

Making cognitive science even better

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Preliminaries

Overview

- The hardest science
- Why it's hard
- Making cognitive science even better

Psychology is the hardest science

(Harder than physics)

Why it's hard

Logically separable, but embedded realms

- Body (B) within world (W)
- Nervous system (N) within body (B)
- Mind (M) within nervous system (N)

Mutually coupled dynamic states

$$\dot{M} = f(M, N)$$

$$\dot{N} = f(N, B)$$

$$\dot{B} = f(B, N, W)$$

$$\dot{W} = f(W, B)$$

Measure

- W, B, N more or less **directly**
 - Across multiple spatial & temporal scales
-

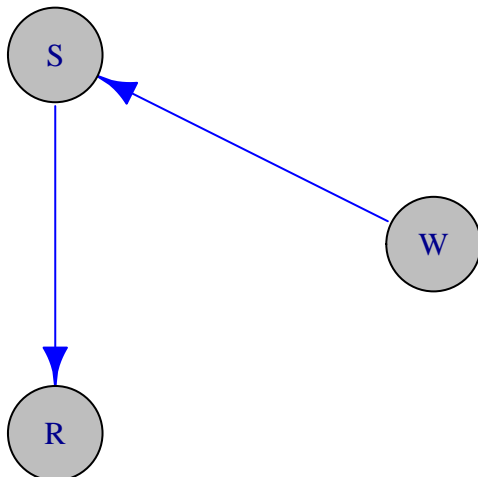
Sejnowski, Churchland, & Movshon, 2014

- Measure mental states M **indirectly**
- Via N, B, W (+ prior beliefs/knowledge)

Linear/open-loop theoretical frameworks dominate

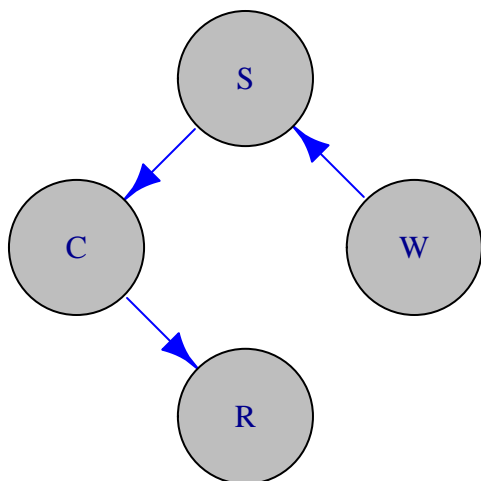
B.F. Skinner

$Stimulus(S) \rightarrow Response(R)$

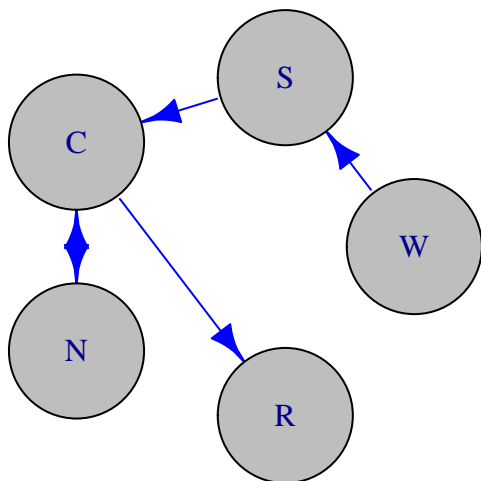


Noam Chomsky

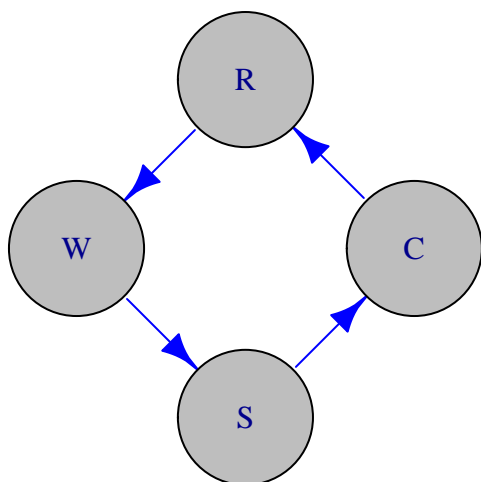
$Stimulus(S) \rightarrow Cognition(C) \rightarrow Response(R)$



$S \rightarrow N \leftrightarrow C \rightarrow R$



Closed-loop causal chains better reflect the underlying reality



Responses (R) affect the World (W) W states evoke stimuli (S) S affect C (cognition) C affects R (... repeat)

but even when W , S , C , and R are *completely* known

Jonas & Kording 2017

“We show that [classic analytic neuroscience] approaches reveal interesting structure in the data...”

Jonas & Kording 2017

“...but do not meaningfully describe the hierarchy of information processing in the microprocessor.”

Jonas & Kording 2017

“This suggests current analytic approaches in neuroscience may fall short of producing meaningful understanding of neural systems, regardless of the amount of data.”

Jonas & Kording 2017

Computational algorithms are powerful, but

By Nicolás Pérez, CC BY-SA 3.0, Link

- How to regulate the speed of a Watt-style steam engine?
-

1. Measure the speed of the flywheel.
 2. Compare the actual speed against the desired speed.
 3. If there is no discrepancy, return to step 1. Otherwise,
 - a. measure the current steam pressure;
 - b. calculate the desired alteration in steam pressure;
 - c. calculate the necessary throttle valve adjustment.
 4. Make the throttle valve adjustment.
 5. Return to step 1.
-

Algorithms vs. Dynamics (Van Gelder, 1995)

- “If all you have is a hammer, everything looks like a nail.” (Maslow)
- How much do we *really* understand about biological computing?

Biological computing

- Constrained by space, time, energy
-

25 W vs. ?? MW

- Computes with chemistry (neurotransmitters, hormones) when possible
 - With ‘wires’ (axons & dendrites) when necessary
-

Biological computing

- Engages in real-time behaviors with existential consequences (e.g., ingestion, defense, reproduction, locomotion, pursuit)
 - Operates effectively in complex, dynamic environments
 - Operates in single cells to aggregates of quadrillions. . .
-

To live is to move, sense, compute, adapt. . .

Yet big data (-omics) approaches to other questions in biomedicine largely overlook *behavior*

Krakauer et al. 2017

“Behavior is the linchpin of the most vexing problems in public health. . .”

Gilmore, Adolph, & Tamis-LeMonda, 2019

“Behavior contributes to the progression or prevention of disease, defines a disorder or marks recovery, and provides mechanisms for therapeutic intervention.”

Gilmore, Adolph, & Tamis-LeMonda, 2019

“ . . . a better understanding of behavior is fundamental to achieving positive health outcomes, from prenatal development throughout adulthood.”

Gilmore, Adolph, & Tamis-LeMonda, 2019

Is there a reproducibility crisis in science?

-
- Yes, a significant crisis
 - Yes, a slight crisis
 - No crisis
 - Don't know
-

Baker, 2016

Have you failed to reproduce an experiment from your lab or someone else's?

Baker, 2016

Baker 2016

(Munafo et al. 2017)

"...psychologists tend to treat other peoples' theories like toothbrushes; no self-respecting individual wants to use anyone else's." Mischel, 2009

"The toothbrush culture undermines the building of a genuinely cumulative science, encouraging more parallel play and solo game playing, rather than building on each other's directly relevant best work." Mischel, 2009

Making cognitive science even better

Support research that

-
- studies *behavior(s)*

Powers 1973

- samples densely (and/or broadly) in time & space
 - creates meaningful linkages across levels of analysis
-
-

- connects between & among systems/domains
-
-

- “Responses” include changes in (or maintenance of) body configurations
 - AND autonomic/endocrine activity AND...
-
-

Support research that

- attempts to close causal loops
 - via specific algorithms and/or dynamical processes
-

- informed by rich theories of task performance (inputs, controlled variables, outputs)
 - resists “premature simplification”
-

Powers 1973

- demonstrates a meaningful commitment to producing rigorous, reproducible, & robust findings
-

Support research that

- collects & shares video as data & documentation

Why video?

Video...

- Captures (& preserves)
 - Shows (& helps tell...)
 - Expands the scope of inquiry
 - Provides unequalled opportunities for reuse
-

Your browser does not support the video tag.

$n = 900$ 12-, 18-, 24-mo-olds; $n = 30$ sites demographics, health, vocabulary, media use, & temperament openly shared with the research community play-project.org

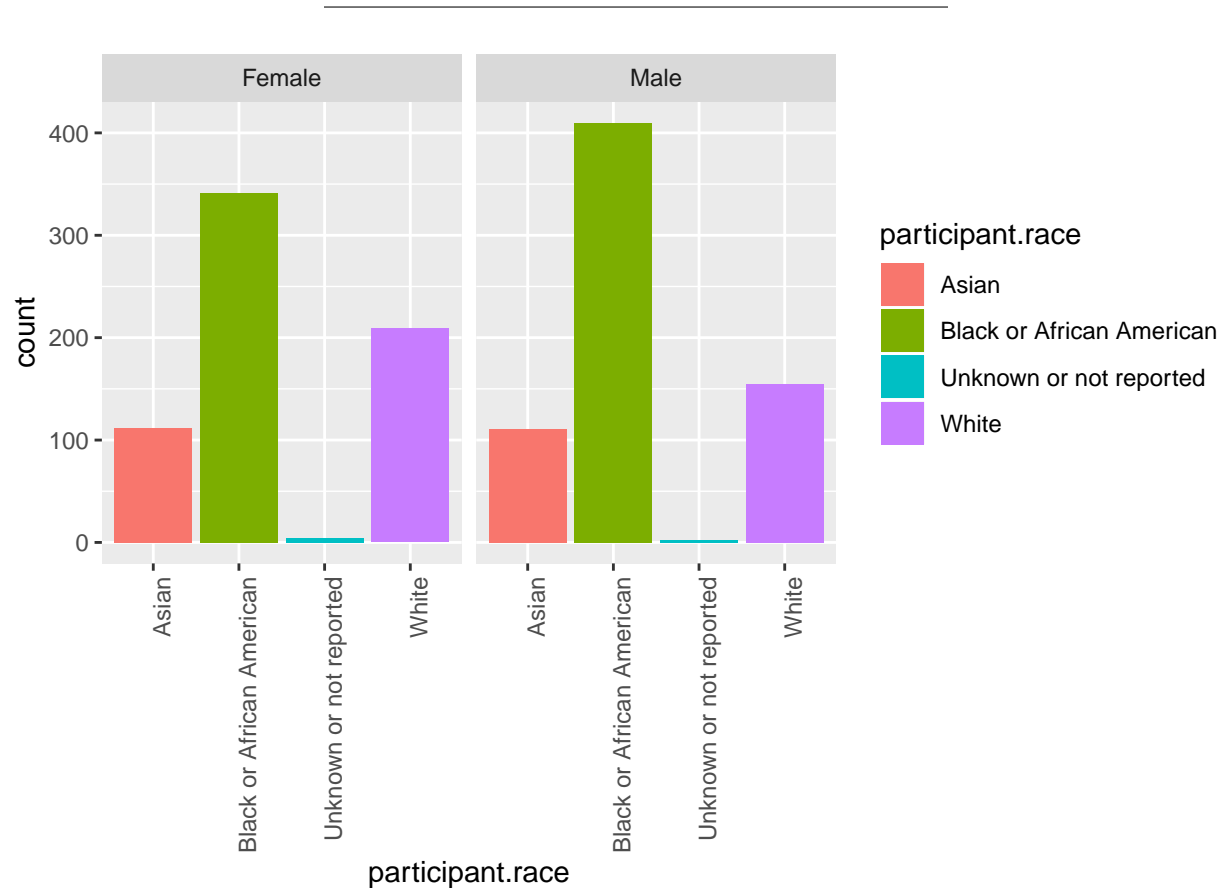
Support research that

- Shares procedures, materials, code, & data openly (but securely)
-
-

- Makes sharing scripted, fully reproducible workflows easy
-

Tamis-LeMonda 2014

```
vol_8 <- databraryapi::download_session_csv(vol_id = 8)
vol_8 %>%
  filter(participant.gender %in% c('Male', 'Female')) %>%
  ggplot() +
  aes(x = participant.race, fill = participant.race) +
  facet_grid(. ~ participant.gender) +
  geom_bar(stat="count") +
  theme(axis.text.x = element_text(angle = 90, hjust = 1))
```



R package <https://github.com/PLAY-behaviorome/databraryapi>

Python package <https://github.com/PLAY-behaviorome/databraryapi>

Support research that

- enables linkages between & across data sets
 - exploits advances in AI and machine learning
-

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Source: Ori Ossmy, NYU

Ossmy, Gilmore, & Adolph 2019

If we do these things...

Thank you

rogilmore@psu.edu <https://gilmore-lab.github.io> <https://gilmore-lab.github.io/2019-06-03-McDonnell-Fdn/>
@rogilmore

Materials

This talk was produced on 2019-06-02 in RStudio version using R Markdown and the revealJS framework. The code and materials used to generate the slides may be found at <https://github.com/gilmore-lab/2019-06-03-McDonnell-Fdn/>. Information about the R Session that produced the code is as follows:

```
## R version 3.5.2 (2018-12-20)
## Platform: x86_64-apple-darwin15.6.0 (64-bit)
## Running under: macOS Mojave 10.14.5
##
## Matrix products: default
## BLAS: /System/Library/Frameworks/Accelerate.framework/Versions/A/Frameworks/vecLib.framework/Versions/
## LAPACK: /Library/Frameworks/R.framework/Versions/3.5/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] stats      graphics  grDevices  utils      datasets  methods    base
##
## other attached packages:
## [1] igraph_1.2.2          forcats_0.3.0
## [3] stringr_1.4.0         dplyr_0.8.0.1
## [5] purrr_0.3.2           readr_1.3.1
## [7] tidyr_0.8.2           tibble_2.1.1
## [9] ggplot2_3.1.0         tidyverse_1.2.1
## [11] databraryapi_0.1.6.9001
##
## loaded via a namespace (and not attached):
## [1] revealjs_0.9          tidyselect_0.2.5 xfun_0.6          reshape2_1.4.3
## [5] haven_2.0.0           lattice_0.20-38  colorspace_1.4-1  generics_0.0.2
## [9] htmltools_0.3.6       yaml_2.2.0      rlang_0.3.3       pillar_1.3.1
## [13] glue_1.3.1            withr_2.1.2     modelr_0.1.2      readxl_1.2.0
```

```

## [17] plyr_1.8.4      munsell_0.5.0    gtable_0.3.0     cellranger_1.1.0
## [21] rvest_0.3.2     codetools_0.2-15 evaluate_0.13     labeling_0.3
## [25] knitr_1.22      curl_3.3         broom_0.5.1      Rcpp_1.0.1
## [29] scales_1.0.0    backports_1.1.3  jsonlite_1.6     hms_0.4.2
## [33] digest_0.6.18   stringi_1.4.3    keyring_1.1.0    grid_3.5.2
## [37] cli_1.1.0       tools_3.5.2      magrittr_1.5     lazyeval_0.2.2
## [41] crayon_1.3.4    pkgconfig_2.0.2  xml2_1.2.0       lubridate_1.7.4
## [45] assertthat_0.2.1 rmarkdown_1.12   httr_1.4.0       rstudioapi_0.10
## [49] R6_2.4.0        nlme_3.1-137     compiler_3.5.2

```