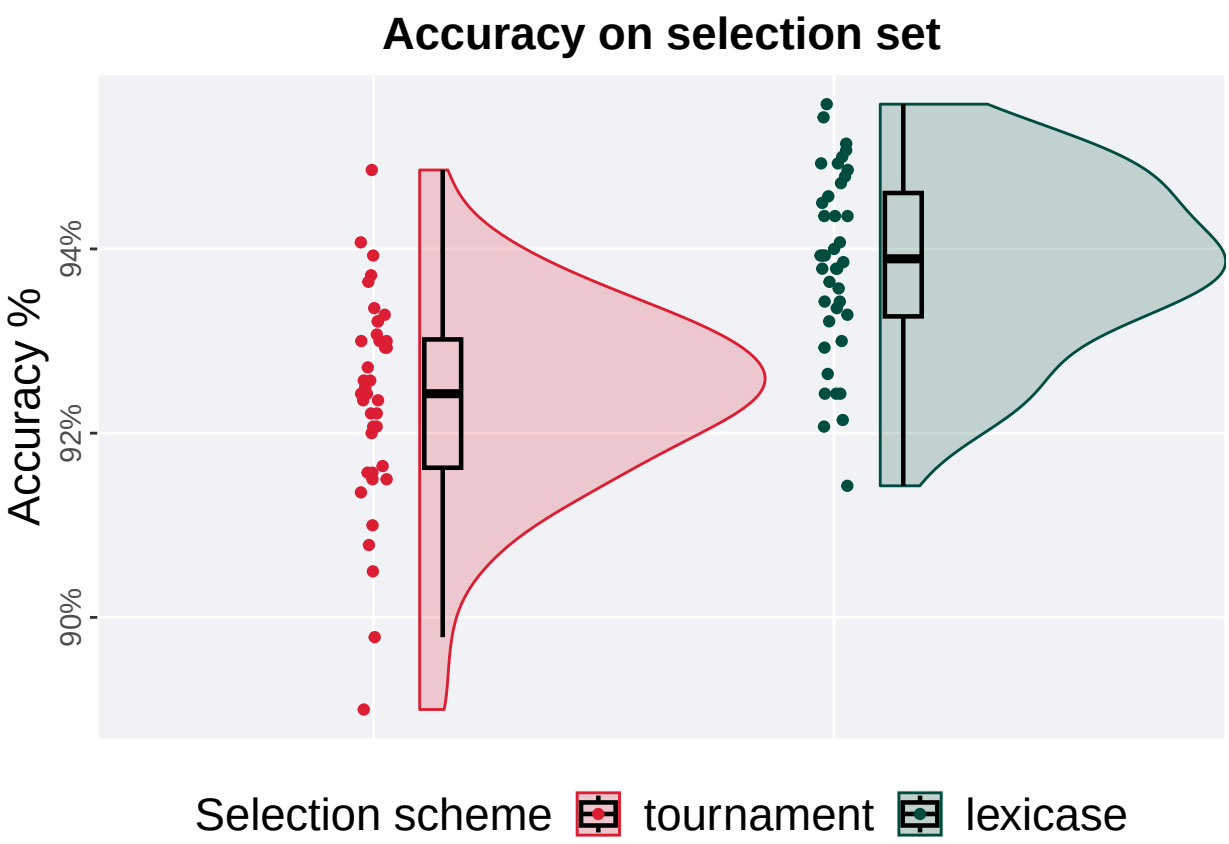
```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 107,
                 alternative = "t")
```

```
## [1] "observed_diff: -0.177387484050444"
## [1] "lower: -1.77714489478587"
## [1] "upper: 1.77714495225199"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.912"
```



12.4.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

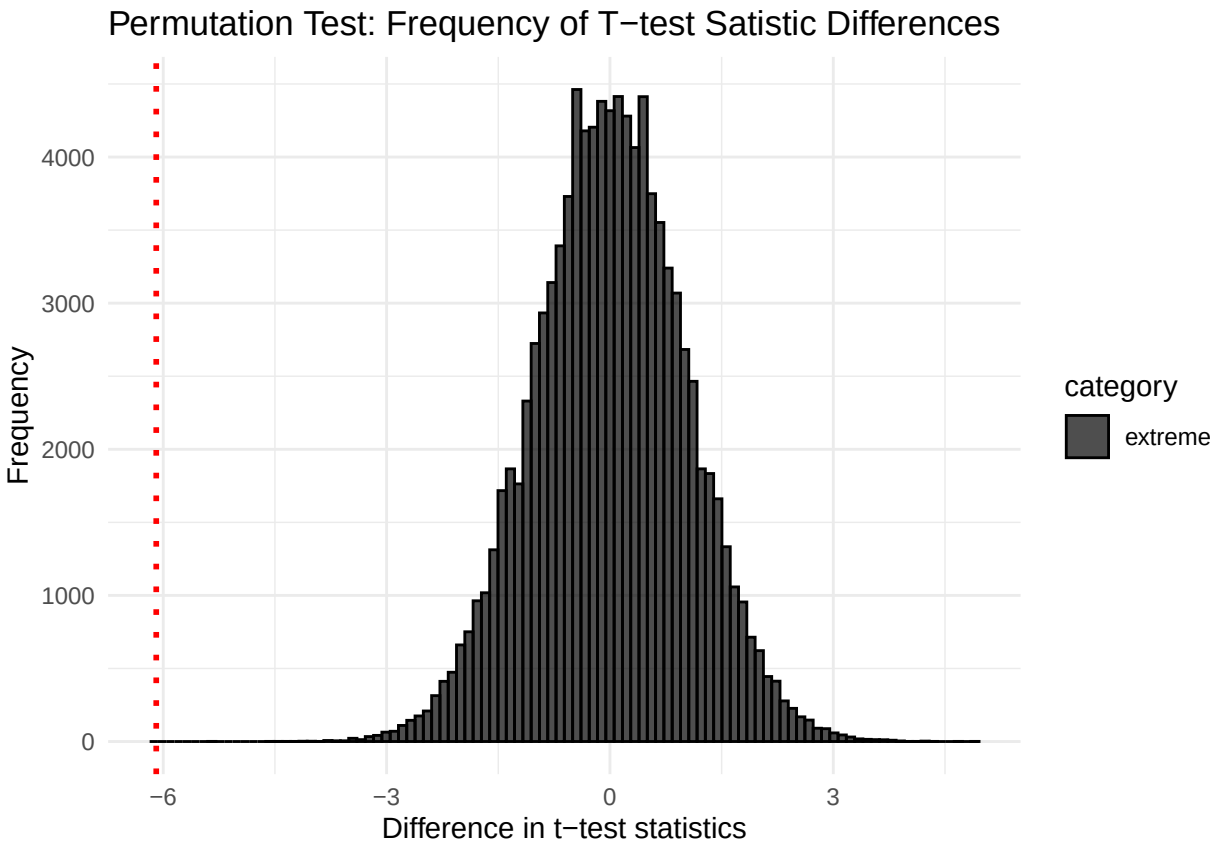
```
selection_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.89   0.924 0.924 0.949 0.0139
## 2 lexicase      40      0 0.914  0.939 0.938 0.956 0.0134
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 108,
                 alternative = "l")
```

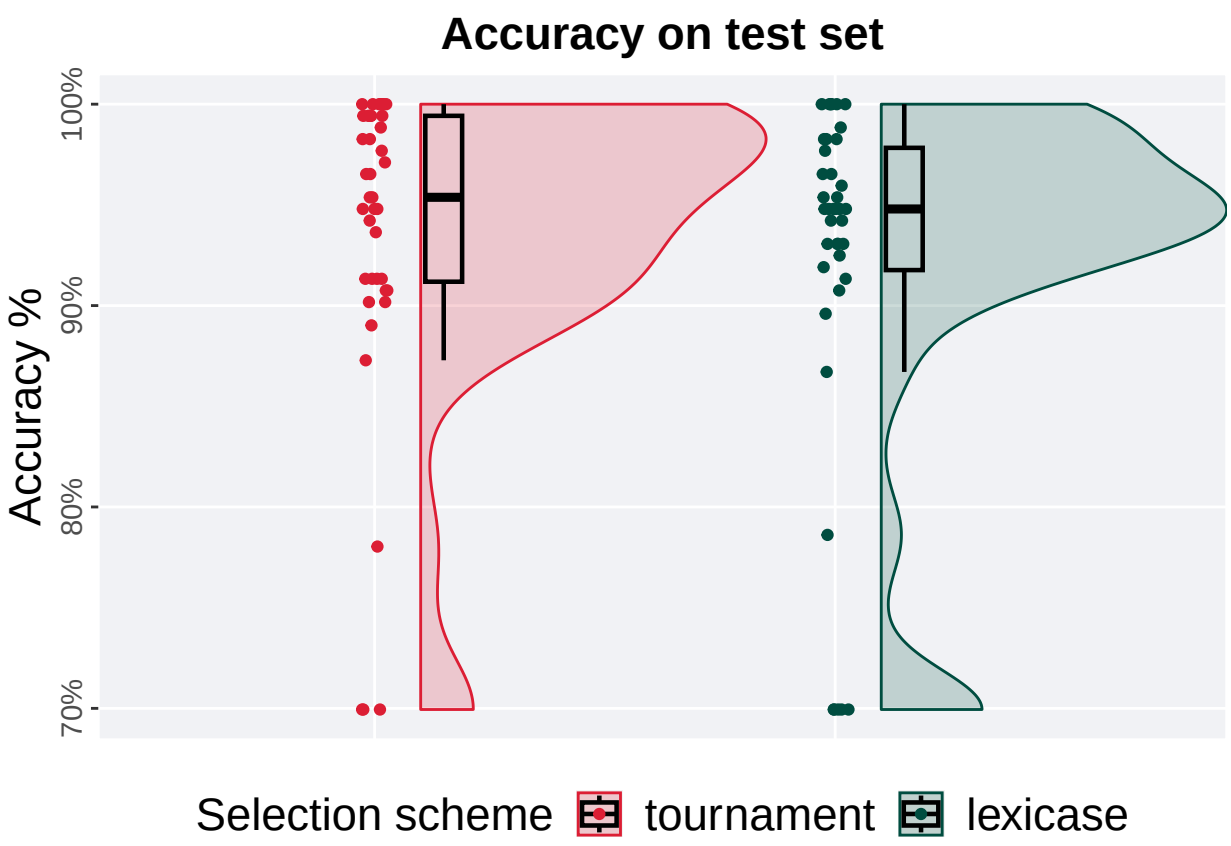
```
## [1] "observed_diff: -6.0941418442466"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.66413613579426"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```



12.5 95%

12.5.1 Testing set accuracy

```
test_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

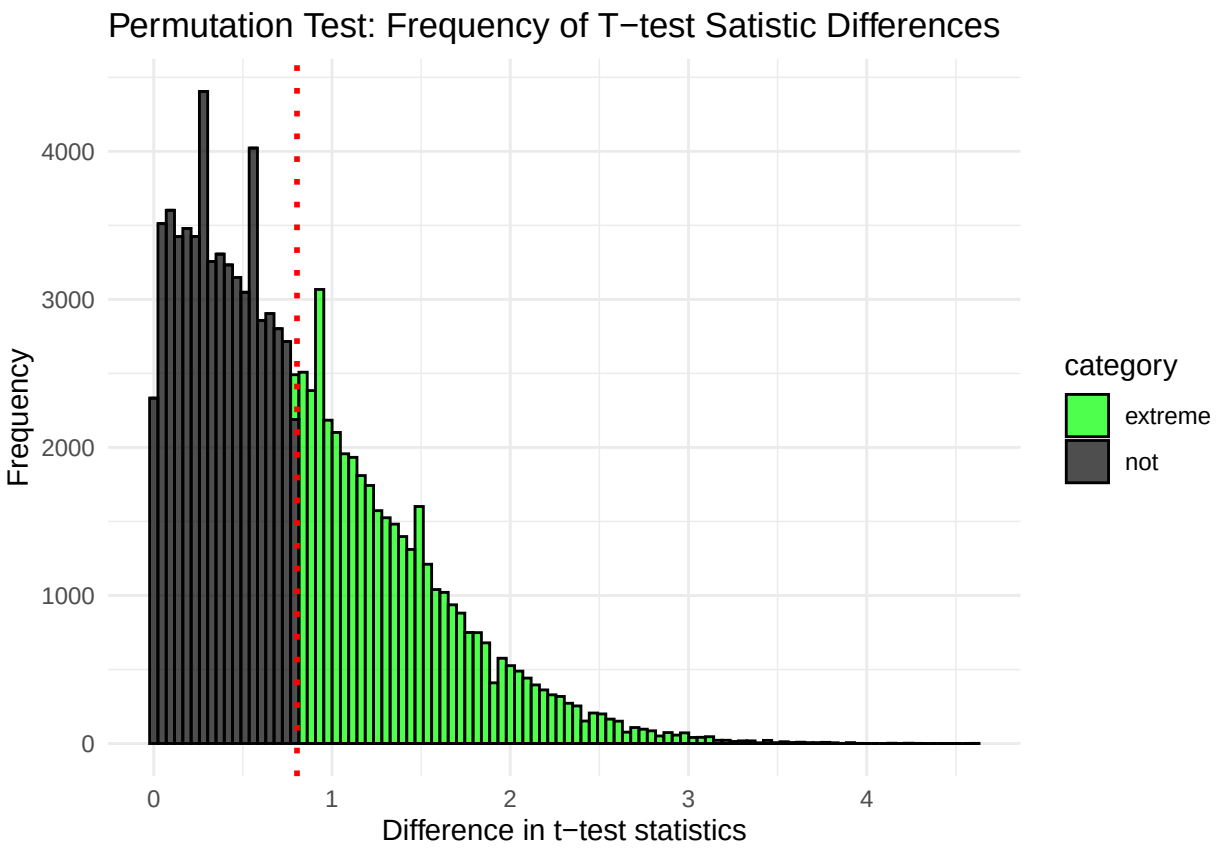
```
test_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.699  0.954 0.934     1 0.0824
## 2 lexicase      40      0 0.699  0.948 0.918     1 0.0607
```

The permutation test revealed that the results are:

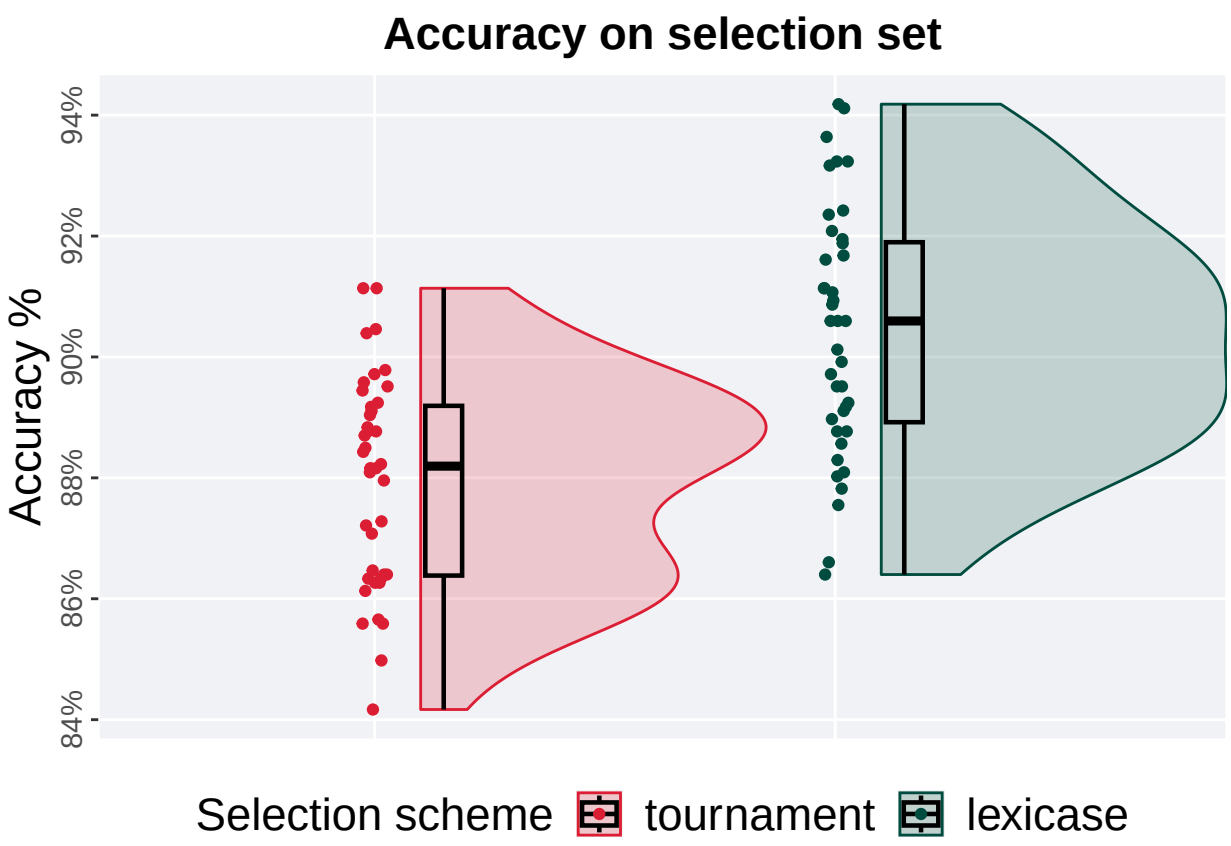
```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 109,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.803639914004292"
## [1] "lower: -1.99477816242174"
## [1] "upper: 1.99477818979544"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.4234"
```



12.5.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

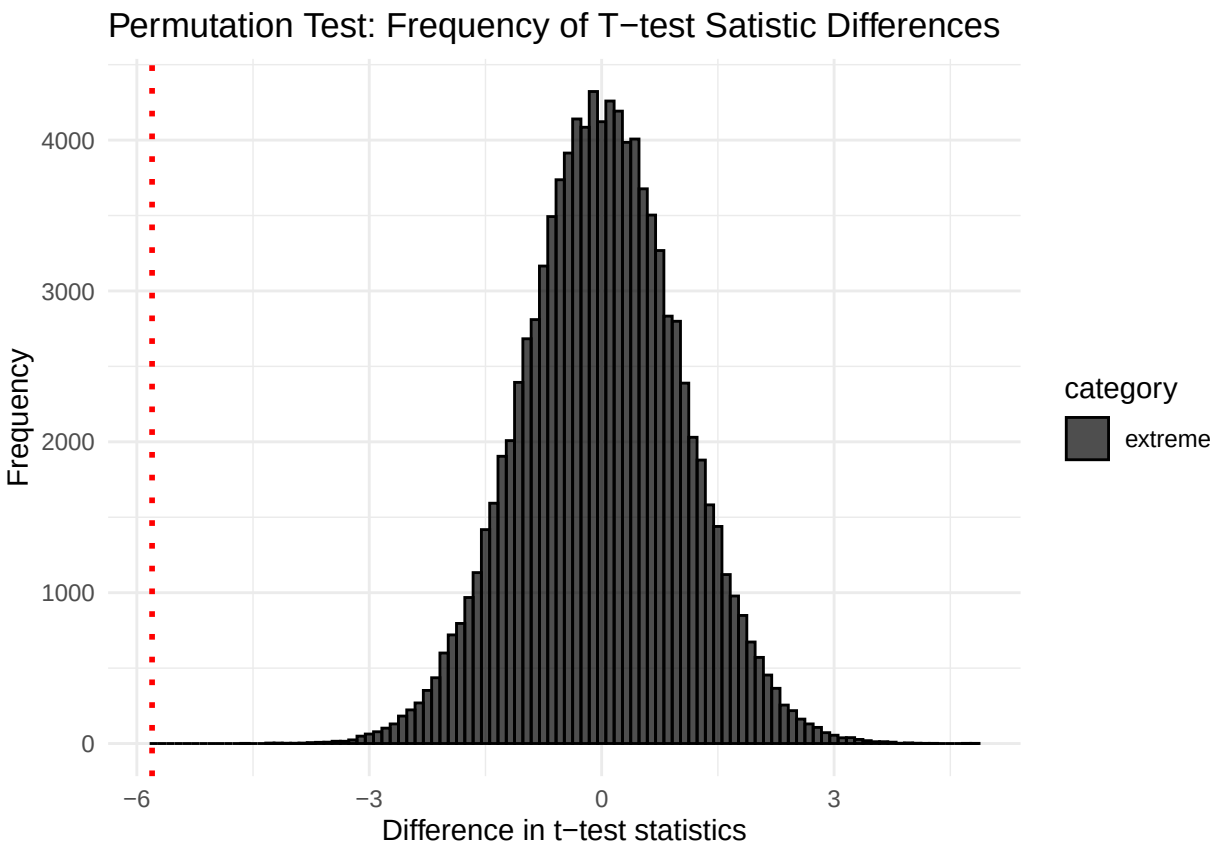
```
selection_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.842  0.882 0.880 0.911 0.0281
## 2 lexicase      40      0 0.864  0.906 0.904 0.942 0.0298
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 110,
                 alternative = "l")
```

```
## [1] "observed_diff: -5.80303164089155"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.66315447368821"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```


Permutation Test: Frequency of T−test Satistic Differences
Frequency
4000
3000
2000
1000
0
−6
−3
0
3
Difference in t−test statistics
category
extreme

Chapter 13

Task 168784

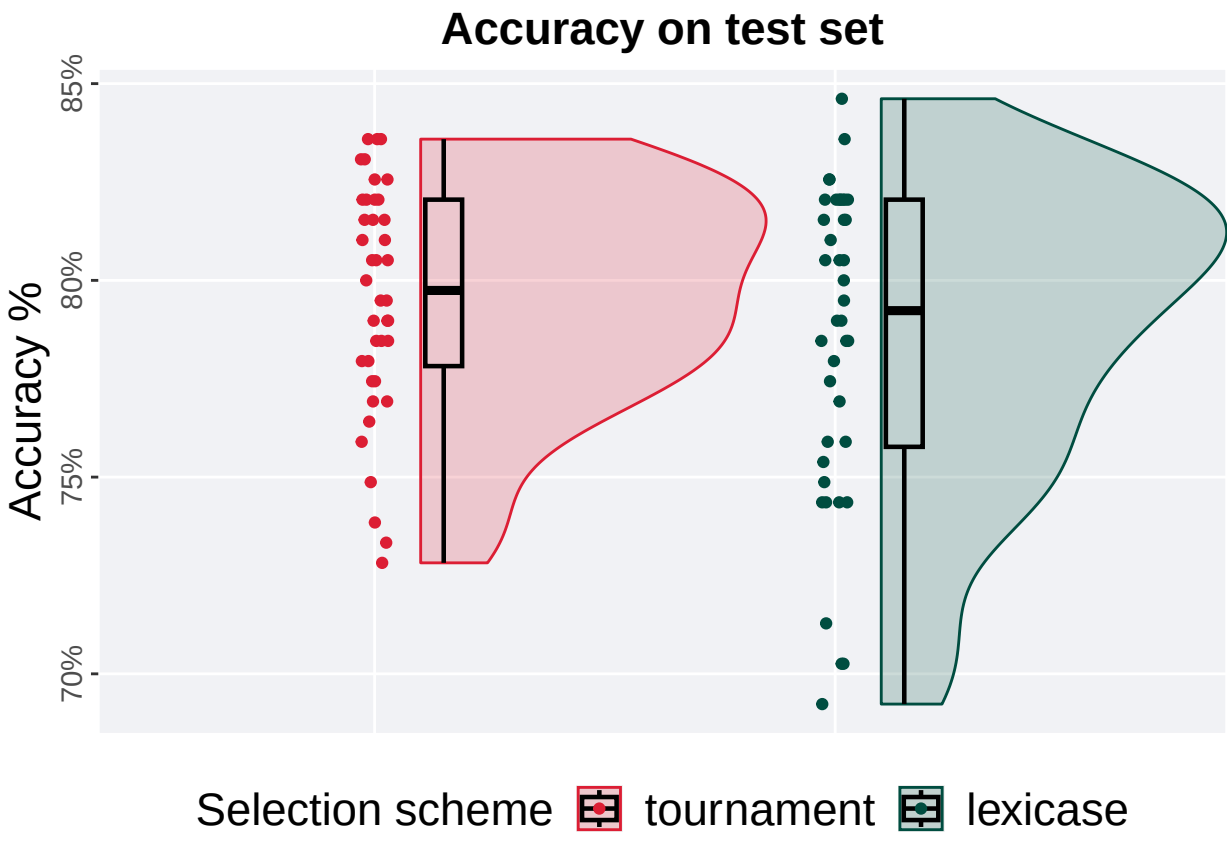
We present the results of our analysis of `task 168784` with the different selection set splits used in our study.

```
task_data <- filter(results, task_id == 168784)
```

13.1 5%

13.1.1 Testing set accuracy

```
test_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

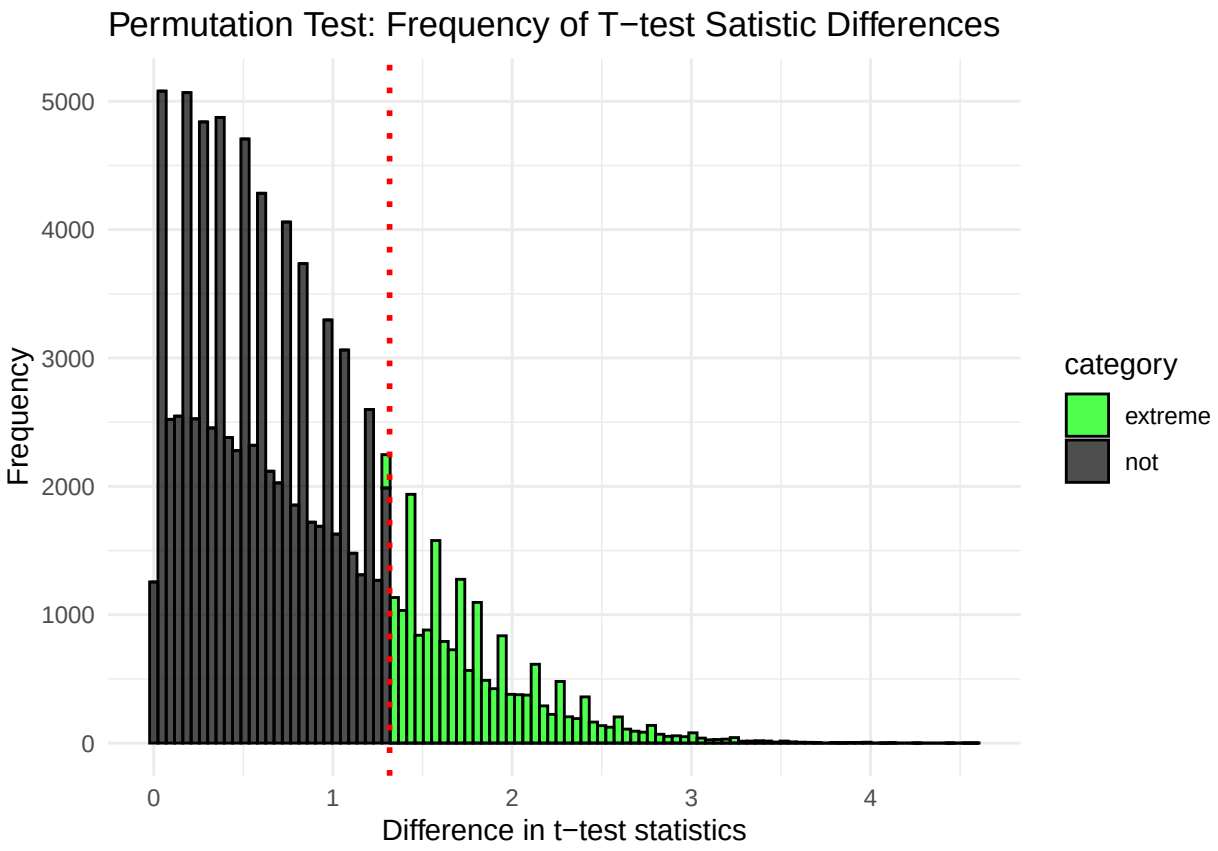
```
test_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.728  0.797 0.795 0.836 0.0423
## 2 lexicase      40      0 0.692  0.792 0.785 0.846 0.0628
```

The permutation test revealed that the results are:

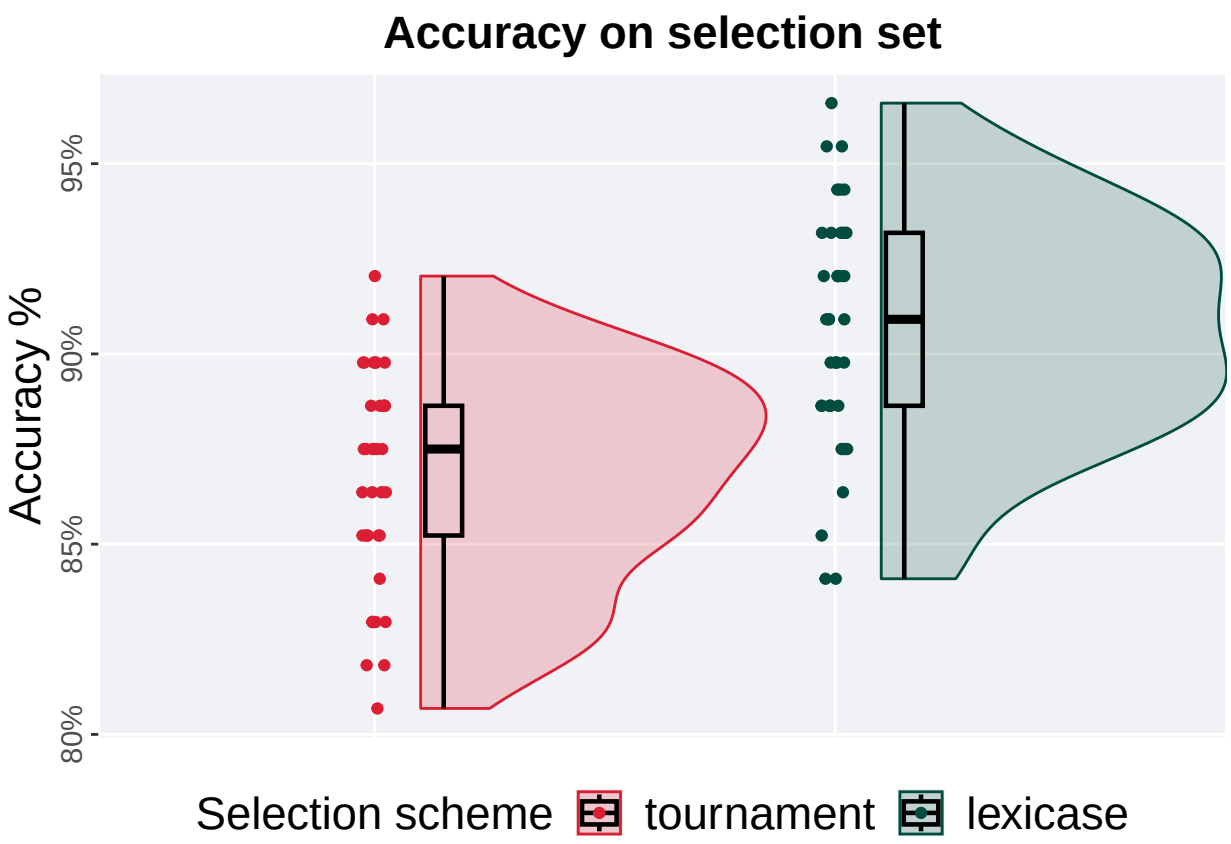
```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 111,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.31597665591326"
## [1] "lower: -2.00194003515967"
## [1] "upper: 2.00194017197189"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.19036"
```



13.1.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

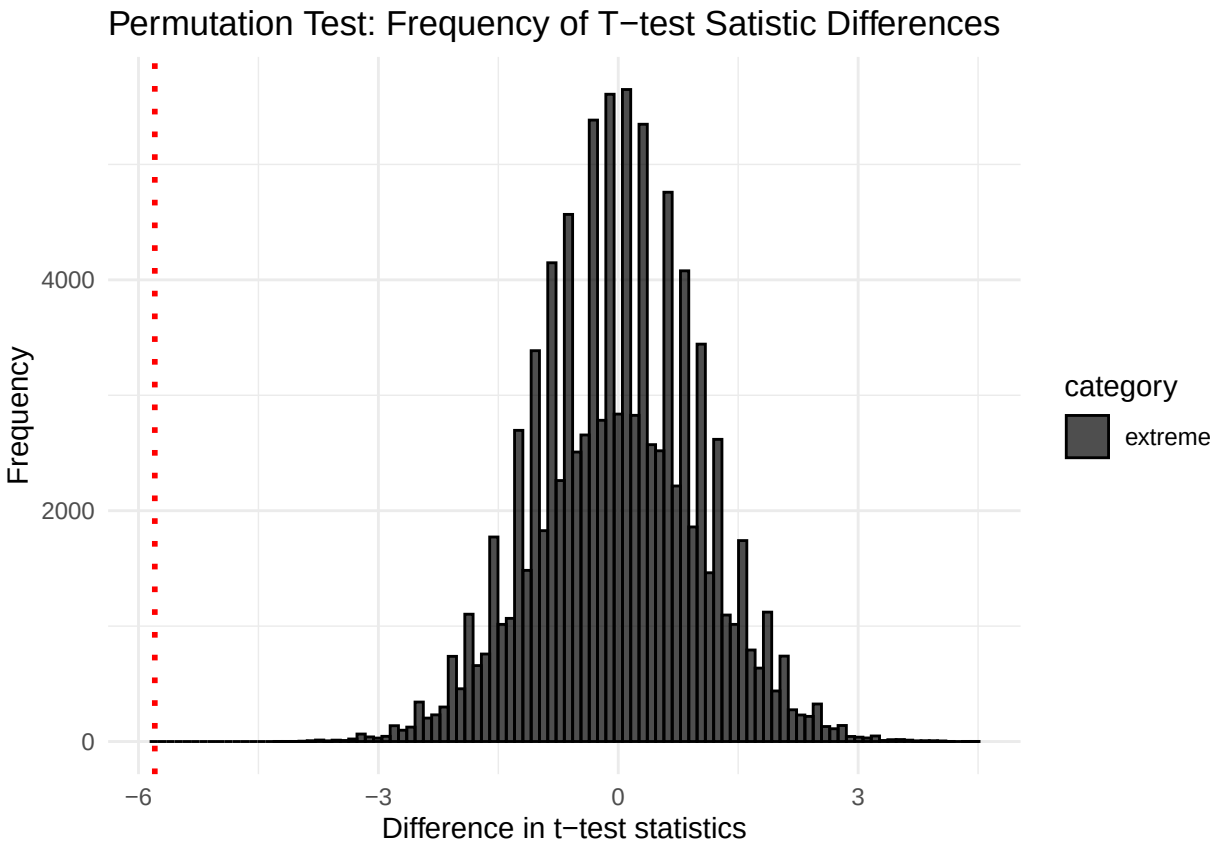
```
selection_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.807  0.875 0.867 0.920 0.0341
## 2 lexicase      40      0 0.841  0.909 0.906 0.966 0.0455
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 112,
                 alternative = "l")
```

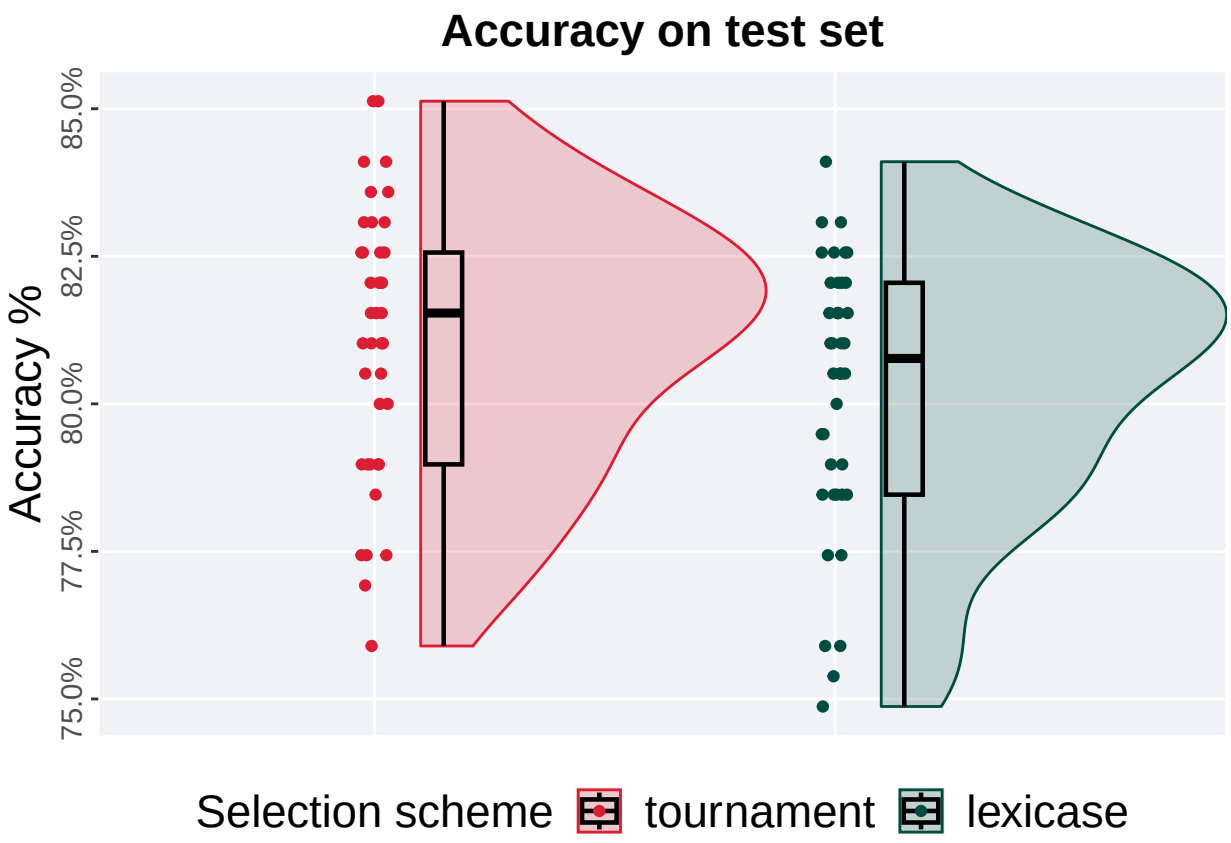
```
## [1] "observed_diff: -5.79635757388812"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.66803276720504"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```



13.2 10%

13.2.1 Testing set accuracy

```
test_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

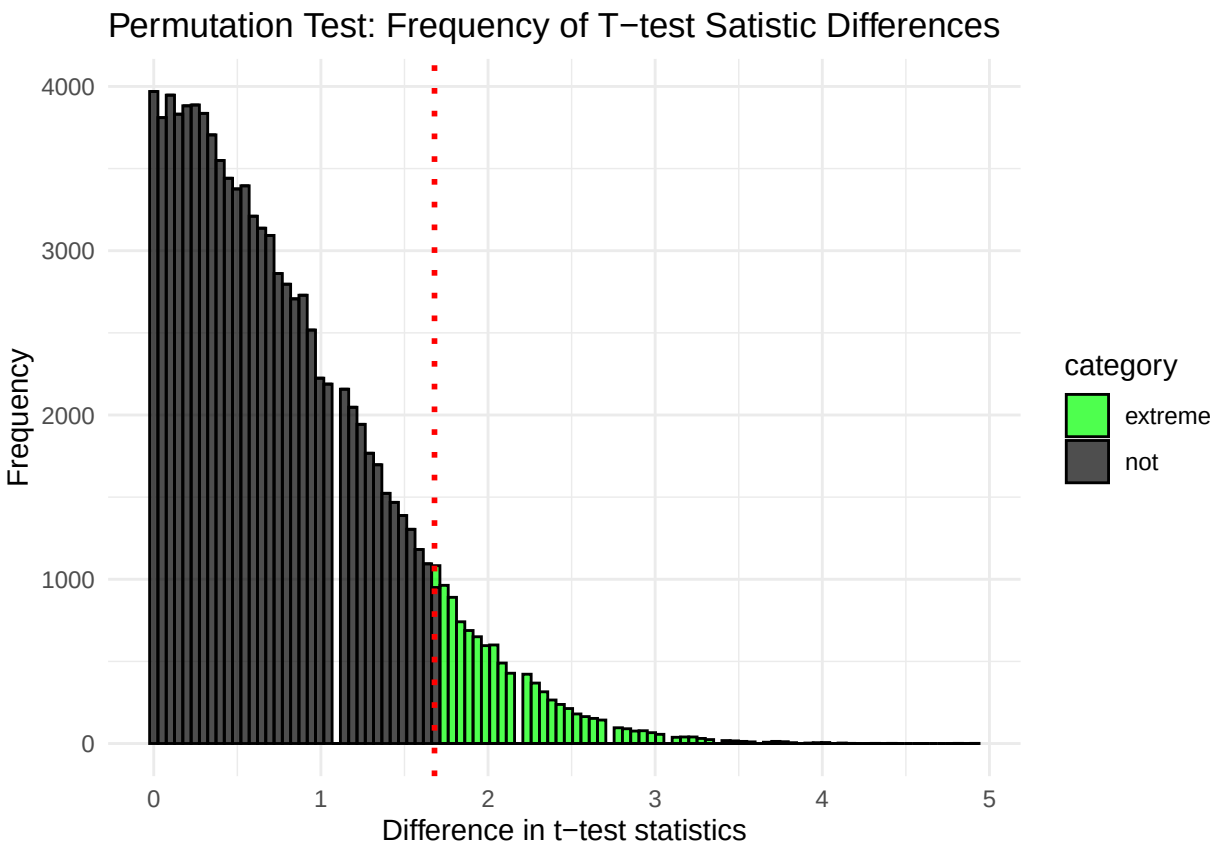
```
test_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.759  0.815 0.811 0.851 0.0359
## 2 lexicase      40      0 0.749  0.808 0.802 0.841 0.0359
```

The permutation test revealed that the results are:

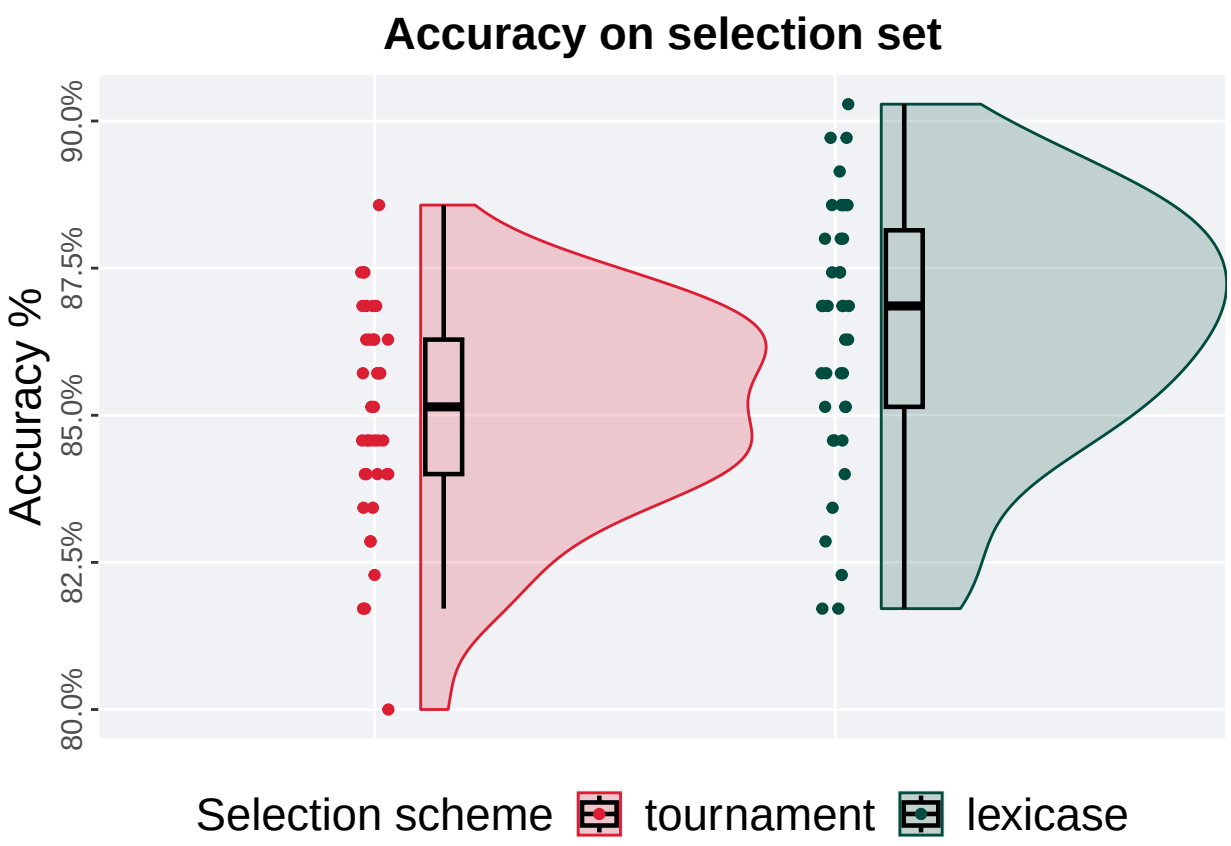
```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 113,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.6796503157697"
## [1] "lower: -1.99461117576958"
## [1] "upper: 1.99461096878831"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.09392"
```



13.2.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

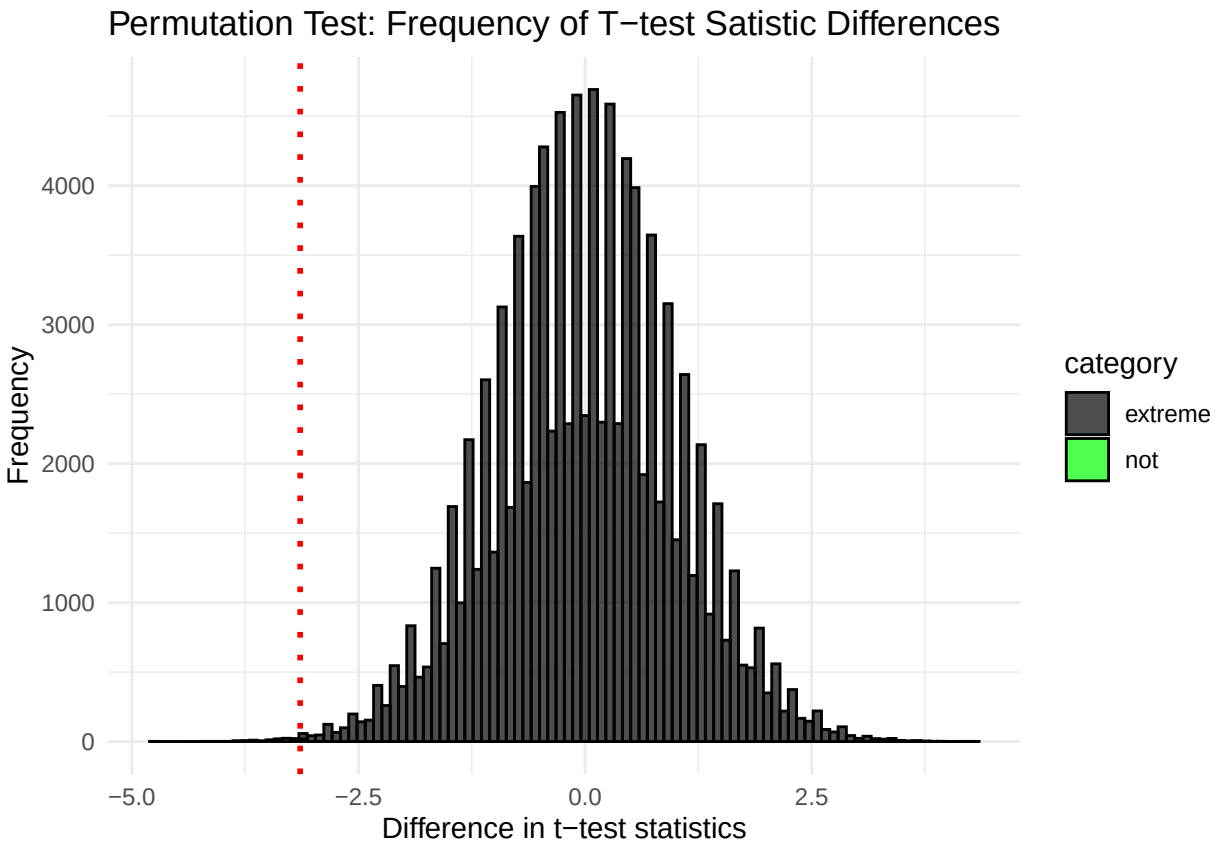
```
selection_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.8    0.851 0.850 0.886 0.0229
## 2 lexicase      40      0 0.817  0.869 0.865 0.903 0.0300
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 114,
                 alternative = "l")
```

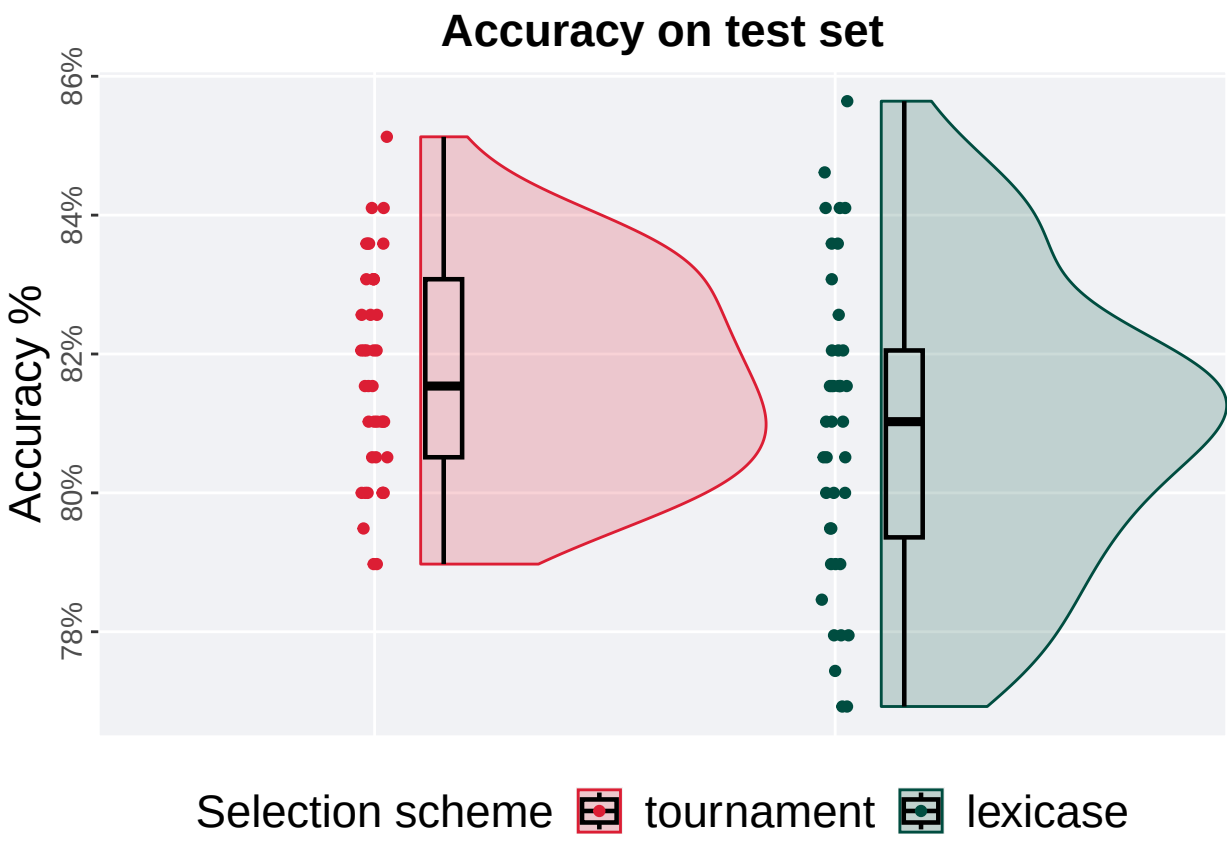
```
## [1] "observed_diff: -3.1433131617963"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.68838346854448"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00117"
```



13.3 50%

13.3.1 Testing set accuracy

```
test_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

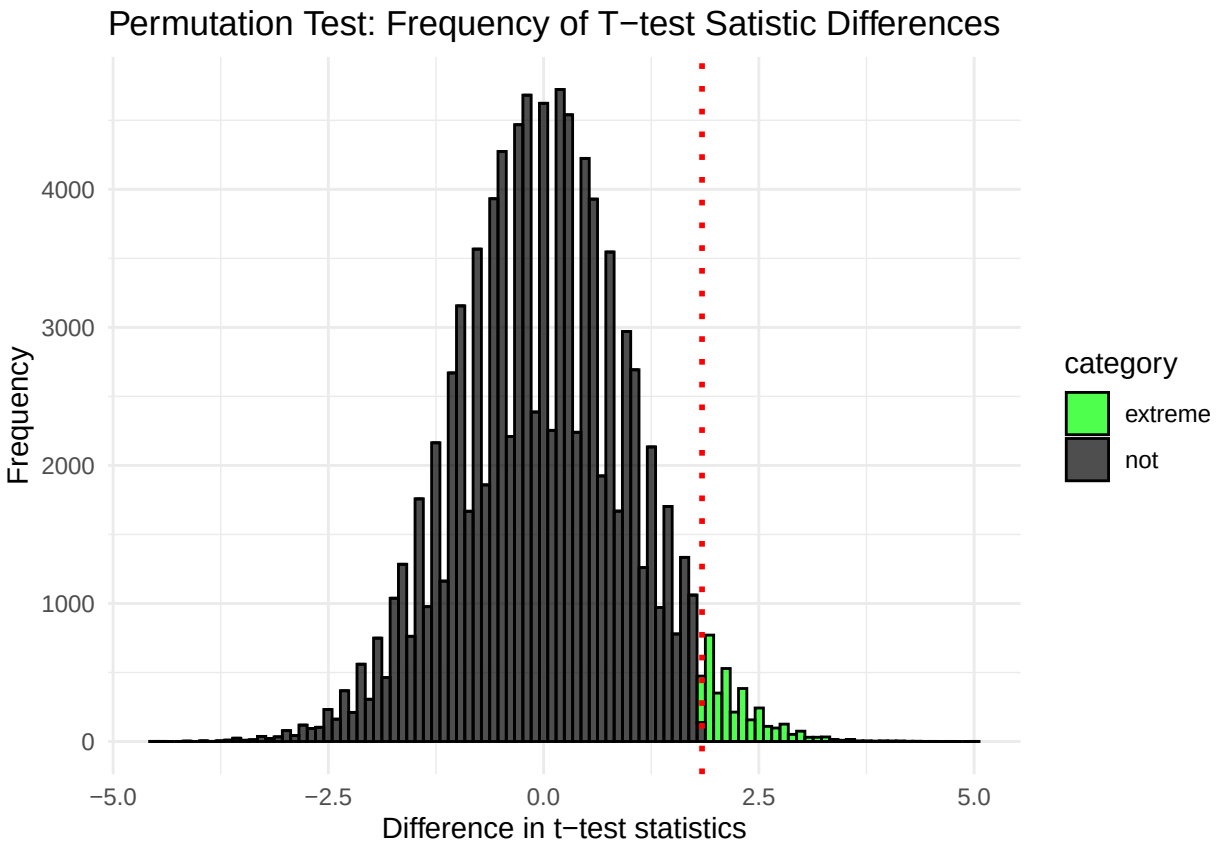
```
test_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.790  0.815 0.817 0.851 0.0256
## 2 lexicase      40      0 0.769  0.810 0.809 0.856 0.0269
```

The permutation test revealed that the results are:

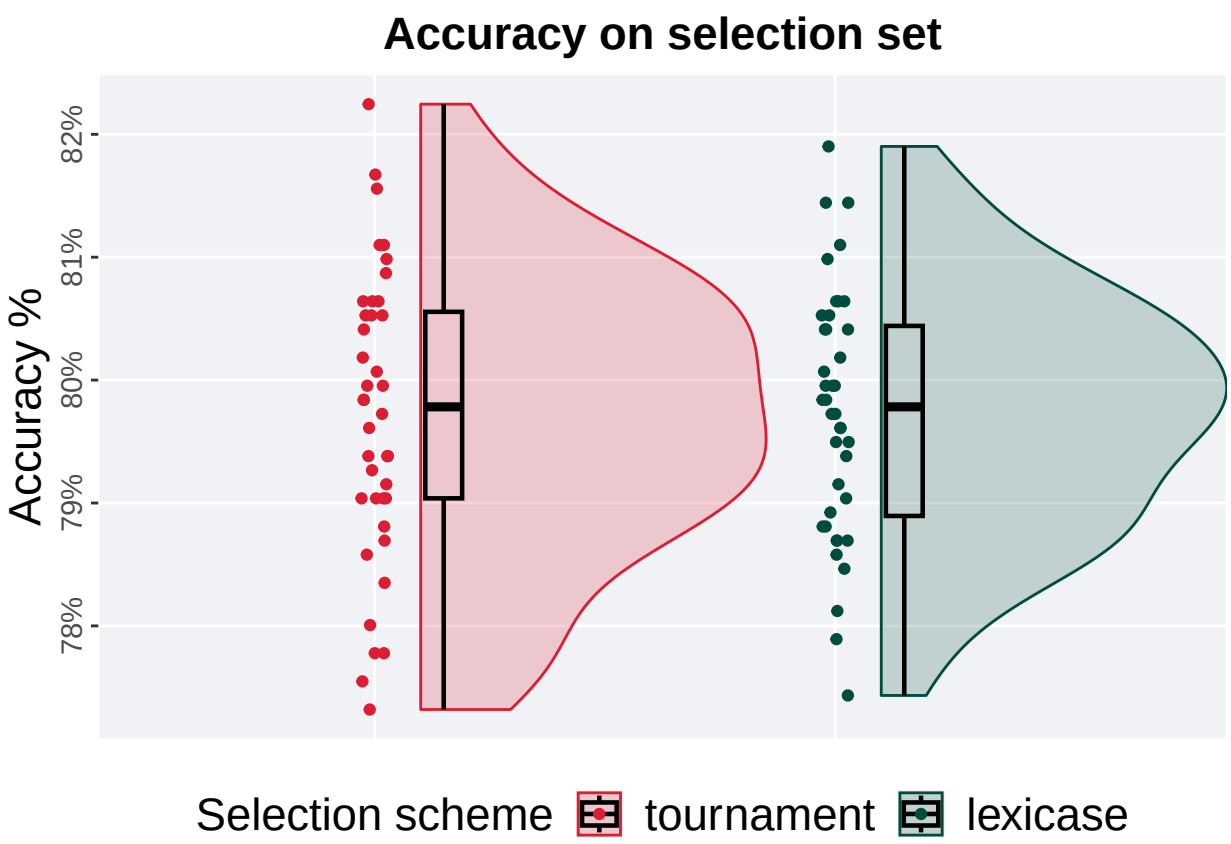
```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 115,
                 alternative = "g")
```

```
## [1] "observed_diff: 1.84018428427782"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.65248732220136"
## [1] "reject null hypothesis"
## [1] "p-value: 0.03586"
```



13.3.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

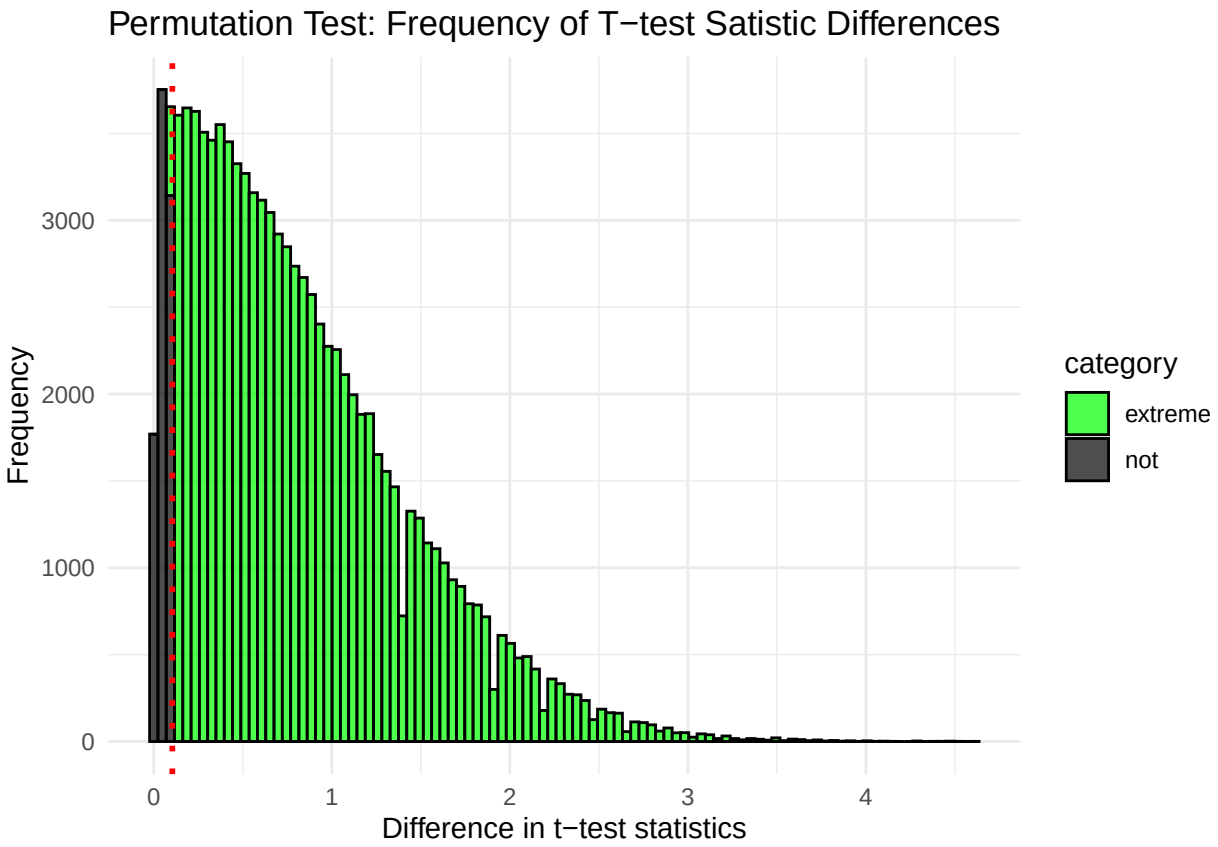
```
selection_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.773  0.798 0.797 0.822 0.0152
## 2 lexicase      40      0 0.774  0.798 0.797 0.819 0.0155
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 116,
                 alternative = "t")
```

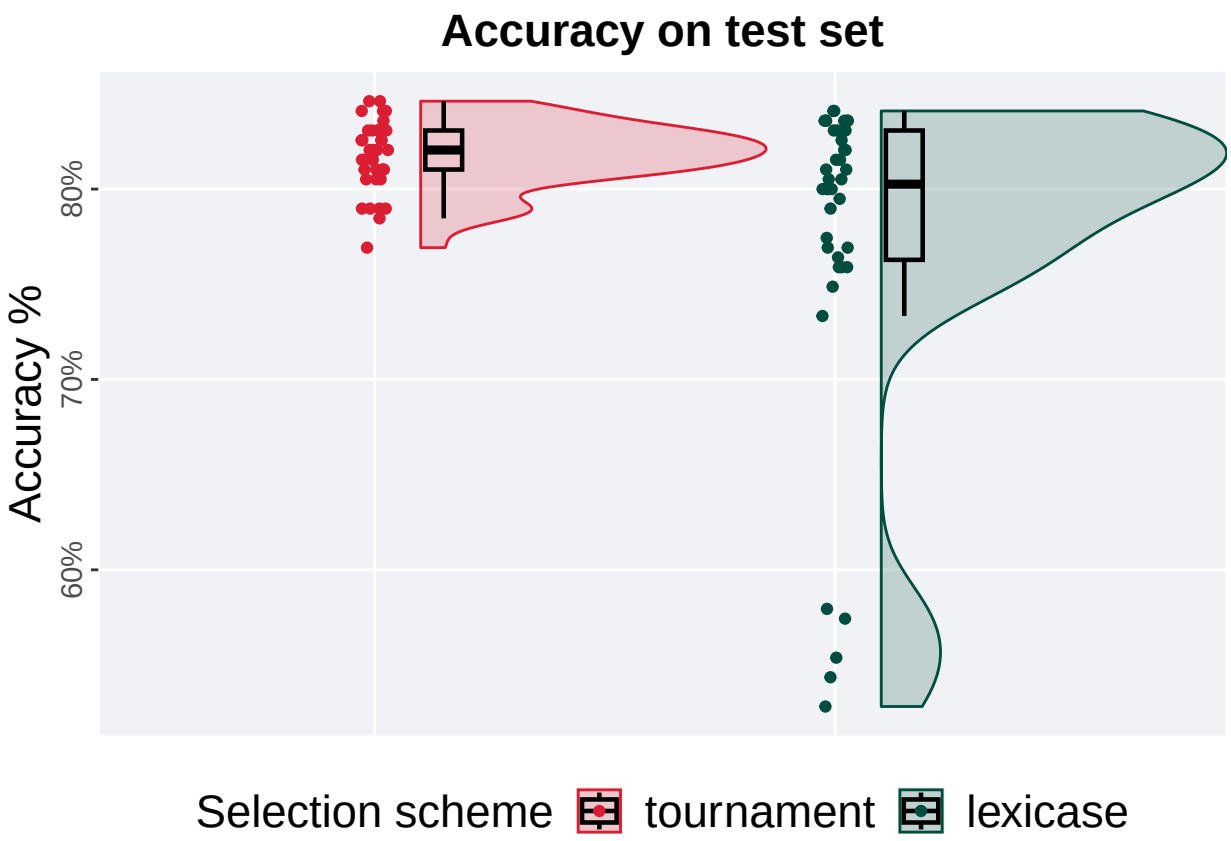
```
## [1] "observed_diff: -0.104445353599085"
## [1] "lower: -1.98629617822013"
## [1] "upper: 1.98629465100794"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.91335"
```



13.4 90%

13.4.1 Testing set accuracy

```
test_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

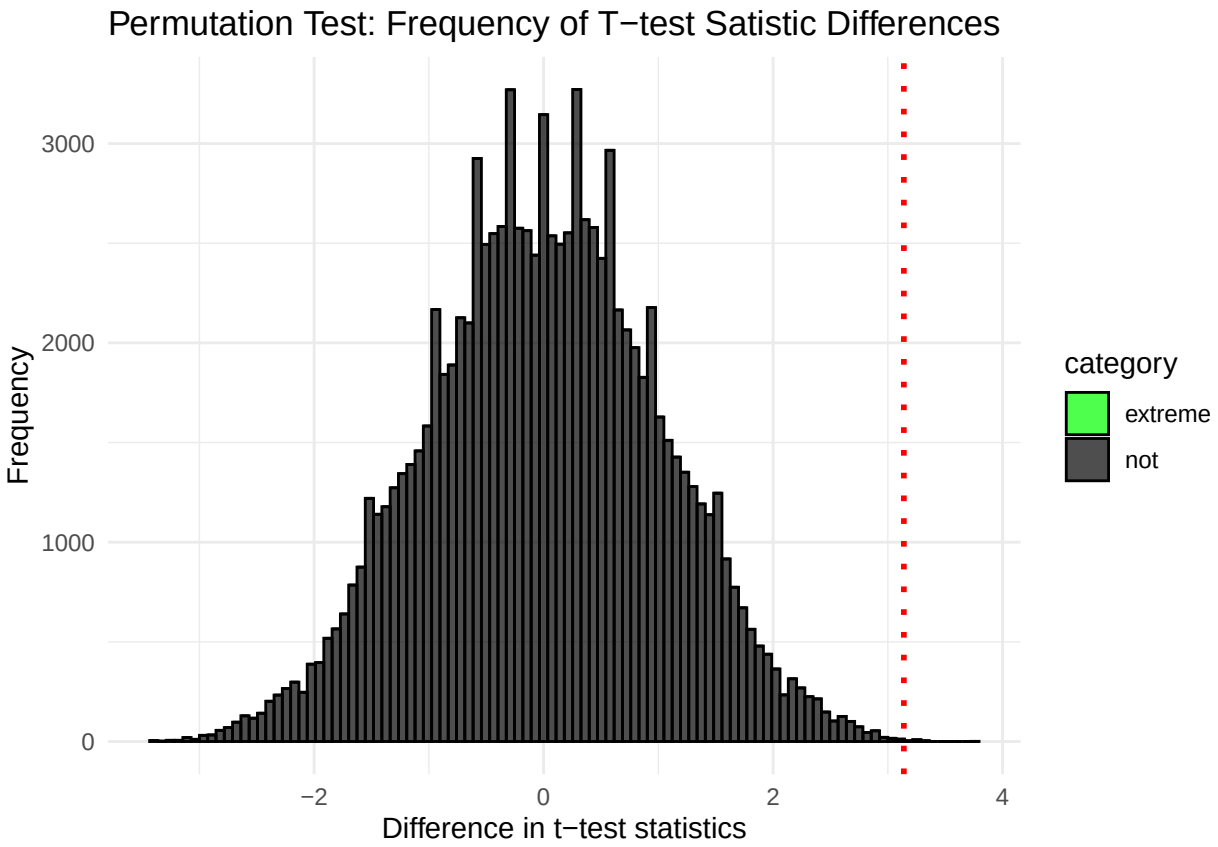
```
test_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.769  0.821 0.818 0.846 0.0205
## 2 lexicase      40      0 0.528  0.803 0.773 0.841 0.0679
```

The permutation test revealed that the results are:

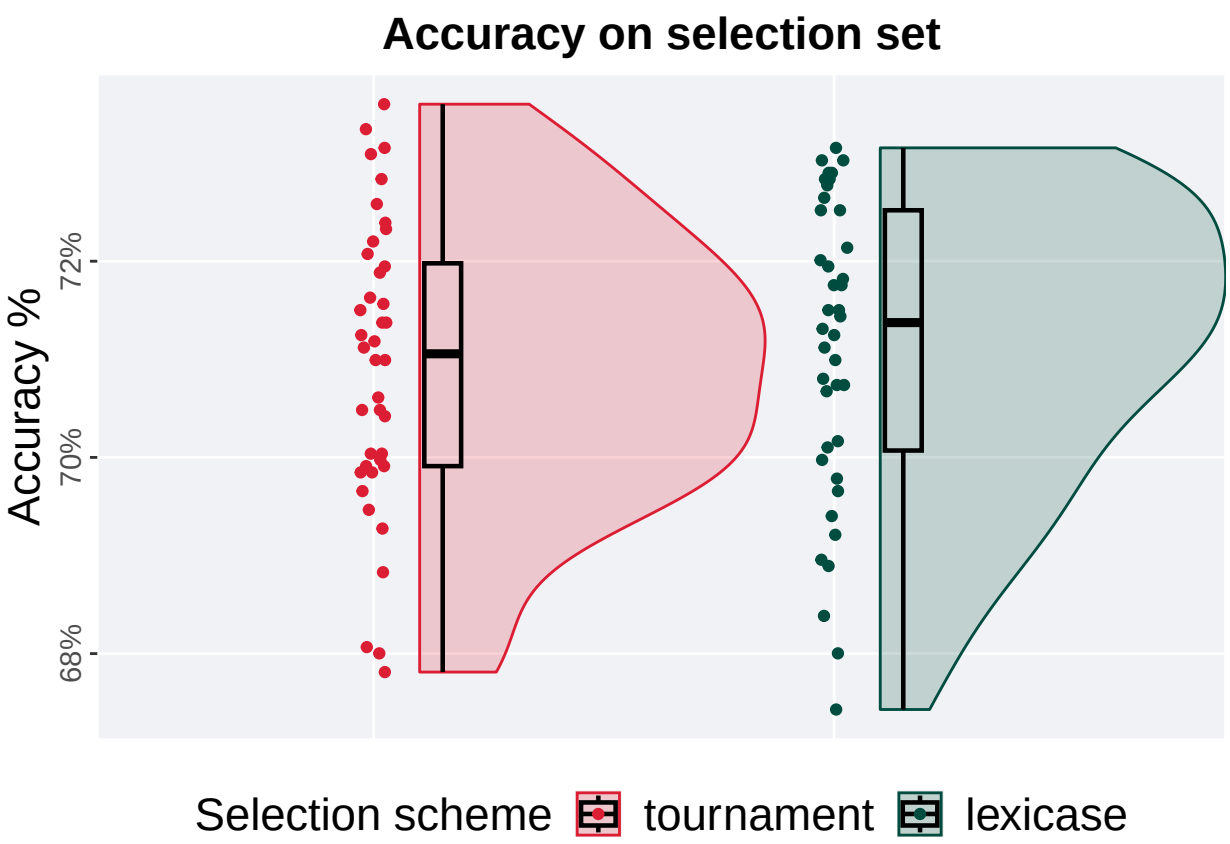
```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 117,
                 alternative = "g")
```

```
## [1] "observed_diff: 3.13974144978373"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.66080565220089"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00024"
```



13.4.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

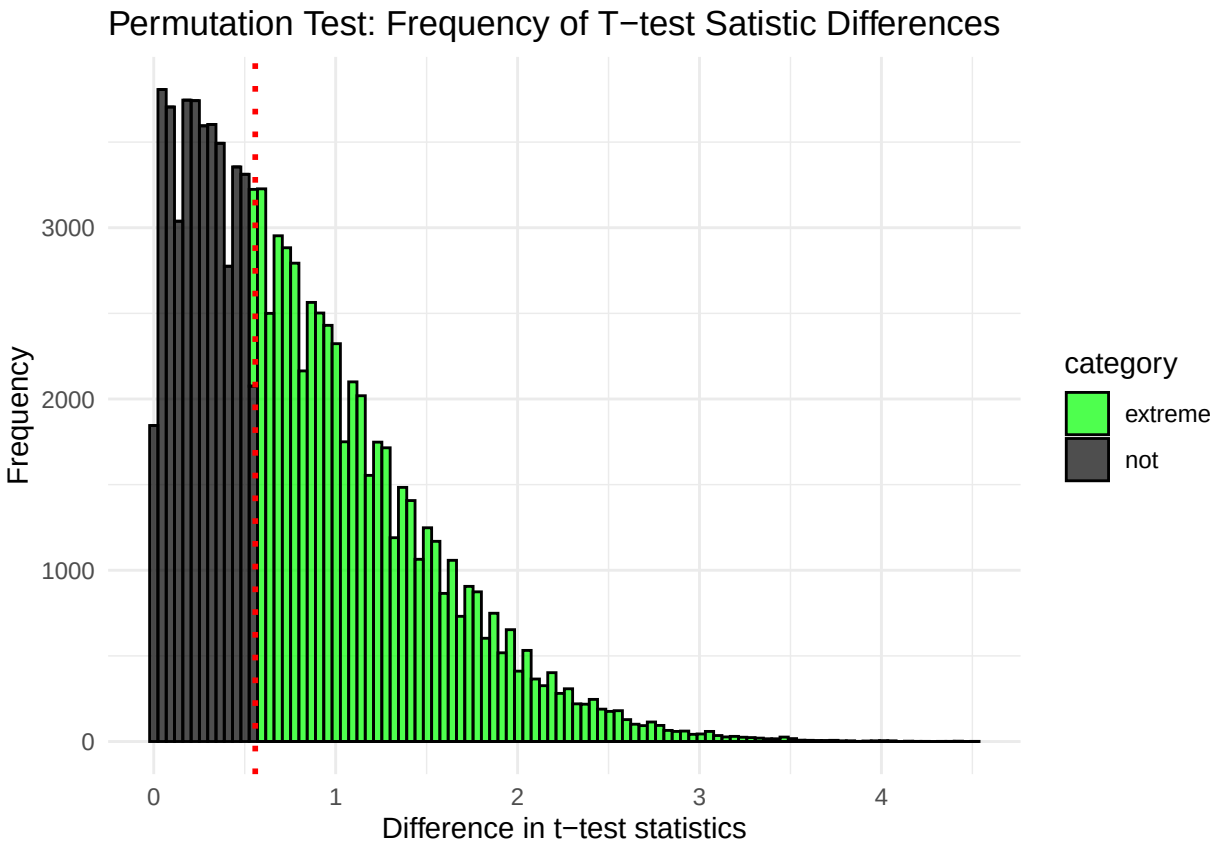
```
selection_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.678  0.711 0.709 0.736 0.0207
## 2 lexicase      40      0 0.674  0.714 0.711 0.732 0.0245
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 118,
                 alternative = "t")
```

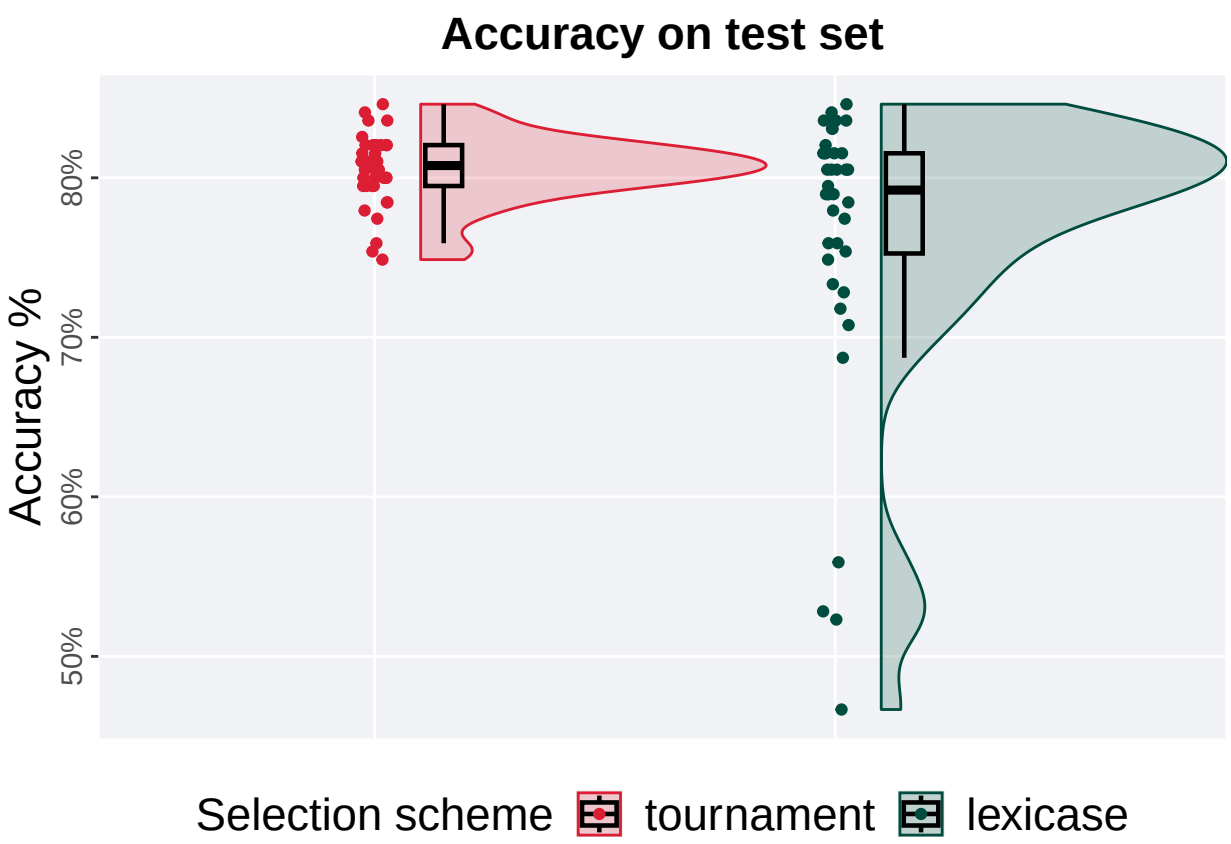
```
## [1] "observed_diff: -0.557779127920981"
## [1] "lower: -1.99247802744732"
## [1] "upper: 1.99247866659252"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.5791"
```



13.5 95%

13.5.1 Testing set accuracy

```
test_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

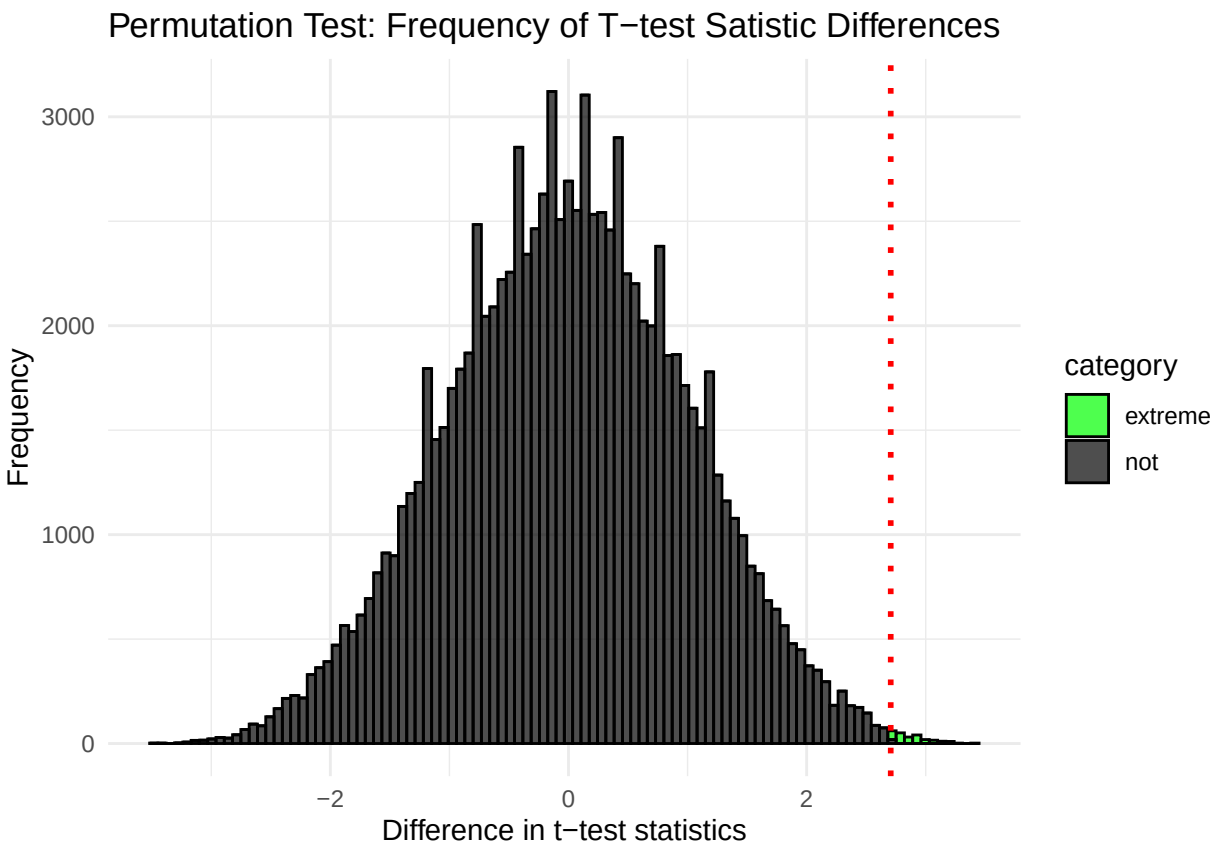
```
test_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.749  0.808 0.805 0.846 0.0256
## 2 lexicase      40      0 0.467  0.792 0.764 0.846 0.0628
```

The permutation test revealed that the results are:

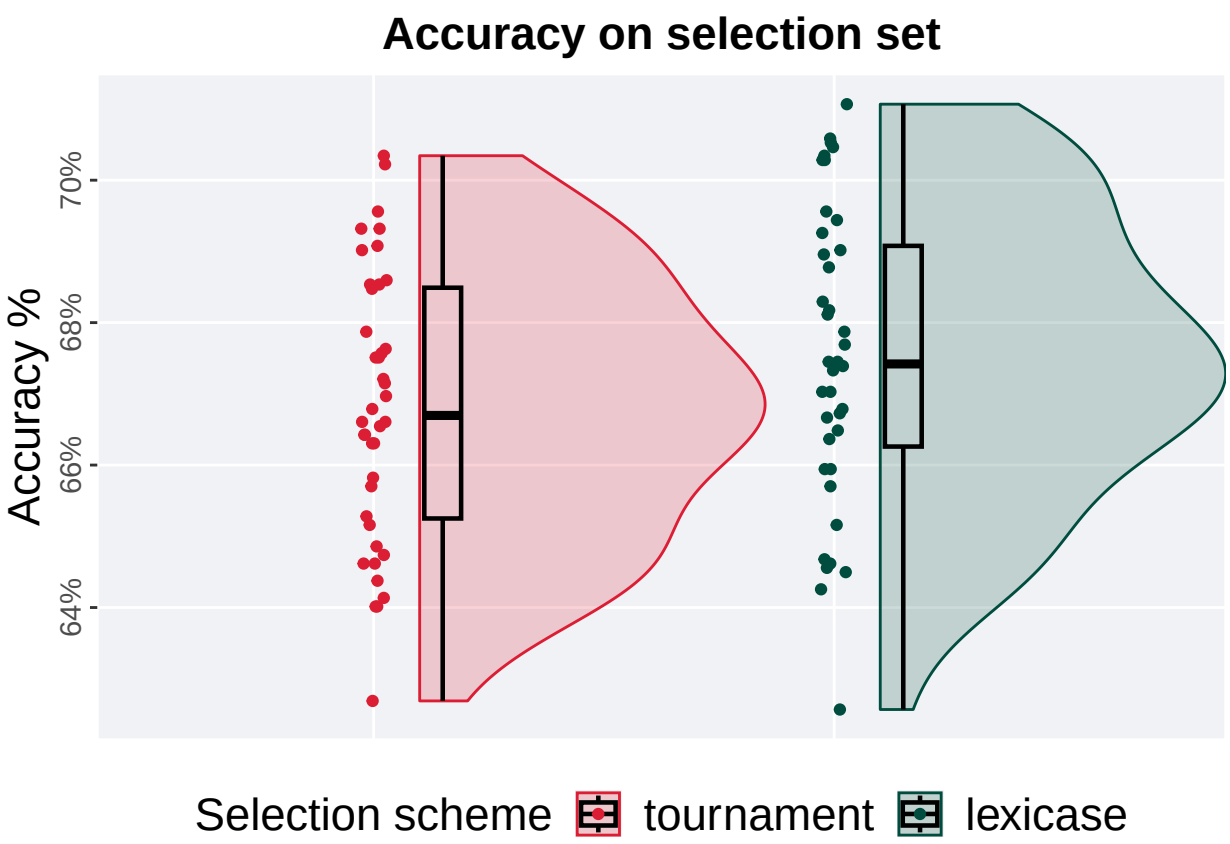
```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 119,
                 alternative = "g")
```

```
## [1] "observed_diff: 2.70614045169234"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.66331762825335"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00225"
```



13.5.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

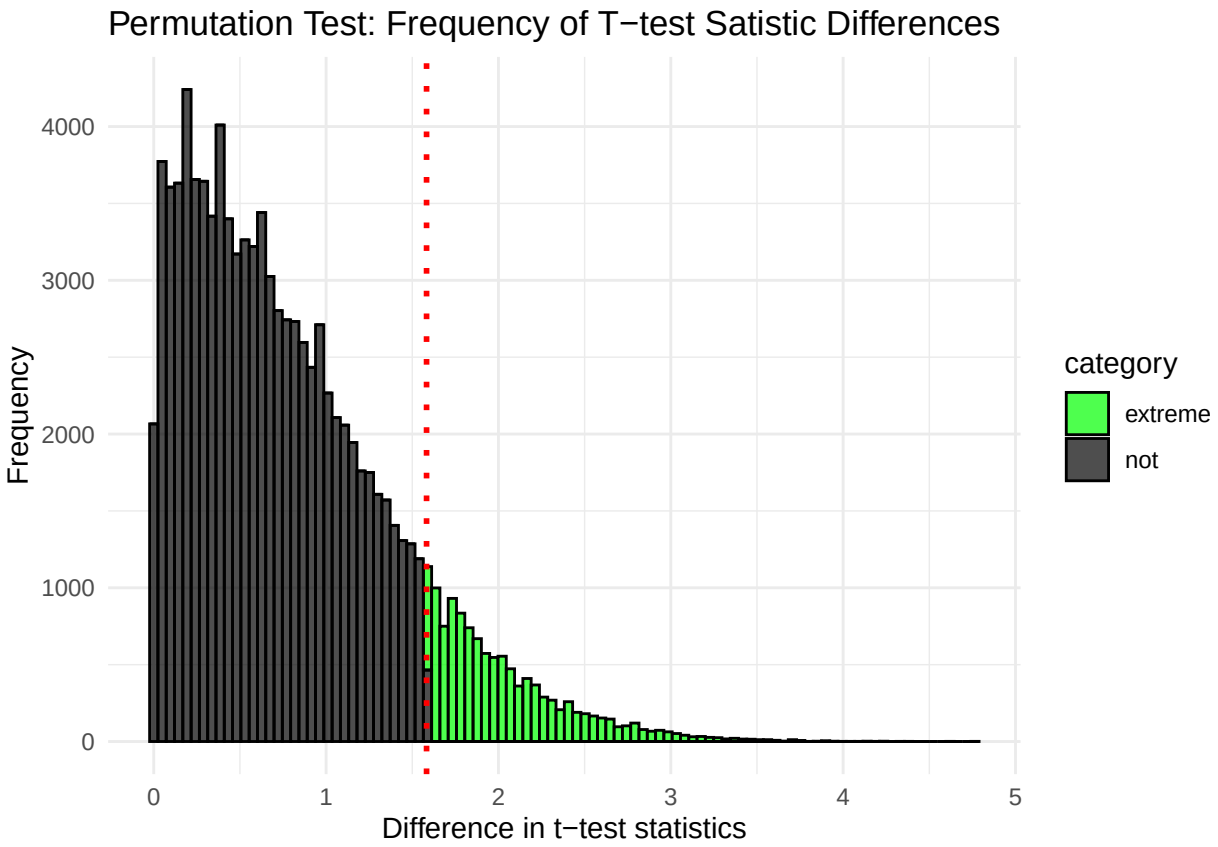
```
selection_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.627  0.667 0.668 0.703 0.0324
## 2 lexicase      40      0 0.626  0.674 0.675 0.711 0.0282
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 120,
                 alternative = "t")
```

```
## [1] "observed_diff: -1.5828085773587"
## [1] "lower: -1.99931288855232"
## [1] "upper: 1.99215361272119"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.11697"
```


Permutation Test: Frequency of T−test Satistic Differences
Frequency
4000
3000
2000
1000
0
0
1
2
3
4
5
Difference in t−test statistics
category
extreme
not

Chapter 14

Task 359962

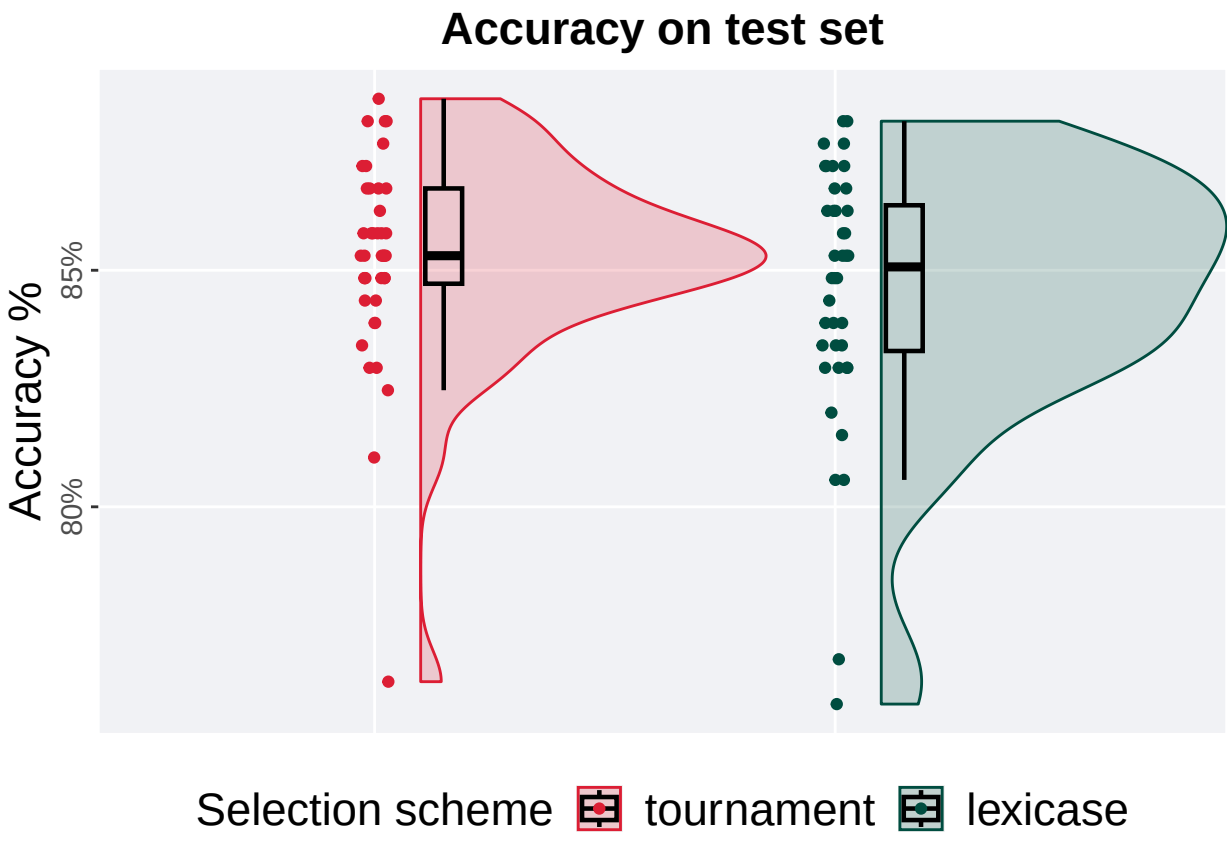
We present the results of our analysis of `task 359962` with the different selection set splits used in our study.

```
task_data <- filter(results, task_id == 359962)
```

14.1 5%

14.1.1 Testing set accuracy

```
test_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

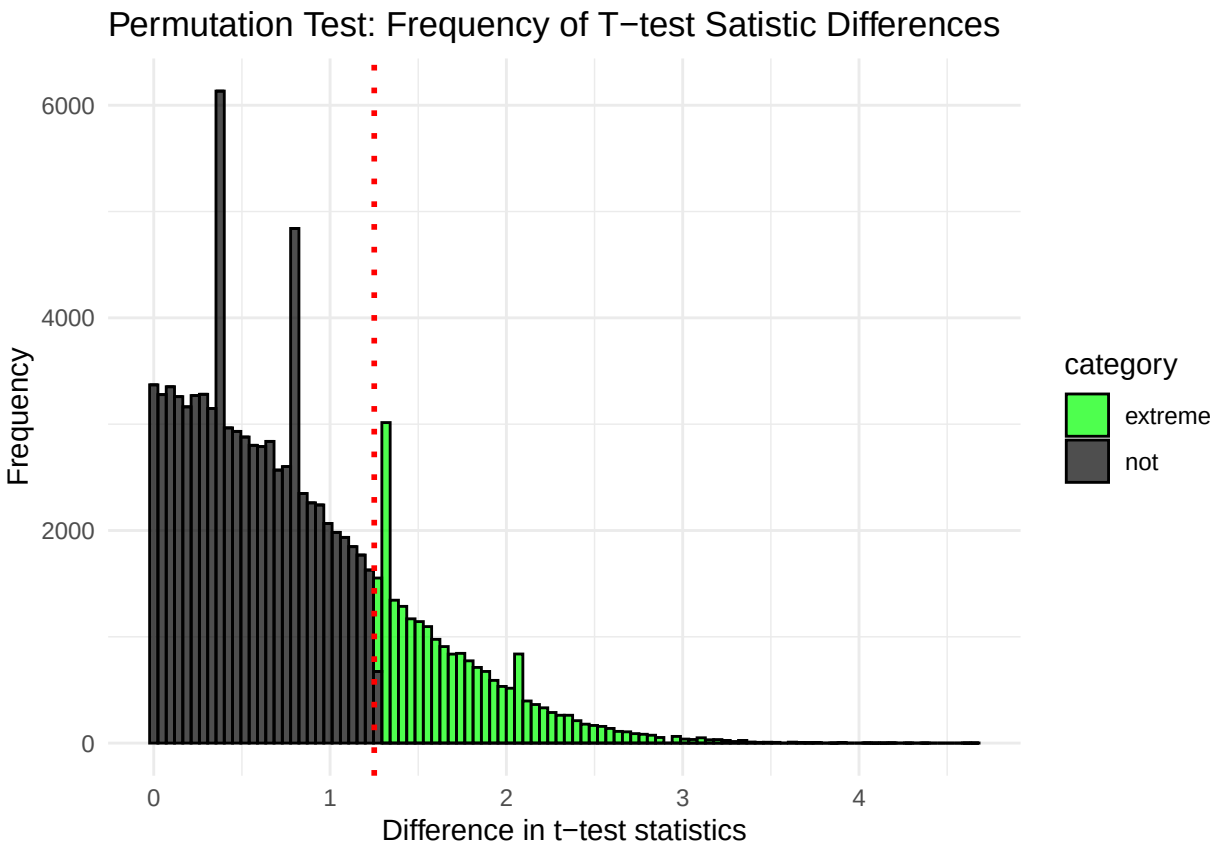
```
test_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.763  0.853 0.852 0.886 0.0201
## 2 lexicase      40      0 0.758  0.851 0.845 0.882 0.0308
```

The permutation test revealed that the results are:

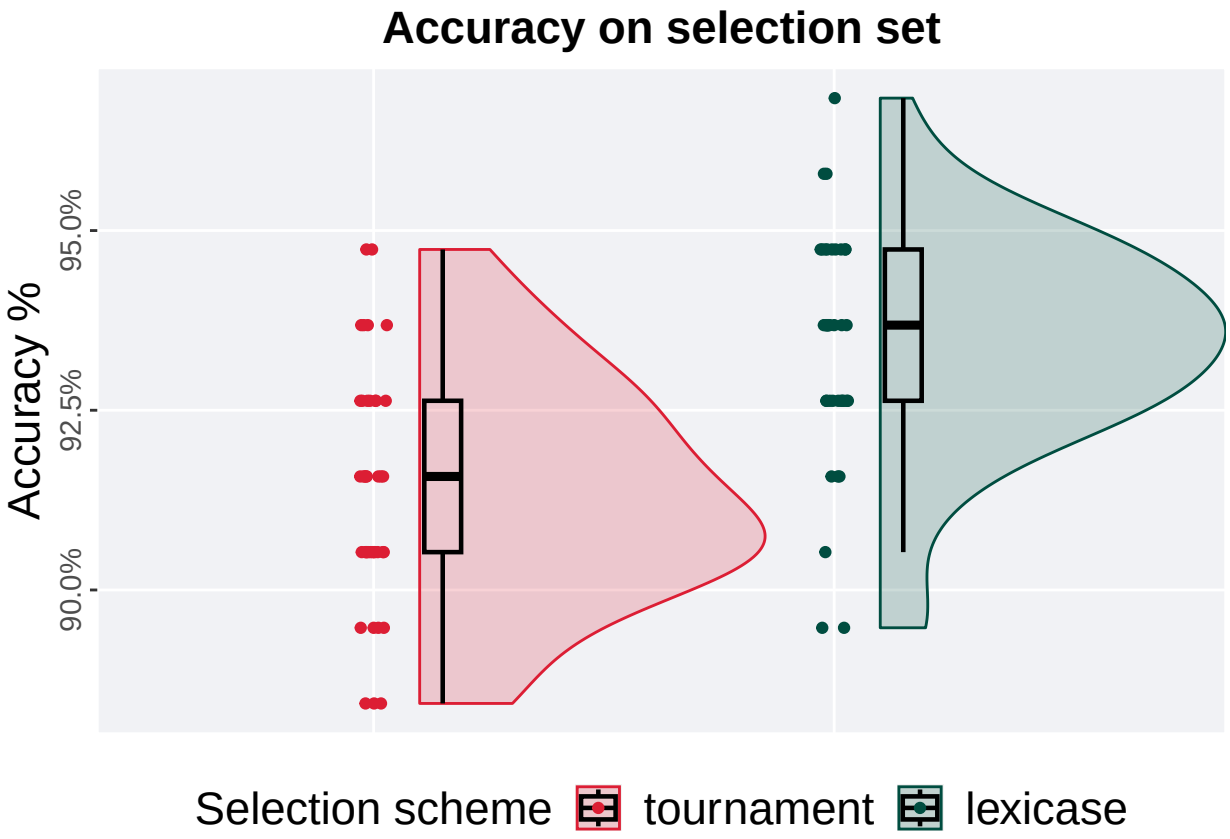
```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 121,
                 alternative = "t")
```

```
## [1] "observed_diff: 1.25048032725024"
## [1] "lower: -2.00109902223407"
## [1] "upper: 1.95593273813578"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.21784"
```



14.1.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '5%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

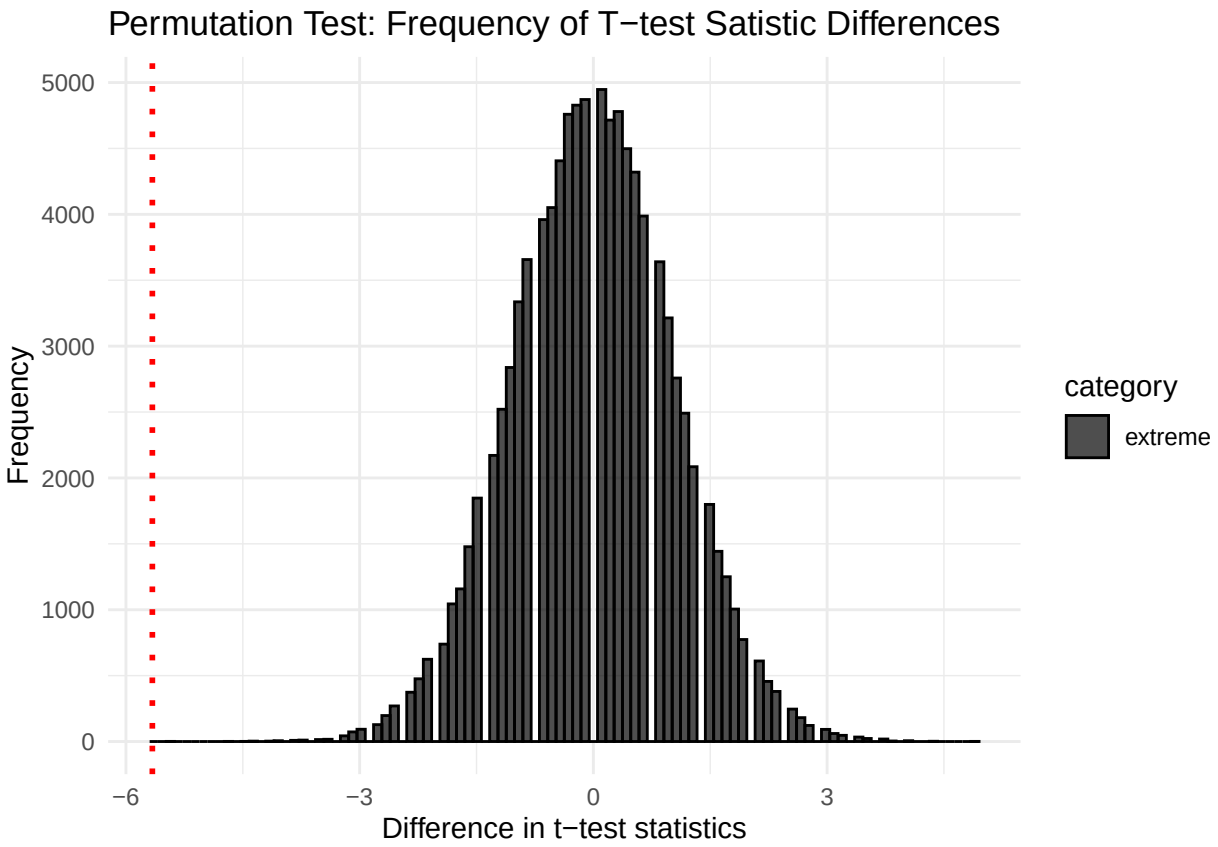
```
selection_results_summary(filter(task_data, split == '5%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.884  0.916 0.914 0.947 0.0211
## 2 lexicase      40      0 0.895  0.937 0.934 0.968 0.0211
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '5%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '5%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 122,
                 alternative = "l")
```

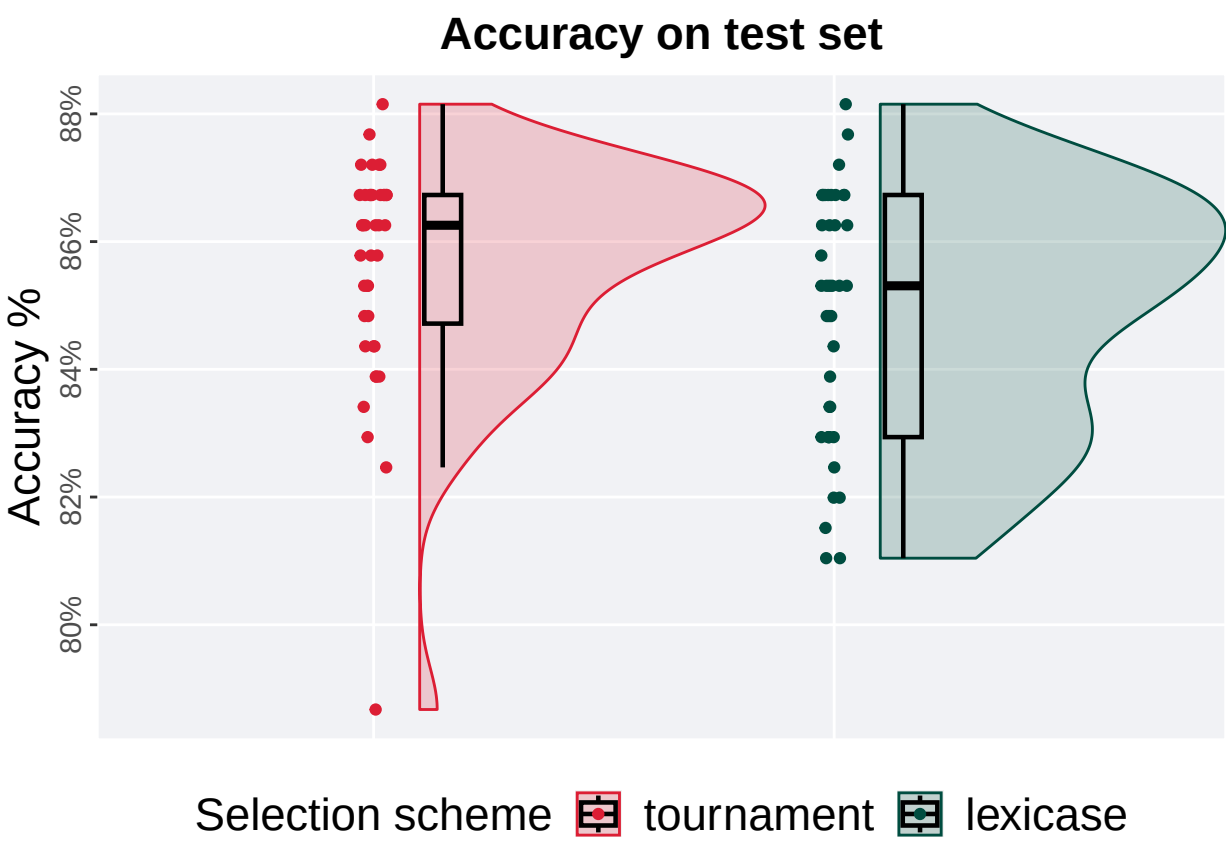
```
## [1] "observed_diff: -5.66114893846717"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.70196523619733"
## [1] "reject null hypothesis"
## [1] "p-value: 1e-05"
```



14.2 10%

14.2.1 Testing set accuracy

```
test_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

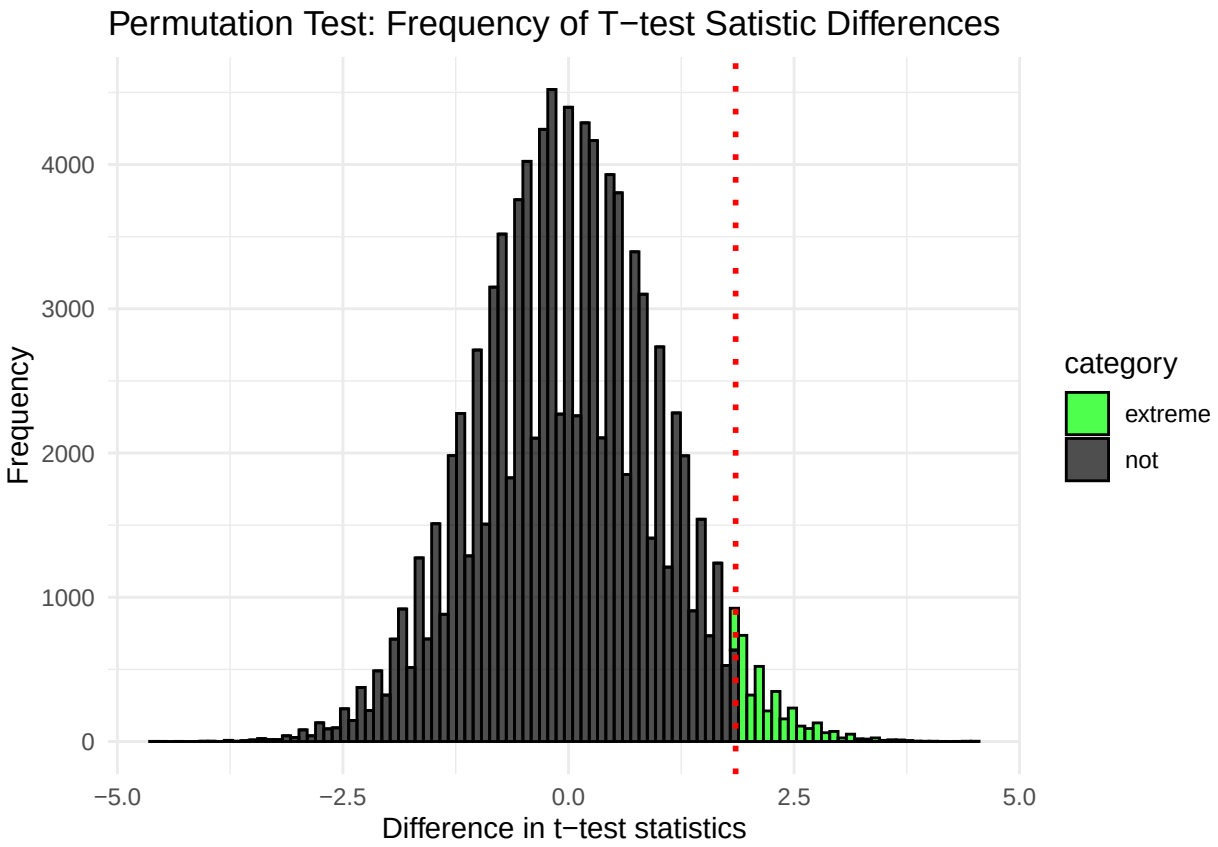
```
test_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.787  0.863 0.856 0.882 0.0201
## 2 lexicase      40      0 0.810  0.853 0.848 0.882 0.0379
```

The permutation test revealed that the results are:

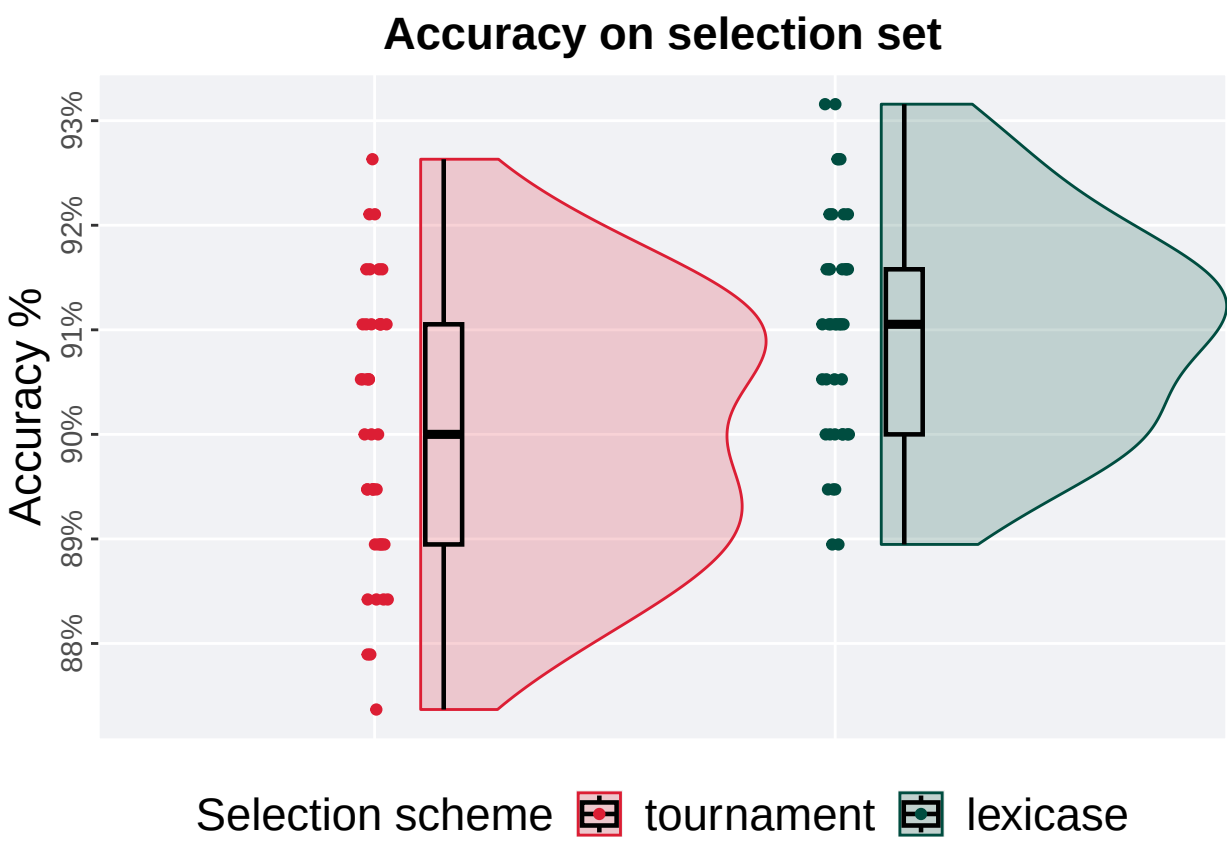
```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 123,
                 alternative = "g")
```

```
## [1] "observed_diff: 1.85272669685502"
## [1] "permutation_diffs[0.95 * n_permutations]: 1.67522717697368"
## [1] "reject null hypothesis"
## [1] "p-value: 0.0345"
```



14.2.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '10%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

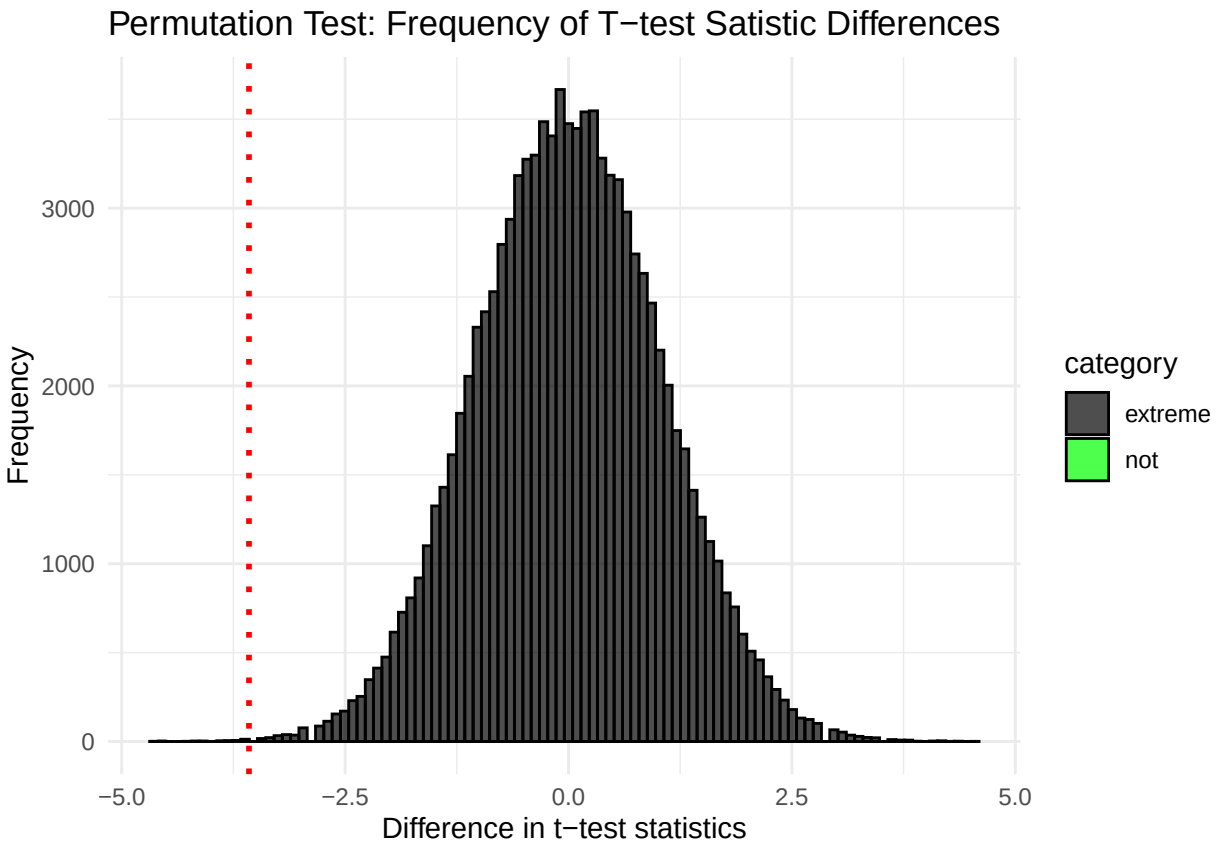
```
selection_results_summary(filter(task_data, split == '10%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.874  0.9   0.900 0.926 0.0211
## 2 lexicase      40      0 0.889  0.911 0.910 0.932 0.0158
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '10%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '10%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 124,
                 alternative = "l")
```

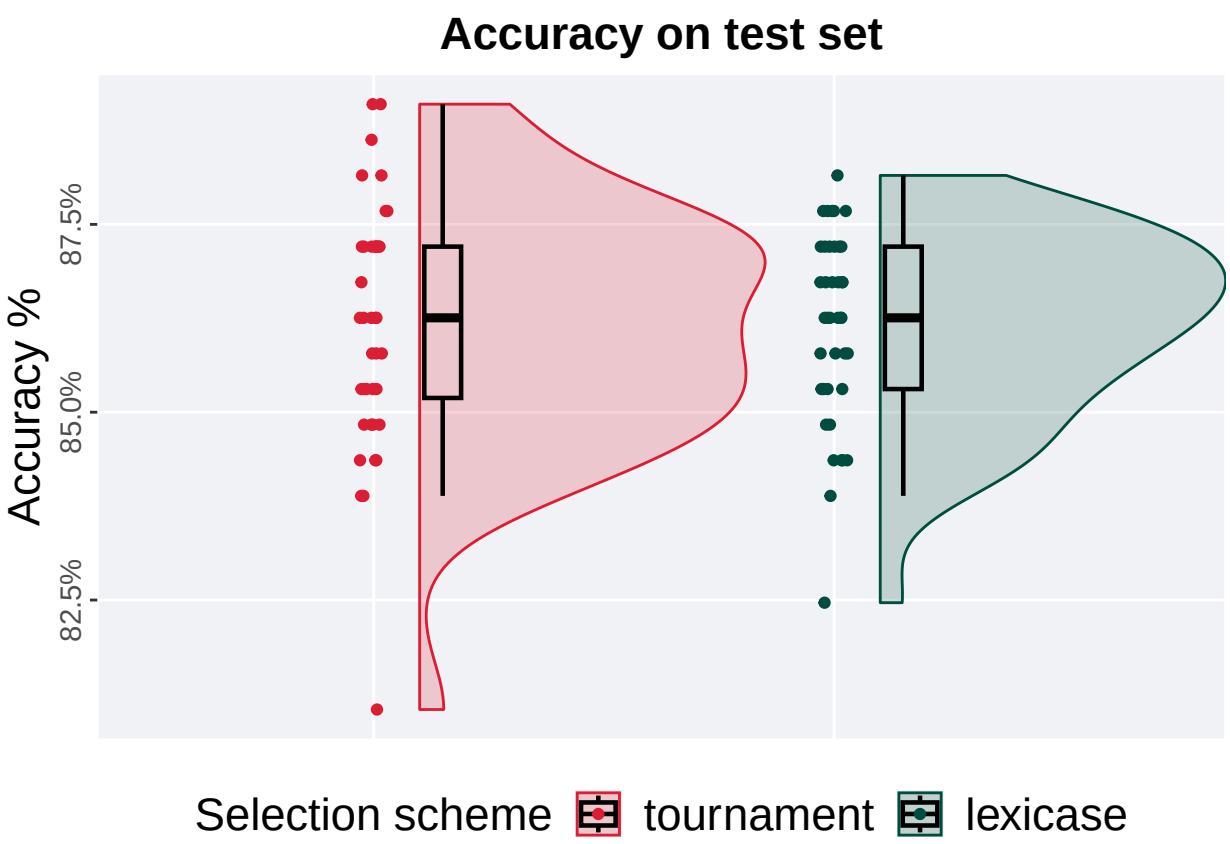
```
## [1] "observed_diff: -3.57585347444171"
## [1] "permutation_diffs[0.05 * n_permutations]: -1.64001739781141"
## [1] "reject null hypothesis"
## [1] "p-value: 0.00031"
```



14.3 50%

14.3.1 Testing set accuracy

```
test_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

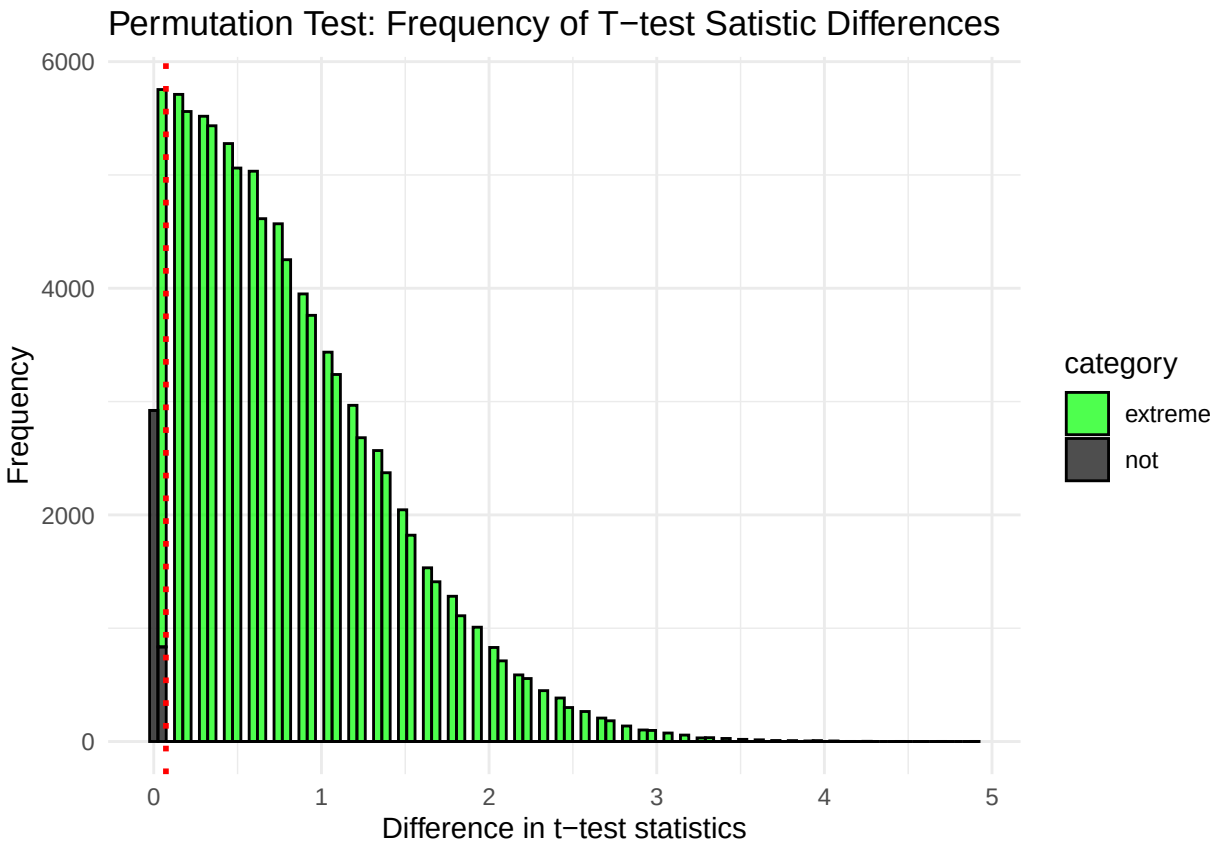
```
test_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max    IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>  <dbl>
## 1 tournament    40      0 0.810  0.863 0.862 0.891 0.0201
## 2 lexicase      40      0 0.825  0.863 0.861 0.882 0.0190
```

The permutation test revealed that the results are:

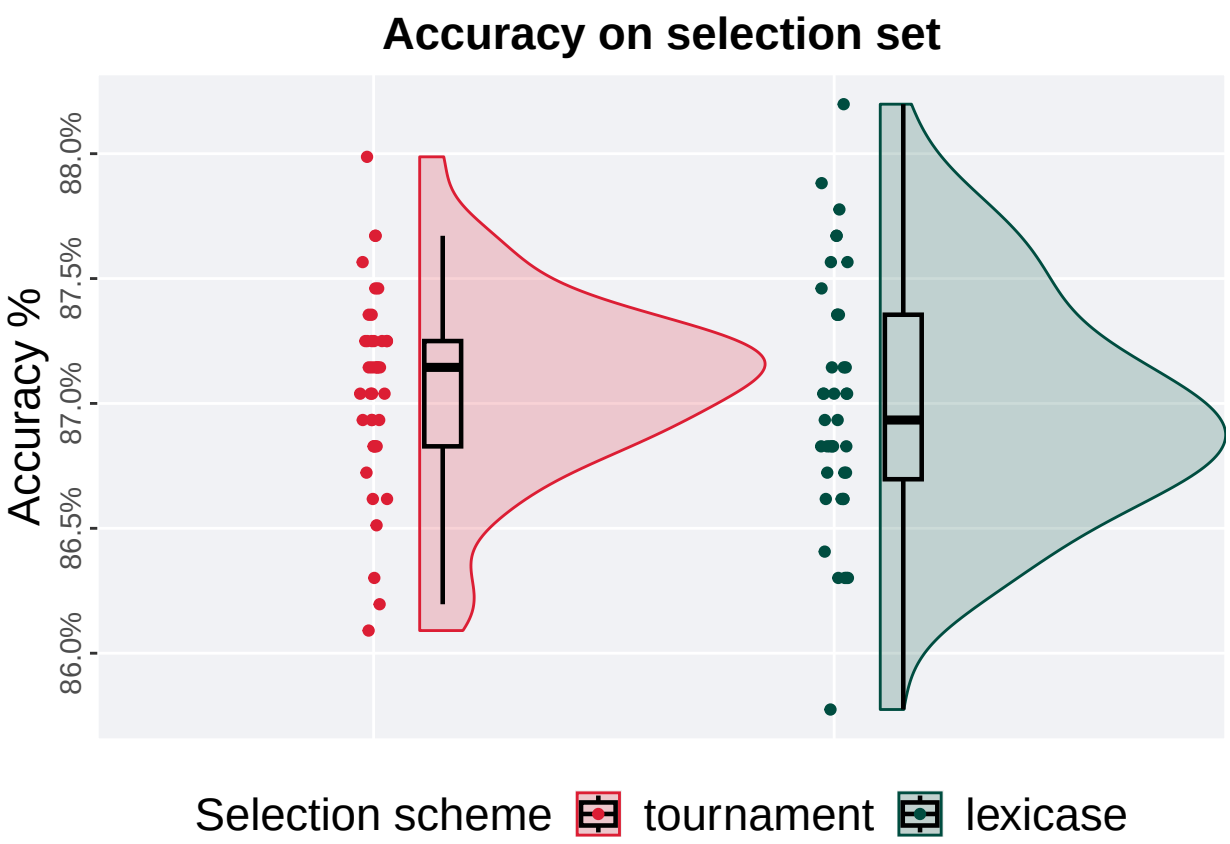
```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 125,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.0725999889735864"
## [1] "lower: -2.01031173065856"
## [1] "upper: 2.010313713565"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.96243"
```



14.3.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '50%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

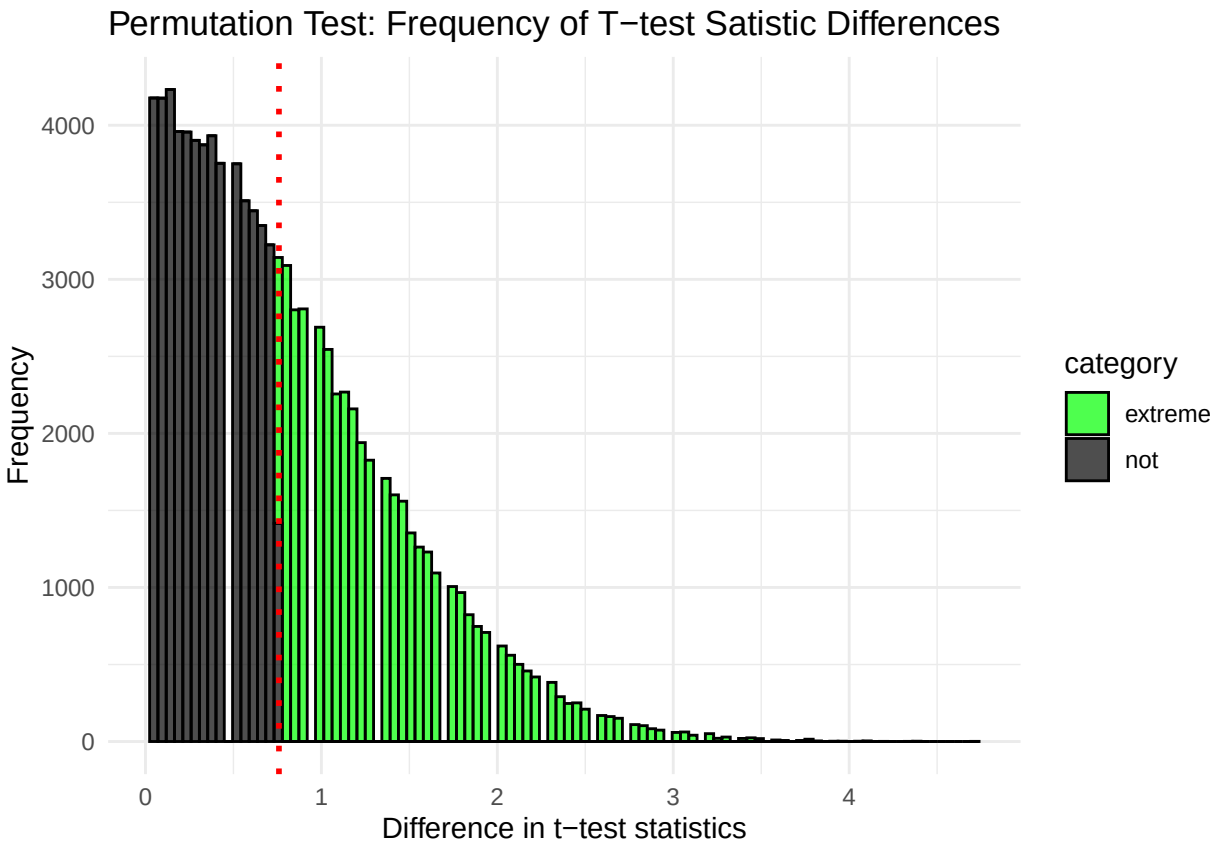
```
selection_results_summary(filter(task_data, split == '50%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.861  0.871 0.871 0.880 0.00421
## 2 lexicase      40      0 0.858  0.869 0.870 0.882 0.00659
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '50%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '50%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 126,
                 alternative = "t")
```

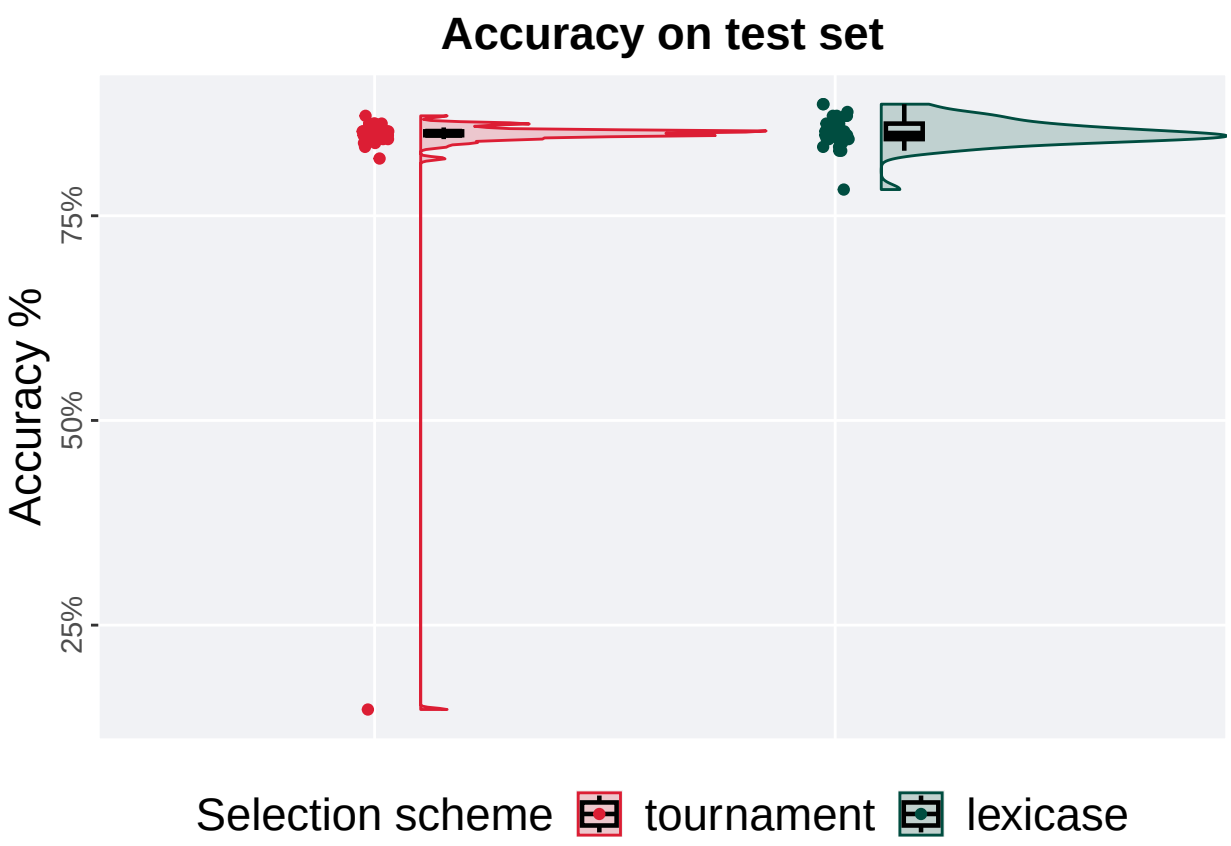
```
## [1] "observed_diff: 0.758730494171471"
## [1] "lower: -2.00476759324351"
## [1] "upper: 2.00476866020914"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.45346"
```



14.4 90%

14.4.1 Testing set accuracy

```
test_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

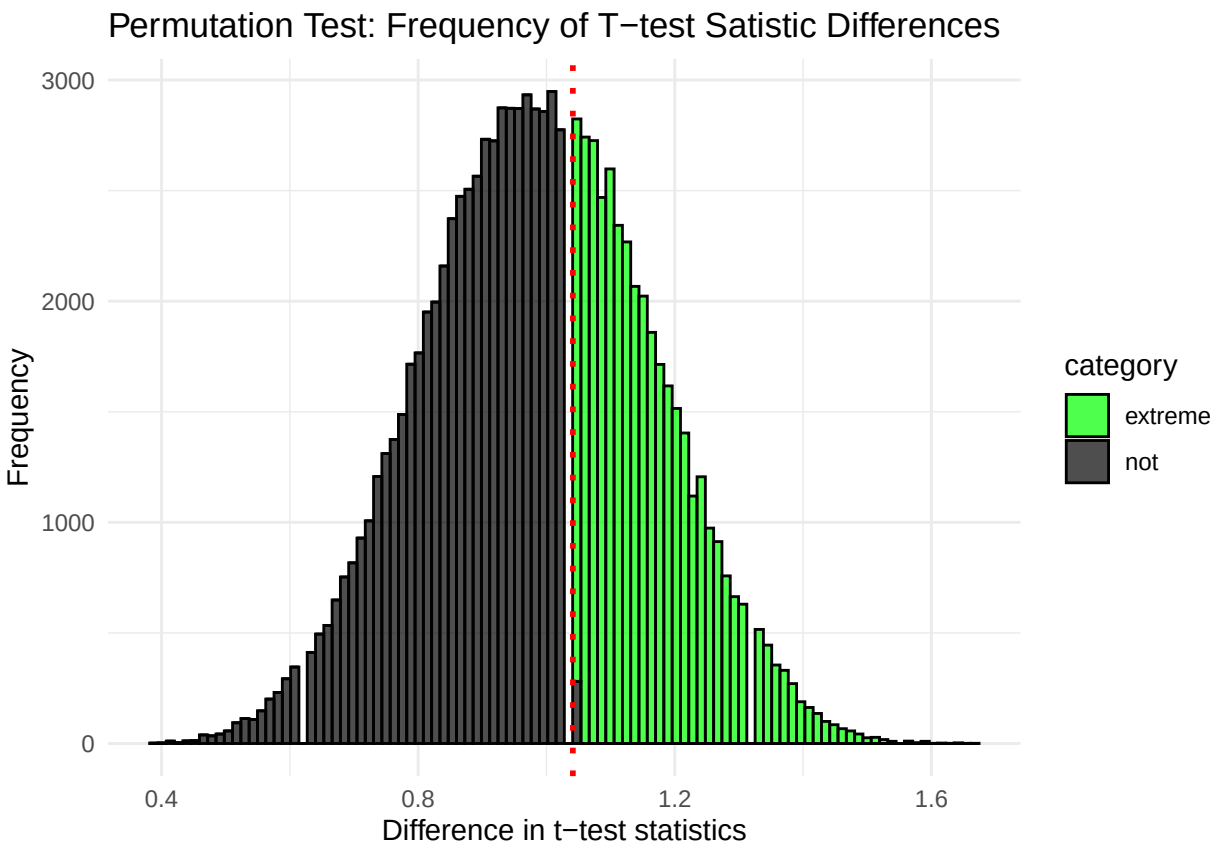
```
test_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.147  0.851 0.833 0.872 0.00474
## 2 lexicase      40      0 0.782  0.848 0.851 0.886 0.0190
```

The permutation test revealed that the results are:

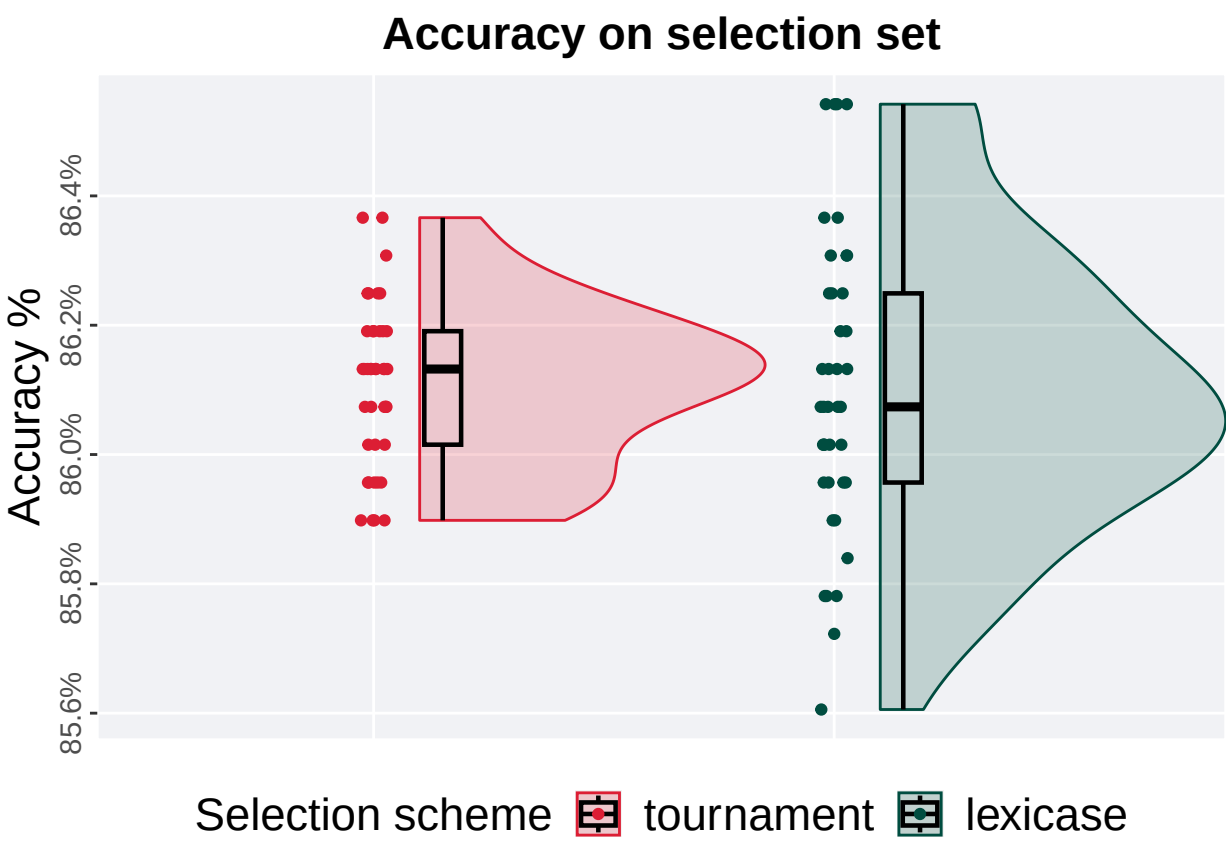
```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 127,
                 alternative = "t")
```

```
## [1] "observed_diff: -1.04113830032943"
## [1] "lower: -1.27085455535858"
## [1] "upper: 1.27085472731831"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.39026"
```



14.4.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '90%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

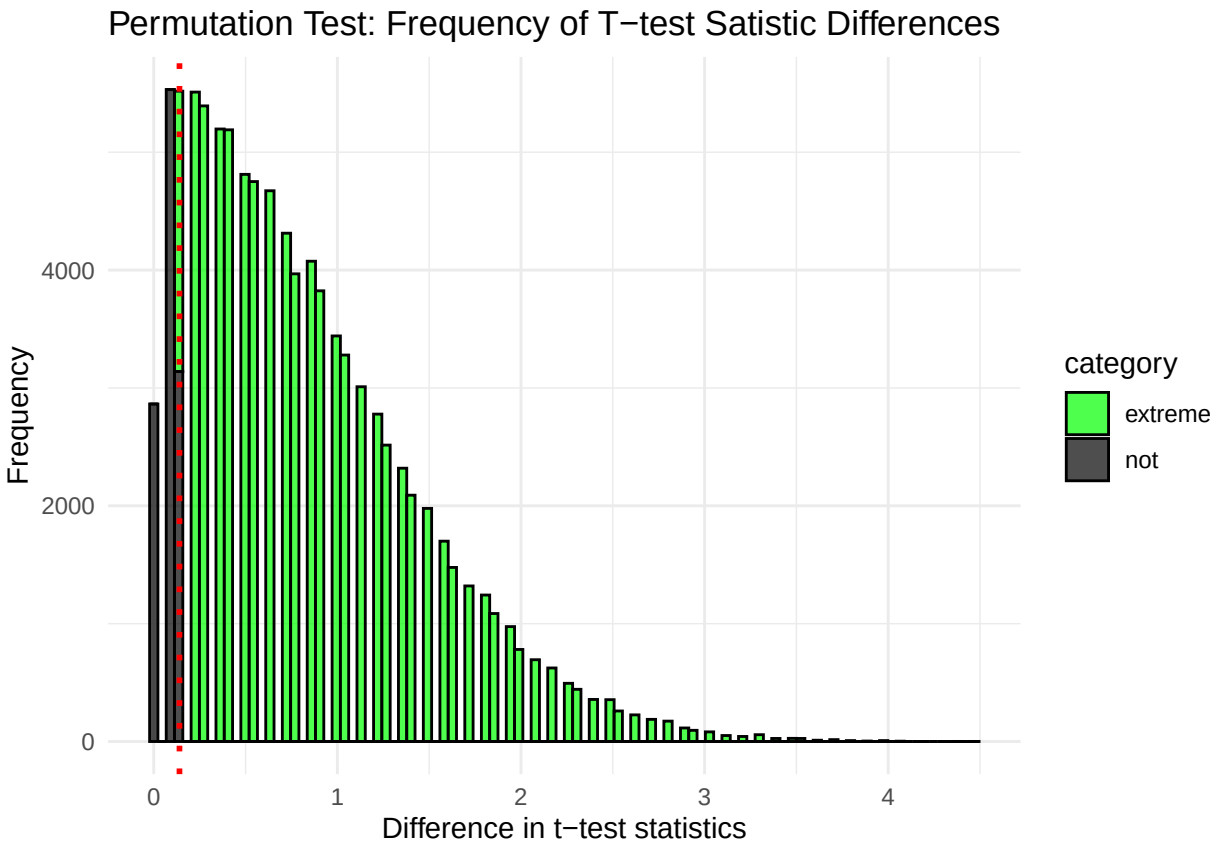
```
selection_results_summary(filter(task_data, split == '90%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.859  0.861 0.861 0.864 0.00176
## 2 lexicase      40      0 0.856  0.861 0.861 0.865 0.00293
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '90%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '90%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 128,
                 alternative = "t")
```

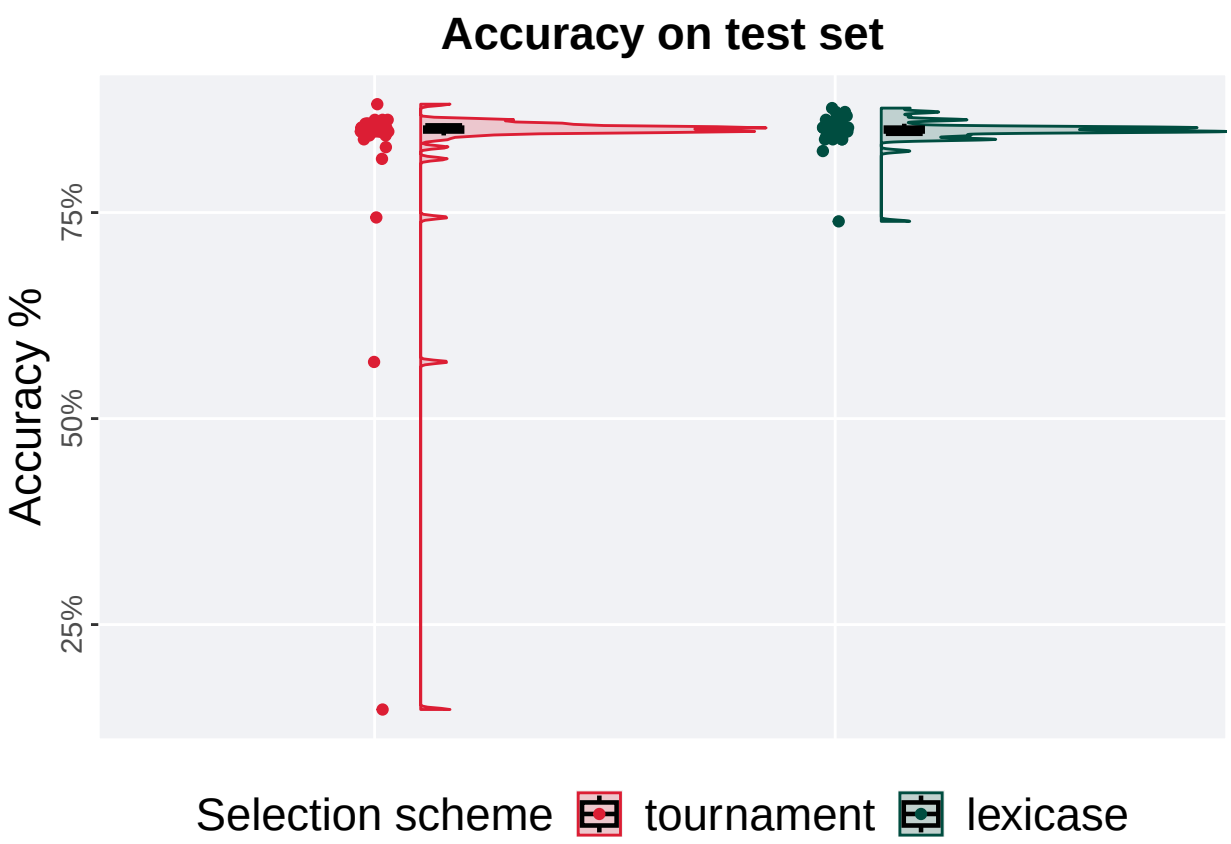
```
## [1] "observed_diff: 0.140015429975094"
## [1] "lower: -2.01007682745605"
## [1] "upper: 2.01007940828714"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.88465"
```



14.5 95%

14.5.1 Testing set accuracy

```
test_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

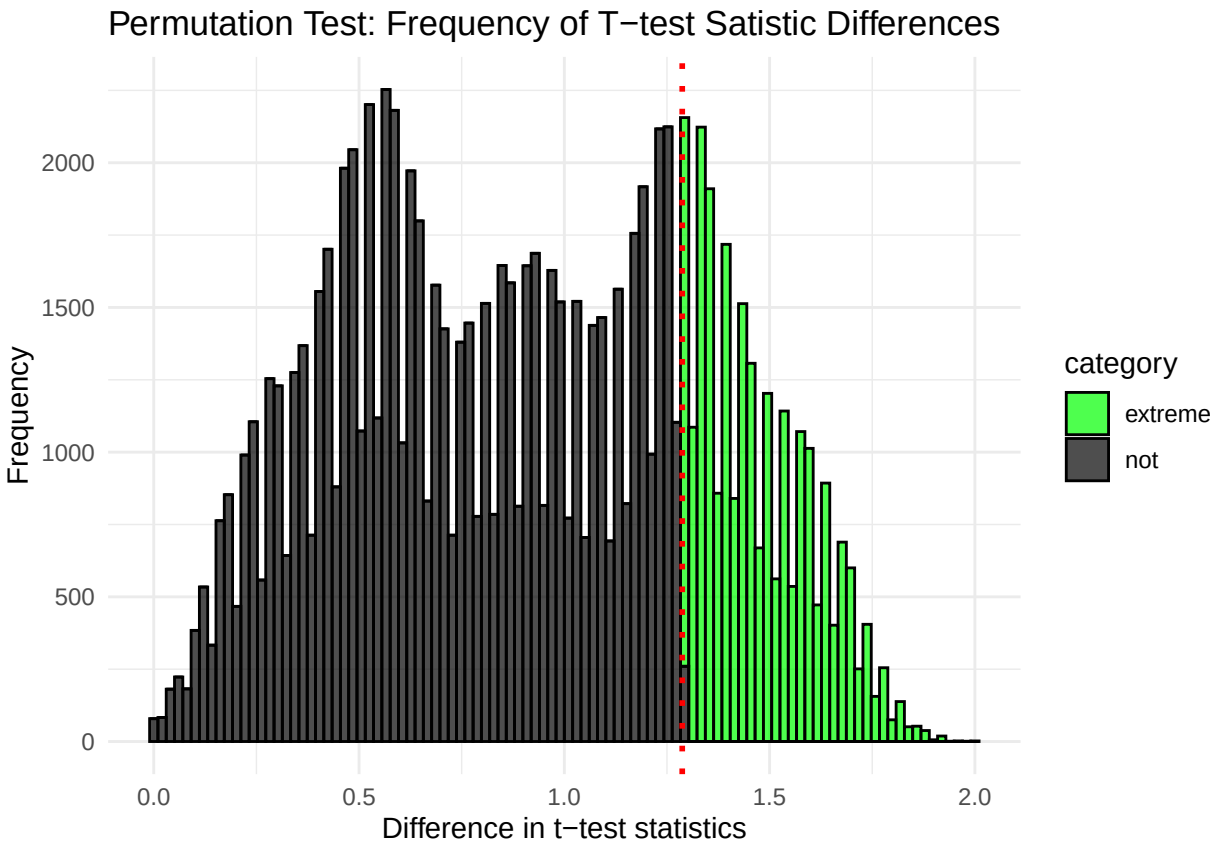
```
test_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.147  0.853 0.824 0.882 0.00474
## 2 lexicase      40      0 0.739  0.848 0.849 0.877 0.00474
```

The permutation test revealed that the results are:

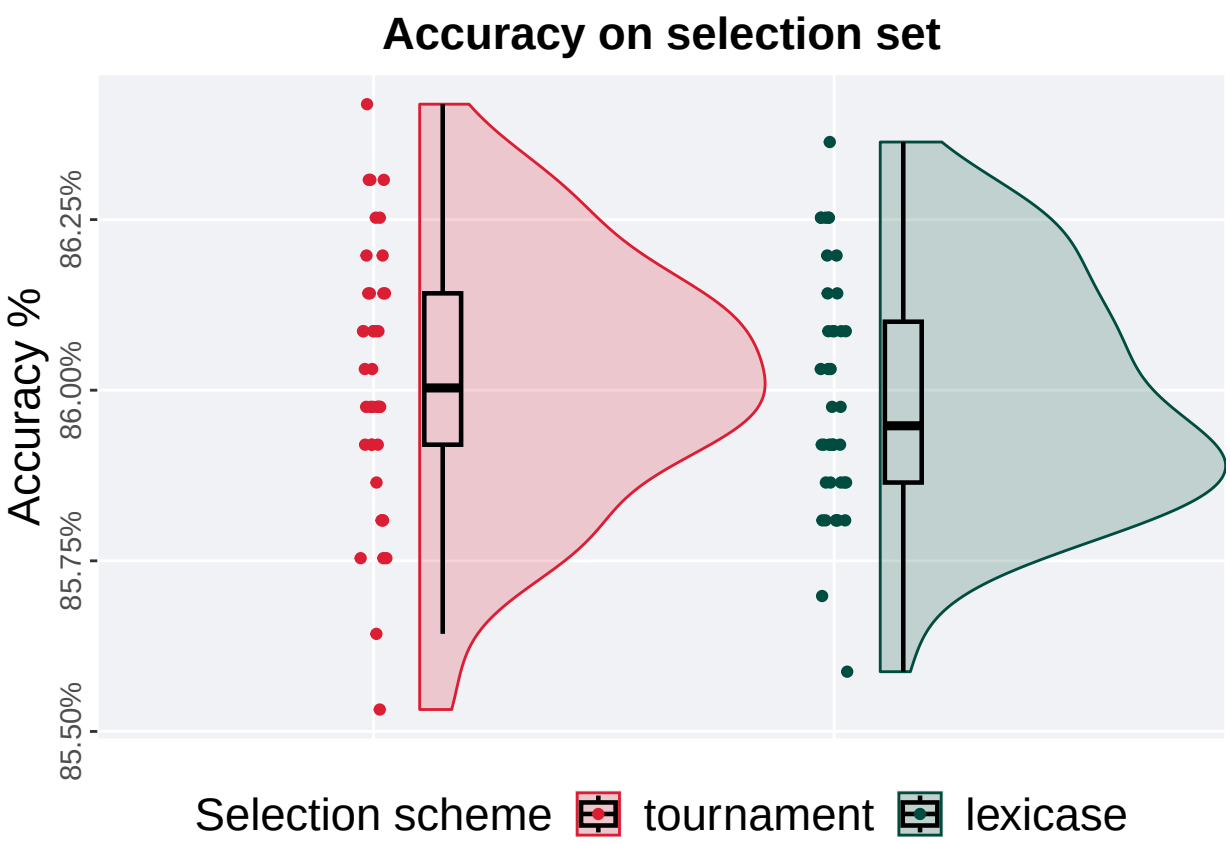
```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$testing_performance,
                 lexicase_results$testing_performance,
                 seed = 129,
                 alternative = "t")
```

```
## [1] "observed_diff: -1.28720945209971"
## [1] "lower: -1.60430871420884"
## [1] "upper: 1.59151668419804"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.23956"
```



14.5.2 Selection set accuracy

```
selection_plot(filter(task_data, split == '95%'))
```



Summary statistics for the testing performance of the selection schemes at the 5% selection set split:

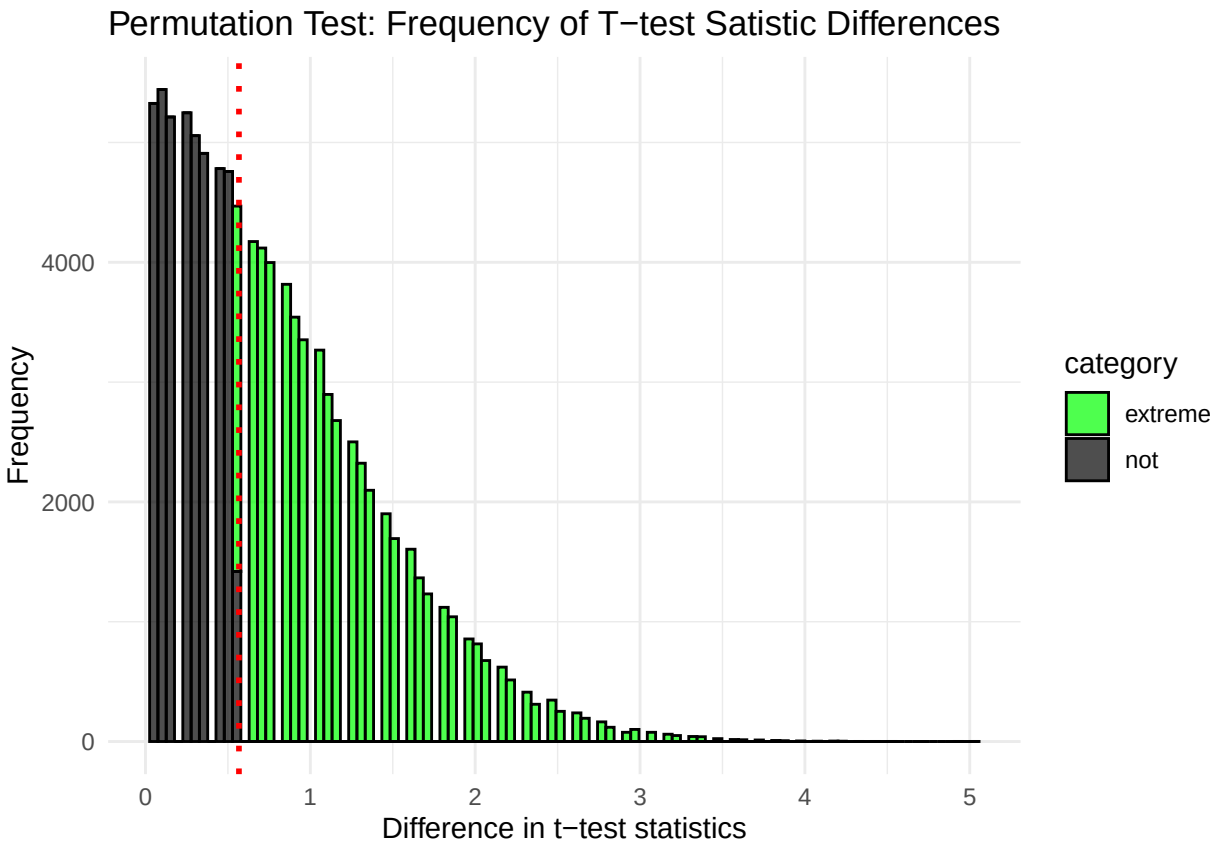
```
selection_results_summary(filter(task_data, split == '95%'))
```

```
## # A tibble: 2 x 8
##   selection  count na_cnt   min median  mean   max     IQR
##   <fct>      <int>  <int> <dbl>  <dbl> <dbl> <dbl>   <dbl>
## 1 tournament    40      0 0.855  0.860 0.860 0.864 0.00222
## 2 lexicase      40      0 0.856  0.859 0.860 0.864 0.00236
```

The permutation test revealed that the results are:

```
tournament_results <- filter(task_data, split == '95%' & selection == 'tournament')
lexicase_results <- filter(task_data, split == '95%' & selection == 'lexicase')
permutation_test(tournament_results$training_performance,
                 lexicase_results$training_performance,
                 seed = 130,
                 alternative = "t")
```

```
## [1] "observed_diff: 0.567026129247492"
## [1] "lower: -2.01431137808478"
## [1] "upper: 2.01431267396974"
## [1] "fail to reject null hypothesis"
## [1] "p-value: 0.57846"
```


Permutation Test: Frequency of T−test Satistic Differences
Frequency
4000
2000
0
0
1
2
3
4
5
Difference in t−test statistics
category
extreme
not