

INTRODUCTION TO R

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- What is R?
- R pros and cons
- What working with R looks like
- Use R with the RStudio Development Environment
 - Get help / documentation
 - Work with contributed packages
 - Read and store data
 - Explore / transform / aggregate data
 - Diagrams
 - Statistical tests & regression models

- Radiation dose to the heart in 3D conformal tangential breast cancer radiotherapy
- 3D Raytracing Diagrams
- Rhineland-Palatinate Mortality Monitoring Dashboard

WHAT IS R?

- ~~Statistics program~~
- Free statistical environment for interactive use
- (Scripting programming language)
- Base R = GNU R interactive console + base packages
 - vs. Integrated development environment (IDE)
 - vs. Microsoft R, ...
 - vs. Contributed extension packages

PROS: WHY USE R?

- **It works** (Windows, MacOS, Linux)
- Widely used: biometry, bioinformatics, data science
 - Active development & growing community
- Free & open source
 - No cost / no licensing issues → use anywhere
- Powerful extension mechanism: Packages
 - Fast moving innovation
- Very good support for reproducible data analysis
- Platform beyond traditional statistical analysis

CONS: WHAT'S NOT THAT GREAT ABOUT R

- First steps easy but hard to master
 - Use it or lose it r4stats.com/articles/why-r-is-hard-to-learn/
- Organic growth → Inconsistent naming scheme
 - `read.table()`, `seq_int()`, `TukeyHSD()`, `trimws()`
- Built-in documentation very terse, technical
- There's more than one way to do it
 - Base R solutions vs. contributed packages
 - Inconsistent approaches & confusion
- Non-academic sector: maybe less mainstream than SAS
- Performance issues with very large datasets

SWITCHING FROM SAS – KEY DIFFERENCES

- Real programming language vs. MACROs
- More low-level syntax (LEGO vs. FisherPrice)
- No restriction to working with just 1 data set
- Different philosophy – default output: little vs. much
- Run R from SAS/IML: `submit/r; ... endsubmit;`

SHOULD YOU SWITCH TO R?

- Results matter
 - Tools matter only insofar as they enable results
- Do you have to? (SAS not available ...)
- Can you afford to invest time?
 - ...and keep doing so?
- Do you have a concrete project / task?
- Do you have an R guru next door?
- Will there be interference with learning SAS?

CURRENT DEVELOPMENTS

- Base R: stable, improvements under the hood
- Dynamically growing ecosystem around base R
 - Books, conferences, user groups, online courses
 - Contributed packages – long-term stability issues
- Hot topics
 - Machine learning
 - Interactive web applications
 - Reproducible analysis & reports

- Integrated help system with executable examples
- Official introduction and FAQs www.r-project.org
- Books
 - link.springer.com/book/10.1007/978-3-662-61736-6
 - link.springer.com/book/10.1007/978-3-662-49102-7
 - www.routledge.com/Chapman--HallCRC-The-R-Series/book-series/CRCTHERSER
- Online courses
 - <https://www.edx.org/course/statistics-and-r>
- Cheat sheets www.rstudio.com/resources/cheatsheets/

- Google "R"
- Email-lists (low signal-to-noise ratio) : `r-project.org`
- Q&A: `stackoverflow.com/tags/R`
- Q&A: `stats.stackexchange.com/tags/R`
- Twitter: `#rstats`

Beware

Quality issues – wrong / outdated info?

USING R IN RSTUDIO

- Get R from `cloud.r-project.org/`
- Get a free integrated development environment (IDE)
 - **RStudio** ←
`www.rstudio.com/products/rstudio/download/`
Supported: Windows, MacOS, Linux
- ~~Graphical user interfaces~~ (limited functionality)
 - Rcmdr (R Commander)
 - Jamovi `www.jamovi.org`

- R session: Working directory
- Use the integrated help system
- Objects
 - Create, show & remove objects
 - Classes: vector, matrix & data frame
 - Types: character, numerical, logical, factor, date / time
- Arithmetic
- Logic: Operators → associativity, ()
- Numerical precision – FAQ 7.31
- Functions: Arguments & return values

- `getwd()`, `setwd()`
- `?<function>`, `??<word>`, `help()`, `help.start()`, `example()`
- `?Reserved`, `<-`, `=`
- `print()`
- `ls()`, `rm()`
- `?Arithmetic`
- `round(<number>, digits=<digits>)`
- `exp()`, `factorial()`
- `TRUE`, `FALSE`, `!`, `==`, `!=`, `<`, `>`, `<=`, `>=`, `|`, `&`, `xor()`

HANDS ON – RUN R WITHIN RSTUDIO

- Do some arithmetic
- Does $1 - 49\frac{1}{49} = 0$ hold?
- Store an integer each in objects a, b, c
- Is 1 the same as "1"? Why?
- What is function `cv.glm()` about? (no Google!)
- What arguments can be supplied to function `mean`?
- Run the examples for `var()`
 - What is going on – how is this all related to `var()`?

FREQUENT SOURCES OF CONFUSION & FRUSTRATION

- R is case sensitive – objects, functions, arguments
- Mis-spelled objects, functions, arguments
- () vs. [] vs. { } – always close when open
- Whitespace is often meaningless – but not always
- Handling of missing values – NA (not available)
- Handling of categorical variables (factors)
- Execution order (associativity) → use () liberally
- Undocumented code → use comments # liberally

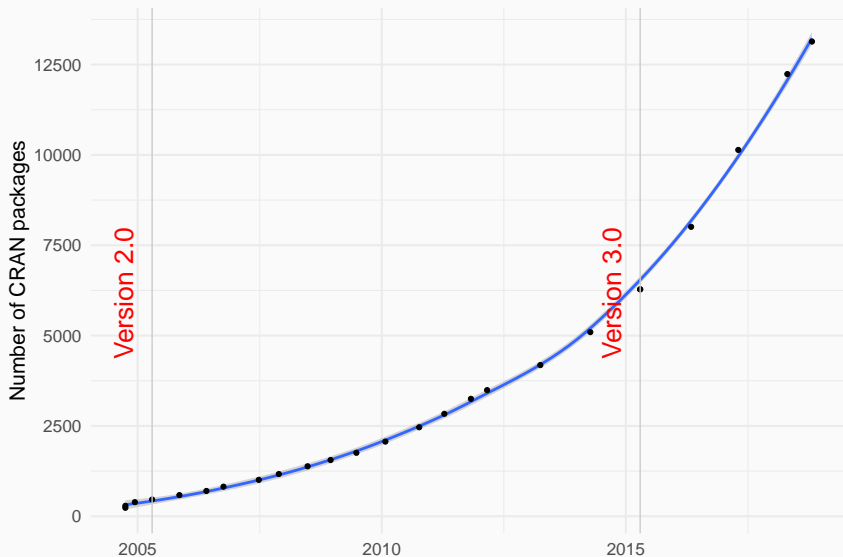
USING R PACKAGES

- Extend base R functionality for a specific purpose
 - Specialized statistical analysis
 - Tools for specialized data
 - More convenient solutions than base R
- Bundle new functions, data sets and documentation
- Contributed by independent developers
- Have dependency management

1. Install – once for every major R version
2. Load – each session
3. Use like any base R functionality

- CRAN
 - Curated official package repository network
 - Some quality assurance for submitted packages
 - Can be installed, run, are documented, not malicious
 - **But:** No guarantee for working correctly
 - Task Views `cran.r-project.org/web/views/`
- GitHub
 - Not curated, no QA, bleeding edge

GROWTH OF CRAN PACKAGE REPOSITORY



USING PACKAGES – VOCABULARY

- `install.packages("<package name>")`
- `installed.packages(), .libPaths()`
- `update.packages()`
- `library(<package name>)`
- `sessionInfo()`
- `help(package="<package name>")`
- `data()`
- `vignette(package="<package name>"),`
- `vignette("<topic>"),`
- `citation("<package name>")`

- Load package `dplyr`
- What help topics are documented in package `ggplot2`?
- Where are your packages stored on disk?
- What packages are currently active in your session?
- Look at the `dplyr` vignette [Introduction to dplyr](#)
- Run the examples for `filter()` from package `dplyr`
- Check if there are updates for your installed packages
 - But don't install them

- `dim()`, `nrow()`, `ncol()`
- `head()`, `tail()`, `names()`, `View()`
- `str()`, `summary()`
- `[,]`, `drop=FALSE`, `$`

- Import → clean → transform ↔ explore
 - ~ 80% of the work, then → model
- Import data
 - Files, Clipboard, URL
 - Plain text file: Comma-separated, tab-delimited, ...
 - R format file
 - SAS / Stata / SPSS file: package haven
 - Spreadsheet (Excel): package readxl
 - Database: RSQLite, RPostgreSQL, RMySQL, ...
- Packages readxl, openxlsx

- `read.table()`, `write.table()`
- `file="clipboard"`, `file=pipe("pbpaste")`, `file=url()`
- `stringsAsFactors=FALSE`
- `load()`, `save()`
- Package `haven`
 - `read_sas()`, `read_spss()`
 - `write_sas()`, `write_sav()`

- Variable names (coerced to legal names)
- Date & time formatting
- Names
 - Umlauts, hyphens, whitespace, capitalization
 - Given names, family names – which is which
- Measurement units
- Missing data coding
- Plausibility: Valid dates / categories / values, date logic,
...

- Select subsets
 - Cases
 - Variables
 - Remove duplicates
- Change & create new variables
 - Recode variables
 - Cut continuous variables into categories
 - Calculate new based on old variables
 - Generate sequences
 - Simulate using random numbers
- Sort cases & variables

- Package dplyr
 - `filter()`
 - `select()`, `everything()`
 - `mutate()`, `rename()`, `if_else()`
 - `arrange()`, `desc()`
- `unique()`, `na.omit()`
- `scale()`, `cut()`, `as.Date()`, `strptime()`,
- `:`, `seq()`, `rep()`
- `sample()`, `runif()`, `rnorm()`

- Read text file
 - `http://dwo11.de/dat_passos.csv`
- How large is the data set?
- What variables of what kind are there?
- Take a look at the first / last 10 observations
- Save the data set to an R file
- Save the data set as a tab-separated ASCII file

- Check and transform the PASSOS data set
 - Sort according to tumor side and age
 - Subset: Only women age ≥ 60 with left-sided tumor
 - Re-order variables: observed comes 1st, metric 2nd
 - Build age-groups (10 years)
 - Do a median split for BMI
 - Check that age is consistent with DOB and RT start
 - Center observed
 - Add normal random variable

- Descriptive statistics
- Group wise operations
- Frequency tables

SUMMARISE DATA – VOCABULARY

- Package dplyr
 - `group_by()`
 - `summarise(), n()`
- `sum(), min(), max(), range(), diff(), quantile()`
- `mean(), median(), sd(), var(), IQR(), modeest::mlv()`
- `DescTools::Skew(), DescTools::Kurt()`
- `cov(), cor()`
- `xtabs(), table()`
- `prop.table(), addmargins()`

- Books
 - R Graphics Cookbook www.r-graphics.org
 - Graphical data analysis with R www.gradaanwr.net
 - Datenvisualisierung mit R www.datendesign-r.de
- Base graphics
- Package ggplot2 ←
- 2D interactive graphics
 - www.htmlwidgets.org/showcase_plotly.html
 - gallery.htmlwidgets.org/
- 3D interactive graphics: Package rgl

- `ggplot2`
 - `ggplot()`, `aes()`
 - `group=`, `linetype=`, `shape=`, `color=`, `fill=`
 - `geom_point()`, `geom_line()`, `geom_bar()`
 - `geom_histogram()`, `geom_boxplot()`
 - `geom_smooth()`, `geom_abline()`, `geom_text()`
 - `position=position_jitter()`, `position_dodge()`
 - `ggtitle()`, `xlab()`, `ylab()`
 - `facet_grid()`, `facet_wrap()`
- `ggsave()`
- `pdf()`, `jpeg()`, `dev.off()`

- Vectors
 - Recycling
- Factors
- Data frames
- Lists

- `c()`, `numeric()`, `character()`, `logical()`
- `LETTERS`, `letters`
- `[]`, `length()`
- `which()`, `%in%`
- `factor()`, `ordered()`
- `nlevels()`, `levels()`, `droplevels()`, `interaction()`
- `data.frame()`, `list()`
- `cbind()`, `rbind()`, `order()`
- `lapply()`, `sapply()`

SPECIFIC DATA TYPES

- Missing values
- Character strings
- Date & time

SPECIFIC DATA TYPES – VOCABULARY

- Missing values
 - `NA`, `is.na()`, `anyNA()`, `na.omit()`
 - `na.rm=TRUE`, `use="pairwise"`, `use="complete"`
 - Multiple imputation: Package `mice`
- Character strings
 - `nchar()`, `trimws()`, `tolower()`, `toupper()`
 - `paste()`, `paste0()`, `sprintf()`
 - `grepl()`, `gsub()`, `glob2rx()`
 - Package `stringr`
- Date & time
 - `Sys.date()`, `as.Date()`, `strptime()`
 - Package `lubridate`

- Split
- Combine
- Merge
- Transform between wide ↔ long format

- `split()`, `lapply()`
- `dplyr`
 - `bind_rows()`, `bind_cols()`
 - `left_join()`
- `tidyr`
 - `gather()`, `spread()`
 - `separate()`, `unite()`

- Linear regression (OLS)
 - Goodness of fit
 - Diagnostics
 - Variable selection
- t -test, ANOVA, ANCOVA
- GLM: Logistic, Poisson regression
- Goodness-of-fit tests
- Independence tests

- `lm()`, `summary()`, `anova()`, `step()`, `add1()`, `drop1()`
- `coef()`, `confint()`, `fitted()`, `residuals()`, `rstandard()`
- Package `car`
 - `vif()`, `residualPlots()`, `qqPlot()`
 - `spreadLevelPlot()`, `influenceIndexPlot()`
- `t.test()`, `alternative=`, `aov()`
- `glm()`, `MASS::polr()`
- `binom.test()`, `chisq.test()`, `fisher.test()`

- Books
 - Reproducible research with R & RStudio
`christophergandrud.github.io/RepResR-RStudio/`
 - Dynamic Documents with R and knitr (Yihui Xie)
`yihui.name/knitr/`
- Create reproducible reports – docx, pdf, html
 - knitr
 - rmarkdown `rmarkdown.rstudio.com`
- Tables `https://davidgoheh.github.io/flextable/`
- Publication-ready diagrams

CREATE DOCUMENTS & SHARE RESULTS – VOCABULARY

- `knitr::kable()`, `flextable`, `huxtable`
- `scale_x_continuous()`, `scale_x_discrete(labels)`
- `coord_cartesian(xlim, ylim)`, `coord_fixed()`
- `theme()`, `guides()`, `annotate()`, `ggthemes`
- `ggtitle()`, `xlab()`, `ylab()`
- `scale_fill_grey()`, `scale_color_grey()`
- `scale_fill_brewer()`, `scale_fill_viridis()`
- `scale_color_discrete(name, labels)`
- `scale_shape_discrete(name, labels)`
- `cowplot::plot_grid()`
- `ggsave()`, `pdf()`, `tiff()`, `svg()`

- Books
 - Programmieren mit R (Uwe Ligges)
 - Advanced R: <https://adv-r.hadley.nz/> (Hadley Wickham)
 - R packages: r-pkgs.had.co.nz (Hadley Wickham)
- Control structures
 - Conditions
 - `if() { ... } else { ... }`
 - `switch() { ... }`
 - Loops
 - `for() { ... }`
 - `while() { ... }`

- Function signature
 - Formal arguments and defaults
- Function body
 - Check actual arguments
 - Handle errors
 - Return value
 - Scope
- Generic functions
- Analyze functions
- Debugging