CSCI 275: Programming Abstractions

Lecture 28: Control Flow Design

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This Semester Thus Far

Thus far:

- First month we thought about how to *write* Racket
- Second month we thought about to *execute* Racket

The rest of the semester:

- Thinking about context *beyond* Racket (theory & practice)

Reminder: This Week’s Goal

Talk about design of a language and how it impacts implementation

- In MiniScheme, you are implementing a certain language that has certain rules

- Many times, we have choices for these rules

- Wednesday & Today: what we *could* and *can* do for rules in language design
  - Another “instantiate your subconscious process” topic!
  - Another way to think about how your knowledge applies after this class

Language Design

Ways MiniScheme did not *deviate* from Racket

We decided to include control flow via:

- If-then-else statements
- Recursive evaluation of procedural approaches

Language structures that allow us to make choices about what statement happens next

Which of the following **control flow statements** are *not* part of the MiniScheme language?

A. for loops

B. while loops

C. if statements

D. cond statements

E. More than one of the above

Final MiniScheme grammar

EXP → number

| symbol

| （ if _EXP EXP EXP_ ）

| （ let （ _LET-BINDINGS_ ） _EXP_ ）

| （ letrec （ _LET-BINDINGS_ ） _EXP_ ）

| （ lambda （ _PARAMS_ ） _EXP_ ）

| （ set! symbol _EXP_ ）

| （ begin _EXP_* ）

| （ _EXP EXP_* ）

LET-BINDINGS → _LET-BINDING_*

LET-BINDING → ［ symbol _EXP_ ］*

PARAMS → symbol*

Ways MiniScheme did not *deviate* from Racket

We decided to include control flow via:

- If-then-else statements
- Recursive evaluation of procedural approaches

We did not consider other types of iteration or control flow constructs such as:

–`for` loops
–`while` loops
–(`switch/match` statements)

Why did we not consider other control flow?

Why did we not consider other control flow?

- If-then-else statements are *fundamental* in most languages
- Iteration via recursion is fundamental *to Racket* and, more broadly, to functional programming overall
  - Also an added benefit of reducing the need for additional special forms!
- These are also “standard” design constructs, that we see in many many languages

A (Very Different) Language Construct

Reminder from last time: Scope of a declaration

The *scope* of a declaration is the portion of the expression or program to which that declaration applies

Lexical binding

- Scope of a variable is determined by textual layout of the program
- C, Java, Scheme/Racket use lexical binding

Dynamic binding

- Scope of a variable is determined by most recent *runtime* declaration
- Bash and classic Lisp use dynamic binding

`goto` Statements

`goto` statements are a (classic) way to handle control flow in some programming languages

`goto` statements rely on two parts:

1. Add labels that reference specific code segments
2. Use `goto` label to move between code segments

This is C++ code. What does it print out?

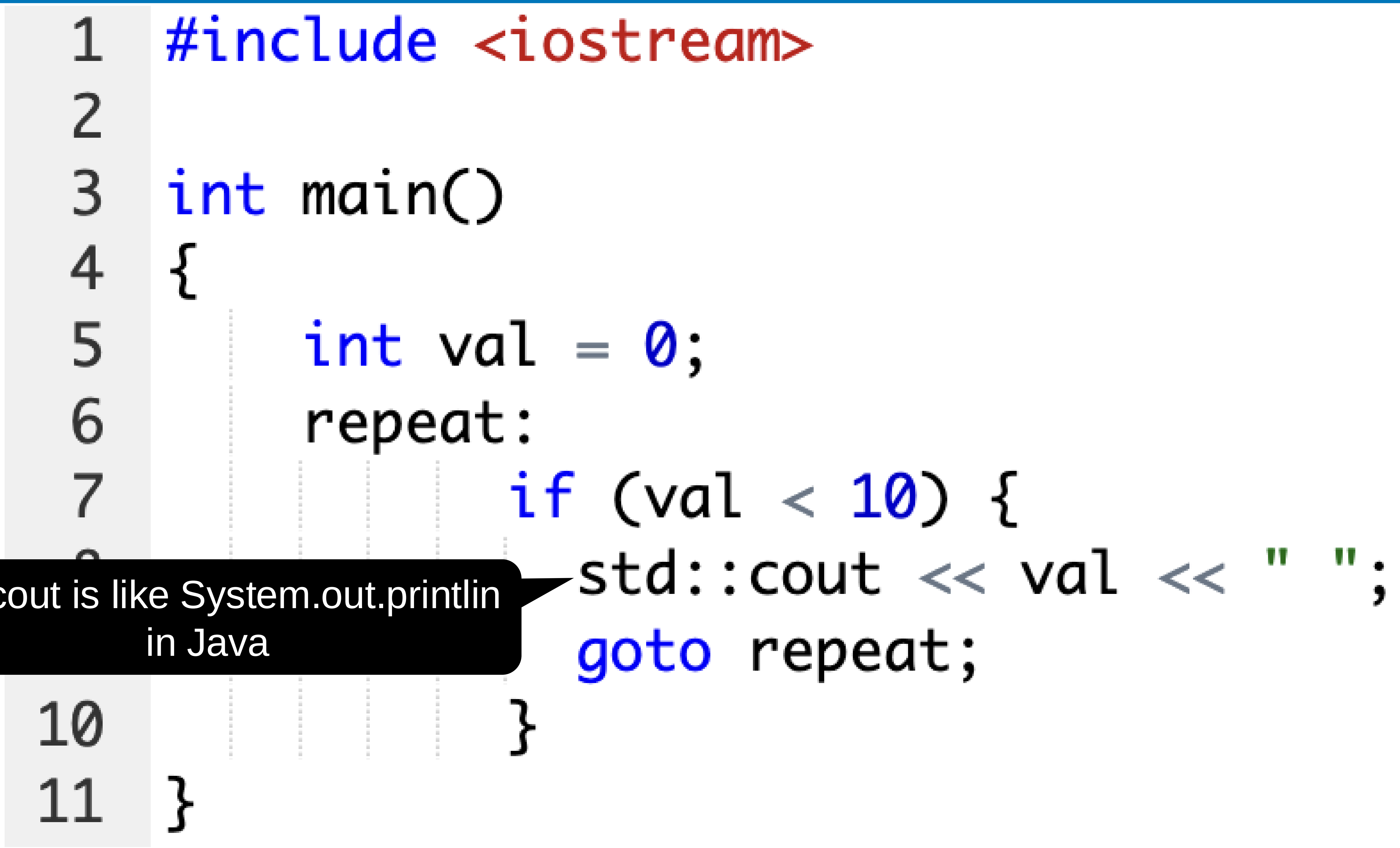
A. 0 1 2 3 … 9

B. 9 8 7 6 … 0

C. 0 1 2 3 … 10

D. Infinite sequence of 0s

E. Something else



```
#include <iostream>

int main()
{
    int val = 0;
    repeat:
          if (val < 10) {
            std::cout << val << " ";
            goto repeat;
          }
}
```

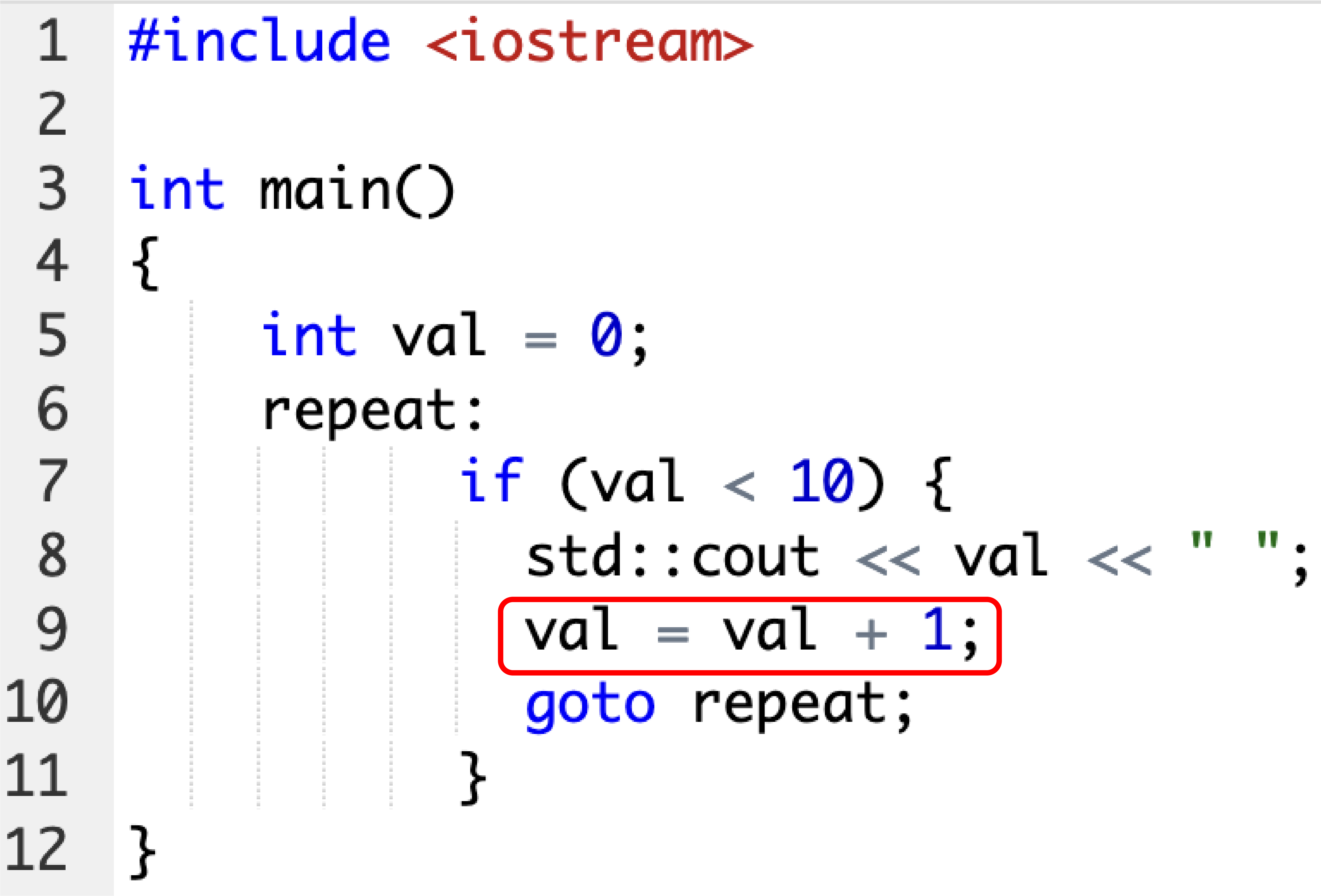
std::cout is like System.out.printlin in Java

Does this change to the code solve the problem?

A. Yes

B. No

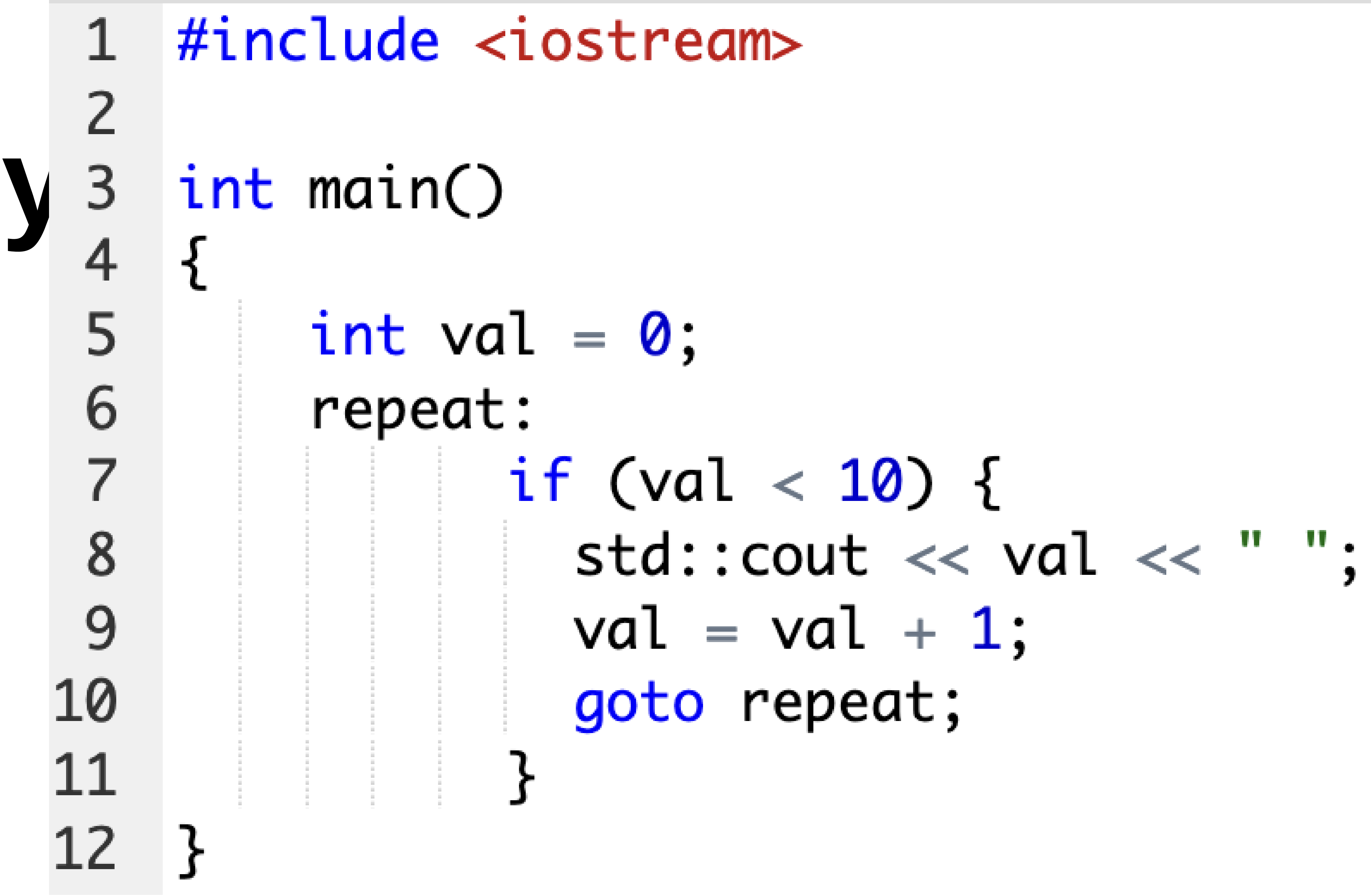
C. In some cases



```
#include <iostream>

int main()
{
    int val = 0;
    repeat:
          if (val < 10) {
            std::cout << val << " ";
            val = val + 1;
            goto repeat;
          }
}
```

Introducing Complexity



```
#include <iostream>

int main()
{
    int val = 0;
    repeat:
          if (val < 10) {
            std::cout << val << " ";
            val = val + 1;
            goto repeat;
          }
}
```

This example seems like “another way to iterate”

`goto` can introduce interesting consequences - especially for scope!

Languages with `goto`

Languages with `goto`:

- APL
- Ada
- Fortran
- Perl
- Assembly (you build if/for/while out of conditional gotos!)
- ***C/C++***

A Bit of Context: Objects in C++

```
class ObjectD {
    public:
        char val;
        //constructor
        ObjectD(char v) {val = v;};
        // non-trivial destructor
        ~ObjectD() {std::cout << val << ":d! "; }
};
```

- Destructors start with ~ in C++
- Destructors called whenever an object is going to be destroyed
- Happens when they are called **explicitly** or **object goes out of scope**

Walk through an example!

Goal: how is this different than code you’ve walked through before?

`goto` examples adapted from the C/C++ guides:

https://en.cppreference.com/w/c/language/goto

https://en.cppreference.com/w/cpp/language/goto

```
#include <iostream>

//In Class Goto Example
//Adapted from https://en.cppreference.com/w/cpp/language/goto

class ObjectD {
    char val;
    public:
        //constructor
        ObjectD(char v) {val = v;};
        // non-trivial destructor
        ~ObjectD() {std::cout << val << ":d! "; }
};

int main() {

    int a = 10;

    std::cout << "before label" << "\n";

    label:
        if (a == 10) {
        ObjectD obj = ObjectD('a');
        }
        else {
          ObjectD obj = ObjectD('b');
        }
        std::cout << a << " ";
        a = a - 2;

        if (a != 0) {
            goto label;
        }

        std::cout << "\n";
        for (int x = 0; x < 3; x++) {
            for (int y = 0; y < 3; y++) {
                std::cout << "(" << x << "|" << y << ")" << "\n";
                if (x + y >= 3) {
                    goto endloop;
                }
            }
        }

    endloop:
        std::cout << "end loop" << "\n";
        goto label3;

    label3:
        std::cout << "label3" << "\n";
}
```

Why is this not something we tend to use?

Why are `goto` statements not common in other languages?

Why did we not implement this in MiniScheme?

How did the *community* decide this?

- In conversation
- Overtime
- Due to real world challenges / challenging use cases

Goto Considered Harmful (1968)

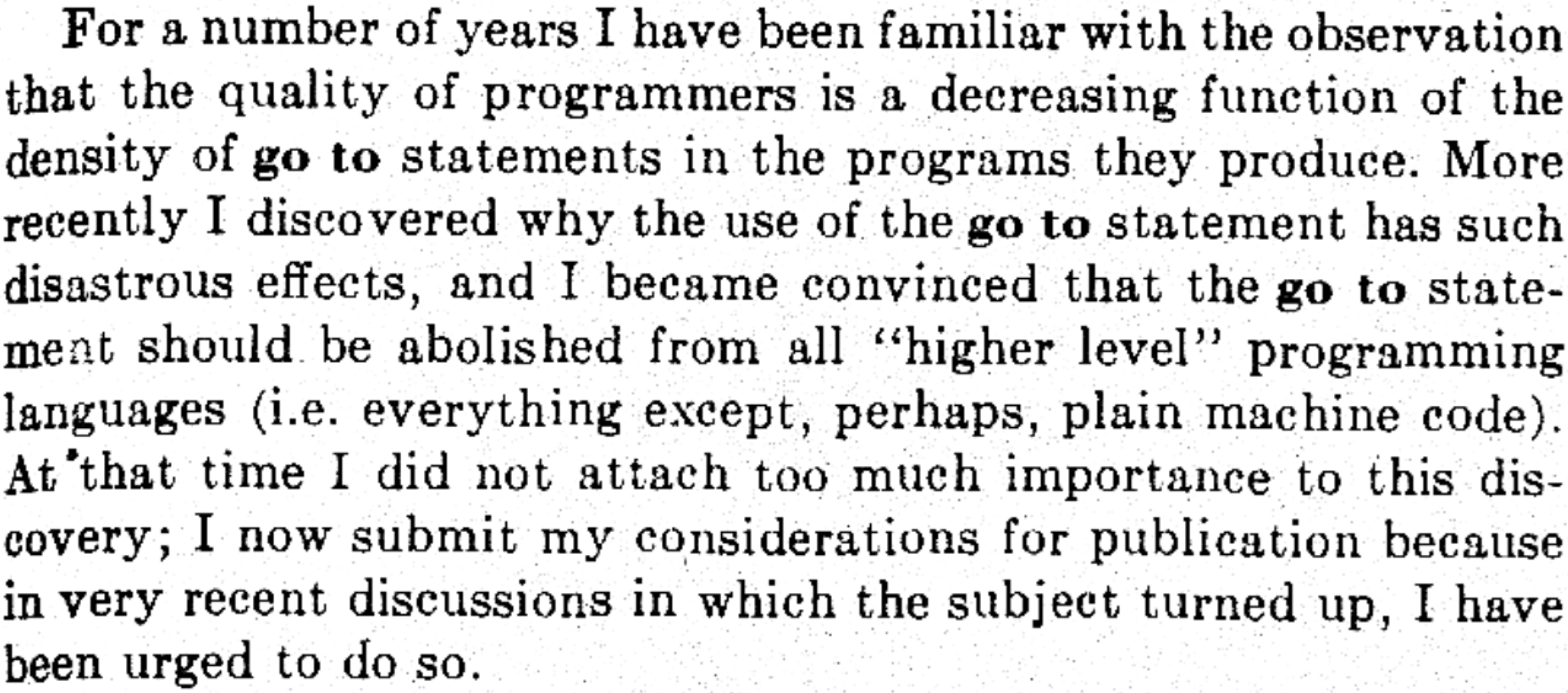
Edsger Dijkstra wrote a letter to the editor as part of the Communications of the ACM

This letter is very well-known by academics (for instance, part of “Great Works” reading groups)

You might ask: ***why?***

NOTE: This is a paper from 1968, the terminology & approach is not modern.

https://homepages.cwi.nl/~storm/teaching/reader/Dijkstra68.pdf



For a number of years I have been familiar with the observation that the quality of programmers is a decreasing function of the density of **go to** statements in the programs they produce. More recently I discovered why the use of the **go to** statement has such disastrous effects, and I became convinced that the **go to** statement should be abolished from all "higher level" programming languages (i.e. everything except, perhaps, plain machine code). At that time I did not attach too much importance to this discovery; I now submit my considerations for publication because in very recent discussions in which the subject turned up, I have been urged to do so.

https://homepages.cwi.nl/~storm/teaching/reader/Dijkstra68.pdf

The **go to** statement as it stands is just too primitive; it is too much an invitation to make a mess of one's program.

https://homepages.cwi.nl/~storm/teaching/reader/Dijkstra68.pdf