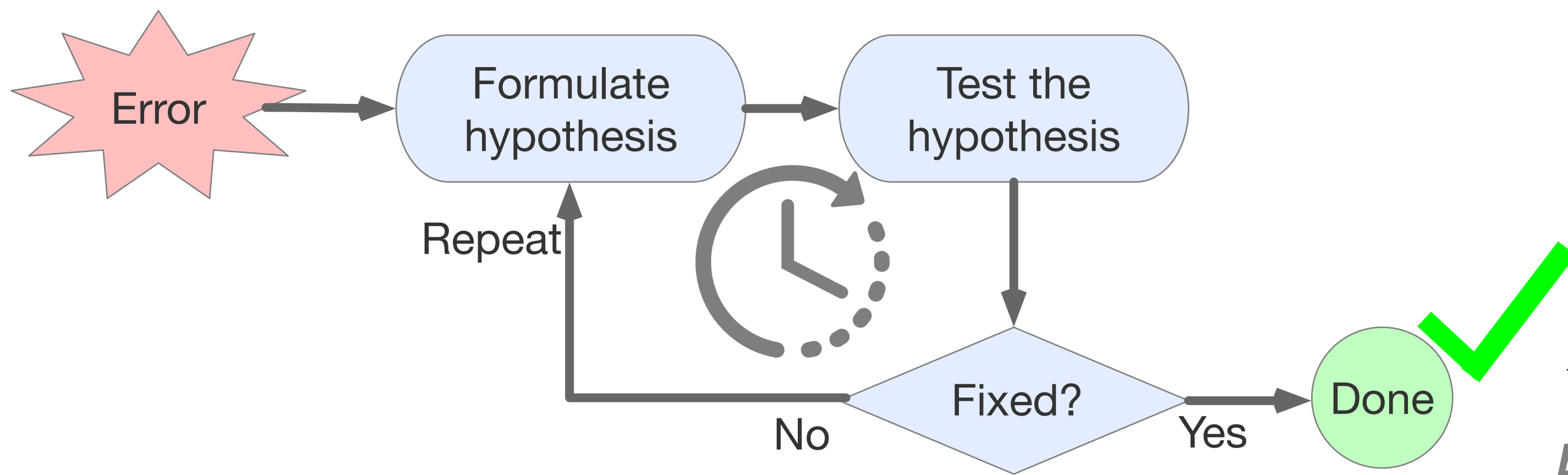


### Context: The debugging process

Debugging is a time consuming iterative process:



What is the  
cause of the error?



\*\*Trying to understand the program emoji\*\*

To understand the behavior of a program, developers ask program comprehension questions

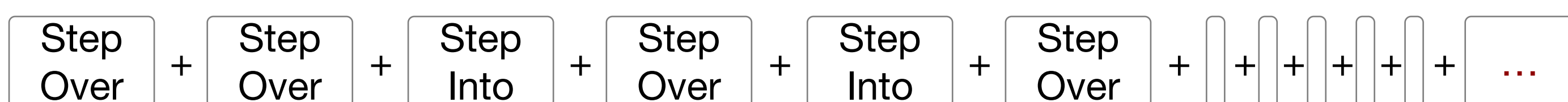
- When during the execution is this method called?
- Where are instances of this class created?
- Where is this variable or data being accessed?
- Etc.

**BETTER PROGRAM COMPREHENSION => SHORTER DEBUGGING PROCESS**

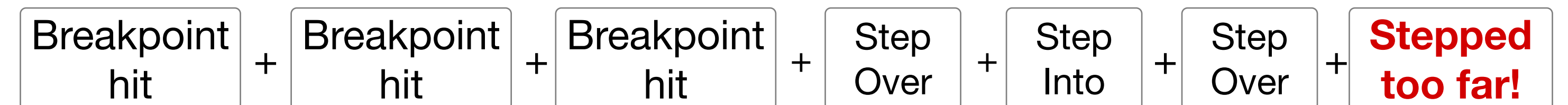
### Problem: Understanding programs for debugging is difficult

To find answers, developers explore their program executions using debugging tools

**Debugging Question: What is the value of this variable during the execution?**



**Tedious!** 😞



**Missed the target!** 😞

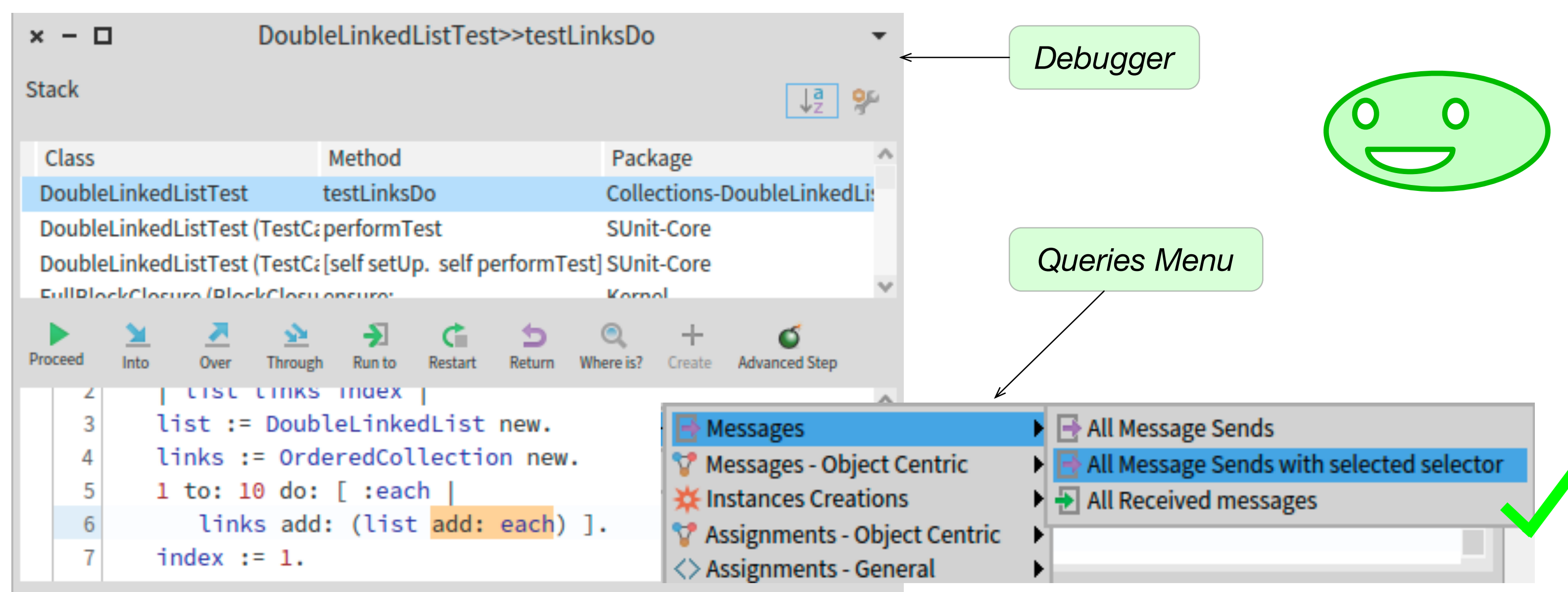
**Can we do better?**

### Solution: Time-Traveling Queries

#### Time-Traveling Queries (TTQs)

Do you have a Debugging Question?

Select a Time-Traveling Query from the Queries Menu!



- TTQs request information of an execution related to **common debugging questions**.

- **Find answers directly** in your query result (Don't miss target!).

- **"Click & Time-Travel"**

Reverse or advance the execution jumping directly to any of the results timestamp (Less tedious!).

- Explore your execution states forward or backward.

Step number (timestamp)      Query results

Step	Msg Receiver	Oid	Msg Selector
1	56	list (DoubleLinkedList)	8
2	104	links (OrderedCollection)	18
3	138	list (DoubleLinkedList)	8
4	191	links (OrderedCollection)	18
5	225	list (DoubleLinkedList)	8
6	278	links (OrderedCollection)	18
7	312	list (DoubleLinkedList)	8

Showing 20 results, fetched in: 282ms.  
ExecutedBytecode: 56 (3.06% of known execution)

Do you have different debugging question? **Just select another query!**

There is no query for your Debugging Question? **Write your own TTQ!**

Example:

```

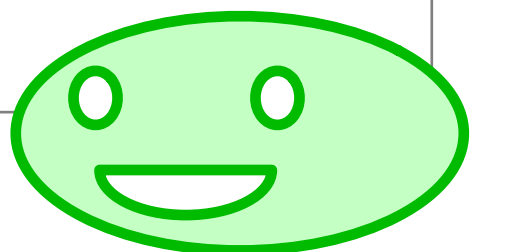
"Lists global variables assignments"
^ UserTTQ from: programStates
  select: [ :state | state isAssignment and: [ state node variable isGlobalVariable ] ]
  collect: [ :state |
    ResultItem new
      bytecodeIndex: state bytecodeIndex;
      variableName: state assignmentVariableName;
      yourself ]
  
```

From where to extract the data?      What program states are relevant?      What should be included in the results?



#### Time-Traveling Queries Evaluation

**With TTQs, developers perform program comprehension tasks more accurately, faster, and with less effort than with standard debugging tools.**



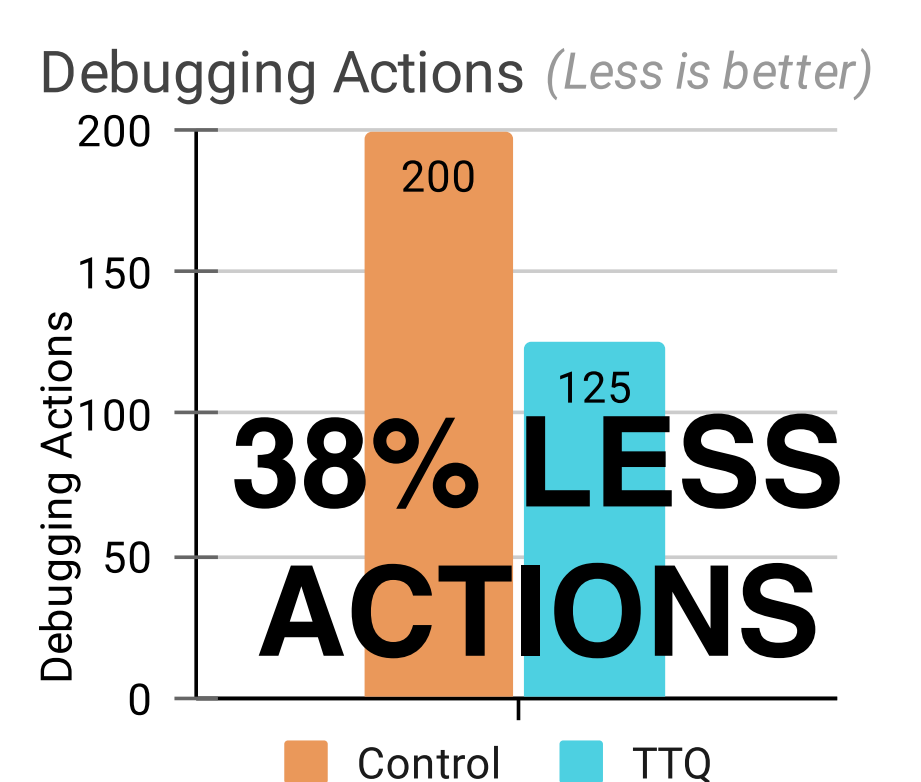
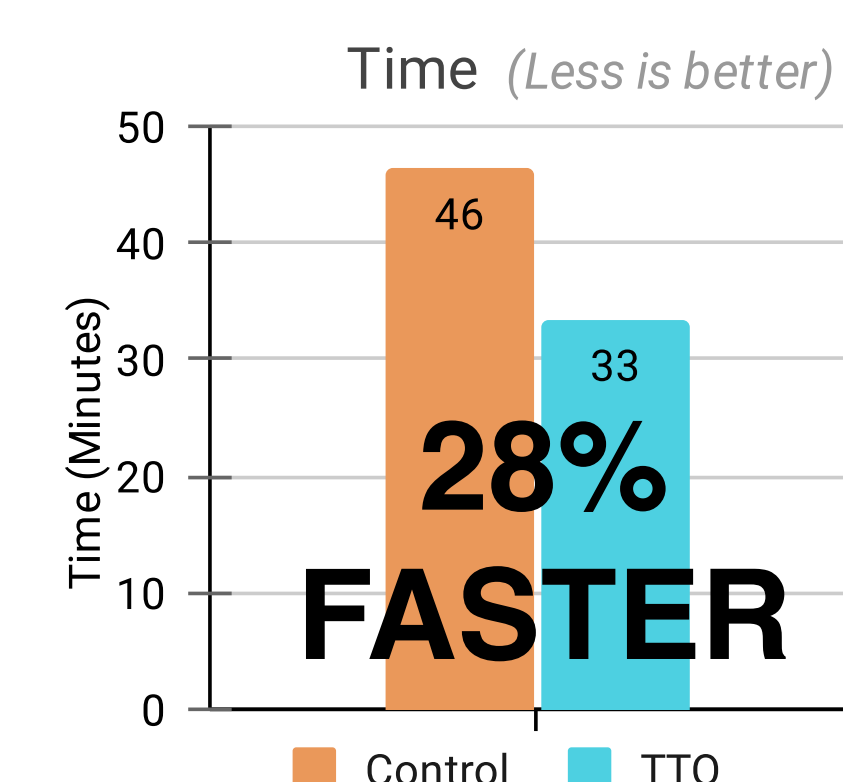
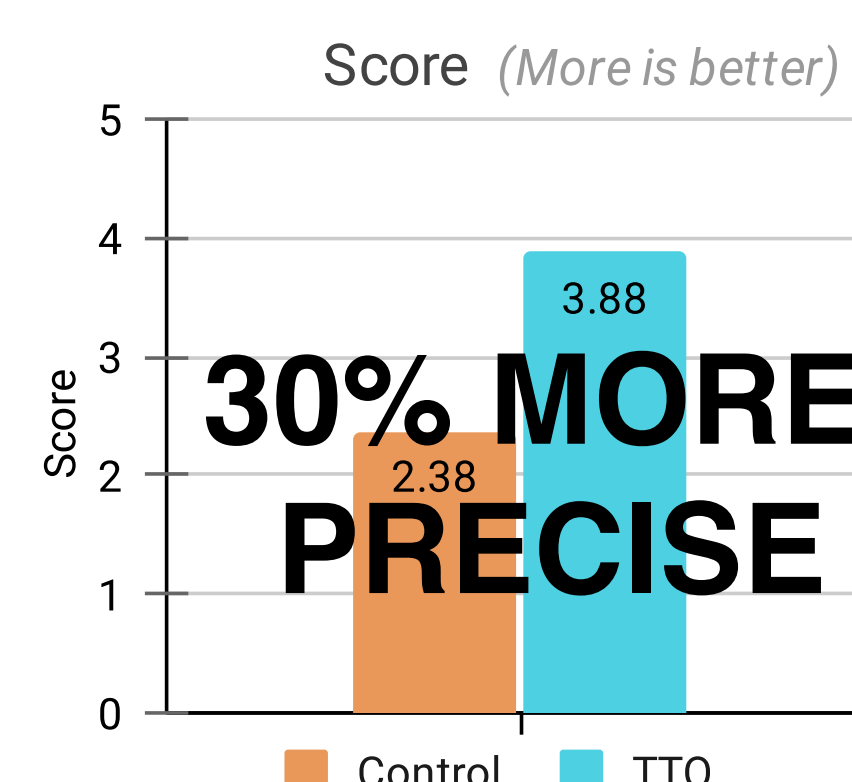
#### Controlled Experiment

- Repeated Measures Design (Within-subject)
- **34 Participants.**

#### Research Question

Do TTQs improve program comprehension tasks, of participants regarding precision, time spent and efforts? (vs using standard debugging tools)

#### Results



**Control:** Without Time-Traveling Queries

**TTQ:** Using Time-Traveling Queries

#### Future work

- Scaling the solution to quotidian debugging scenarios.
- Studying new relevant queries.
- Research TTQs generalization to different programming languages.
- Designing new TTQs-based debugging tools.