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Console Clutter: A Cross-Browser Measurement of Console Messages

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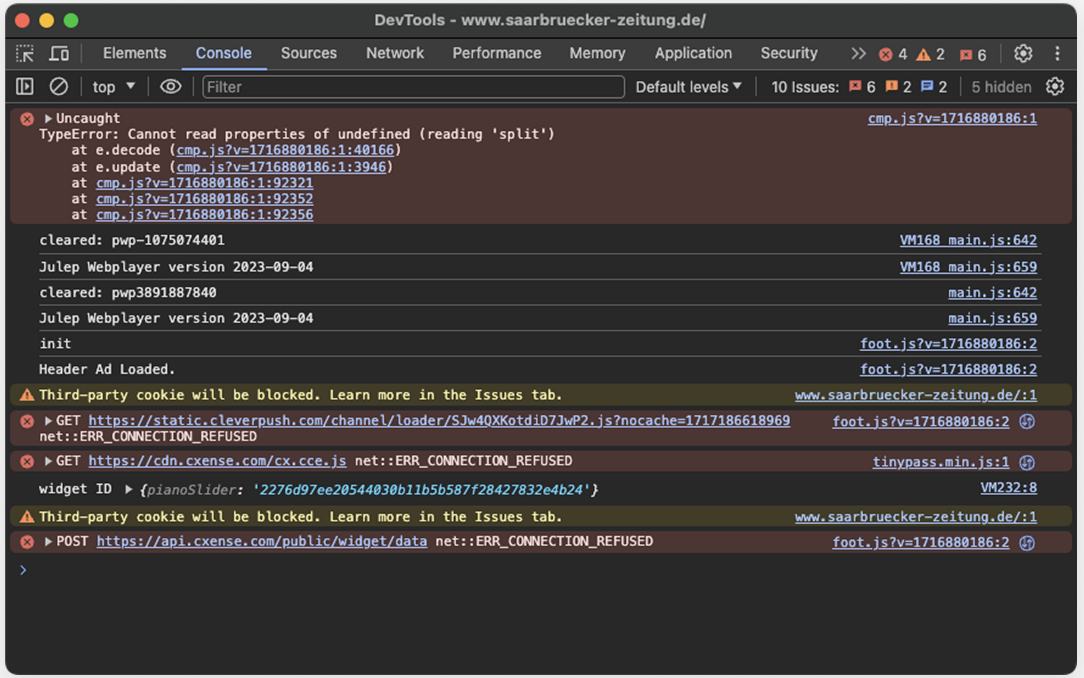
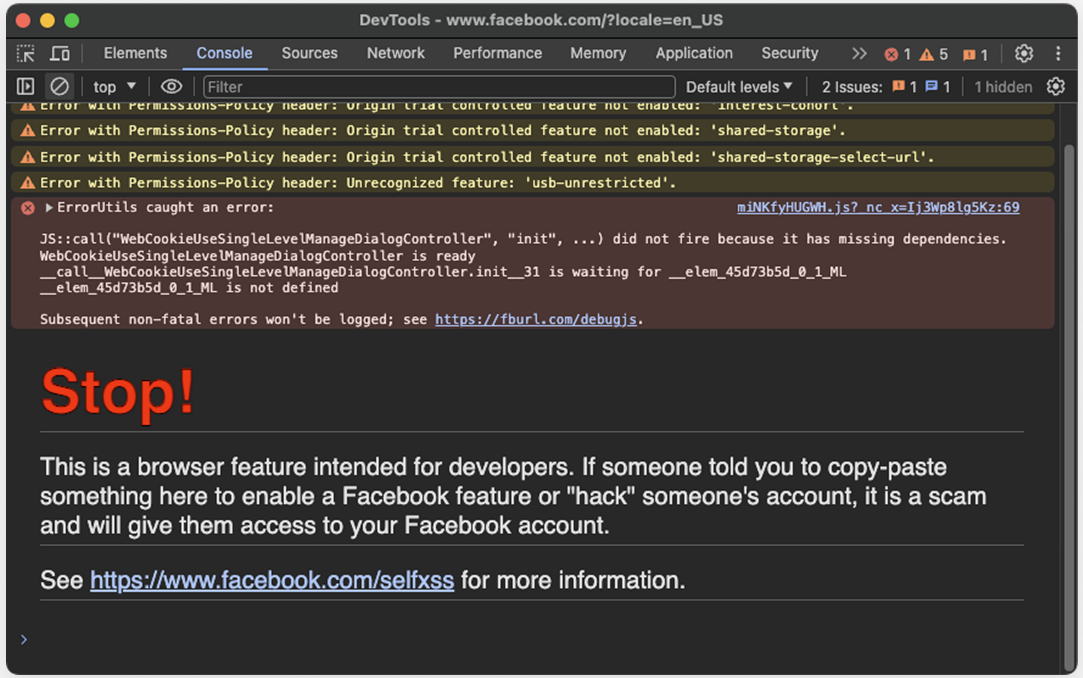
The Browser Console is Web Infrastructure

- Resides in modern web browsers' developer tools
- Developers can use it for monitoring application behavior on the client





Why should we care?

https://localhost:3001/test.html

```html
<!DOCTYPE html>
<html lang="en">

<head>
    <meta charset="UTF-8">
</head>

<body>
    <form action="http://localhost:3000/hello" method="post">
        <input type="text">
        <button type="submit">Submit form</button>
    </form>
</body>

</html>
```

v130.0.6723.31

```
<empty />
```

v131.0

```
<empty />
```

v18.0

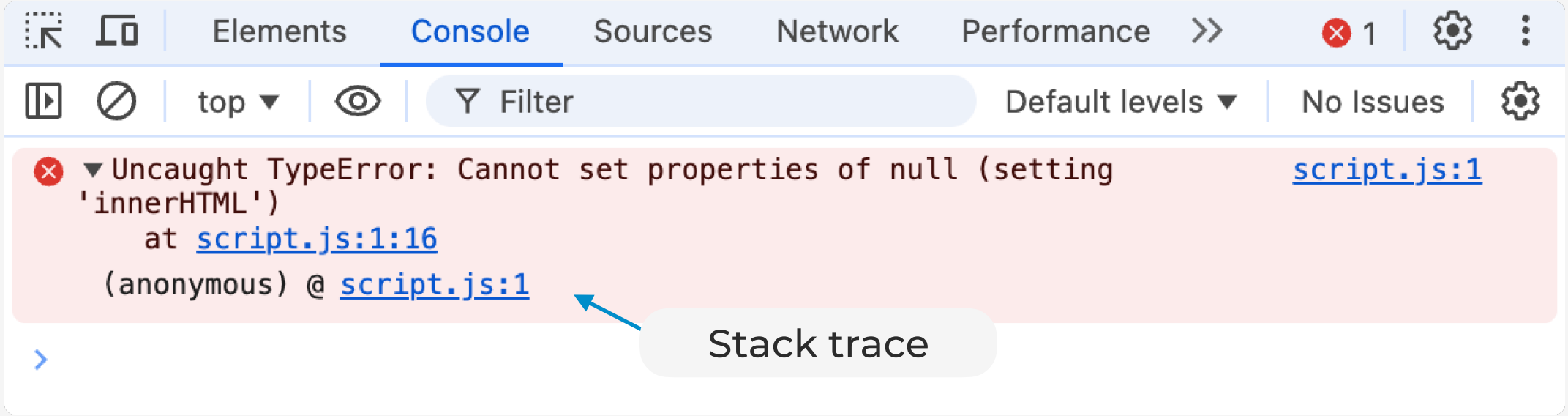
```
warning <URL> line_number: 9 column:number: 12
The page at https://localhost:3001/test.html contains a form which
targets an insecure URL http://localhost:3000/hello.
```

- Console might help developers write more secure code
- W3C Mixed Content Candidate Recommendation Draft states that user agents "**MAY** choose to warn users of [...] not potentially trustworthy URLs."

see https://www.w3.org/TR/mixed-content/#requirements-forms

Other Console Output: Page Errors

- Uncaught JavaScript exceptions during page visits
- Stack traces identify responsible code



Example: TypeError with stack trace

Console Message Origin

```
1  console.log("Hello World!")
2  // Output: Hello World!
3
4  console.warn("Hello World!")
5  // Output [severity=warn]: Hello World!
6
7  console.error("Hello World!")
8  // Output [severity=error]: Hello World!
9
10 console.table([1,2,3])
11 // Output [table representation]: (index) => value
12
13 console.count("Hello")
14 // Output: Hello: 1
```

example.js

```
1  // static
2  ...::CreateConsoleMessageAboutFetchAutoupgrade(
3      ... main_resource_url,
4      ... mixed_content_url) {
5    String message = String::Format(
6        "Mixed Content: The page at '%s' was loaded over HTTPS, but requested an "
7        "insecure element '%s'. This request was "
8        "automatically upgraded to HTTPS, For more information see "
9        "https://blog.chromium.org/2019/10/"
10       "no-more-mixed-messages-about-https.html", ...);
11   return MakeGarbageCollected<ConsoleMessage>(
12       mojom::ConsoleMessageSource::kSecurity,
13       mojom::ConsoleMessageLevel::kWarning, message);
14 }
15   return MakeGarbageCollected<ConsoleMessage>(
```

mixed-content-checker.cc

Developer-caused Console Messages

- Available through the Console API in JavaScript
- Controlled by web developers

Browser-caused Console Messages

- Signals issues detected during page visit
- Embedded in the browser code as templates

Research Gap

Message Volume

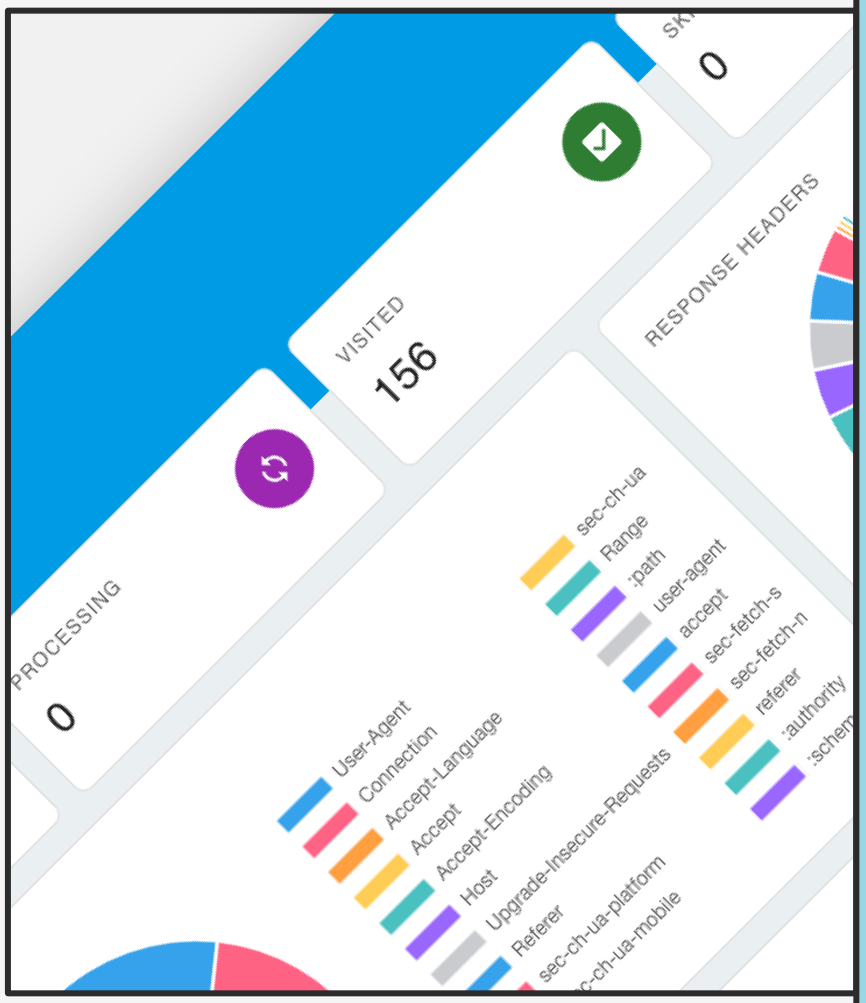
- Lack of insights about console output in the wild (at scale)

Origin Attribution

- Missing separation in existing tooling

Cross-Browser Consistency

- No data on consistency across browsers on public websites

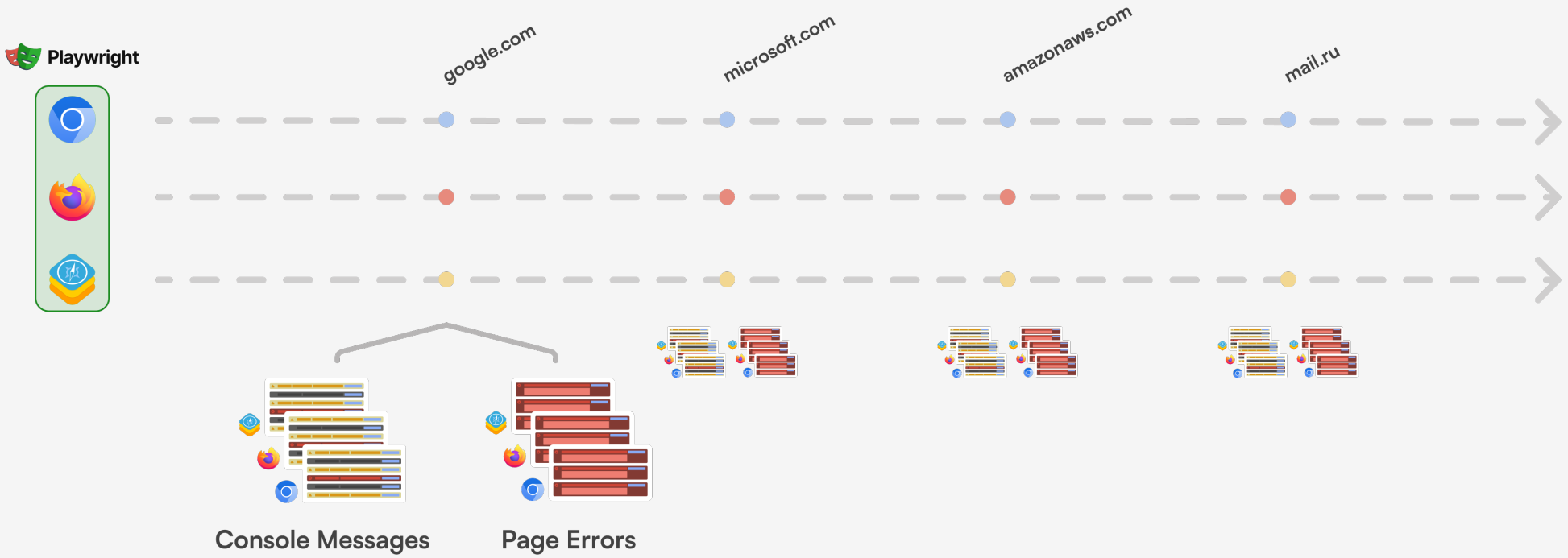


Our Measurement Approach for Collecting Console Output

Using Real Websites from Tranco

Data Collection

- Gather console output by visiting websites obtained from Tranco
- Same landing page for 30 seconds in Chromium, Firefox and WebKit



What about the Message Origin?

```
warning  <URL>  line_number: -  column:number: -

Mixed Content: The page at '<URL>' was loaded over HTTPS, but requested
an insecure element '<URL>'. This request was automatically upgraded to
HTTPS, For more information see https://blog.chromium.org/2019/10/no-
more-mixed-messages-about-https.html
```

```js
console.warn(`Mixed Content: The page at '<URL>' was loaded over HTTPS, but requested an
insecure element '<URL>'. This request was
automatically upgraded to HTTPS, For more information see
https://blog.chromium.org/2019/10/
no-more-mixed-messages-about-https.html`)
```

test.js

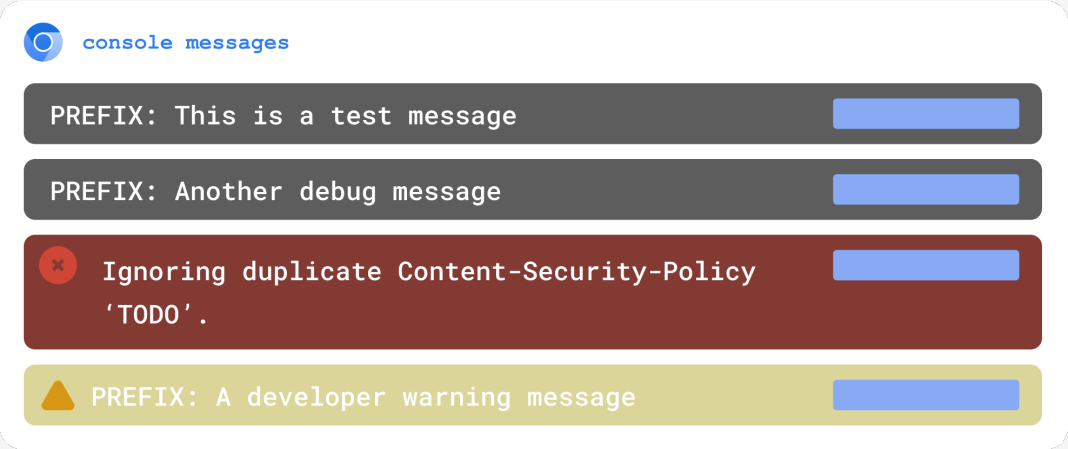
```cpp
// static
...::CreateConsoleMessageAboutFetchAutoupgrade(
    ... main_resource_url,
    ... mixed_content_url) {
  String message = String::Format(
      "Mixed Content: The page at '%s' was loaded over HTTPS, but requested an "
      "insecure element '%s'. This request was "
      "auto
      "http
      "no-more-mixed-messages-about-https.html".
```

third_party/blink/renderer/core/loader/mixed_content_checker.cc

- Lack of distinction of message origin in existing browser tooling
- Patched variants of Chromium, WebKit and regular expression for Firefox to prefix messages

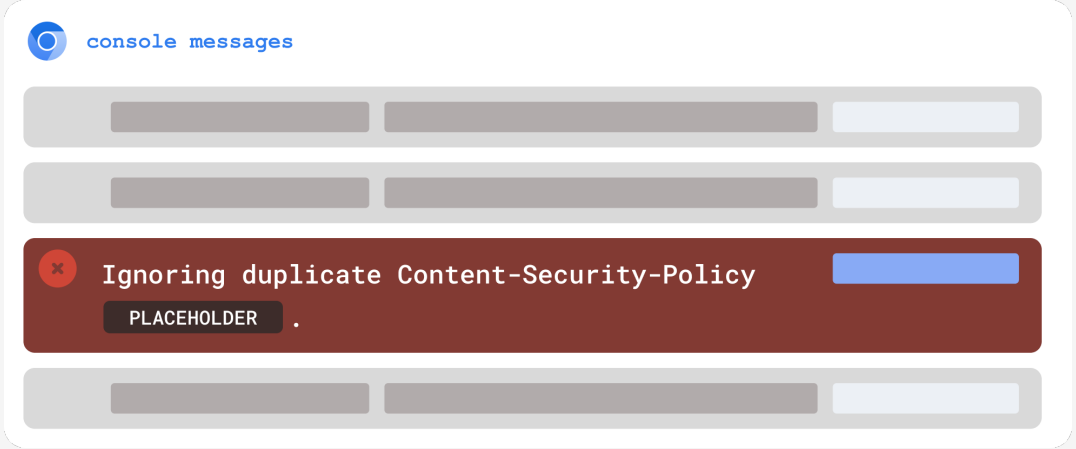
Obtaining Actual Templates

Filtering for browser-caused console messages through prefix/message structure



Capturing of prefixed and non-prefixed messages

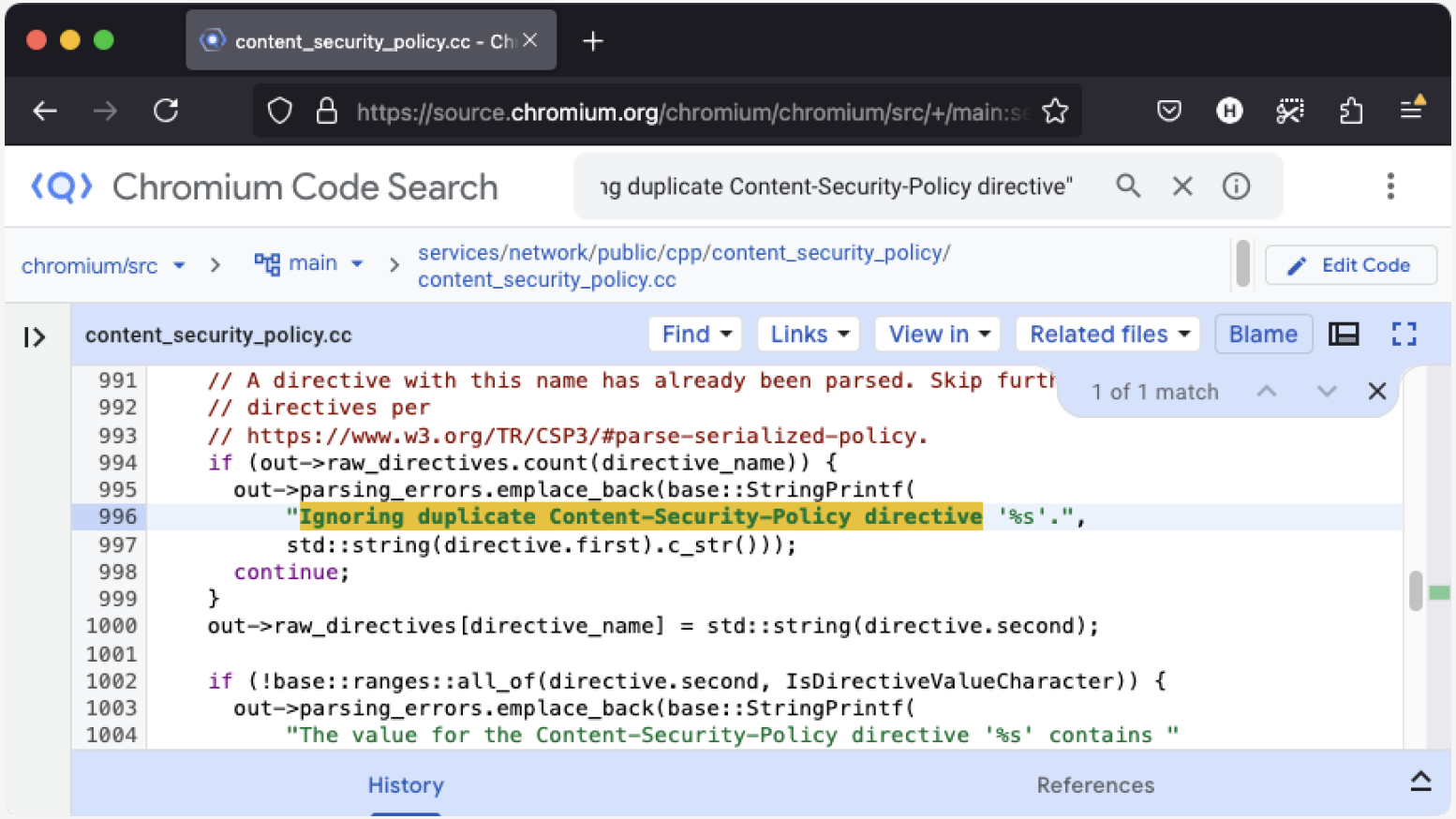
Replace dynamic data with placeholders to obtain template candidates



Replace dynamic data in browser-caused console output

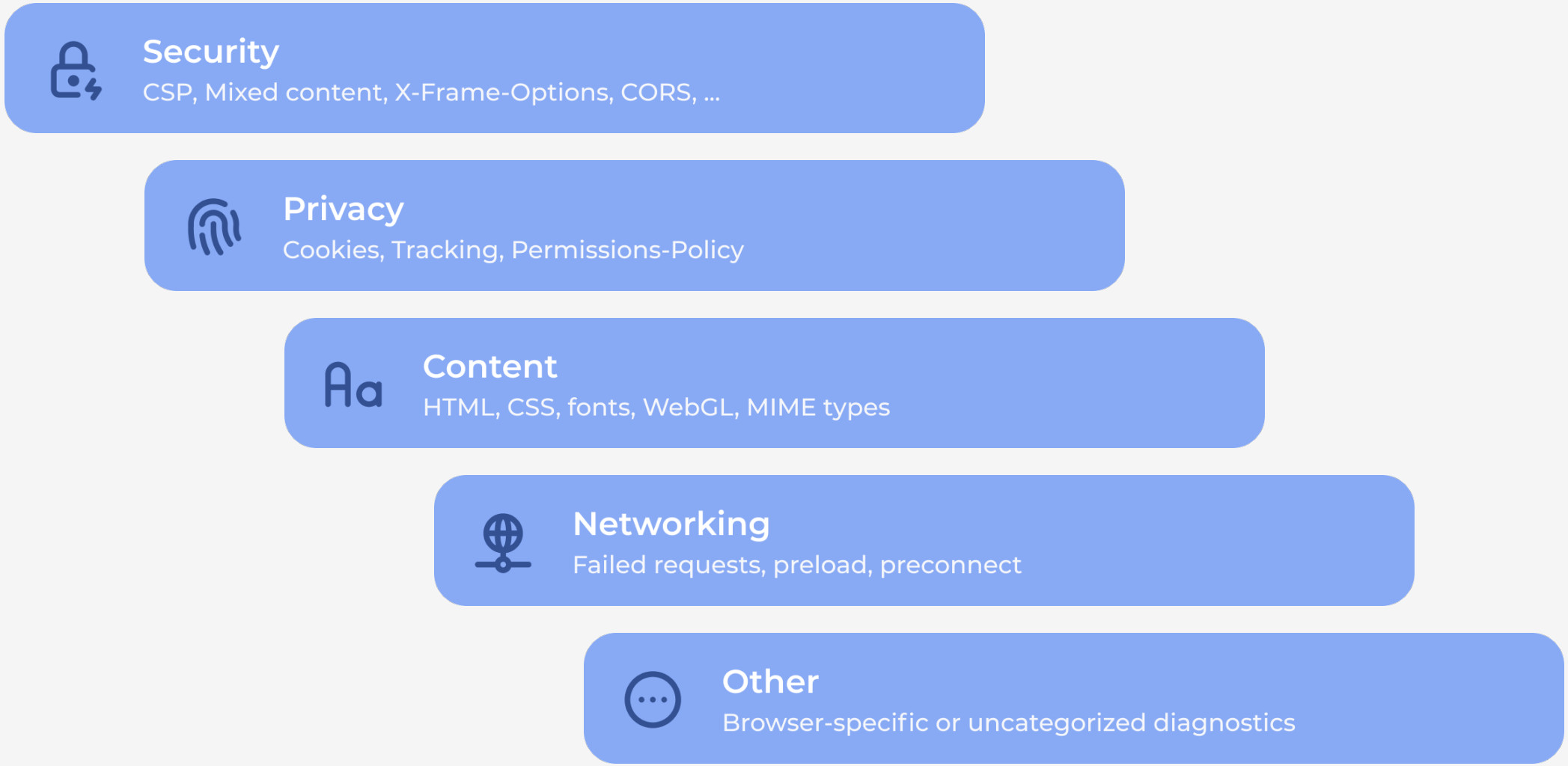
Obtaining Actual Templates

- Using template candidates, query browser source code repositories
- Label colocated templates with high-level concept



Chromium Code Search

High-level Concepts for Comparing Browser-caused Console Messages

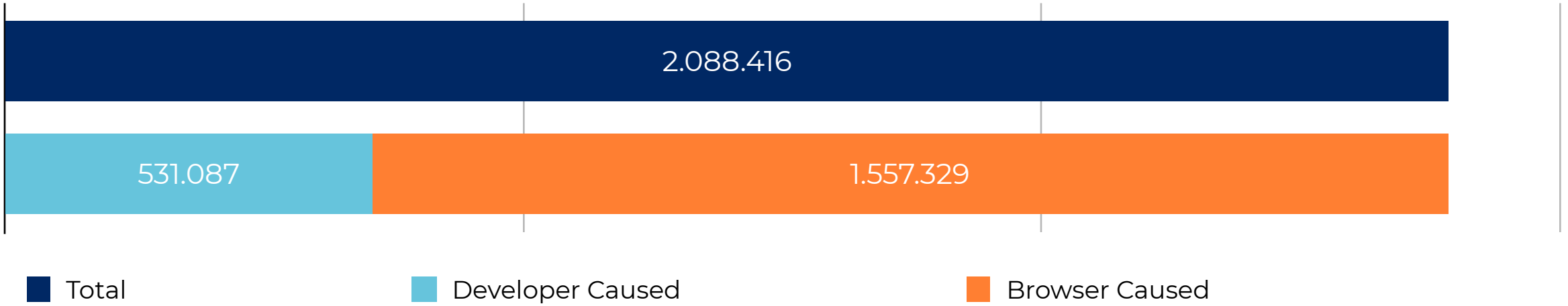


Insights from our Data Collection

Results and Discussion

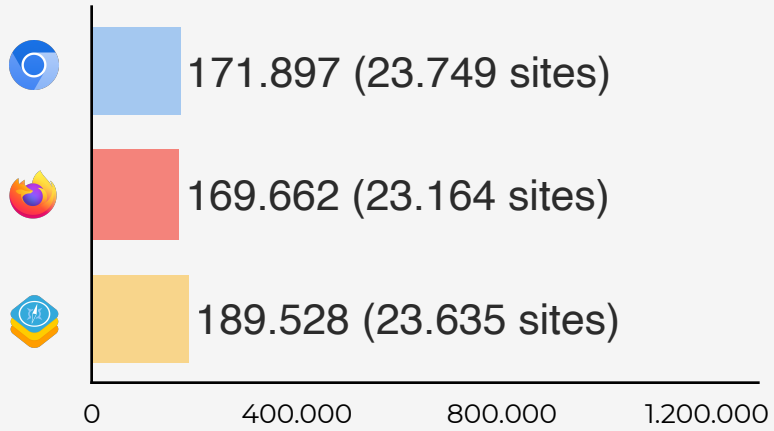
Overview

- Visited 51,984 websites in Chromium, Firefox and WebKit
- Practical relevance: More than 78% of visited websites had at least one message (13.39 on average)



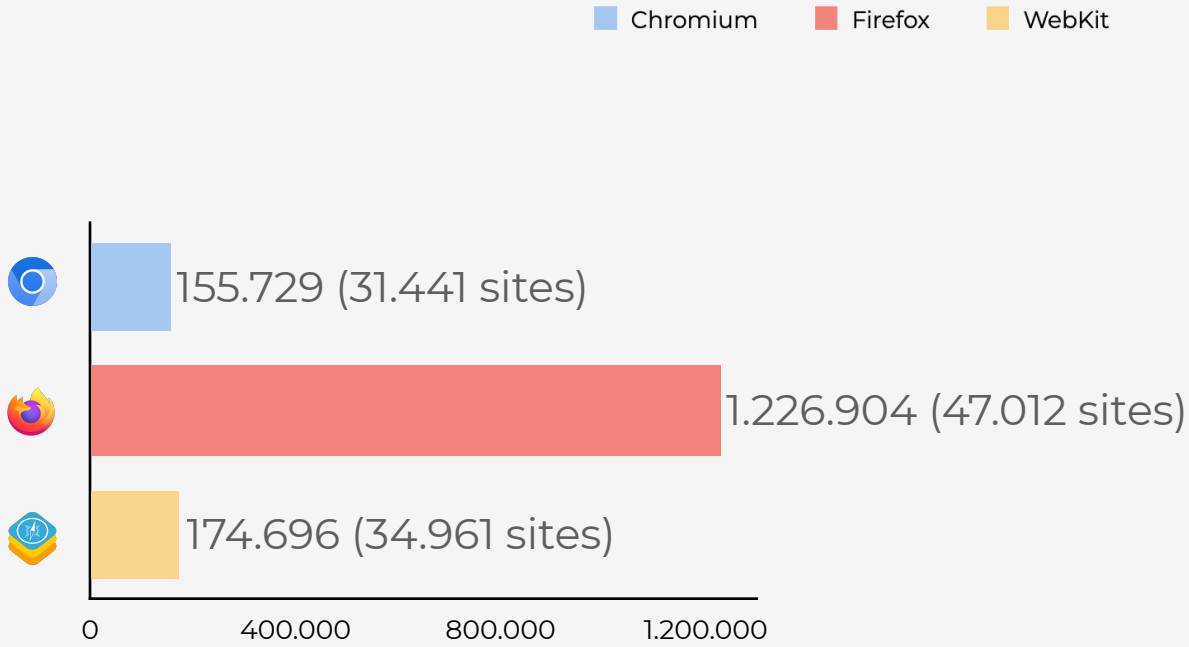
Total count of console messages

Origin Attribution



Distribution of developer-caused console messages (total and sites)

Similar quantities of developer-caused console output

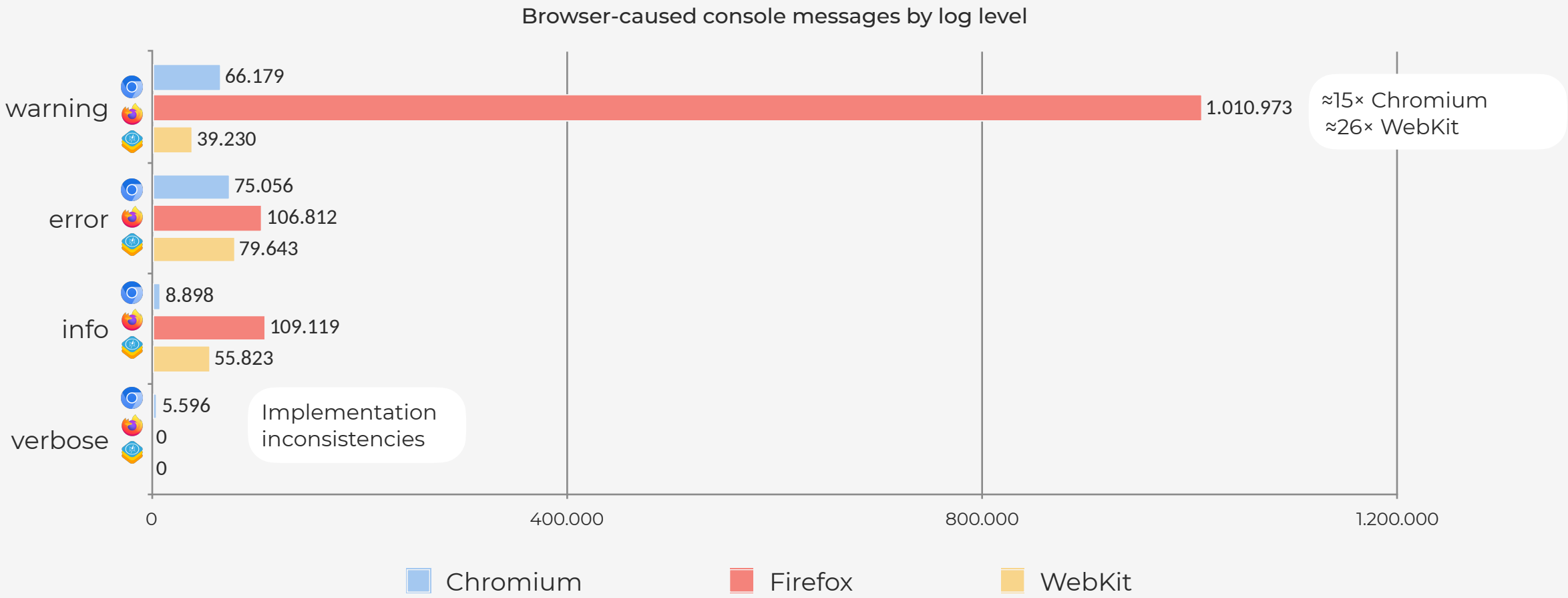


Distribution of browser-caused console messages (total and sites)

Firefox produces ~7× more than Chromium/WebKit

Browser-Caused Messages Drive Cross-Browser Differences

Log Levels Differ Strongly Across Browsers



The console is not only browser-specific in volume, but also in log level.

Different Console Worlds

Chromium		Firefox		WebKit	
Failed resource load		SameSite cookie warning		Failed resource load	
request-failures (N)	18,664	cookies (P)	35,147	request-failures (N)	19,168
WebGL software fallback		Cookie attribute overwritten		Preconnect success	
webgl (C)	5,995	cookies (P)	19,251	preconnect (N)	18,266
Unused preload		Non-standard CSS zoom		Unused preload	
preload (N)	4,493	styles (C)	17,717	preload (N)	5,497

Top 3 browser-caused templates by number of affected sites

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- The most visible console warnings differ ***across browser engines***

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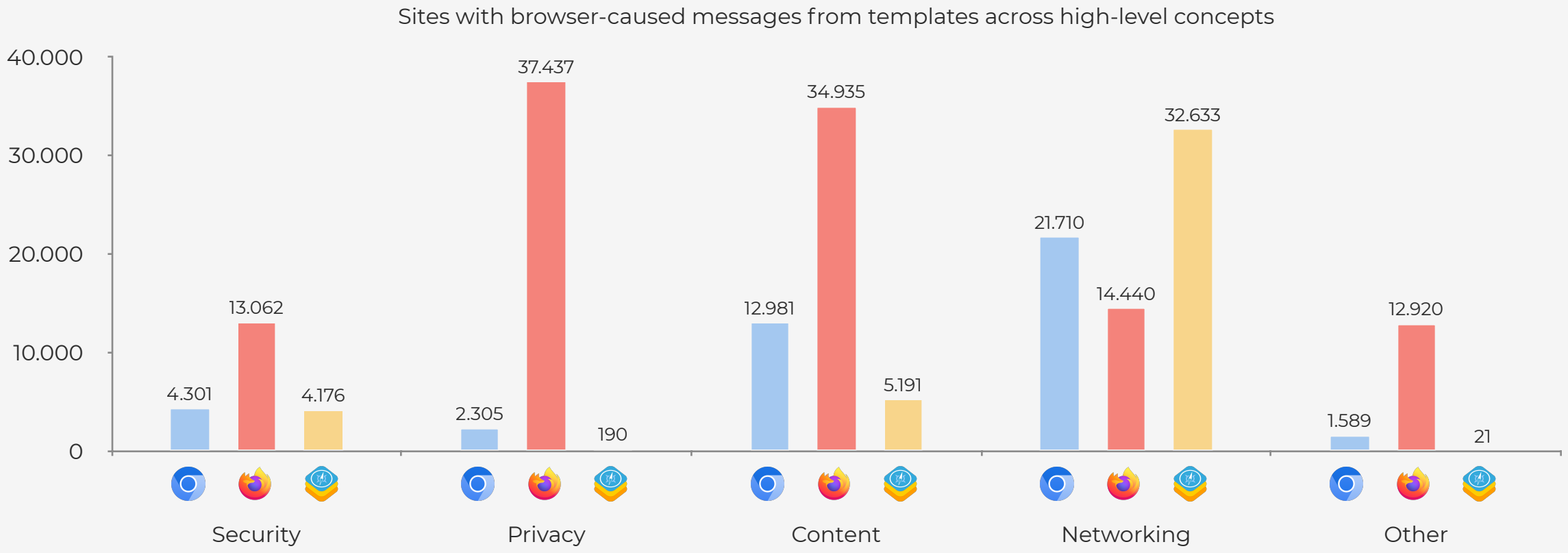
Top 3 browser-caused templates by number of affected sites

- The most visible console warnings differ ***across browser engines***
- Reappearing categories may surface shared web engineering issues

Templates Across High-Level Concepts



Significant differences in issue categories between browsers

Page Errors

- 92,518 page errors across 12,241 sites
- WebKit exposes 13k “ConsoleMessageLike” entries as page errors, revealing a browser/tooling classification artifact

Error Name	Chromium		Firefox		WebKit	
	Total	Sites	Total	Sites	Total	Sites
TypeError	17.726	3.514	11.006	3.565	5.614	3.918
ReferenceErrror	8.760	1.818	9,640	2.071	3.700	2.078
ConsoleMessageLike	0	0	0	0	13.288	4.884
Error (Generic)	4.545	889	6.270	832	1.532	1.082
Error (Custom Name)	1.822	924	1.466	740	1.934	1.142
SyntaxError	1.538	1.062	578	272	1.502	1.198
DOMException	591	351	748	120	147	133
RangeError	37	5	30	1	34	5
EvalError	3	3	2	2	2	2
URIError	1	1	1	1	1	1
Total	35.023	7.190	29.741	6.559	27.754	11.429

Count and unique sites per JavaScript error

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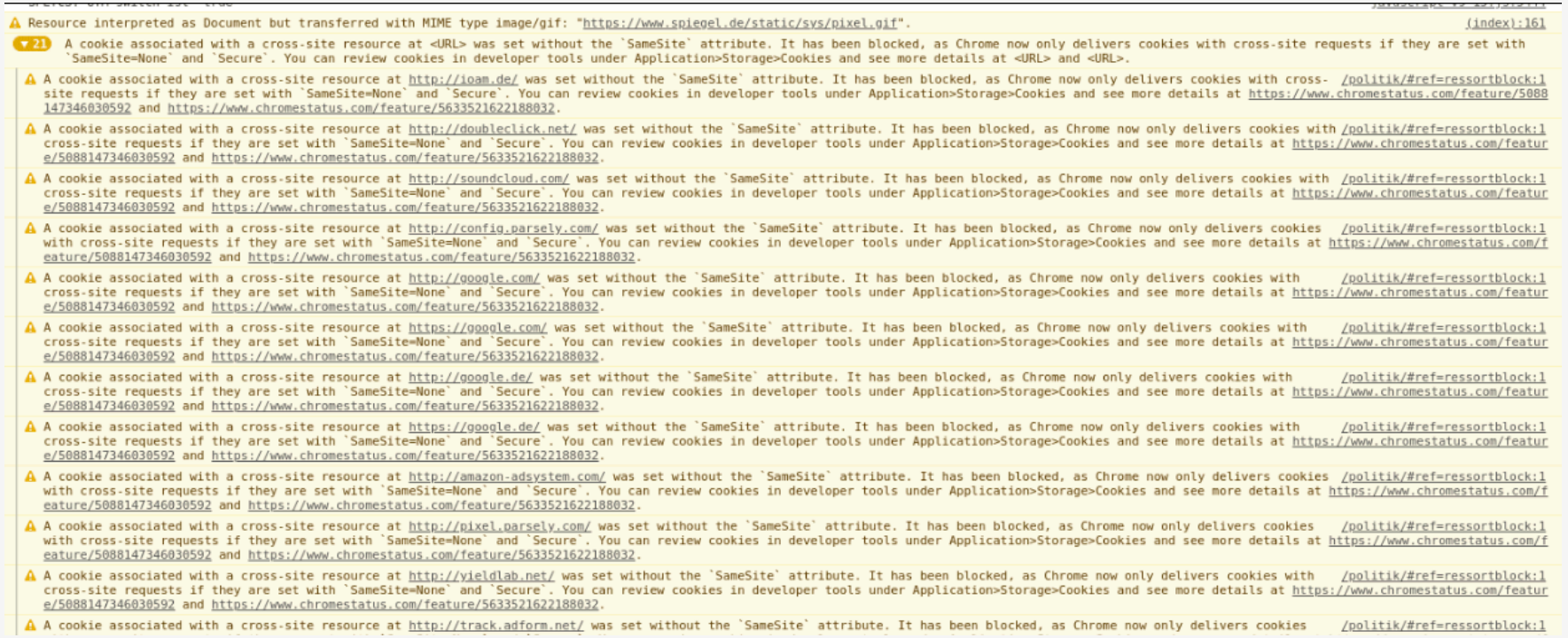
Case Study: Overwhelming Console Output

- 2,605 sites produced more than 100 messages in at least one browser
- Relevant warnings can become indistinguishable from background noise



How we built the Chrome DevTools Issues tab. https://developer.chrome.com/blog/issues-tab

Case Study: Local File Inclusion On The Client

- Console may reveal deployment mistakes (e.g. unintended information leakage)

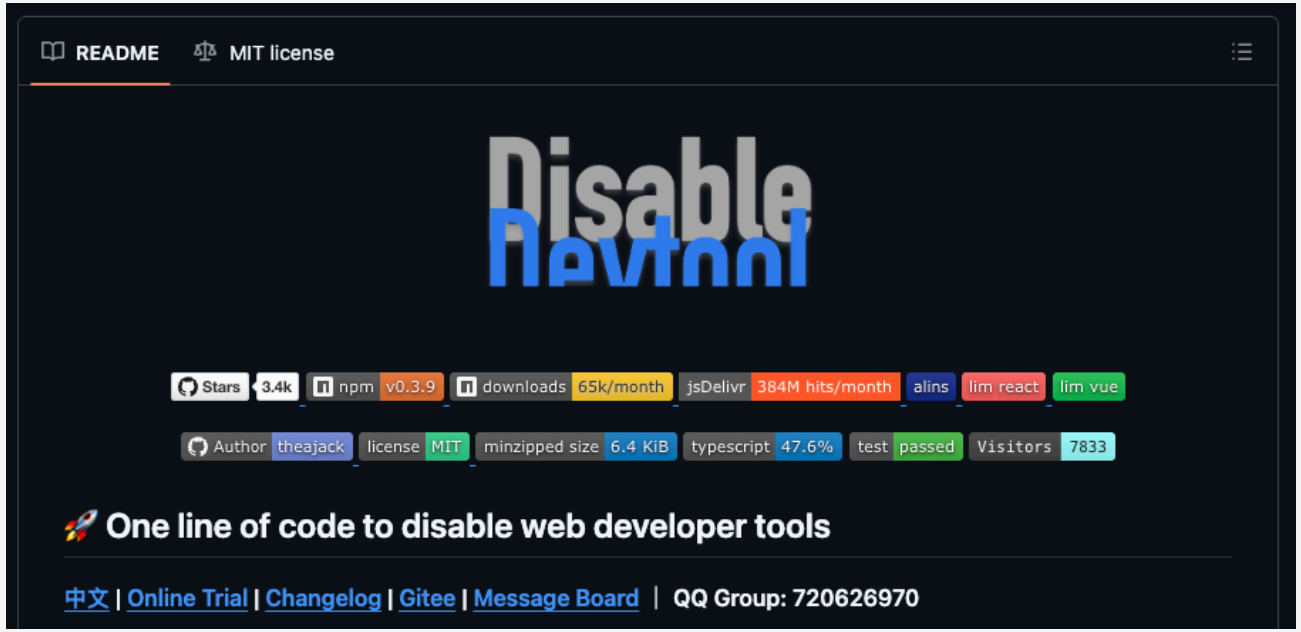
```
error    <URL>  line_number: 9  column_number: 12
Not allowed to load local resource: file:///C%7C/Users/sysw7/
AppData/.../favicon.ico
```

- Similar messages revealed probes for browser-extension resources

```
error    <URL>  line_number: 9  column_number: 12
Not allowed to load local resource:
chrome://rumola/content/rumola48.png
```

Case Study: Anti-Debugging Techniques

- High numbers of console.clear calls indicate anti-debugging behavior
- Use of libraries such as disable-devtool to inhibit usability of the console



disable-devtool. https://github.com/theajack/disable-devtool

Console can reveal attempts to interfere with inspection and debugging

Insights and Future Research Opportunities

Thank you. Questions?

Flood of Messages

- High volume risks notification fatigue

Browser Differences

- Browser-specific observability layer

web

Usage in Measurements

- Leverage browser tooling for research

Plethora of research opportunities with all involved stakeholders