The Good, the Bad, and the Ugly: An Empirical Study of Implicit Type Conversions in JavaScript

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JavaScript: An Unusual Language

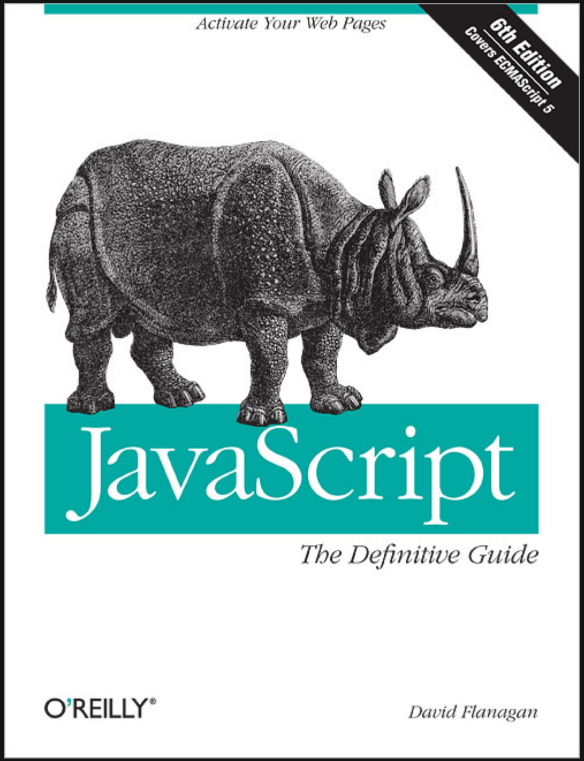
”We need a language for the web.”

JavaScript: An Unusual Language

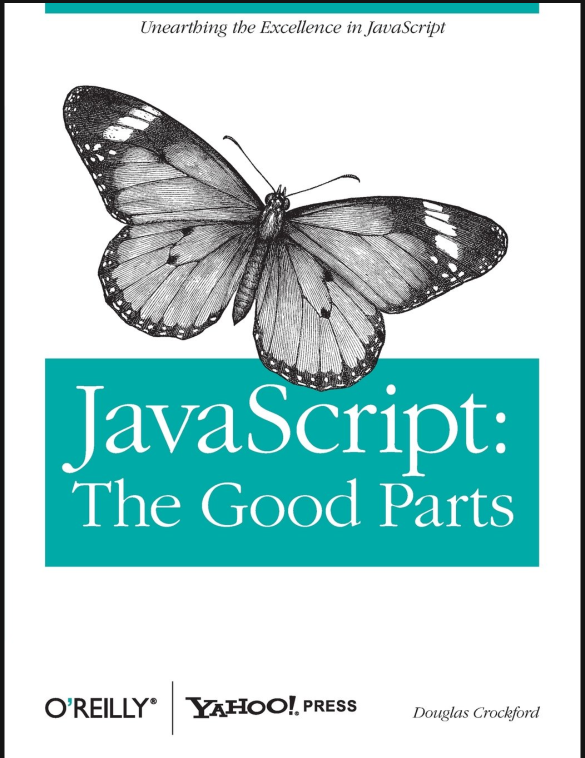
”We need a language for the web.”

”You have 10 days.”

JavaScript: An Unusual Language

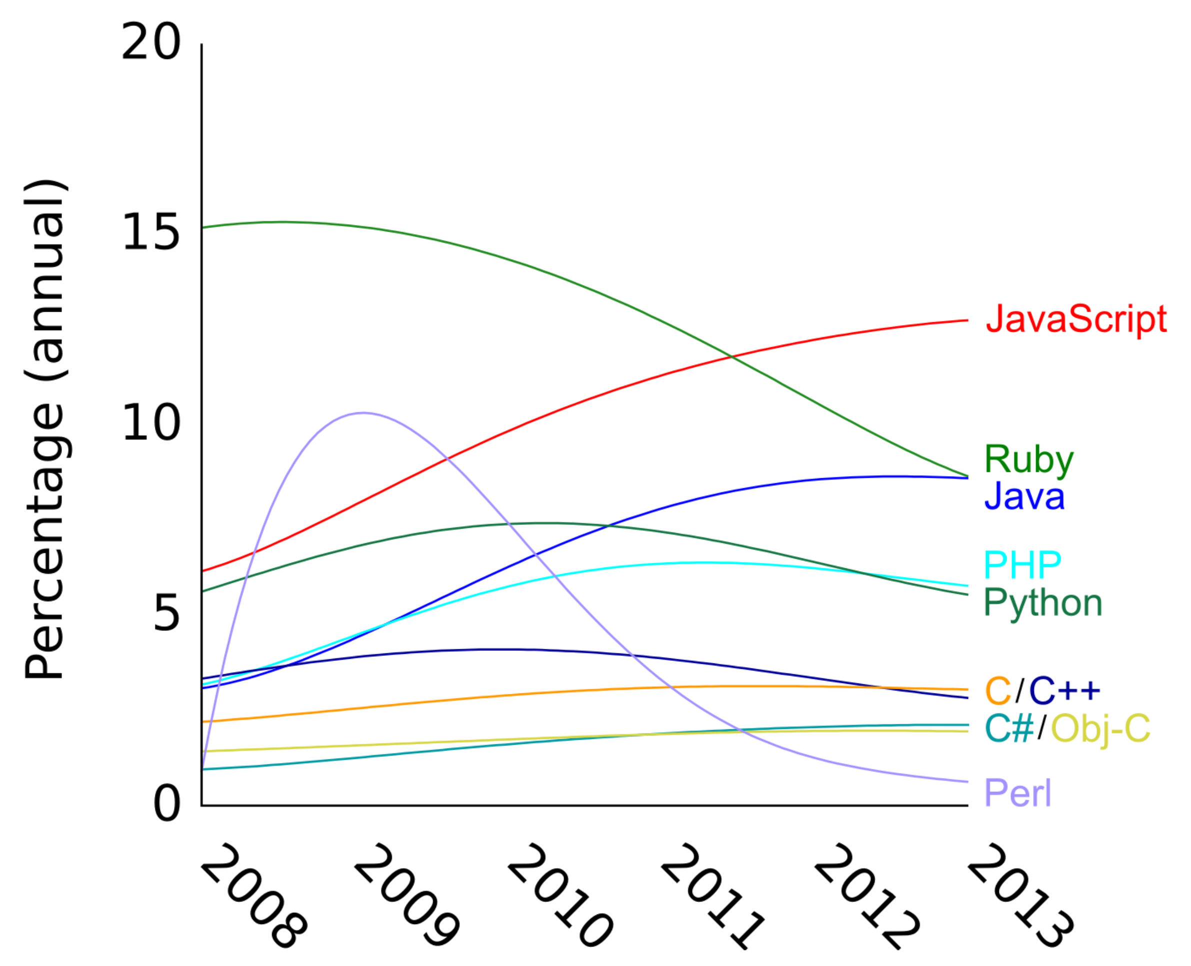


1096 pages



153 pages

JavaScript: An Unusual Language



New projects at Github

(Source: redmonk.com)

Type Coercions

Implicit conversion of a value of one type into a value of another type

Exist in many languages, e.g.

- Java, etc.: Upcasts to supertype
- C, Python, etc.: Integer vs. float

Heavily used in JavaScript

JavaScript Type Coercions

```
"false" == false

"0" == false
```

JavaScript Type Coercions

```
"false" == false   // false

"0" == false       // true
```

When compared to a boolean, strings coerce to numbers

JavaScript Type Coercions

```
new String("a") == "a"


"a" == new String("a")


new String("a") == new String("a")
```

JavaScript Type Coercions

```
new String("a") == "a"               // true

"a" == new String("a")               // true

new String("a") == new String("a")   // false
```

Equality is not transitive

JavaScript Type Coercions

```
[] << "2"

[1] << "2"

[1,2] << "2"
```

JavaScript Type Coercions

```
[] << "2"       // 0

[1] << "2"      // 4

[1,2] << "2"    // 0
```

Should these be valid at all?

Coercions are rarely used

Coercions are error-prone

Coercions make code hard to read

Coercions are rarely used

Really?

Coercions are error-prone

Coercions make code hard to read

This talk:

Empirical Study of JavaScript’s Type Coercions in Practice

Who Needs This Study?

Enables informed decisions

- Program analyses
- Language subsets
- Future languages

Methodology

Subject programs

- Top 100 web sites
- Octane and SunSpider benchmarks

Dynamic analysis

- All operations where coercions may occur
- Based on Jalangi [Sen et al., 2013]

132 programs, 139 million runtime events from 320.000 code locations

How prevalent are coercions?

Photo: A.T.Bueta

Prevalence of Coercions

Function executions with at least one coercion:

- Average over all programs: 80.42%
- Range: 19.95% – 100%

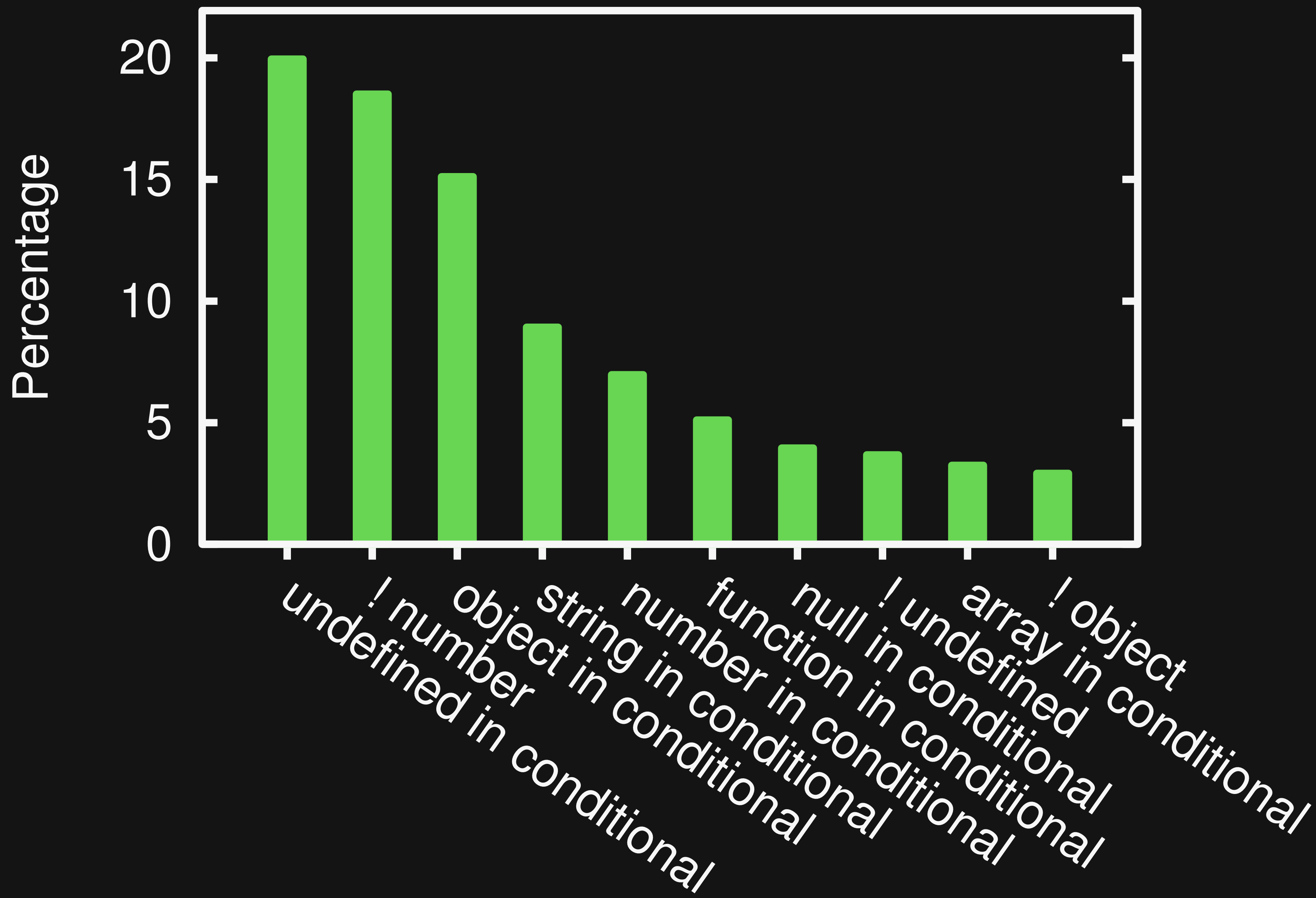
Prevalence of Coercions

Function executions with at least one coercion:

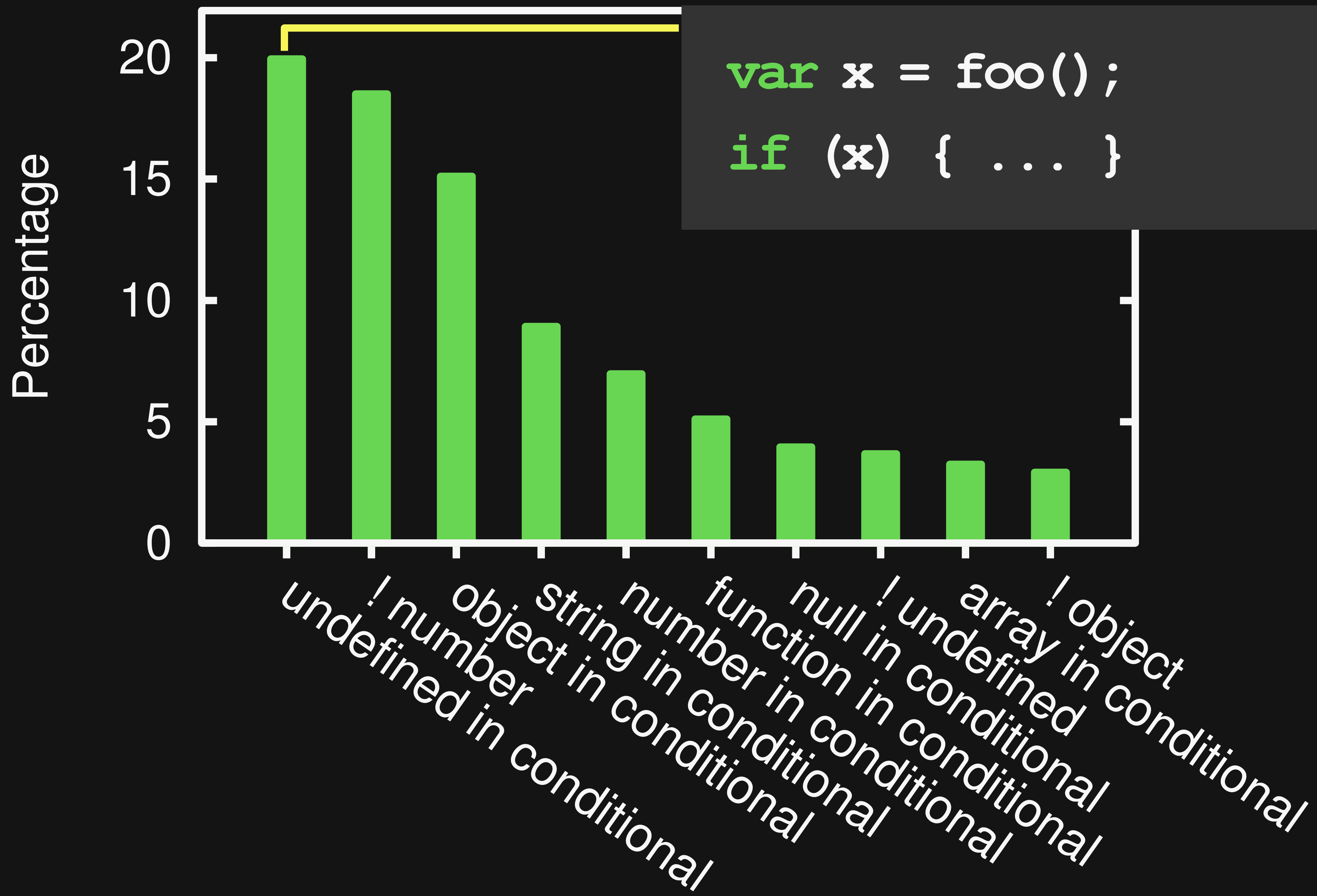
- Average over all programs: 80.42%
- Range: 19.95% – 100%

- Very prevalent
- Certainly non-negligible

What Are Coercions Used For?

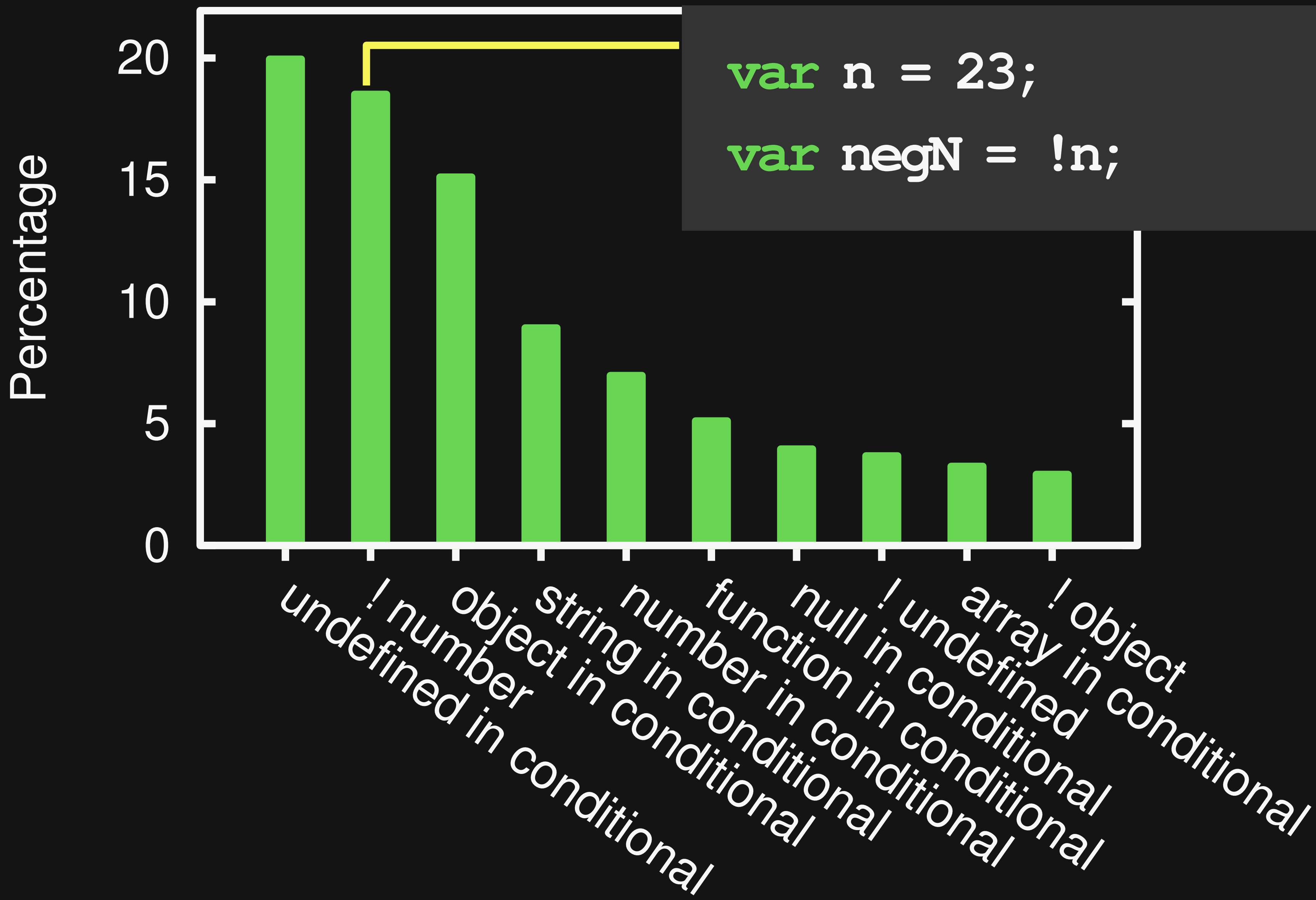


What Are Coercions Used For?



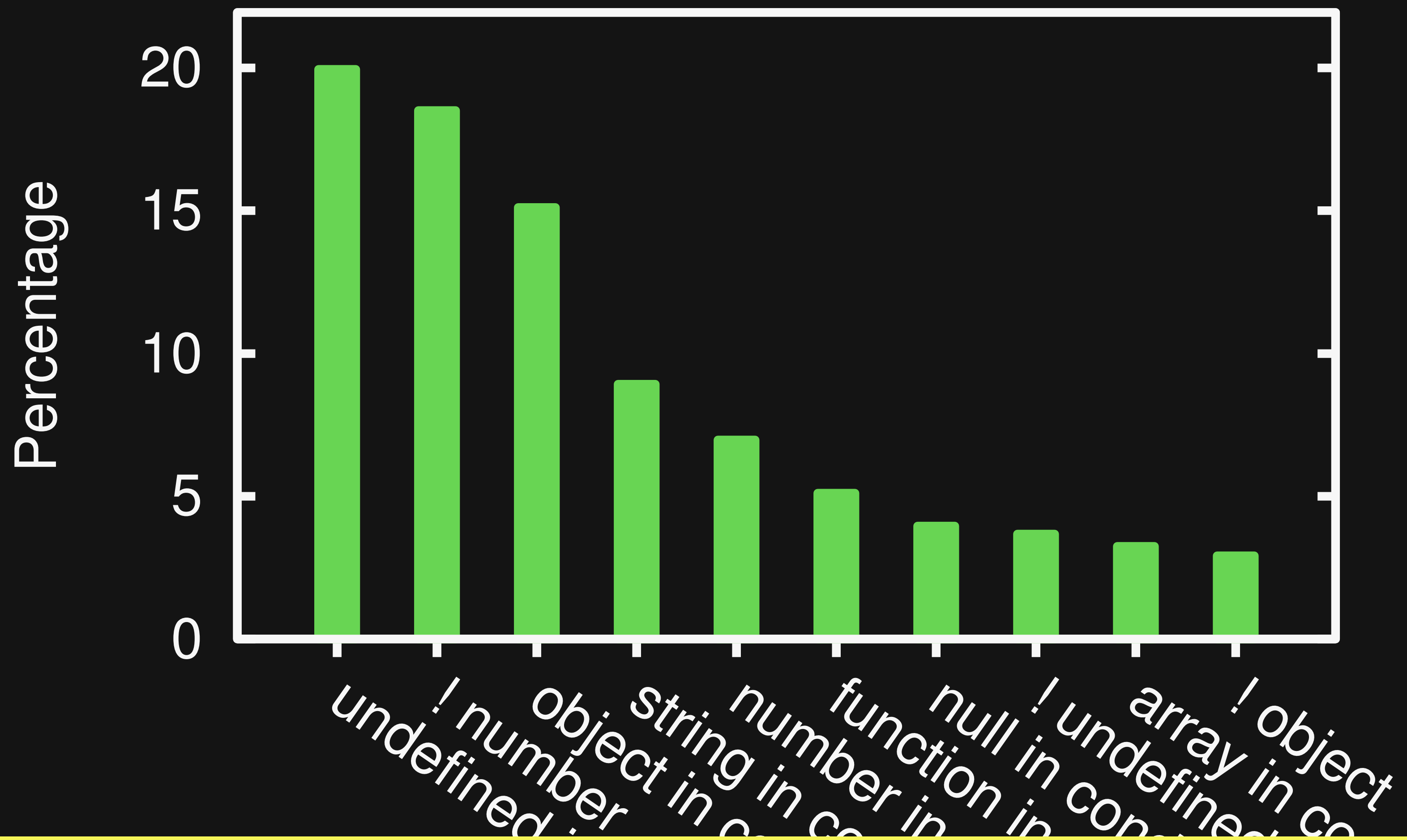
```
var x = foo();
if (x) { ... }
```

What Are Coercions Used For?



```
var n = 23;
var negN = !n;
```

What Are Coercions Used For?



- **Various kinds of coercions**
- **Most prevalent: Conditional-related**

What Are Coercions Used For?

Manual inspection of 30 code locations

- **10 checks if value defined before using it**
- **4 minified booleans: `!0` and `!1`**
- **3 checks if optional argument defined**
- **3 initialization patterns: `x=(x|0)+1`**

Implicit vs. Explicit Conversions

Do developers use explicit conversions?

- E.g., `Boolean(23)`
- 5,497,545 implicit vs. 20,407 explicit

Implicit vs. Explicit Conversions

Do developers use explicit conversions?

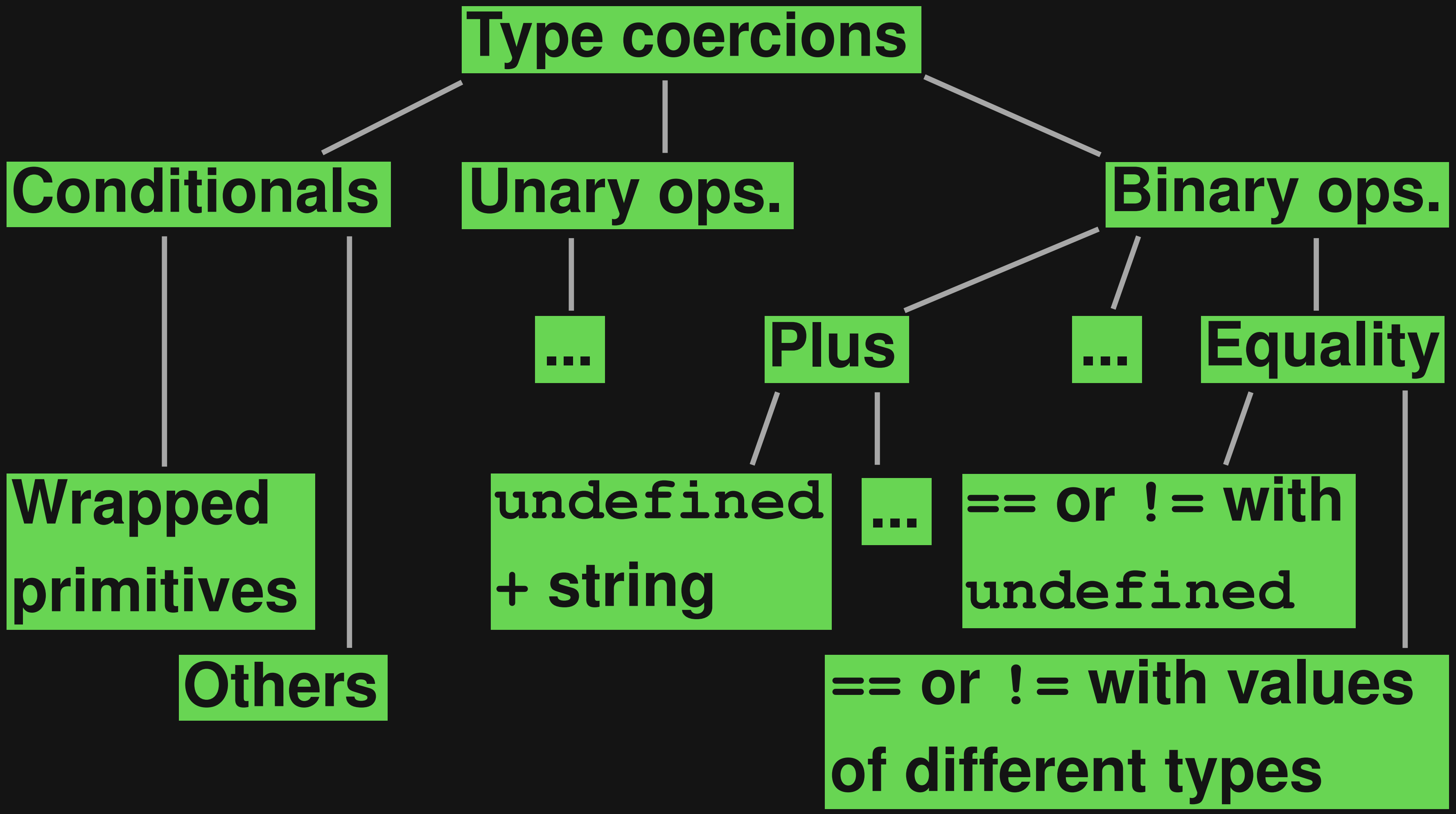
- E.g., `Boolean(23)`
- 5,497,545 implicit vs. 20,407 explicit

Developers prefer implicit conversions

Are coercions error-prone?

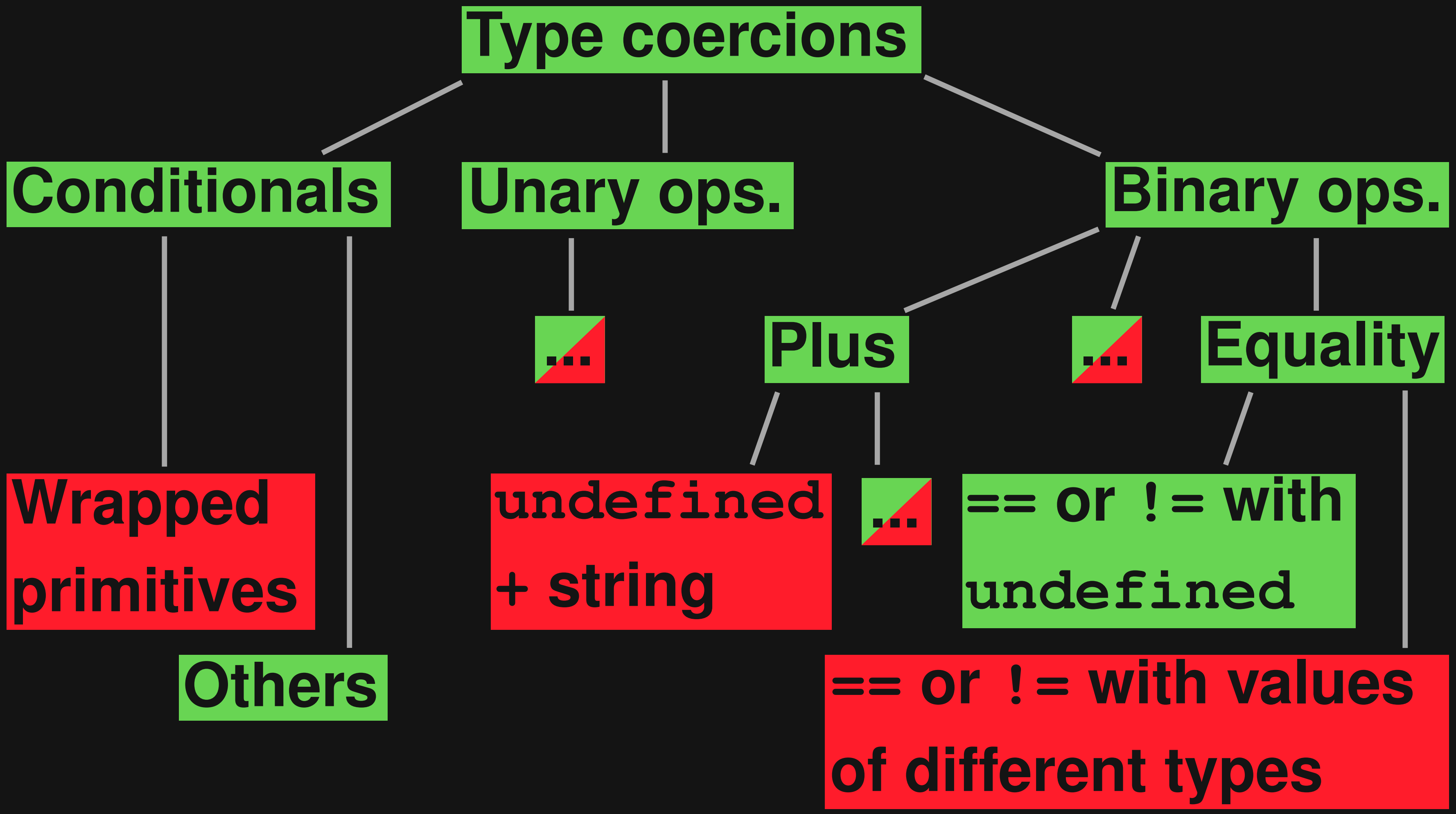
Photo: Raj Alive

Classification of Coercions



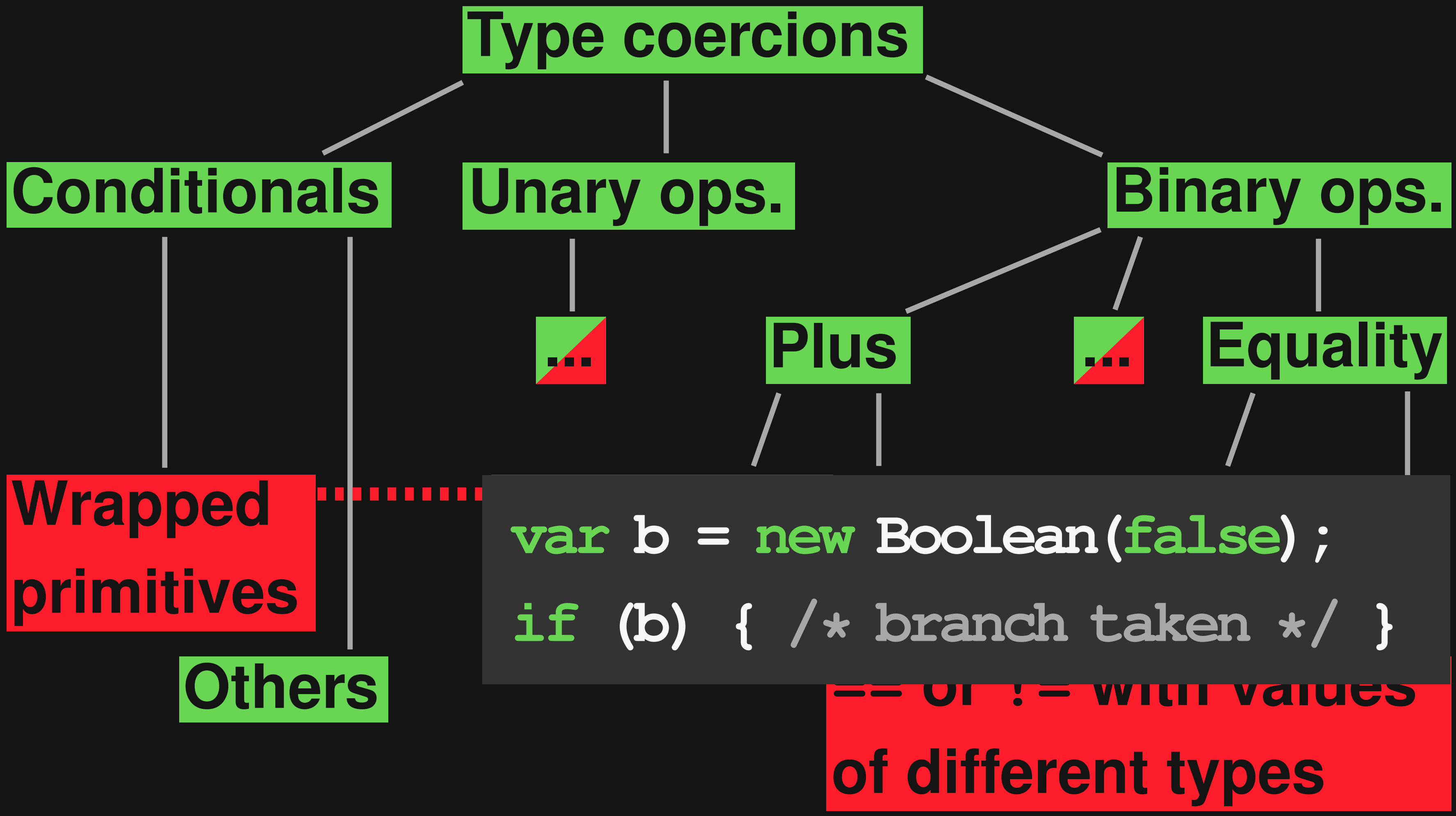
Total: 18 kinds of coercions

Classification of Coercions



Total: 7 harmless, 11 potentially harmful

Classification of Coercions



Type coercions

Conditionals

Unary ops.

Binary ops.

...

Plus

...

Equality

Wrapped primitives

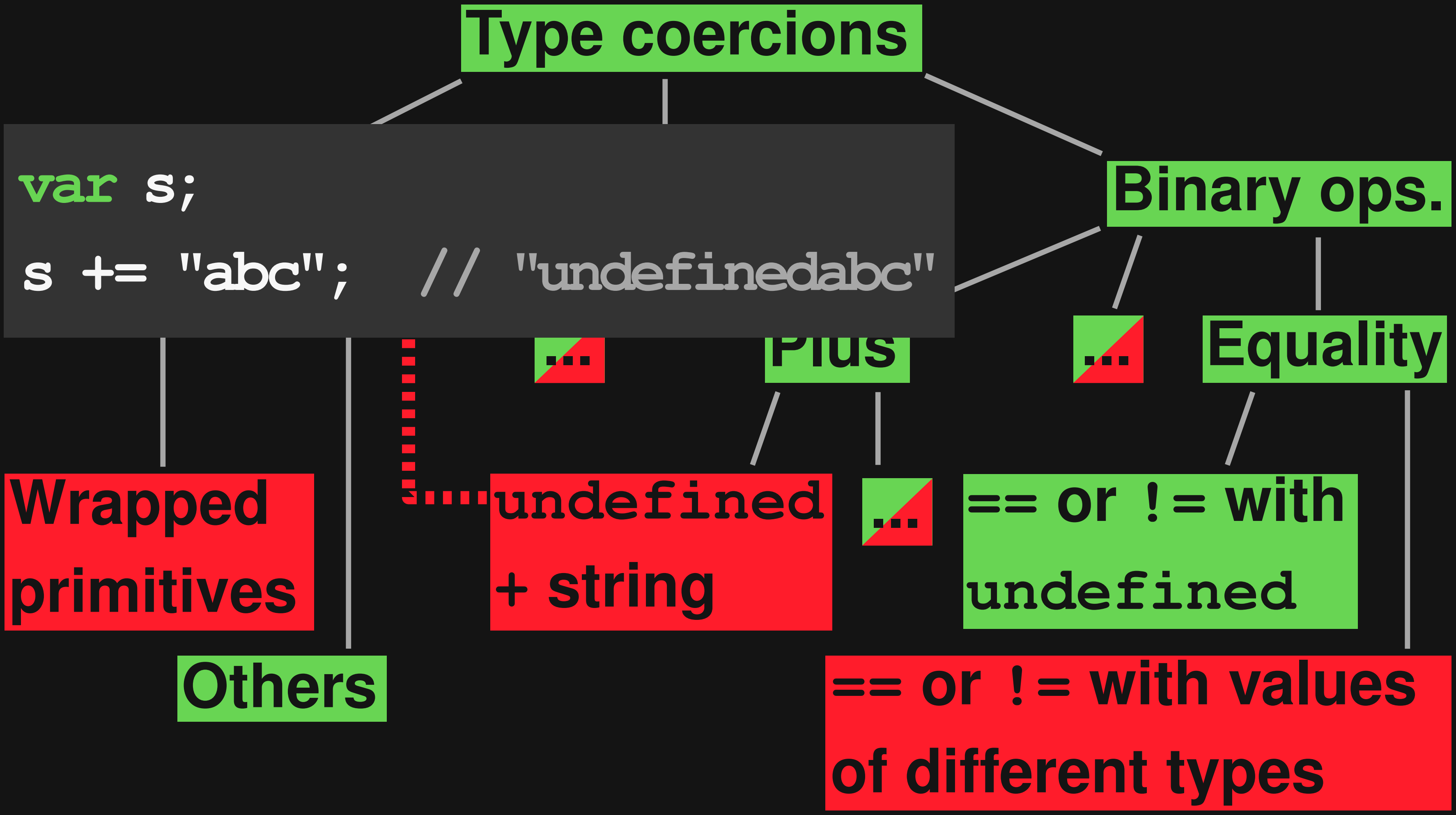
Others

== or != with values of different types

```
var b = new Boolean(false);
if (b) { /* branch taken */ }
```

Total: 7 harmless, 11 potentially harmful

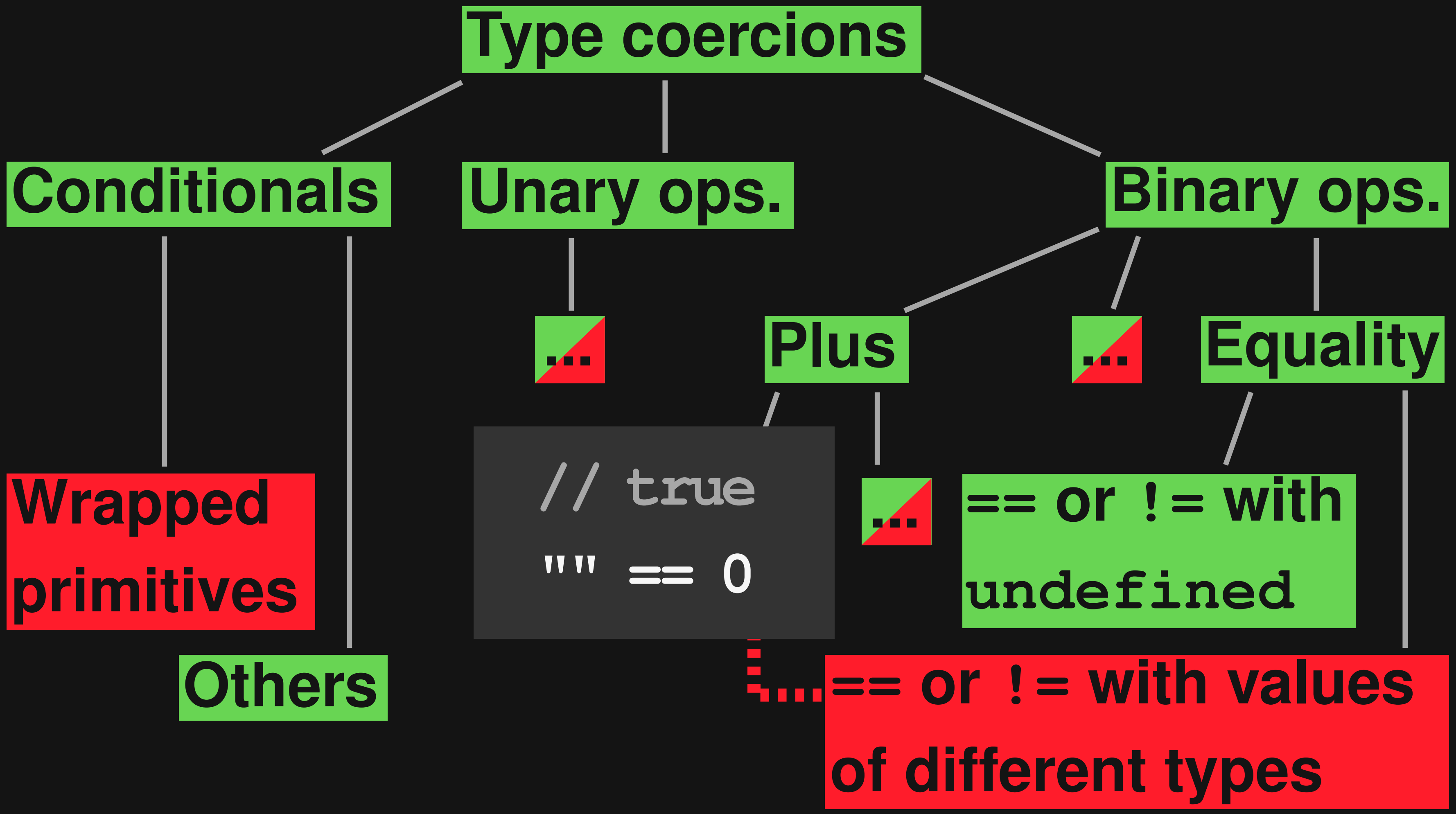
Classification of Coercions



```
var s;
s += "abc";   // "undefinedabc"
```

Total: 7 harmless, 11 potentially harmful

Classification of Coercions



Type coercions

Conditionals

Unary ops.

Binary ops.

...

Plus

...

Equality

Wrapped primitives

Others

```
// true
"" == 0
```

...

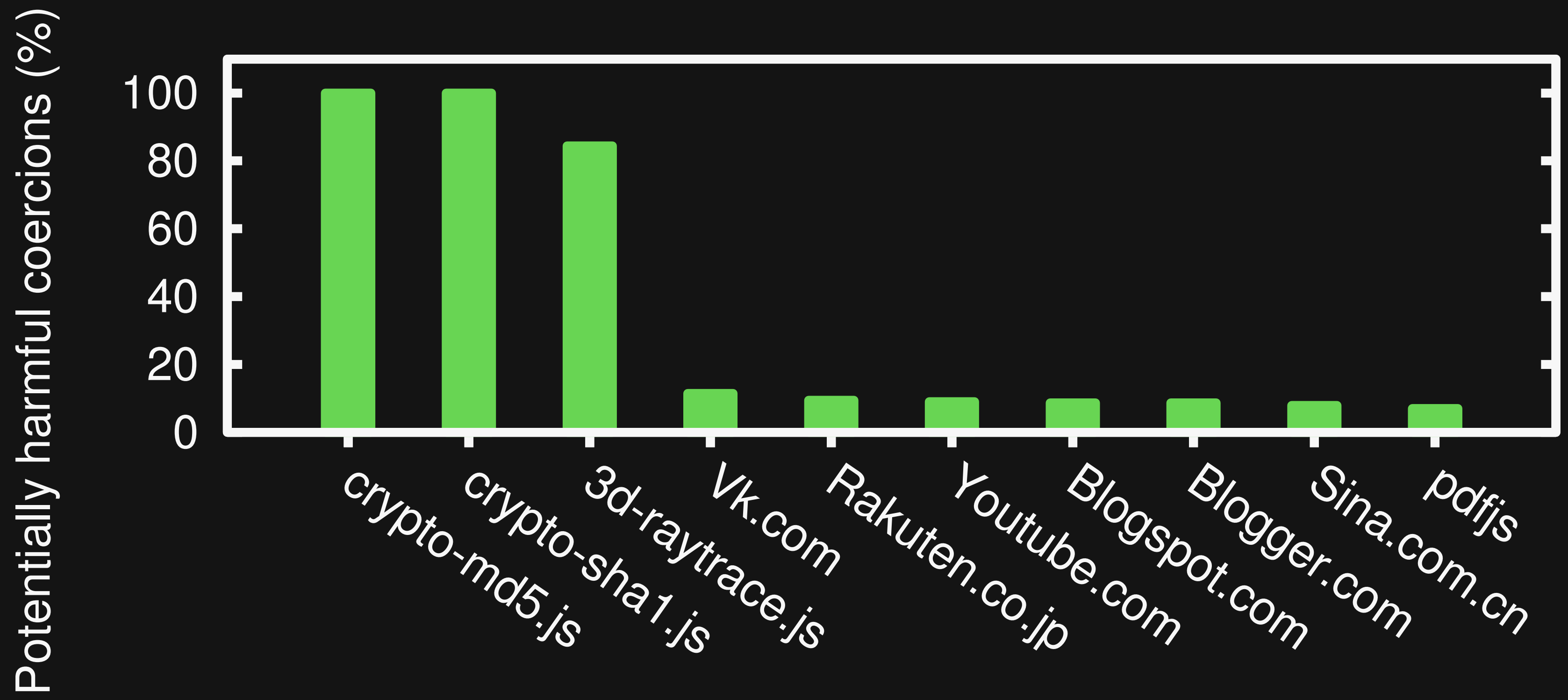
== or != with undefined

== or != with values of different types

Total: 7 harmless, 11 potentially harmful

Are Coercions Harmful?

1.15% of all coercions are potentially harmful



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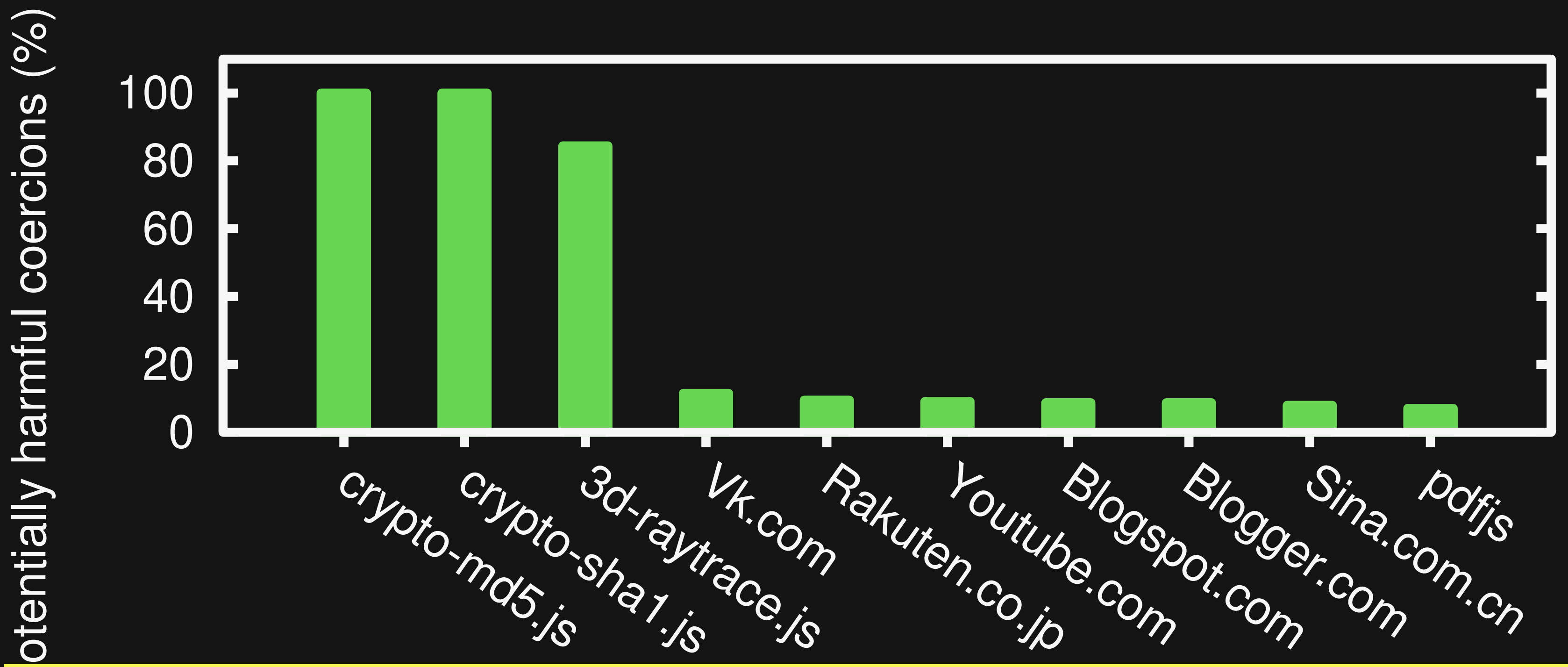
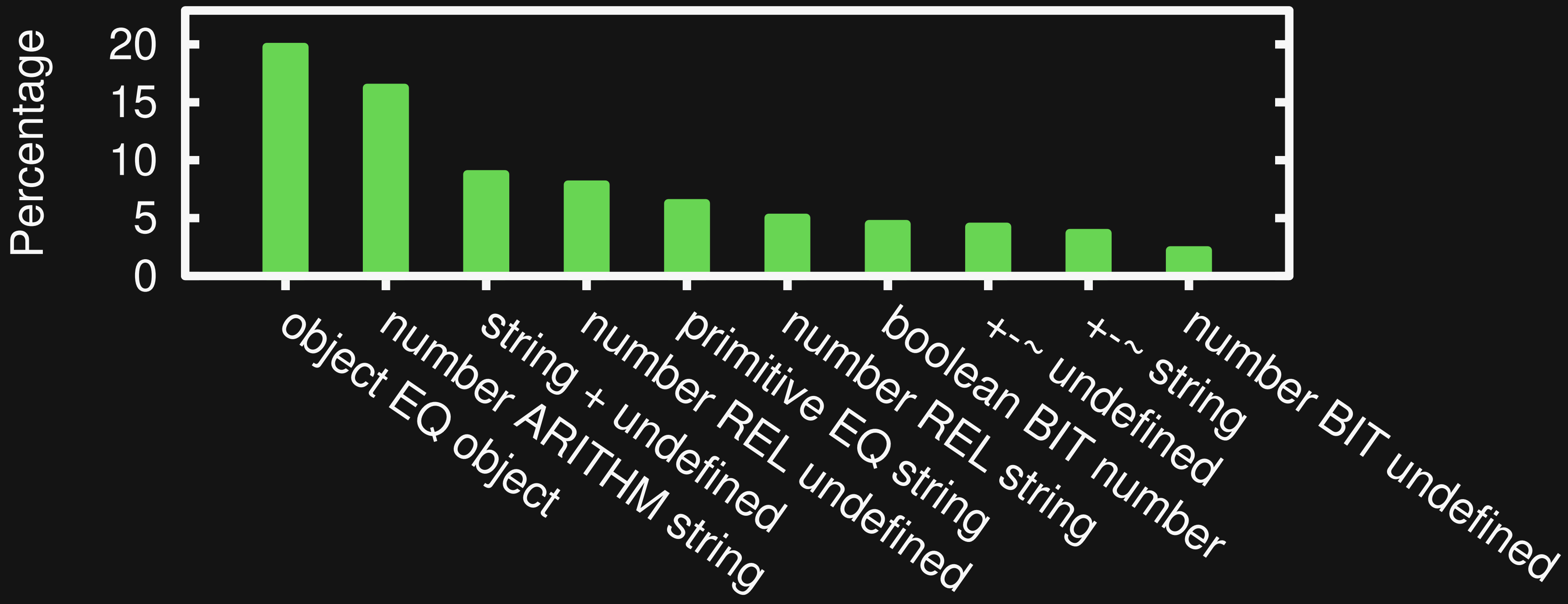


Most coercions are harmless

Potentially Harmful Coercions

Which harmful coercions are the most prevalent?



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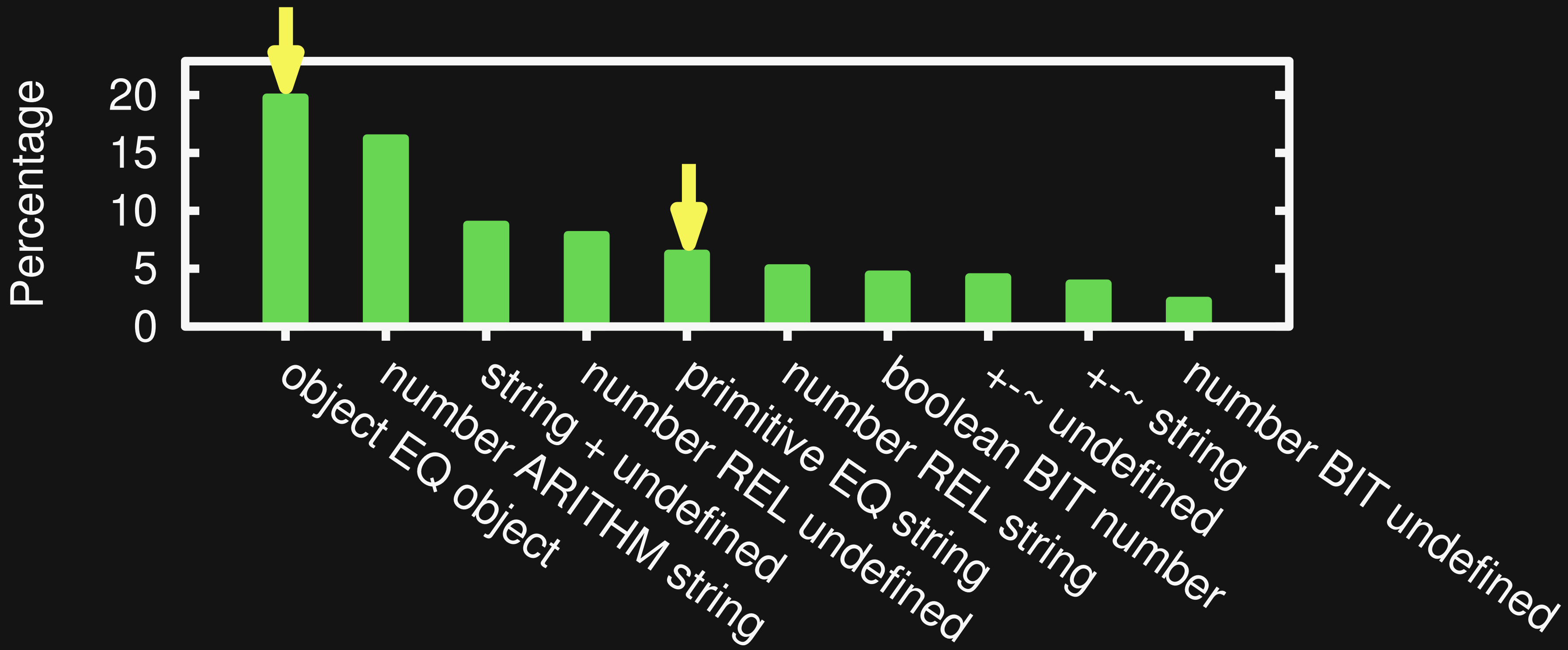
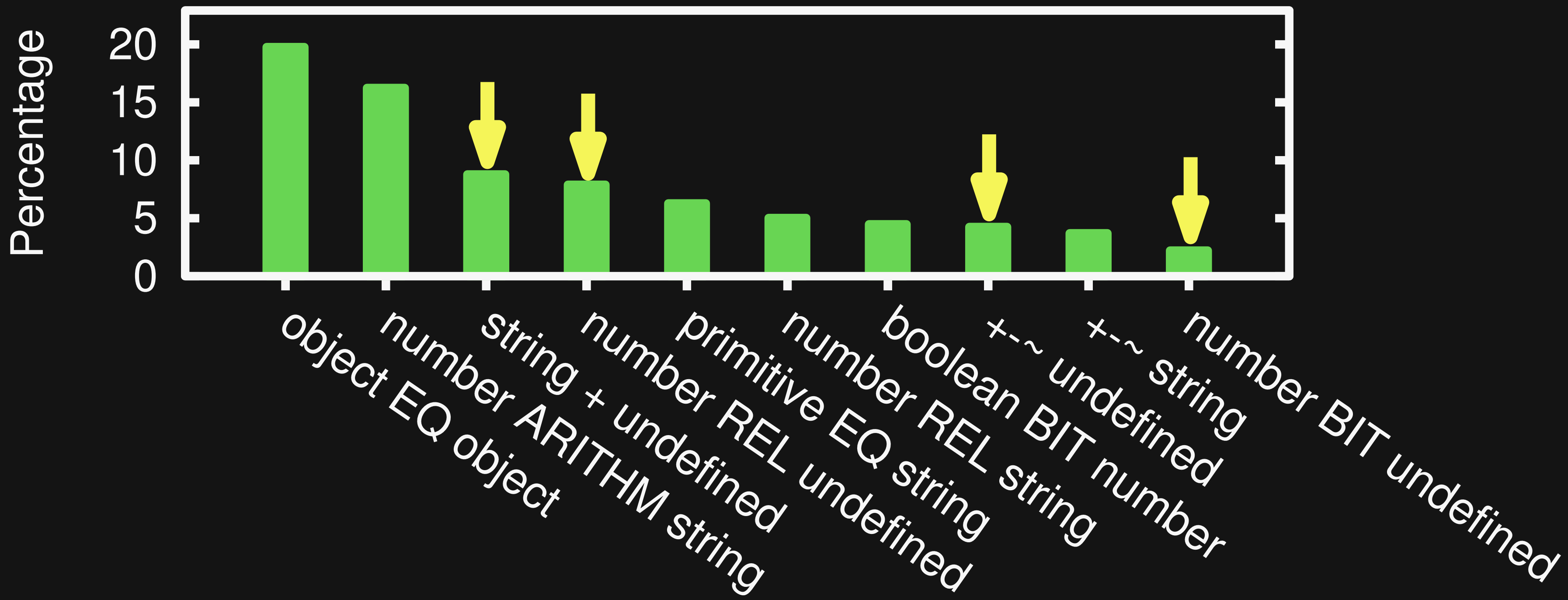


Confusing equality semantics

Potentially Harmful Coercions

Which harmful coercions are the most prevalent?



Propagated `undefined` values

Potentially Harmful Coercions (2)

Manual inspection of 30 potentially harmful coercions

- 22 probably correct
- 1 clear bug
- 3 maybe buggy
- 4 unclear

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- Represent number as string (10x)
- string + `undefined` (3x)
- typeA == typeB (2x)

Potentially Harmful Coercions (2)

Buggy coercion on *www.sina.com.cn*

```
flashVer: function() {
  if (m & 8192 != 8192) {
    return ""
  }
  ..
}
```

Potentially Harmful Coercions (2)

Buggy coercion on *www.sina.com.cn*

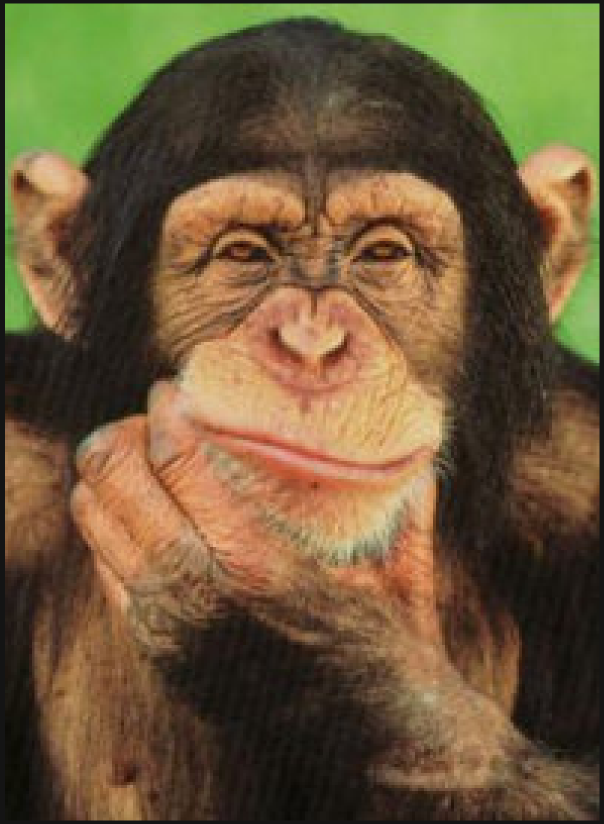
```
flashVer: function() {
  if (m & 8192 != 8192) {
    return ""
  }
  ..
}
```

$\leadsto$ `m & false`

$\leadsto$ `0`

$\leadsto$ `false`

Do coercions harm code understandability?



Coercions vs. Understandability

Polymorphic code locations

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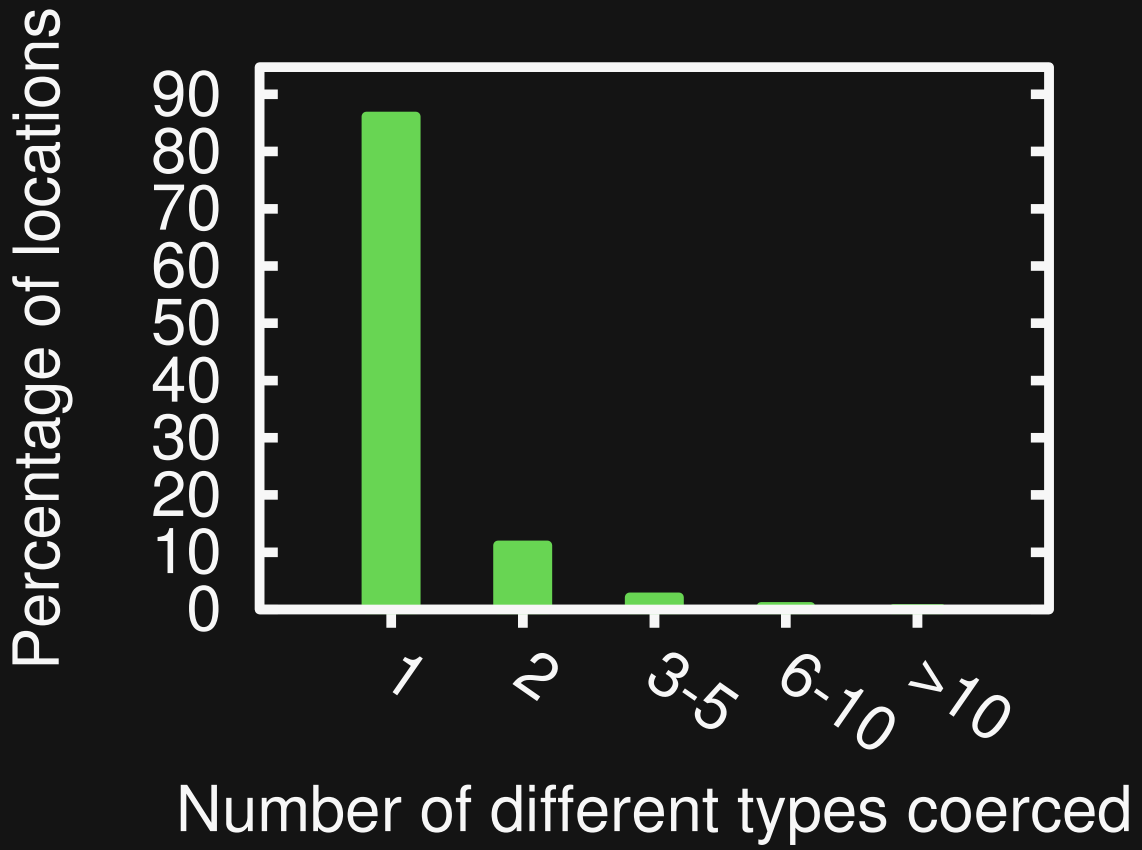
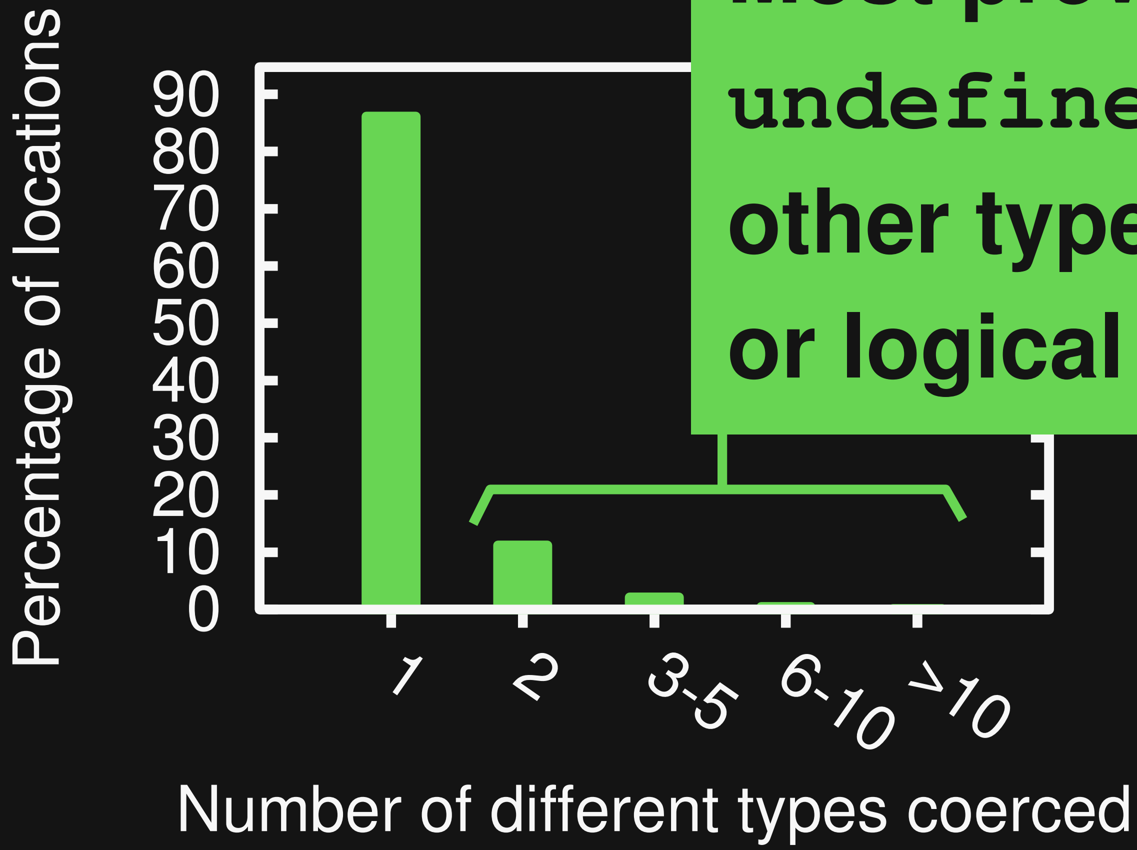


Coercions vs. Understandability

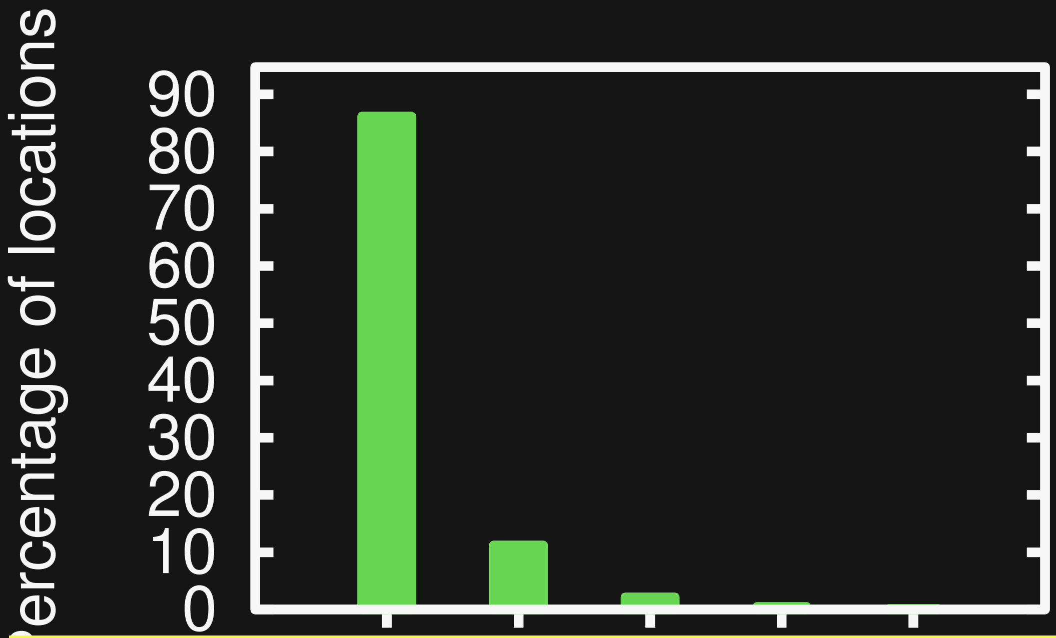
Polymorphic code locations



Most prevalent: `undefined` vs. some other type in conditional or logical negation

Coercions vs. Understandability

Polymorphic code locations



- Most locations are monomorphic
- Polymorphism: Mostly expected

Coercions vs. Understandability (2)

Strict vs. non-strict equality

- `===` and `!==`
- Equal only if same type

- `==` and `!=`
- Considers coercions

Common advice:
Avoid non-strict checks

Coercions vs. Understandability (2)

Strict vs. non-strict equality

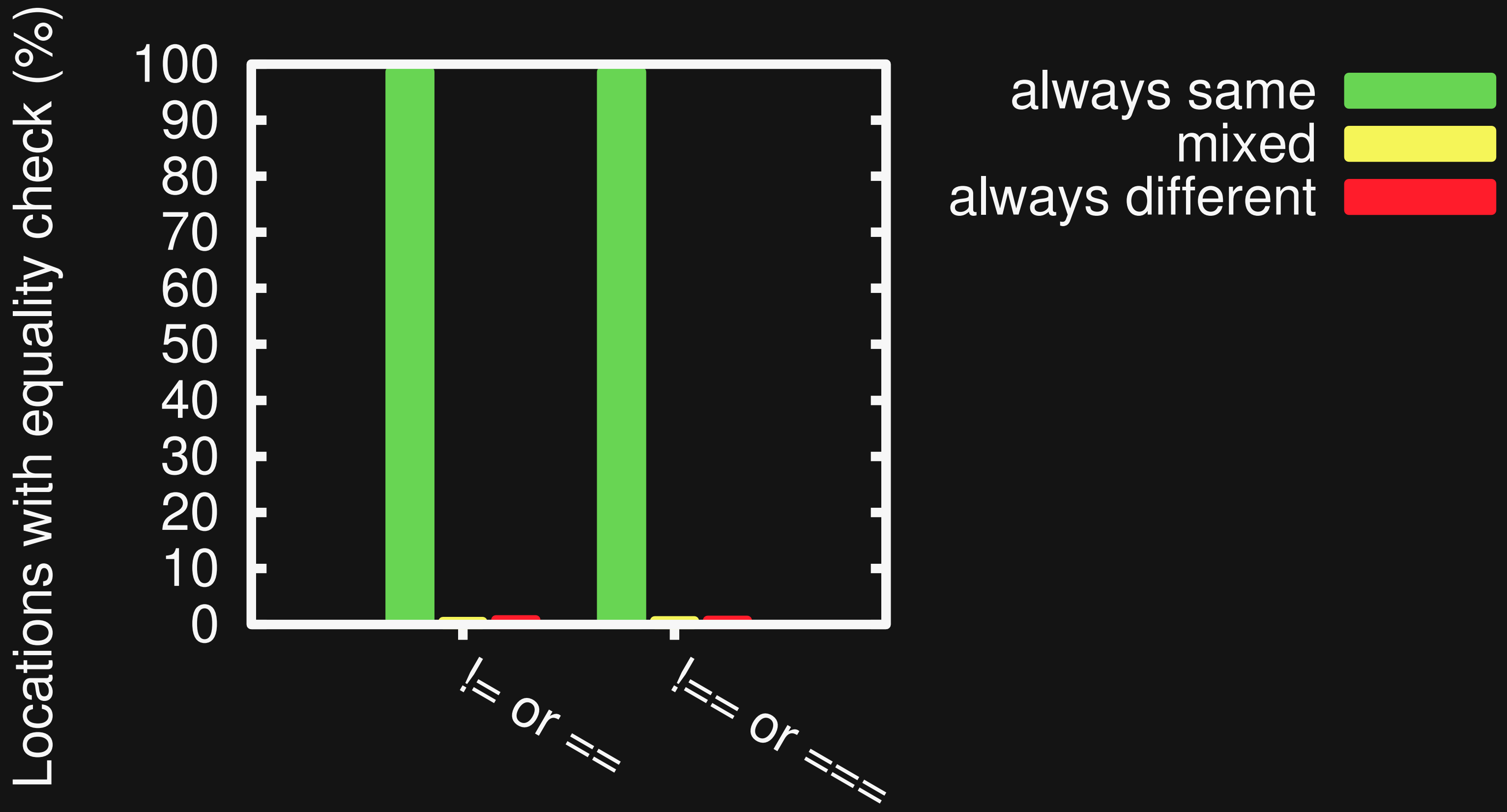
2,026,782 occurrences

3,143,592 occurrences

Coercions vs. Understandability (2)

Strict vs. non-strict equality

Do developers distinguish between them?



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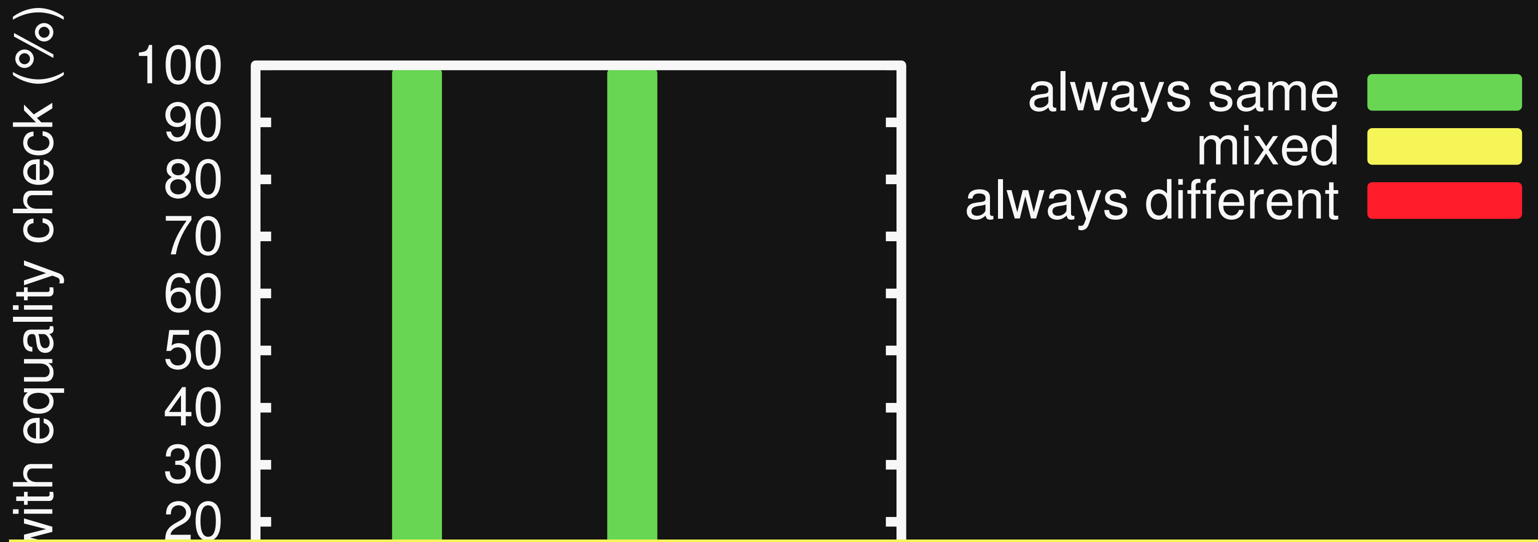

- **Confusing semantics**
- **May refactor into strict checks**

Threats to Validity

- Dynamic analysis: Underestimations
- Harmless vs. harmful: Subjective
- Representativeness of programs
- JavaScript only

Related Work

Studies on language usage

- Dynamic analysis
  Knuth1971, Richards2010/11
- Static analysis
  Tempero2008, Muschevici2008, Malayeri2009
- Humans
  Hanenberg2010

Analyze and restrict usage of types

- Type inference and checking
  Thiemann2005, Jensen2009, Chugh2012
- Language subsets
  strict mode, restrict mode

Conclusions

In-depth study of type coercions

- Coercions are widely used
- Most coercions are harmless
- Equality checks difficult to understand

Implications for future research

- Static analyses must consider coercions
- Languages: Disallow some coercions
- Refactoring of equality checks

http://mp.binaervarianz.de/ecoop2015

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Thanks!

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