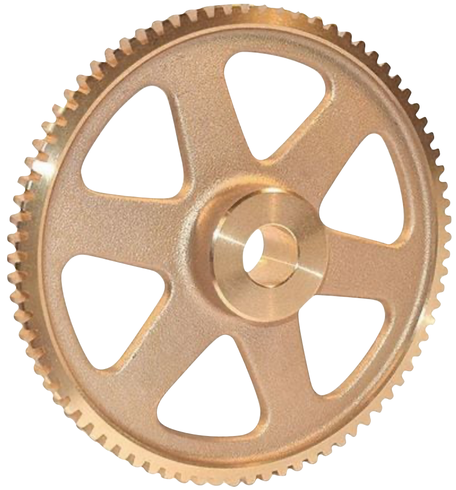
Garbage Collection Makes Rust Easier to Use: A Randomized Controlled Trial of the Bronze Garbage Collector



Michael Coblenz, Michelle Mazurek, Michael Hicks

https://www.zoro.com/boston-gear-wormgear-16dp-145pa-50teeth-rh-bronze-g1045/i/G1235171/

RUST: SAFER BUT HARD TO LEARN

- C, C++ allow dereferencing arbitrary pointers
- Chromium: > 70% of severe security bugs due to memory safety problems [Google]
- Rust is memory-safe (unlike C, C++)
- Ownership mechanism provides memory safety, avoids cost of GC
- Fulton et al.:
  - 59% of survey respondents: Rust is harder to learn than other languages
  - 7/16 interviewees: biggest challenges are ownership/borrowing

[Fulton] Kelsey R. Fulton, Anna Chan, Daniel Votipka, Michael Hicks, and Michelle L. Mazurek. Benefits and Drawbacks of Adopting a Secure Programming Language: Rust as a Case Study. SOUPS '21.

[Google] Memory safety. https://www.chromium.org/Home/chromium-security/memory-safety

BRONZE: A NEW GC FOR RUST

- Idea: mitigate usability cost of ownership with a garbage collector
  - Most code is not performance-critical
  - Use garbage collector for most code
- GCs trace the heap to find live objects, starting from *roots*
- Modified Rust compiler to emit LLVM stack maps
  - Enables prototype's runtime to find roots automatically

DOES BRONZE HELP?

- Randomized controlled trial with 333 participants from a programming languages class

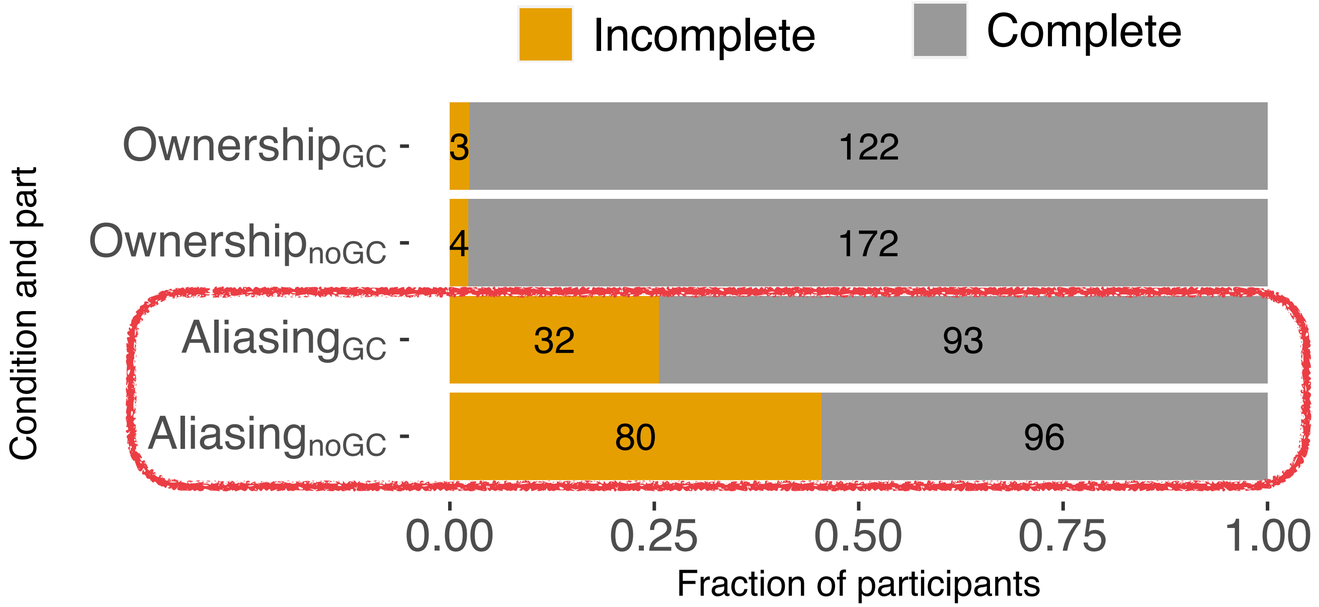
PROCEDURE

- Four lectures on Rust
- Two live-coding demos (after students said the tasks were very hard)
- Survey after each task

	Topic	Traditional	Bronze
8 days	Basics	$\text{Basics}_{\text{noGC}}$	$\text{Basics}_{\text{noGC}}$
12 days	Ownership, lifetimes	$\text{Ownership}_{\text{noGC}}$	$\text{Ownership}_{\text{GC}}$
	Aliased, mutable data	$\text{Aliasing}_{\text{noGC}}$	$\text{Aliasing}_{\text{GC}}$
	Aliased, mutable data	(none)	$\text{Aliasing}_{\text{noGC}}$

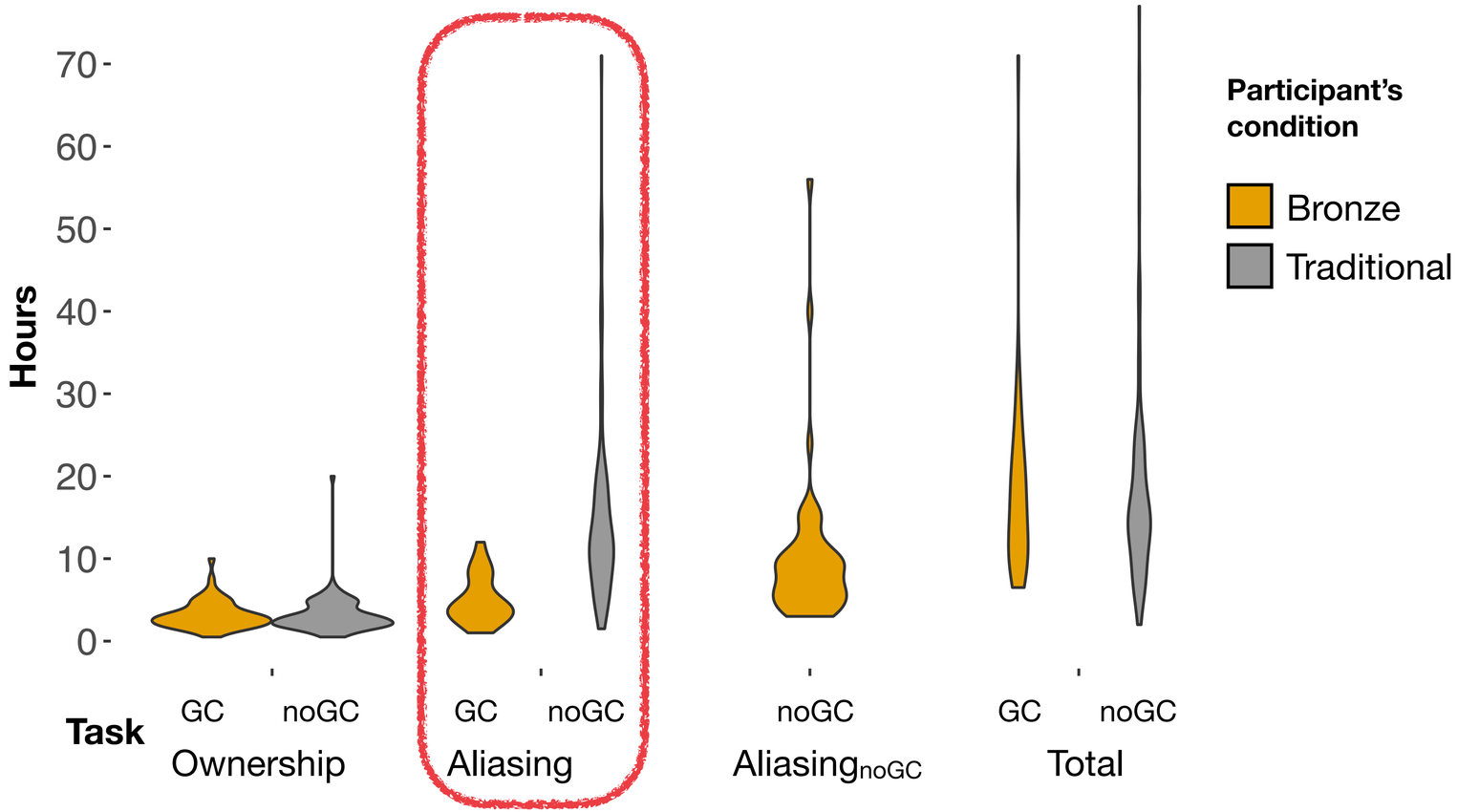
RESULTS: COMPLETION RATE

- No difference in completion rates of Ownership task
- Bronze users were 2.4x as likely to score 100% on Aliasing ($p \approx .006$)



RESULTS: COMPLETION TIMES

- Bronze: finished Aliasing faster (median 4 h. vs. 12 h., $p < .001$)



RESULTS: COMPLETION TIMES

- No significant difference in *total* times

Topic	Traditional	Bronze
Basics	$\text{Basics}_{\text{noGC}}$	$\text{Basics}_{\text{noGC}}$
Ownership, lifetimes	$\text{Ownership}_{\text{noGC}}$	$\text{Ownership}_{\text{GC}}$
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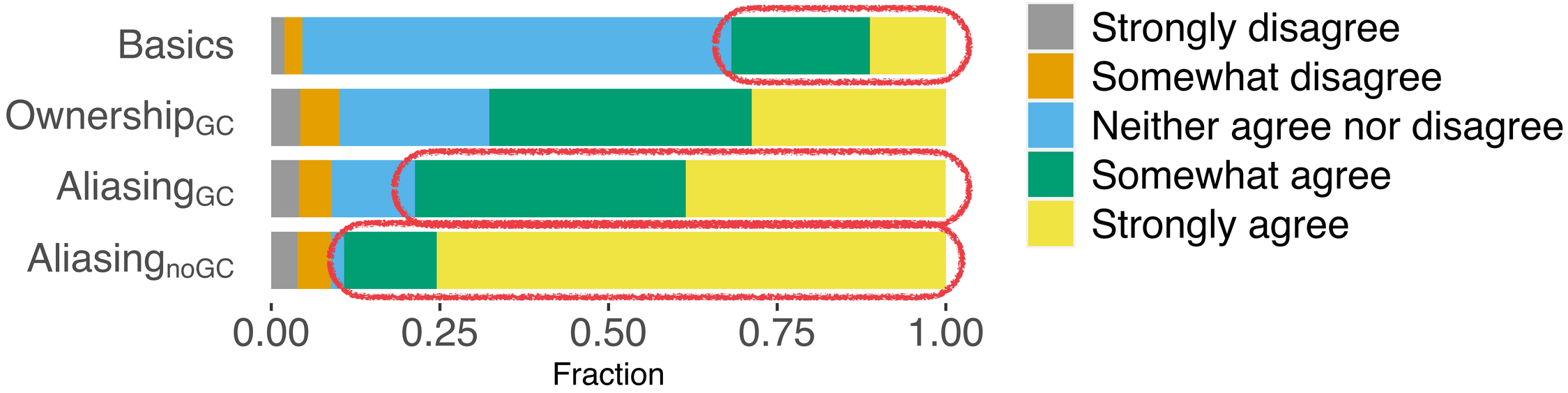
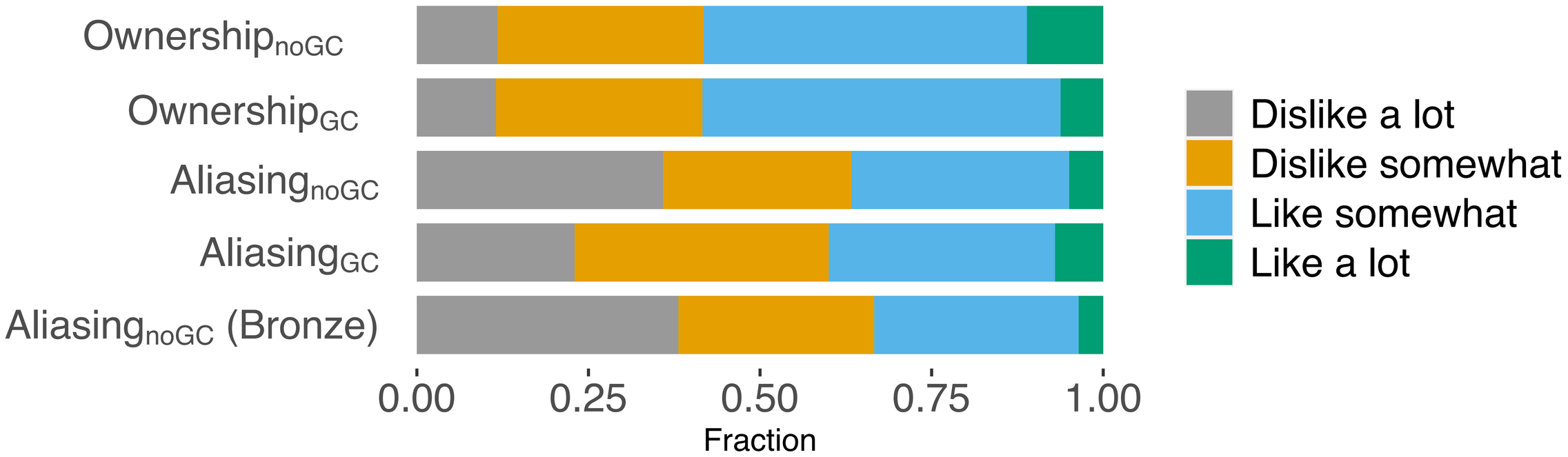
AGREEMENT: "GARBAGE COLLECTION IN RUST MAKES WRITING PROGRAMS EASIER"

- Asked same question after each part
- Participants were more likely to think GC was helpful after doing the assignment than before it ($p < .001$)



"HOW MUCH DO YOU LIKE RUST?"

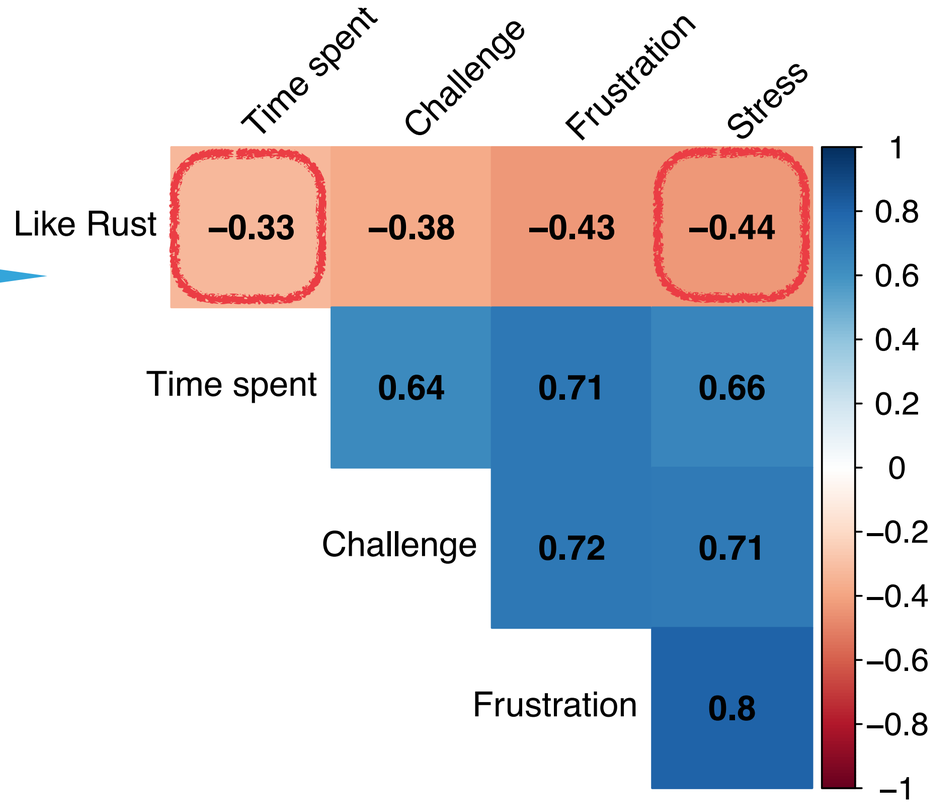
- No significant difference



FACTORS INFLUENCING PERCEPTIONS

- Perhaps future designs should focus on reducing stress rather than time spent!

- 0 would mean "no correlation"
- -1 or 1 would mean "can completely predict perception of time spent from amount liking Rust"



"WHAT WAS MOST DIFFICULT?"

- “Coding with ownership rules and trying to implement mutability, in general, was just such a headache. It is like someone had combined the worst part of C and Java.”
- Interior mutability requires, in API:
  - Managing reference-counted pointers
  - Using dynamic borrowing
- Whereas GC references "just work"

NEXT STEPS

- How can we make Rust even easier to use?
- Observed students in a Rust course
- Key opportunities:
  - Low-level error messages do not teach high-level concepts
  - Fixing compiler errors is like debugging. How to teach debugging effectively?
  - Showing partial lists of errors is misleading
  - Motivating understanding rather than cargo culting

DISCUSSION

- Reaction from the community
- What questions would YOU have asked?
- How would you have changed the study?
- Limitations?
- You could work on this project too!

CONCLUSION

- Garbage collection significantly reduces the architectural burden of ownership in Rust
- GC can enable completion of complex tasks in less time in ownership-based languages