Computing in the Statistics Curriculum:
Lessons Learned from the Educational Sciences

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Computing is fundamental to contemporary statistical practice and scientific inquiry and should be explicitly taught

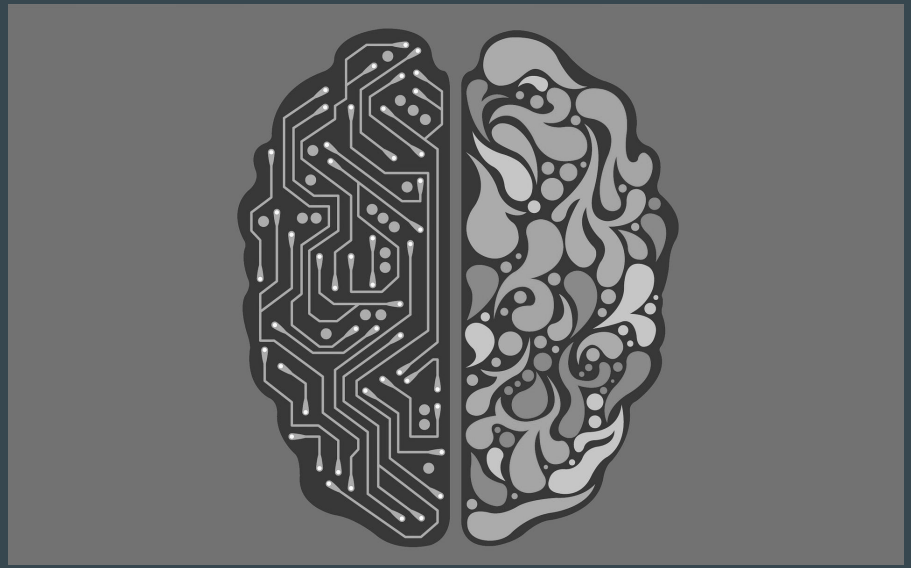
(ASA, 2017; Horton, 2015; NASEM, 2018; Nolan & Temple Lang, 2010)

Cognitive Load: Impediment to Learning

There is a finite amount of information that can be processed or stored in working memory at a time (cognitive load).

Different types of cognitive load (Hermans, 2021):

- *Intrinsic:* characteristics of the information being learned.
- *Extraneous:* the way information is presented.



Statistical Computing and Cognitive Load

- Statistical computing adds cognitive load to the learning process in statistics (e.g., Woodard & Lee, 2021)
    - Computational considerations
        - Syntax
        - Syntactical structure
        - Debugging
        - Computational thinking
    - Coding seems to be difficult for many students

- We can work to manage and lessen cognitive load by thoughtfully considering the specific coding content we teach and how we teach it.

Cognitive *Un*-loading: Make Purposeful Pedagogical Decisions

Pedagogical decisions need to be made about coding content.

- What logistical considerations do you need to account for?
- What will be taught (scope)?
- How will it be sequenced?

Example Pedagogical Decisions

- How will students compute in the course?
  - Desktop / Cloud / Both
- Where and when do students need practice with code?
  - In-class / out-of-class
  - Individual / group
  - Templates / Blank documents (RMD, R script)
- How will coding be introduced in class?
  - Live coding/ Worked examples / Group activities
- What code content do you start the course with?
  - Data structures (e.g., vectors, data frames) / “Cake” (data visualization, EDA)

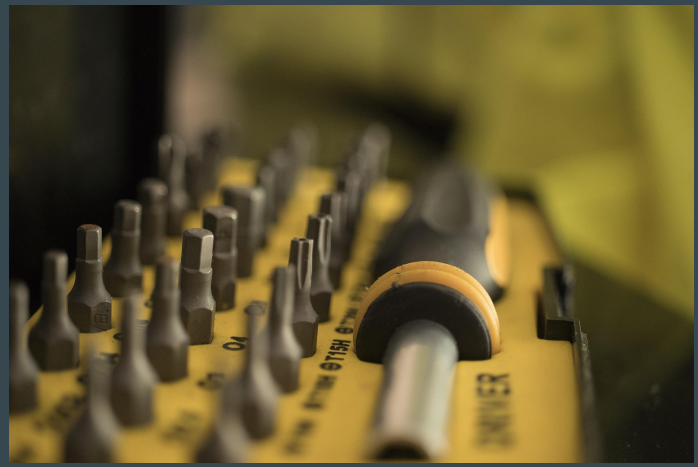
Cognitive *Un*-loading: Use Consistent Syntactic Structure

Using code with the same syntactic structure (common grammar) lessens cognitive load

- Can focus on learning new functions (verbs) and their purpose

Some syntactic structures can emphasize the relationship between syntax and concepts

- E.g., Roles of variables



```r
library(psych)
library(BHH2)
nhanes2017= read.csv("nhanes2017.csv", as.is = F)
table(nhanes2017$exerciseGT60)
par(mfrow = c(1, 2))
hist(nhanes2017$pulse[nhanes2017$exerciseGT60 == "YES"], xlim = c(min(nhanes2017$pulse), max(nhanes2017$pulse)))
hist(nhanes2017$pulse[nhanes2017$exerciseGT60 == "NO"], xlim = c(min(nhanes2017$pulse), max(nhanes2017$pulse)))
par(mfrow = c(1, 1))
tapply(nhanes2017$pulse, nhanes2017$exerciseGT60, summary)
tapply(nhanes2017$pulse, nhanes2017$exerciseGT60, describe)
t.test(pulse ~ exerciseGT60, data = nhanes2017)
```

Authentic example: Analyze the difference in pulse by exerciseGT60 from NHANES

```r
# Load libraries
library(psych)

# Import data
nhanes2017= read.csv("nhanes2017.csv", as.is = FALSE)

# Get levels and sample sizes
table(nhanes2017$exerciseGT60)

# Plot histograms
par(mfrow = c(1, 2))
hist(nhanes2017$pulse[nhanes2017$exerciseGT60 == "YES"], xlim = c(min(nhanes2017$pulse), max(nhanes2017$pulse)))
hist(nhanes2017$pulse[nhanes2017$exerciseGT60 == "NO"], xlim = c(min(nhanes2017$pulse), max(nhanes2017$pulse)))
par(mfrow = c(1, 1))

# Compute summary statistics
tapply(nhanes2017$pulse, nhanes2017$exerciseGT60, describe)

# Carry out two-sample t-test
t.test(pulse ~ exerciseGT60, data = nhanes2017)
```

```r
# Load libraries
library(mosaic)

# Import data
nhanes2017 = read.csv("nhanes2017.csv", as.is = FALSE)

# Get levels and sample sizes
tally(~ exerciseGT60, data = nhanes2017)

# Plot histograms
histogram(~ pulse | exerciseGT60, data = nhanes2017)

# Compute summary statistics
favstats(~ pulse | exerciseGT60, data = nhanes2017)

# Carry out two-sample t-test
t_test(~ pulse | exerciseGT60, data = nhanes2017)
```

Mosaic Package
http://www.mosaic-web.org/mosaic/

The Most Important Template

The following template is important because we can do so much with it.

(~ , data =)

It is useful to name the components of the template:

goal (y ~ x , data = mydata)

We're hiding a bit of complexity in the template, and there will be times that we will want to gussy things up a bit. We'll indicate that by adding ... to the end of the template. Just don't let ... become a distractor early on.

goal (y ~ x , data = mydata , ...)

Questions to help you revise how you teach coding:

- What syntactic structure makes the most sense for my students/course/goals?
- Is the code being presented to students consistent in its structure?
- How does new code connect with previous content?
- Will students see/use this code more than once?
    - **“Stitch in time saves 9”**
- How will students encounter code?
    - Live coding, scaffolded documents, cheatsheet?

Resources and Places to Start

- Introductory statistics labs in R, Amelia McNamara (formula or tidyverse)
- Speaking R, Amelia McNamara (guidance for live coding and reading code)
- Statistical Modeling and Computation for Educational Scientists, Andrew Zieffler (tidyverse)
- Simulation Based Inference, Randy Pruim (formula)
- Data Science in a Box, Mine Çetinkaya-Rundel (tidyverse)

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