

A Large-Scale, Multi-Factor Approach to Understanding and Improving Mobile Application Accessibility

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PhD Defense, University of Washington, Spring 2021

Co-Chairs



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GSR



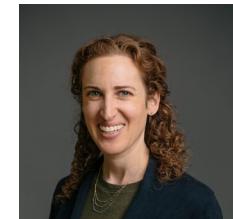
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A Large-Scale, Multi-Factor Approach to Understanding and Improving Mobile Application Accessibility

Anne Spencer Ross (she/her)

PhD Defense, University of Washington, Spring 2021



Outline

App Accessibility

Thesis

Epidemiology-Inspired Framework

Understanding App Accessibility at Scale

Tools to Improve App accessibility

Discussion & Reflection

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Discussion & Reflection

Mobile Applications (apps)



Apps are everywhere
Provide essential functionality

Not accessible to everyone

Accessibility

Disability

- interaction between features of a person's body and features of society



Assistive Technology

- Voice
- Audio
- Eye gaze
- External keyboard

Screen Reader

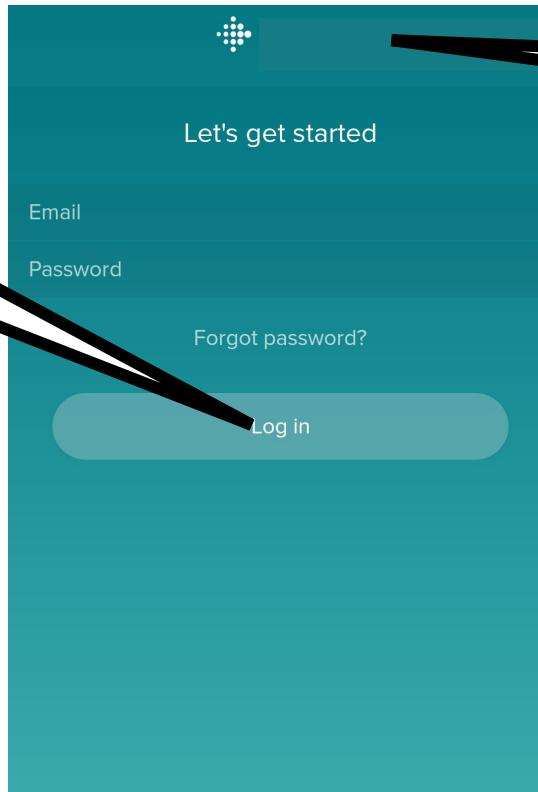
- Visual -> Audio

Fitbit

“Log in”

Labeled
text-based element

```
<Button  
    ...  
    text="Log in"/>
```



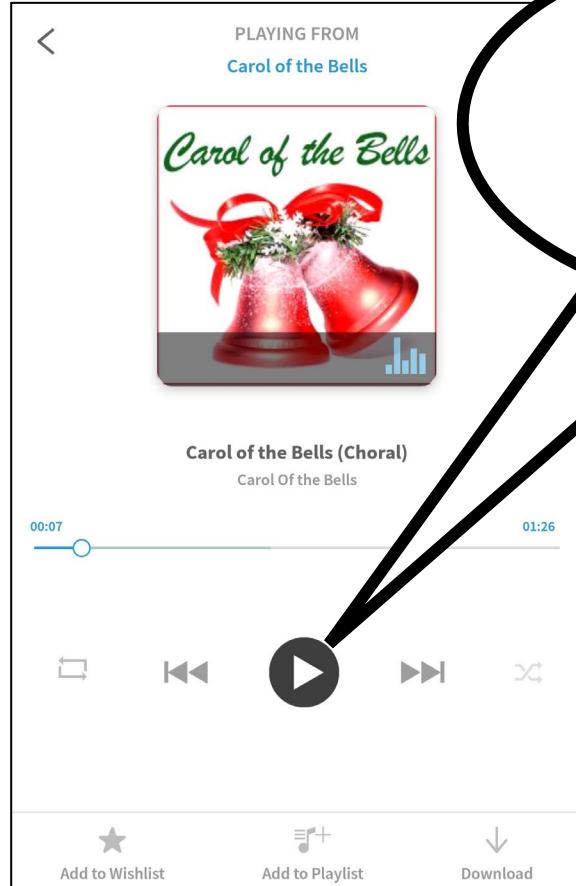
“Fitbit”

Labeled
image-based element

```
<ImageView  
    ...  
    contentDescription="Fitbit"/>
```



Freegal Music



“Unlabeled
Button”

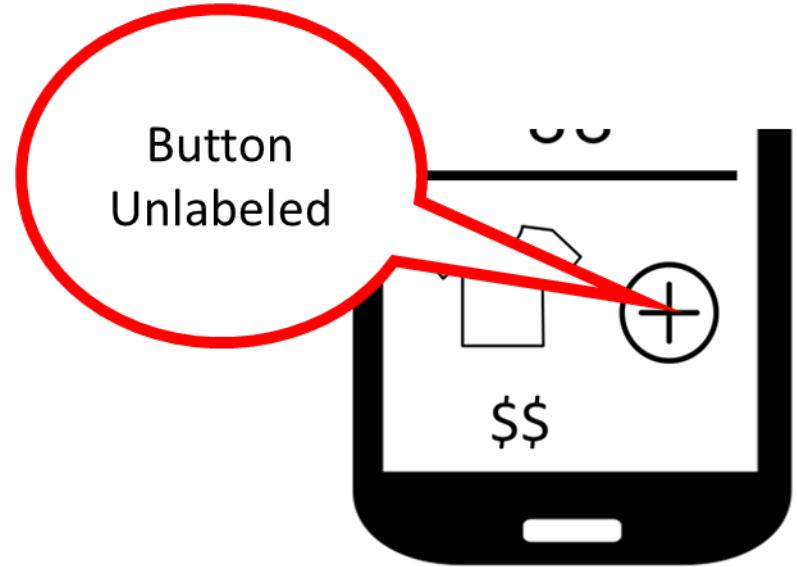
Unlabeled image-based element

<ImageButton

...

contentDescription="Play"/>

Accessibility Failures in Apps



Missing Labels



Buttons Too Small



Screen Completely Inaccessible

We Know Inaccessibility Happens

The Accessibility of Mobile Health Sensors for Blind Users

Accessibility Evaluation of E-Government Mobile Applications in Brazil

Accessibility of mHealth Self-Care Apps for Individuals with Spina Bifida

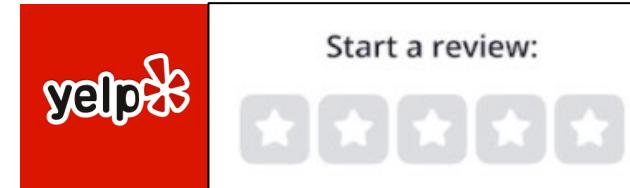
Accessible smart cities?
Inspecting the accessibility of Brazilian municipalities' mobile applications

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Blind Californians and Advocates Sue Greyhound to Make Website and Mobile App Accessible

Posted on June 19, 2017 (September 18, 2018) by Kristopher Nelson

In 2015, Tina Thomas, who is blind, tried to book a train with Greyhound's website. She was unable to do so because the site wasn't accessible.

THE INDUSTRY

When Things Go Wrong for Blind Users on Facebook, They Go Really Wrong

The social network wants to be accessible. Blind users and former Facebook workers say it isn't doing enough.

By APRIL GLASER

NOV 20, 2019 • 2:46 PM



We're sorry about testing voice Tweets without support for people who are visually impaired, deaf, or hard of hearing. It was a miss to introduce this experiment without this support.

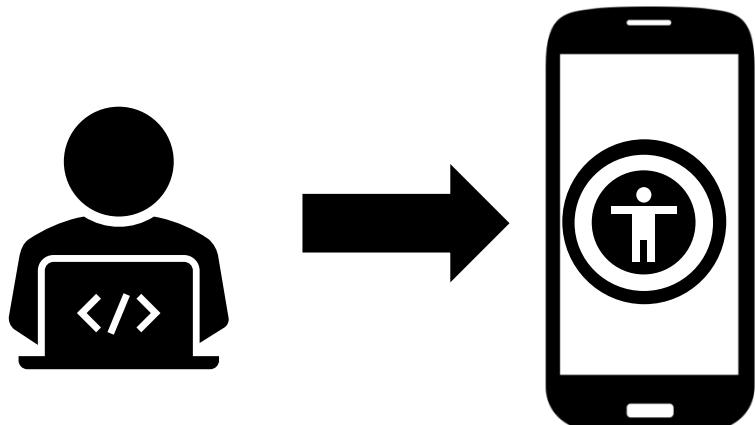
Accessibility should not be an afterthought. (1/3)

Improving App Accessibility

Current Tools

- Designer and developer guides
- Testing tools

Focus on role of individual app developer



Label UI elements

It's important to provide useful and descriptive labels that explain the meaning of an interactive element to users. These labels allow screen readers, such as TalkBack, to read the function of a particular control to users who rely on these services.

You can provide labels for elements in the following two ways:

Study of Accessibility Guidelines of Mobile Applications

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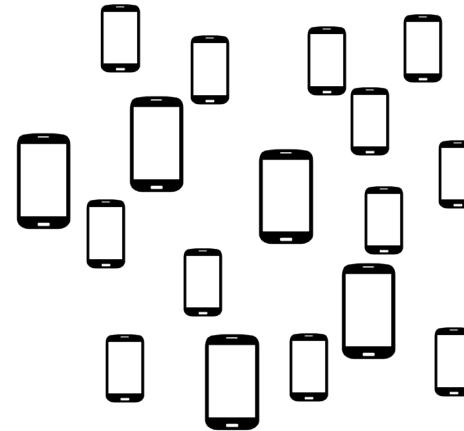
axe™ - The Standard in
Accessibility Testing

Understand and Improve App Accessibility

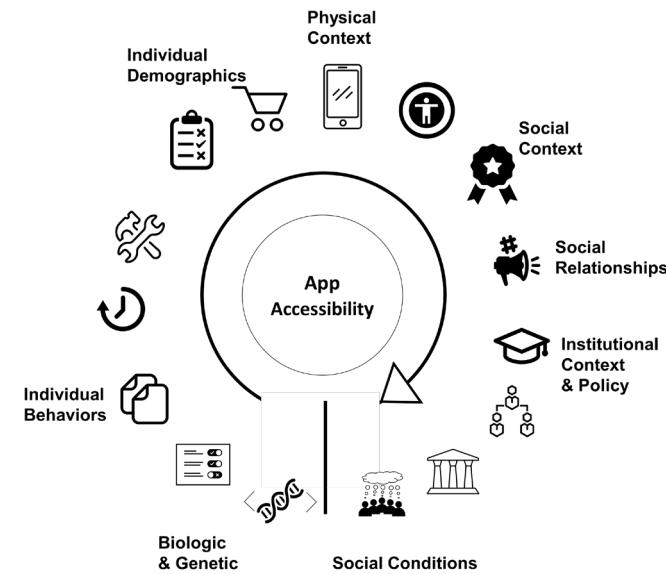
How often and in what contexts do accessibility failures happen?

What impacts app accessibility at scale?

How can tools better support accessibility practices?



Large-Scale



Multi-Factor

Overview

Framework

Understand

Improve

Discuss

Thesis Statement

In mobile app accessibility, applying an **epidemiology-inspired framework** that emphasizes multi-factor and large-scale analyses can:

- (T1) reveal **population-level trends** of accessibility failures;
- (T2) aid in identifying a **range of intrinsic to extrinsic factors** that can impact app accessibility; and
- (T3) inform the **design of tools** for identifying and repairing accessibility failures.

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Epidemiology



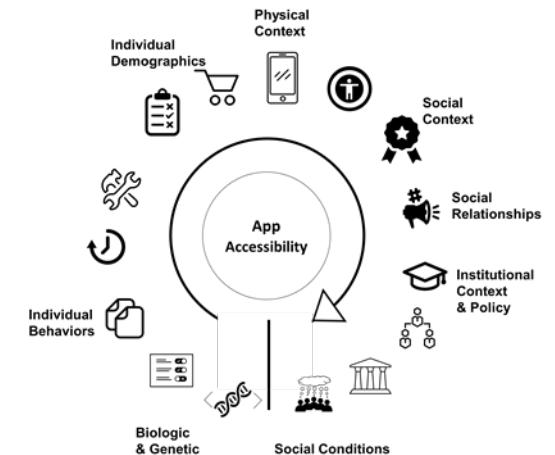
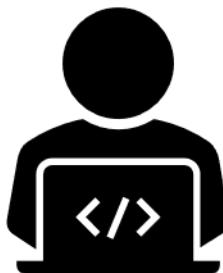
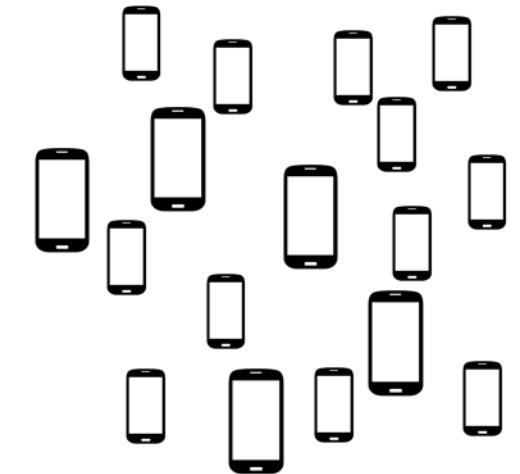
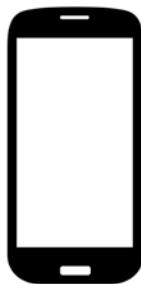
Anne Spencer Ross, Xiaoyi Zhang, James Fogarty, Jacob O. Wobbrock. [Epidemiology as a Framework for Large-Scale Mobile Application Accessibility Assessment.](#) ASSETS 2017.
Best Paper Nominee.

Epidemiology-Inspired Framing

Population-Based

Longitudinal

Multi-Factor



Overview

Framework

Understand

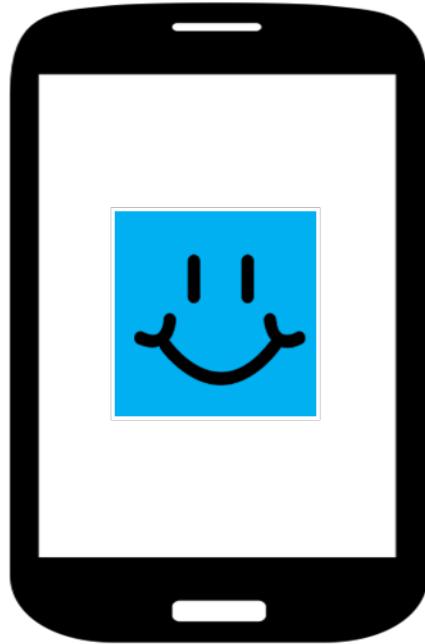
Improve

Discuss

Framework Terminology

Note About Framework

All About the Apps



Framework Terminology

Population:

a group of apps

Disease:

a specific accessibility failure

Health:

a complete state of accessibility



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Tools to Improve App accessibility

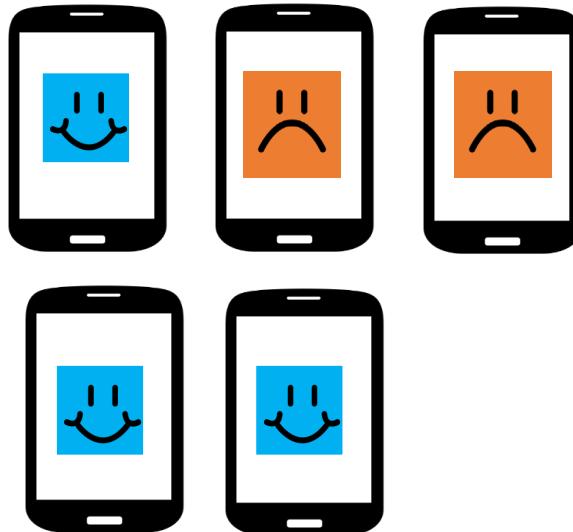
Discussion & Reflection

Determine the Extent of Disease in a Population

How often and in what contexts do accessibility failures occur?

Prevalence

proportion of apps or elements with a specific accessibility failure



100 App Assessment

100 “top downloaded, free” apps from 10 categories in Google Play Store

Accessibility Scanner

9 accessibility failures

4 label-based

1 size-based

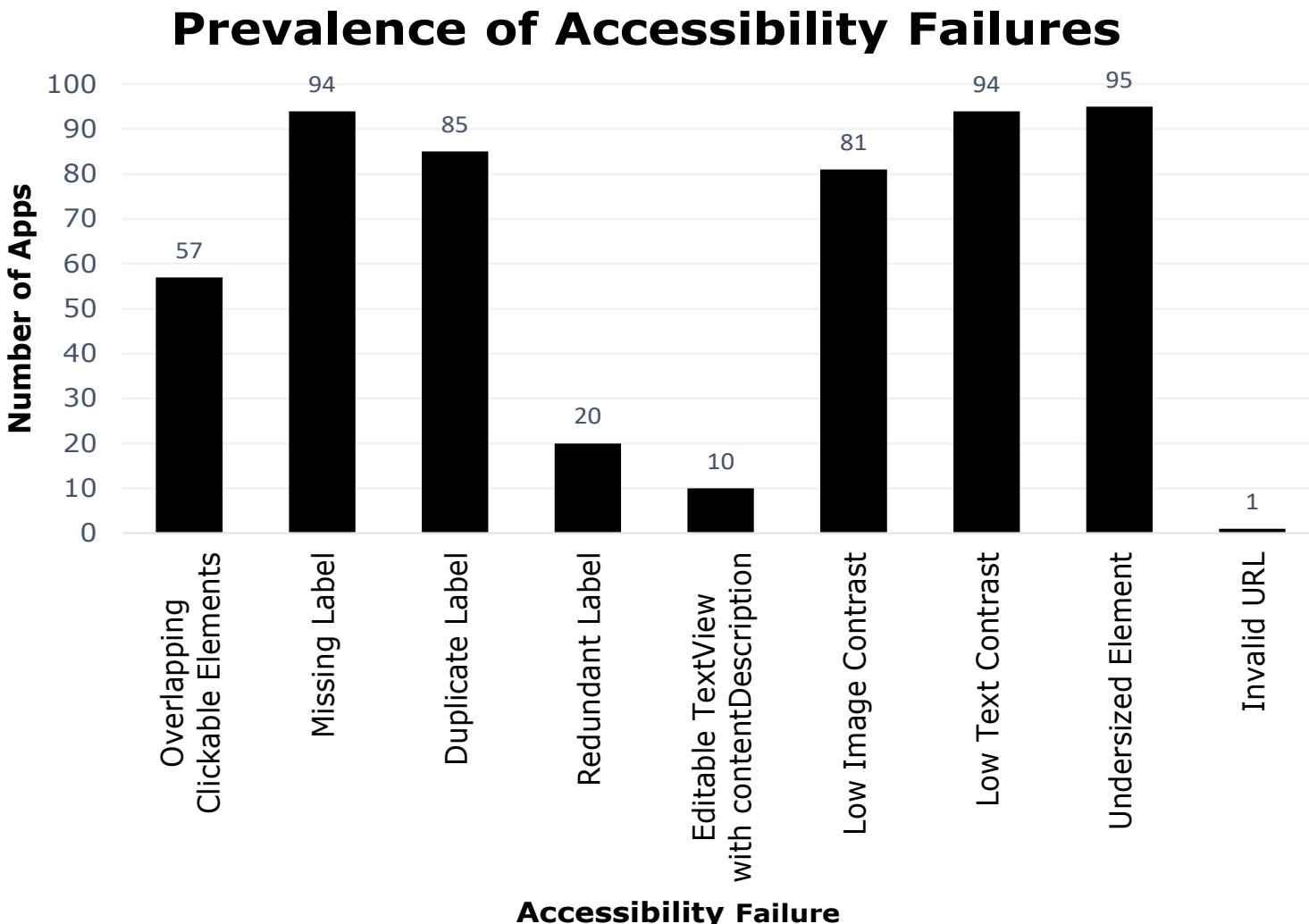
2 contrast-based

Overlapping elements

Invalid link

A. S. Ross, X. Zhang, J. Fogarty, J. O. Wobbrock. Epidemiology as a Framework for Large-Scale Mobile Application Accessibility Assessment. ASSETS 2017.

Failures in Top 100 Apps



10,000 App Assessment

~10,000 free Android apps

Accessibility Test Framework for Android

7 accessibility failures

4 label-based

1 size-based

Overlapping elements

Completely inaccessible screens

10,000 App Assessment

~10,000 free Android apps

Accessibility Test Framework for Android

7 accessibility failures

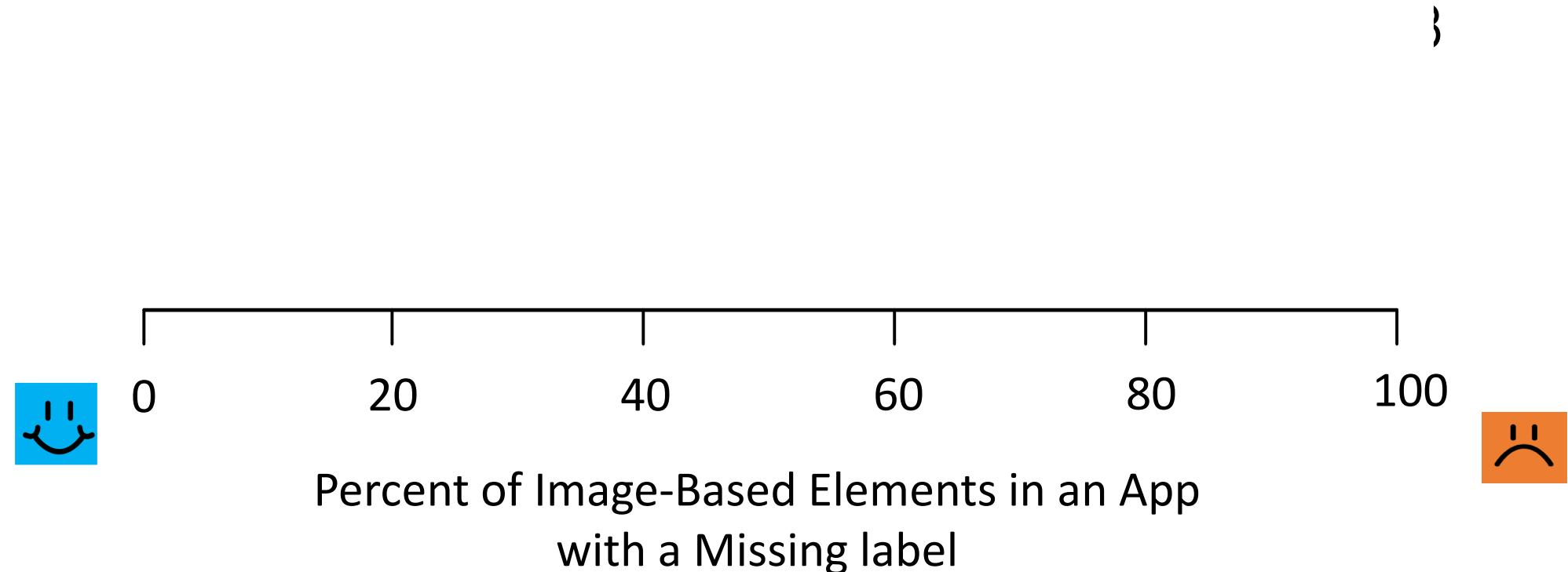
Anne Spencer Ross, Xiaoyi Zhang, James Fogarty, Jacob O. Wobbrock. TACCESS 2020.
[An Epidemiology-inspired Large-scale Analysis of Android App Accessibility.](#)

Anne Spencer Ross, Xiaoyi Zhang, James Fogarty, Jacob O. Wobbrock. ASSETS 2018.
[Examining Image-Based Button Labeling for Accessibility in Android Apps through Large-Scale Analysis.](#) Best Paper Nominee.

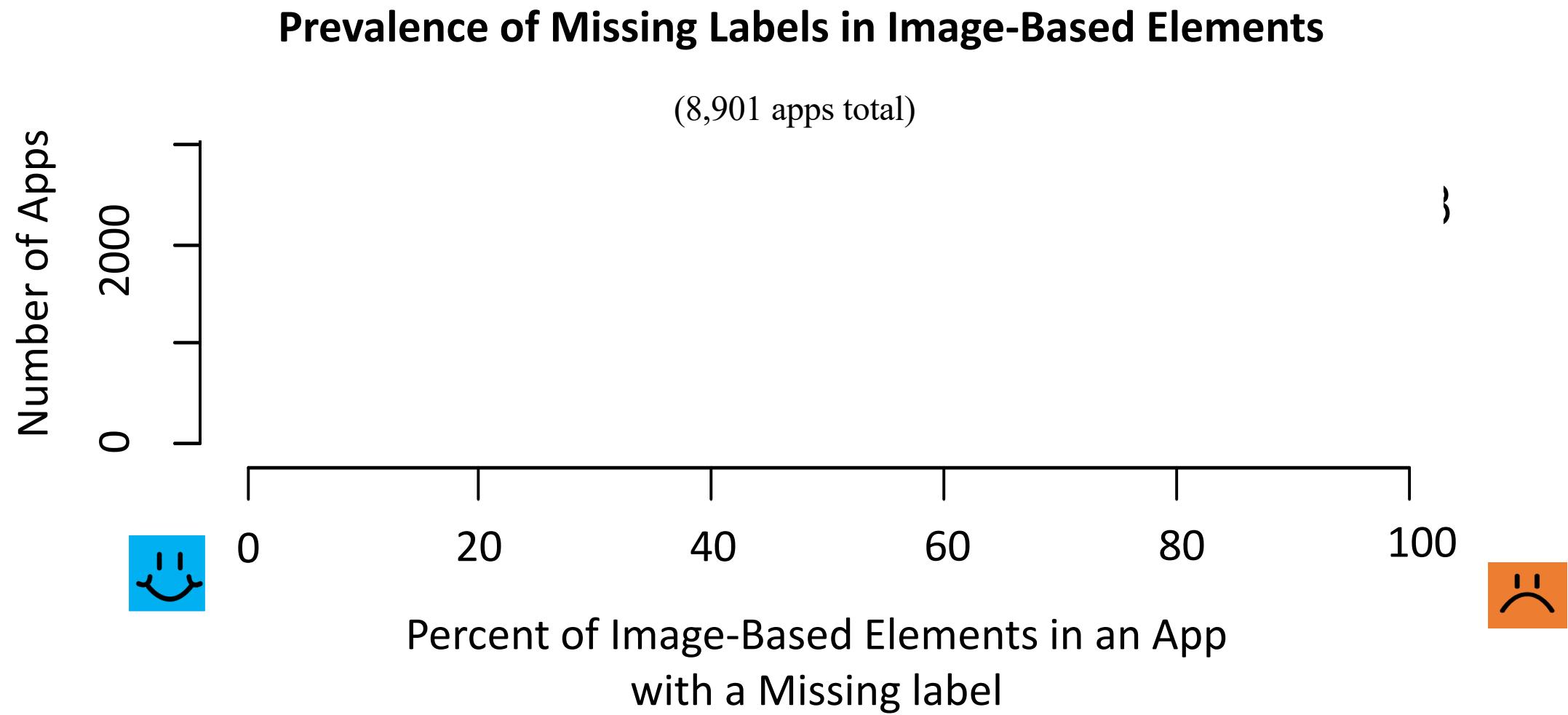
Missing Labels

By-App Prevalence of Missing Labels

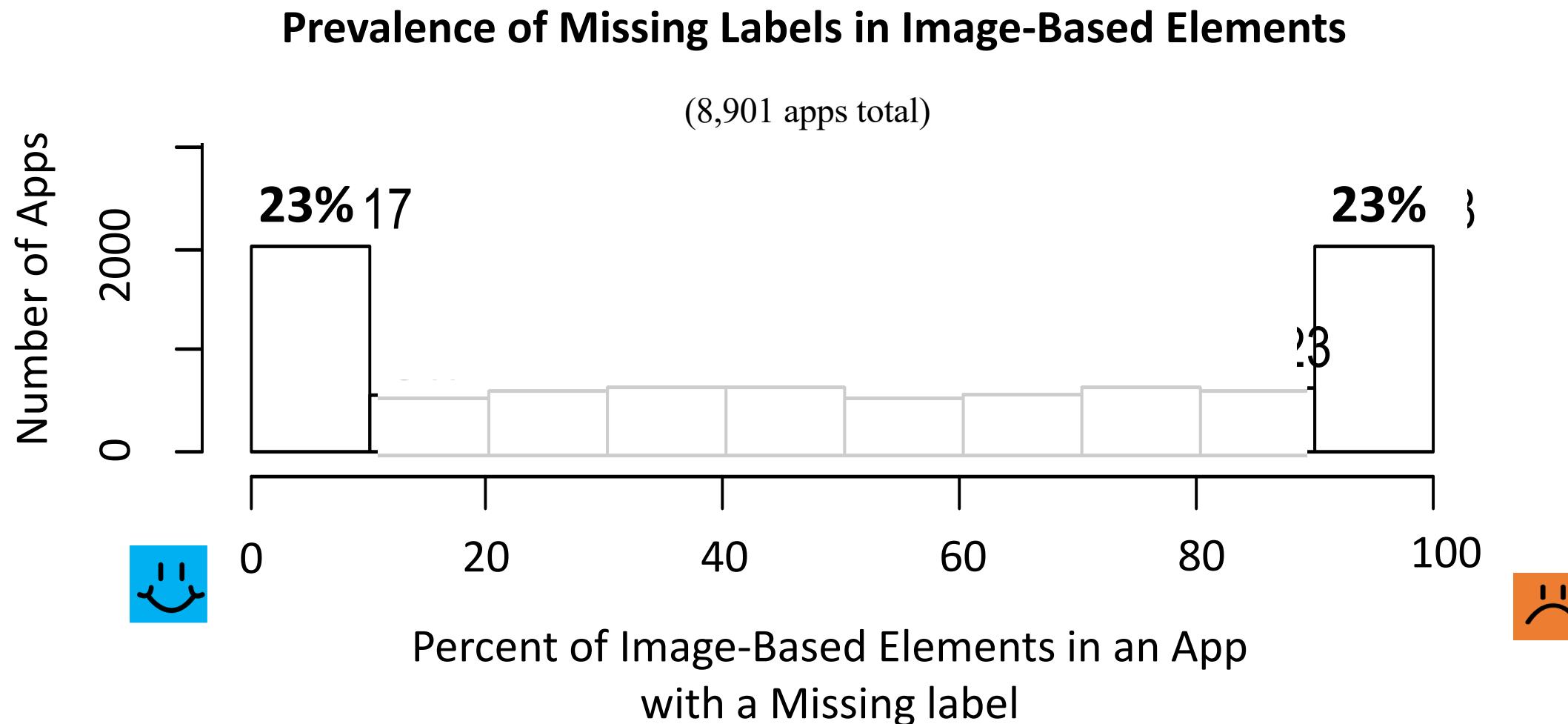
Prevalence of Missing Labels in Image-Based Elements



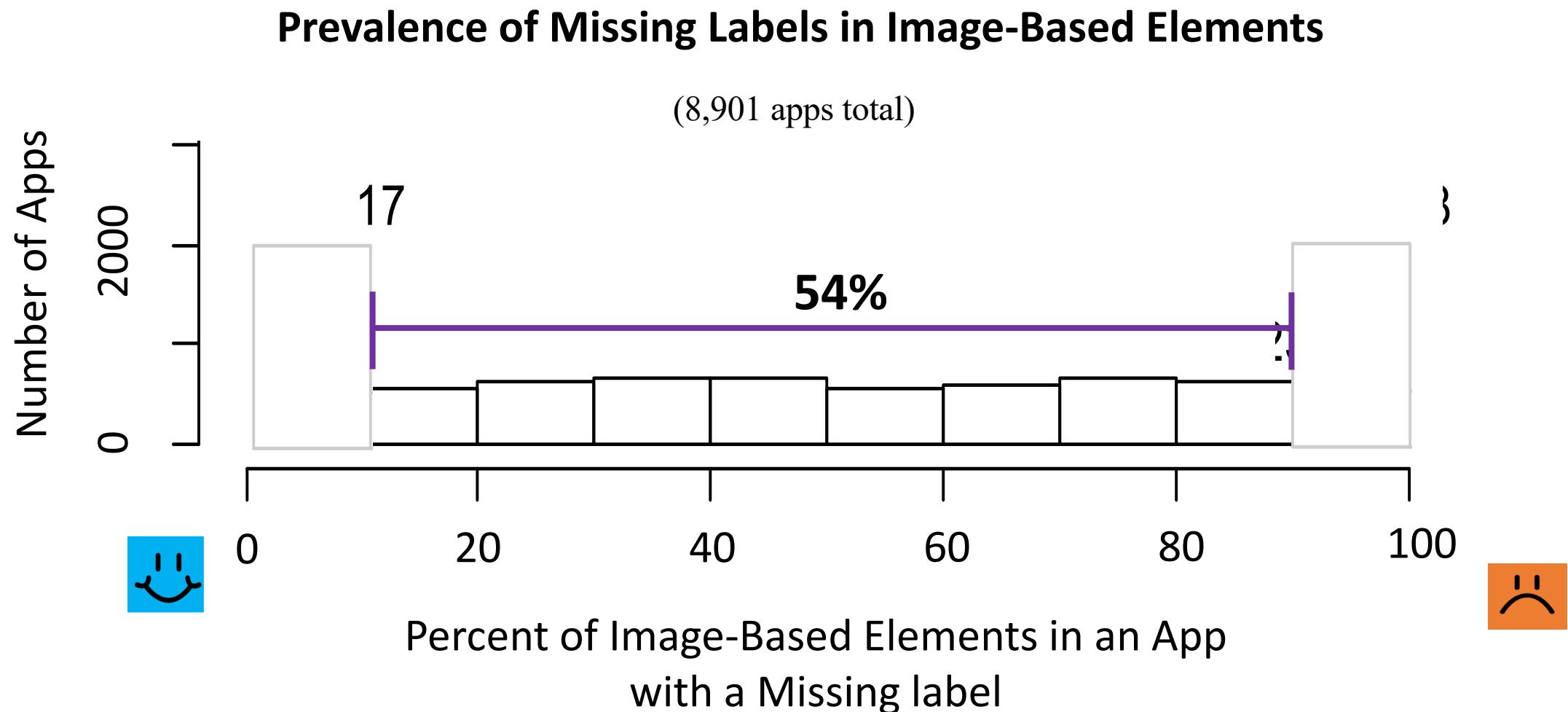
By-App Prevalence of Missing Labels



By-App Prevalence of Missing Labels



By-App Prevalence of Missing Labels



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Understanding App Accessibility at Scale

Large-Scale : How often do failures happen?

Multi-Factor : What contributes to app inaccessibility at scale?

Tools to Improve App accessibility

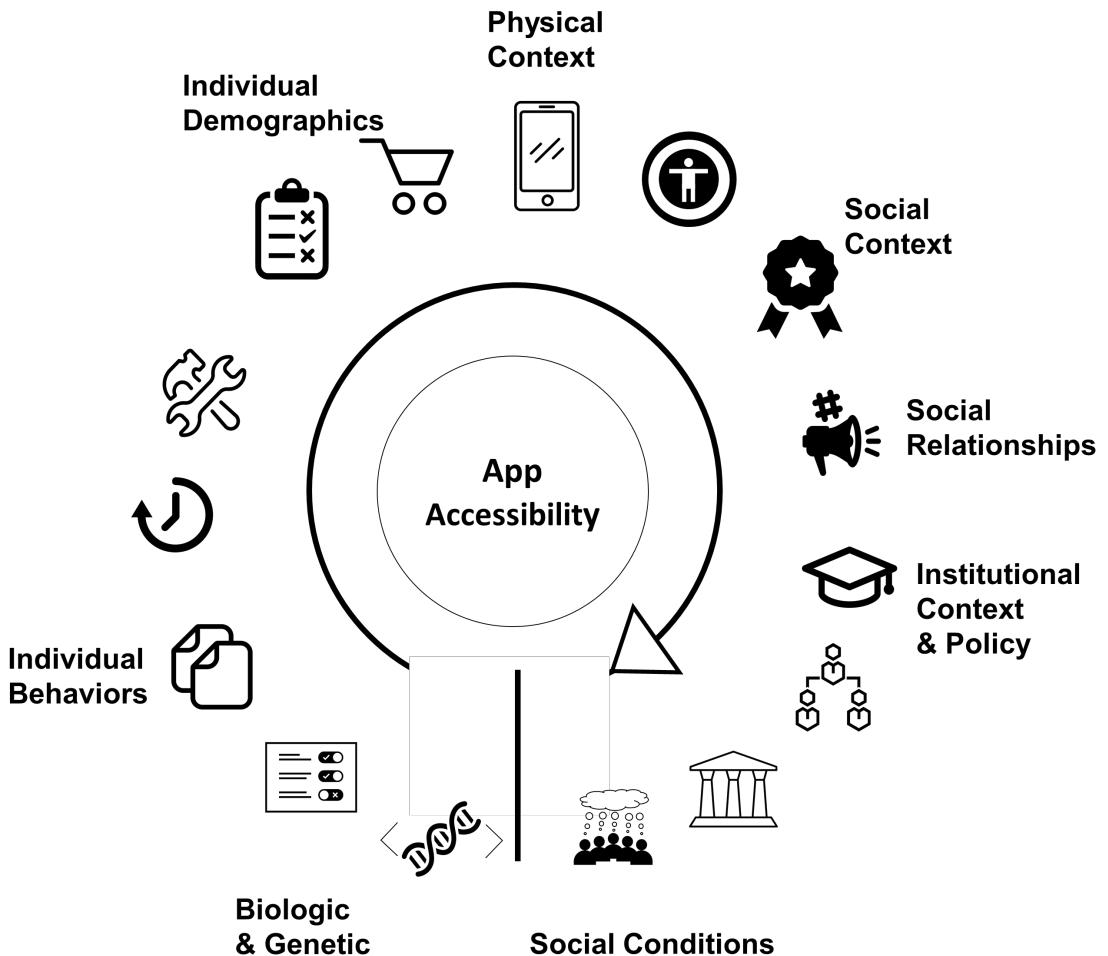
Discussion & Reflection

Identify Environment Factors

What contributes to app inaccessibility at scale?

Factors

characteristic of an app or ecosystem that impact the likelihood of an app having an accessibility failure



Types of Factors

Risk

increase likelihood of inaccessibility disease

Protective

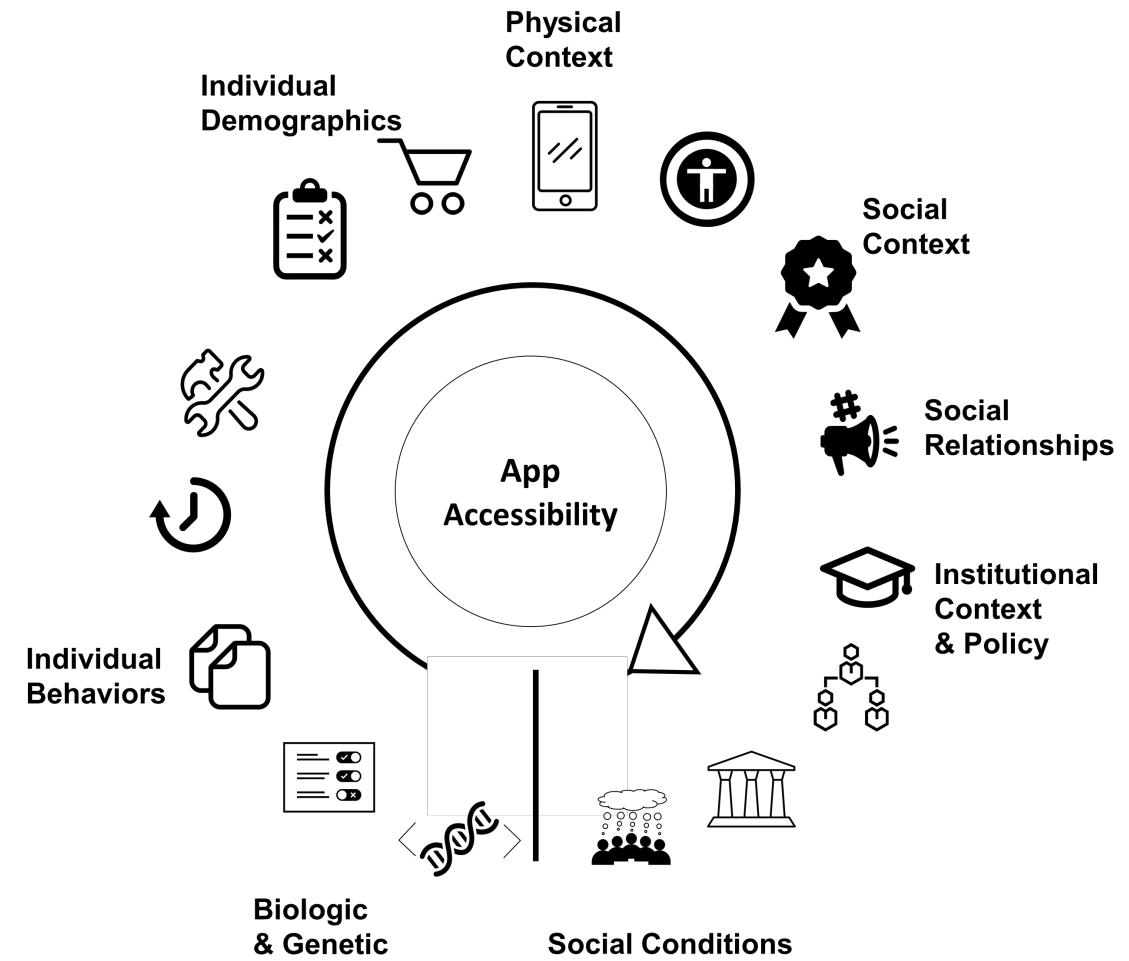
decrease likelihood of inaccessibility disease

Intrinsic

closely related to single app

Extrinsic

indirect, wide-spread effect



Intrinsic Causes of Failures



Source Code

Overview

Framework

Understand

Improve

Discuss

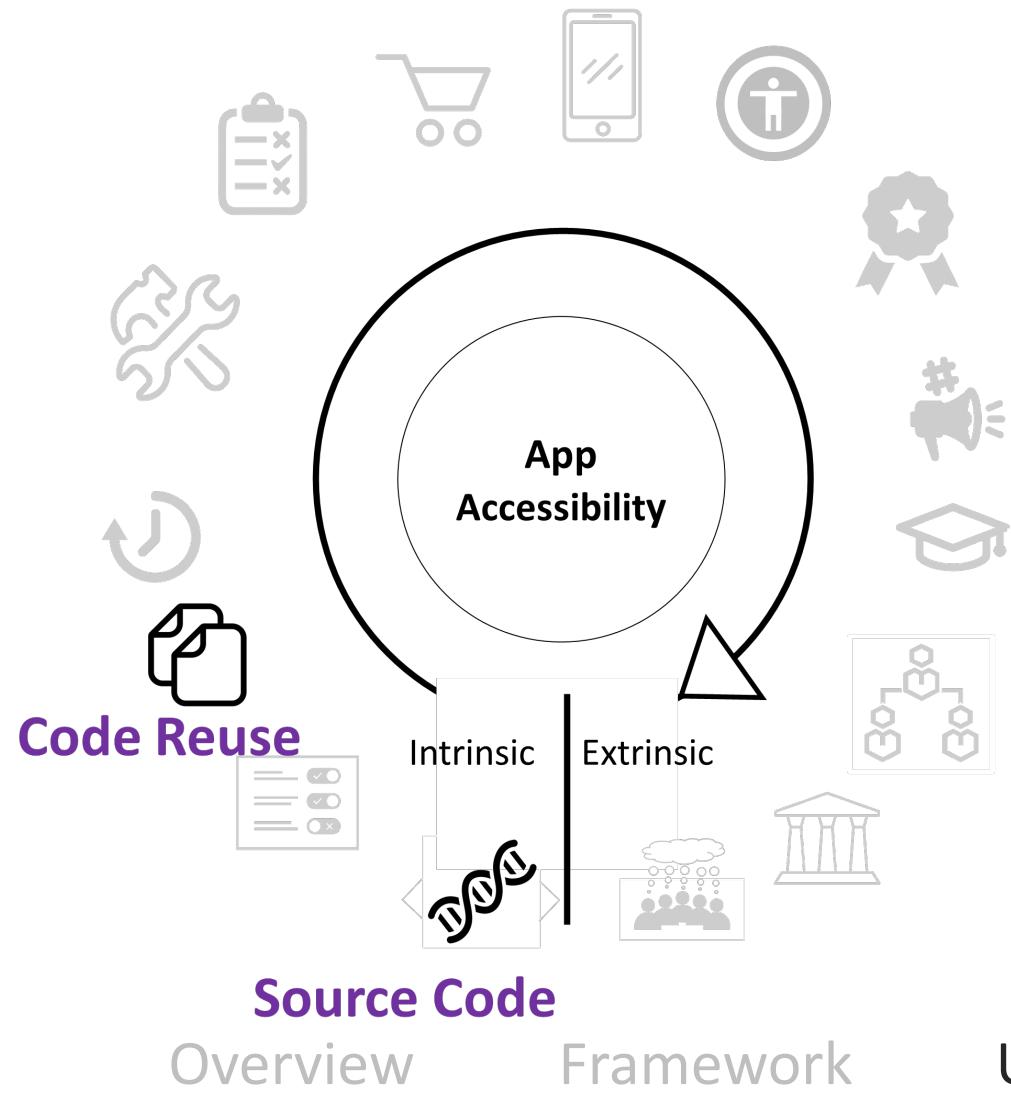
Example Factors



Source Code

```
<ImageButton  
...  
    contentDescription="Add To Cart"/>
```

Where Does Code Come From?



Example Factors



Source Code



Code Reuse



General

- *Buttons*
- *Graphics*

With an icon, using the `ImageButton` class:

```
<ImageButton  
    android:layout_width="wrap_content"  
    android:layout_height="wrap_content"  
    android:src="@drawable/button_image"  
    ... />
```

The XML snippet below shows how to add a drawable resource to an `ImageView` in the XML layout:

```
<ImageView  
    android:layout_width="wrap_content"  
    android:layout_height="wrap_content"  
    android:src="@drawable/my_image" />
```



General

- *Buttons*
- *Graphics*

With an icon, using the `ImageButton` class:

```
<ImageButton  
    android:layout_width="wrap_content"  
    android:layout_height="wrap_content"  
    android:src="@drawable/button_image" />
```

The XML snippet below shows how to add a drawable resource to an `ImageView` in the XML layout:

No Labels

Developer Guides – 2019 Update



Add the floating action button to your layout

The following code shows how the `FloatingActionButton` should appear

```
<android.support.design.widget.FloatingActionButton  
    android:id="@+id/fab"  
    android:layout_width="wrap_content"  
    android:layout_height="wrap_content"  
    android:layout_gravity="end|bottom"  
    android:src="@drawable/ic_my_icon"  
    android:contentDescription="@string/submit"  
    android:layout_margin="16dp" />
```

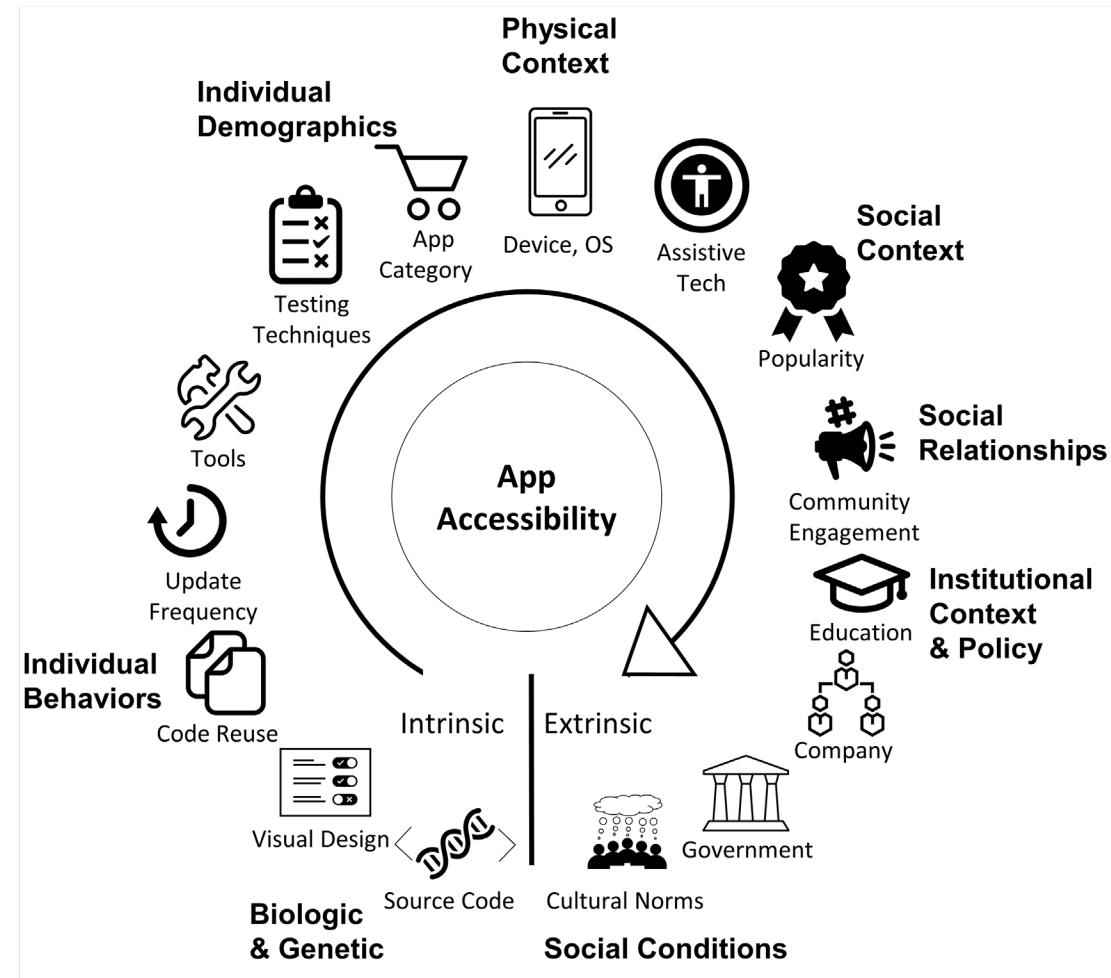


Environmental Factors

Context for accessibility problems

Beyond an individual's influence over their app

Inform effective intervention



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Inform Tools for Improving App Accessibility

How can tools better support accessibility throughout an app's lifecycle?

Treatment

Preventative: before an accessibility failure can be encountered by an end-user

Therapeutic: addressed after released or encountered

Inform Tools for Improving App Accessibility

How can tools better support accessibility throughout an app's lifecycle?

Treatment

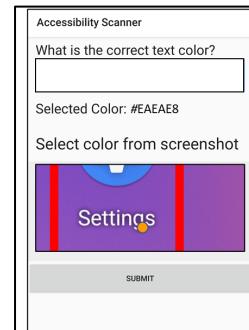
Preventative: before an accessibility failure can be encountered by an end-user

Therapeutic: addressed after released or encountered

Developer Tools



Testing Tools

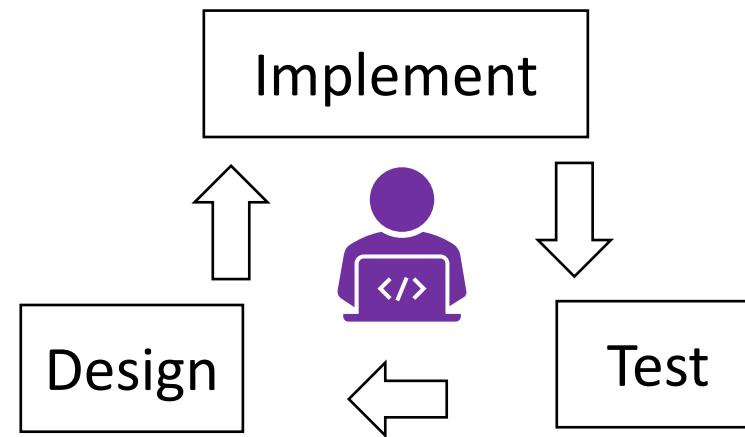


Third-party Repair



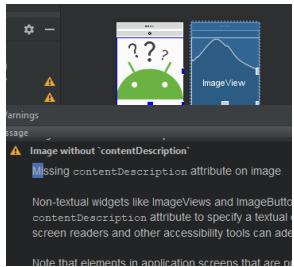
Developer Tools

Developers are a key factor



Current Developer Tools

Source Code



Android
Linters



UI TESTING FOR ANDROID
espresso

Unit Test

Runtime



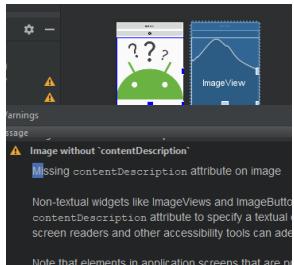
Scanners



Manual
Accessibility Testing

Current Developer Tools

Source Code



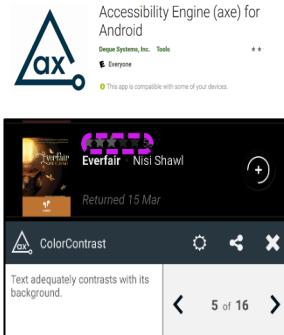
Android
Linters



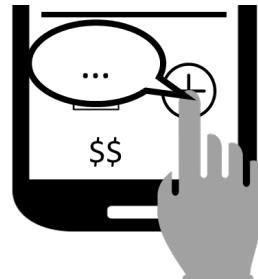
UI TESTING FOR ANDROID
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Scanners



Manual
Accessibility Testing

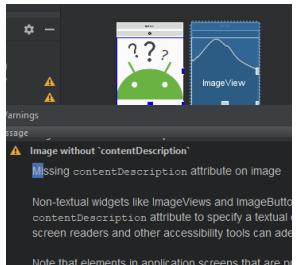
Strengths:

Reduce accessibility expertise needed

Multiple development stages

Current Developer Tools

Source Code

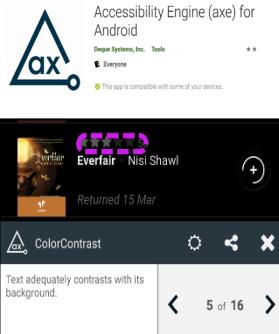


Android
Linters

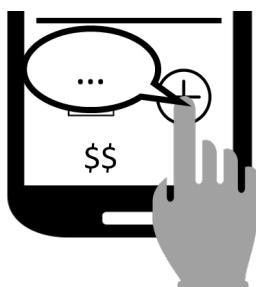


Unit Test

Runtime



Scanners



Manual
Accessibility Testing

Strengths:

Reduce accessibility expertise
Multiple development stages

Opportunities

Time consuming to run,
understand, and repair

Limited approaches to
presenting and repairing

Guiding Design

Goals

Educational

Effective

Efficient

Techniques

Implementation-runtime connection

Multi-modal identification and repair scaffolding

Leverage context

Guiding Design

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Method

Iterative design ideation

Implemented plug-in to Android Studio integrated with on-device runtime testing application

Undersized Elements

Accessible Element Sizing Guides

Make touch target 48dp x 48dp

Use padding, margins, and element size

Guidelines

Use large, simple controls

Your app's UI is easier to use if it contains controls that are easier to see and tap. We recommend that each interactive UI element have a focusable area, or **touch target size**, of at least 48dp × 48dp. Larger is even better.

For a given UI element to have a large enough touch target size, the following conditions should **both** be true:

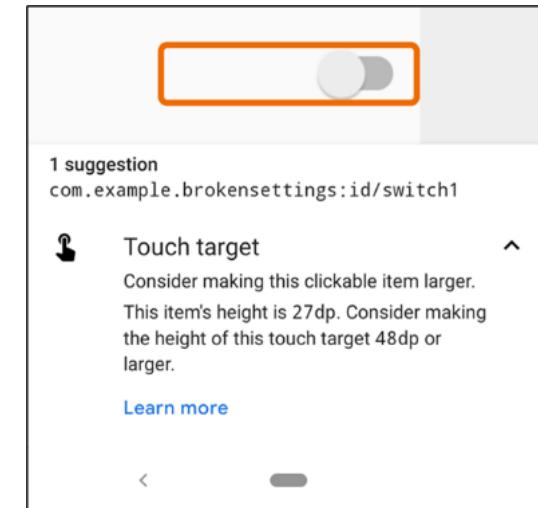
- The sum of the values of `android:paddingLeft`, `android:minWidth`, and `android:paddingRight` is greater than or equal to 48dp.

Undersized Elements

Accessible Element Sizing Guides

Make touch target 48dp x 48dp

Use padding, margins, and element size



Challenges

Undersized elements identified at runtime

Dynamic-sizing supports cross-device design

Recommendations in absolute size

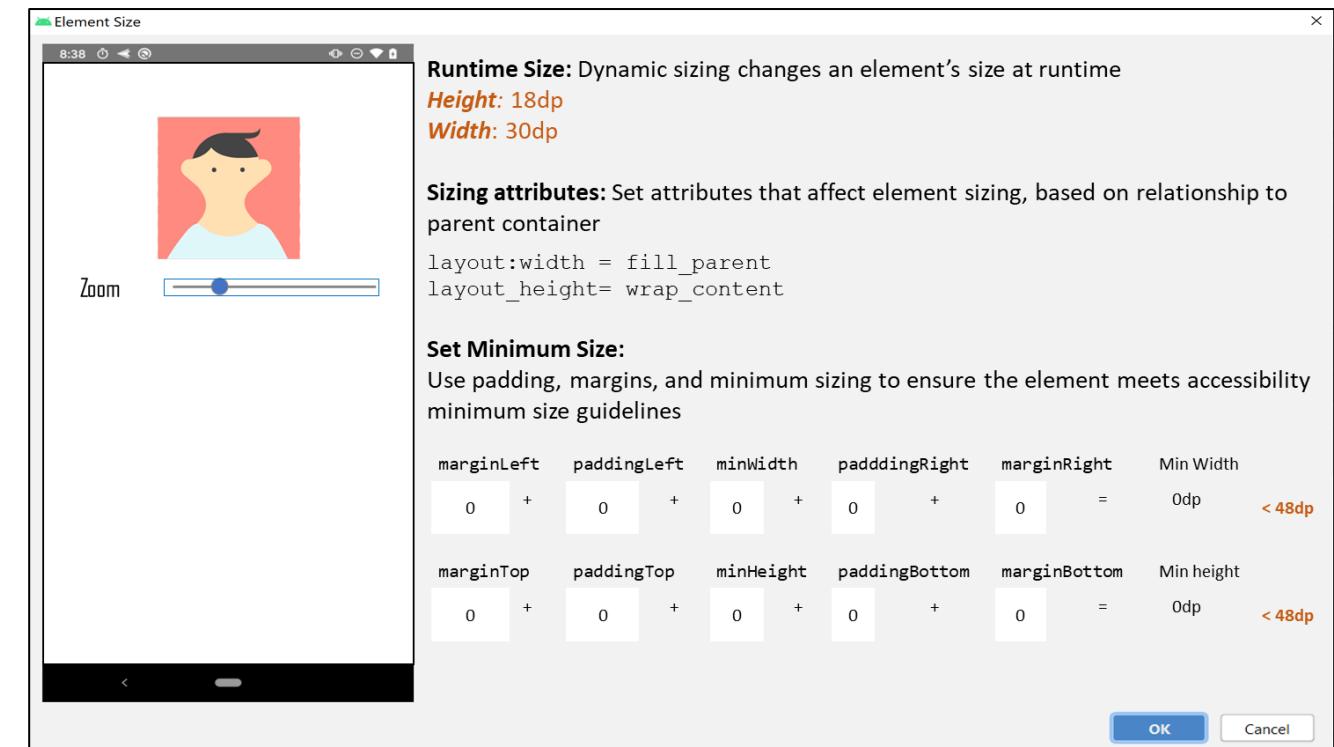
```
<LinearLayout  
    android:layout_width="match_parent"  
    android:layout_height="match_parent"  
    android:orientation="horizontal">  
  
    <Switch  
        android:id="@+id/switch1"  
        android:layout_width="wrap_content"  
        android:layout_height="wrap_content"  
        android:layout_weight="1"  
    />  
...
```

Connecting Runtime and Implementation

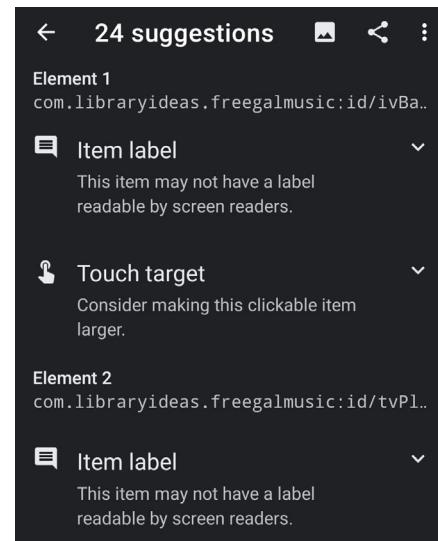
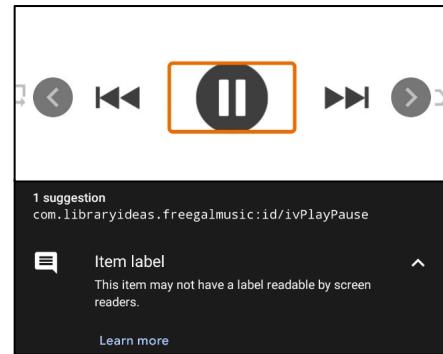
Present runtime results alongside source code
Forefront attributes developers need to change sizing

```
LinearLayout android:layout_width="match_parent"
    android:layout_height="wrap_content"
    android:orientation="vertical"
    android:paddingBottom="16dp"
    android:paddingTop="16dp"
    android:paddingLeft="16dp"
    android:paddingRight="16dp"

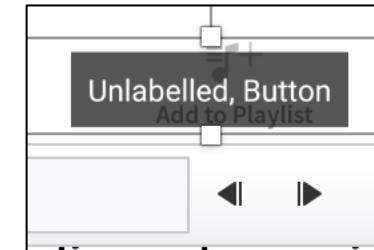
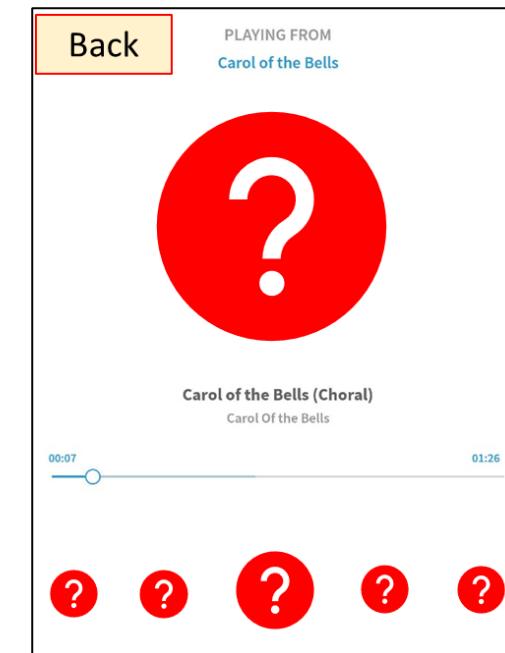
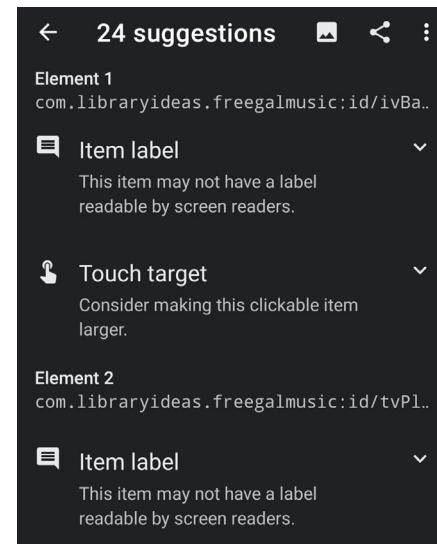
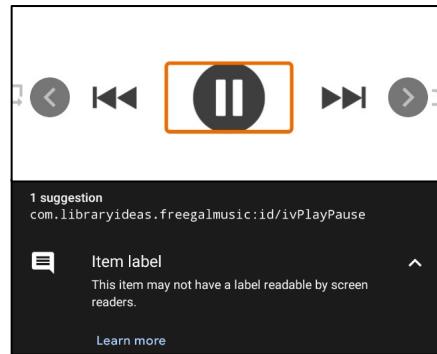
>
<SeekBar
    android:id="@+id/zoom_seekbar"
    android:layout_width="fill_parent"
    android:layout_height="wrap_content"
    android:layout_margin="@dimen/margin_medium"
    android:minHeight="48dp"
    android:minWidth="48dp"/>
/>
```



Multi-Modal Presentation of Labeling



Multi-Modal Presentation of Labeling



Guiding Design

Goals

Educational

Effective

Efficient

Techniques

Implementation-Runtime Connection

Multi-modal identification and repair scaffolding

Leverage Context

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Tools to Improve App accessibility

Developer tools

Testing tools

Third-party repair

Discussion & Reflection

Automated Testing Tools

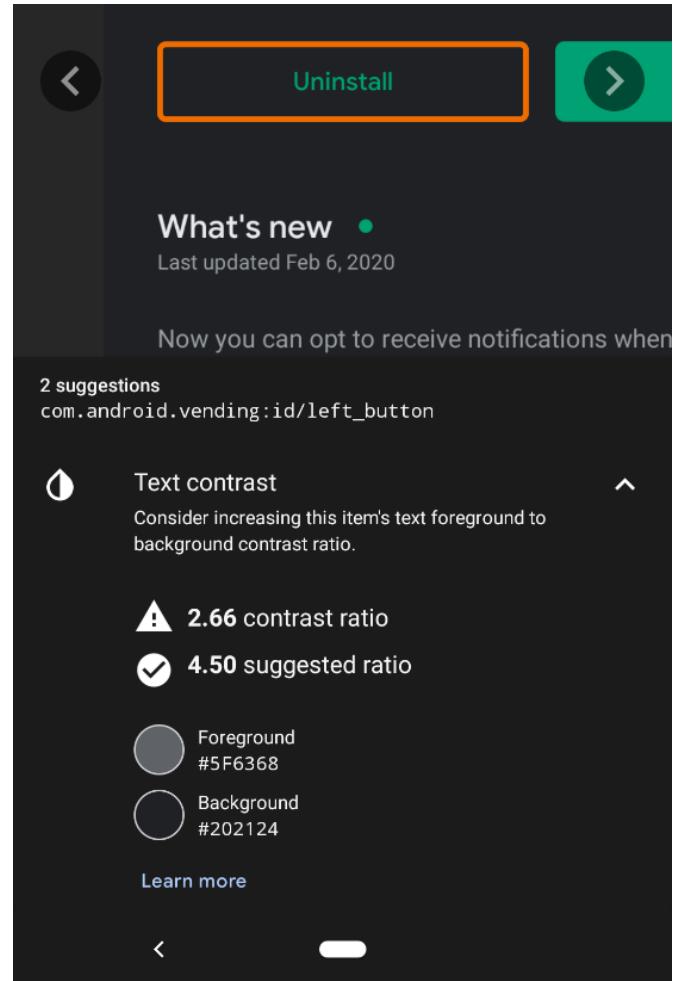
Tools

- Automation supports low accessibility expertise
- Provide technical information for repair

Limitations

- Accuracy
- Coverage

Color Contrast Testing



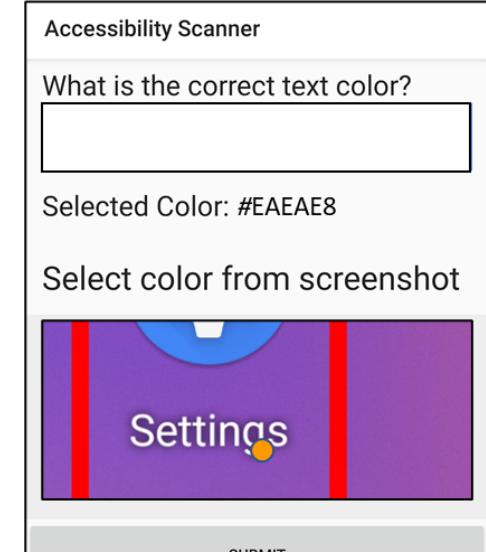
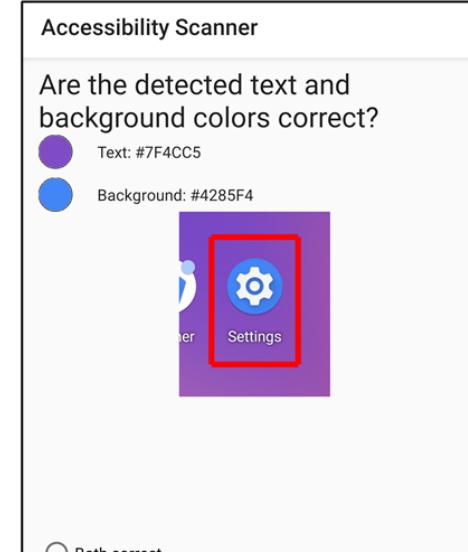
Human Annotation of Automated Results

Question-Answer prompts

Correct inaccurate automated tests

Supply information to increase coverage

Color contrast



Released in:

Accessibility Test Framework for Android API, v3.1, Feb '20

Google's Accessibility Scanner v2.2, Jan '21

User Study with Professional Testers

8 professional app accessibility testers

- Survey + User Study
- Current approaches and challenges with testing

Test



Prototype Feedback

Positive feedback

Simplified their workflow

Annotation as communication

Test



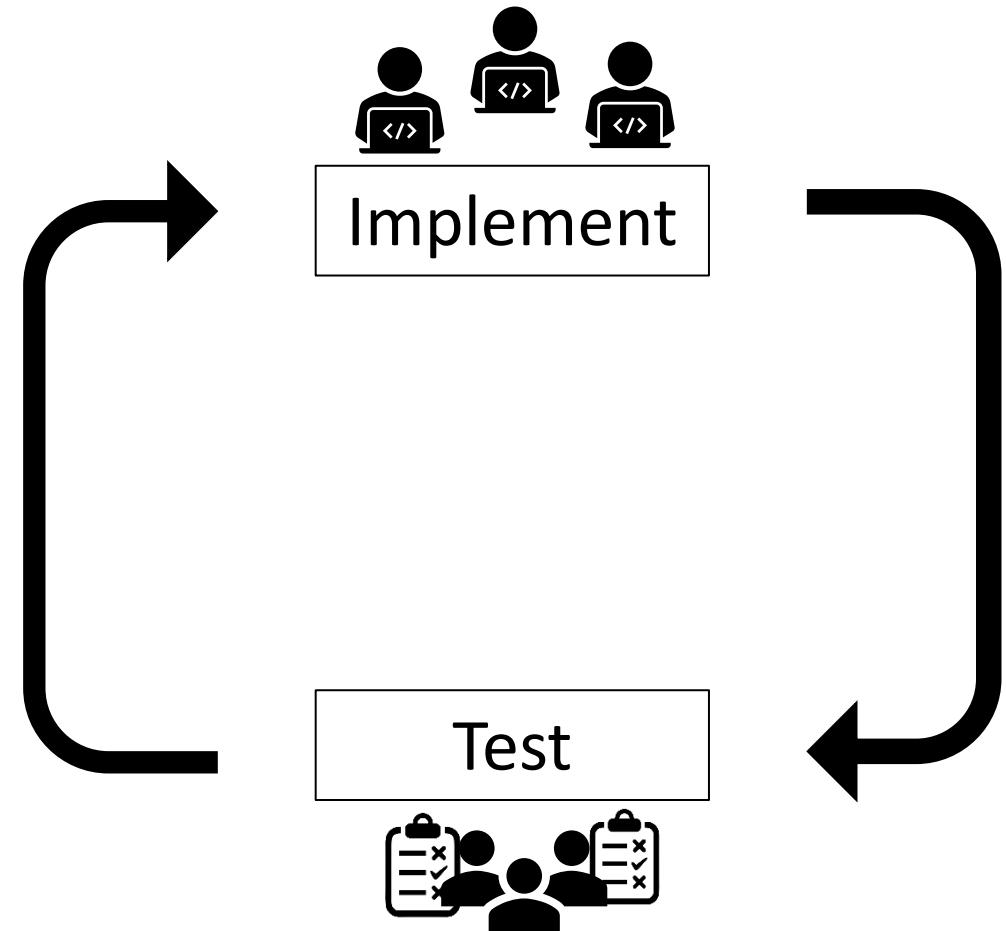
Testing in the Company Ecosystem

Separate testing and developer teams

Follow-up survey

2 testers and 2 developers

Collaborative app accessibility testing



Explaining Accessibility Failure

Challenge

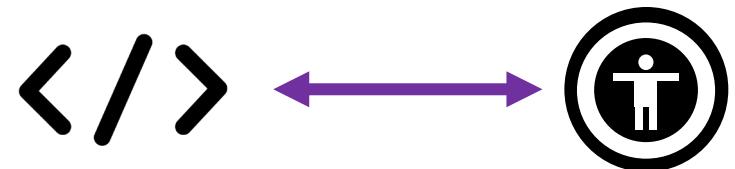
Technical versus accessibility expertise

Communicate in written form with different vocabulary

Opportunities

Cross-discipline education

Tools facilitate communication



In-Scope for Developer

Challenge

Developer cannot fix problems from external sources (e.g., shared component, external library, embedded from another source)

Tester has insufficient information to focus on in-scope failures

Opportunities

Scaffold information exchange

Professional Testing Ecosystem

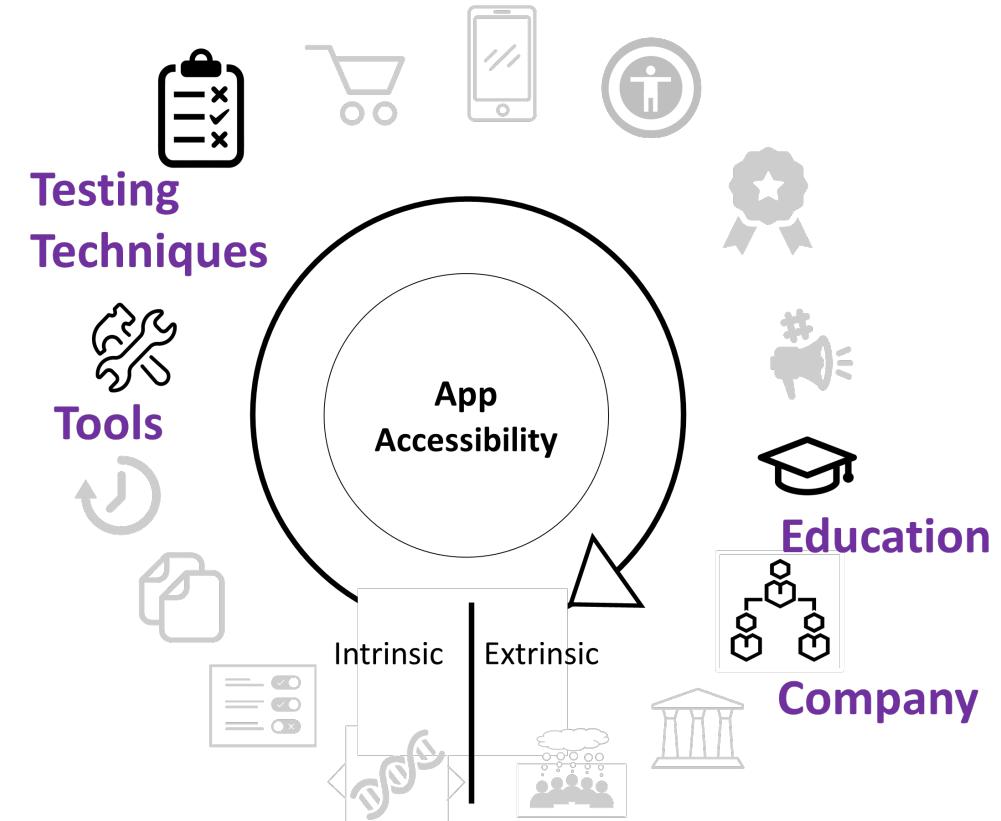
Factors

Mixed expertise
Communication
Social dynamics
Resource discrepancies

**improving app accessibility
testing effectiveness**

>

improving test tool accuracy



Outline

App Accessibility

Thesis

Epidemiology-Inspired Framework

Understanding App Accessibility at Scale

Tools to Improve App accessibility

Developer tools

Testing tools

Third-party repair

Discussion & Reflection

Third-Party Repair

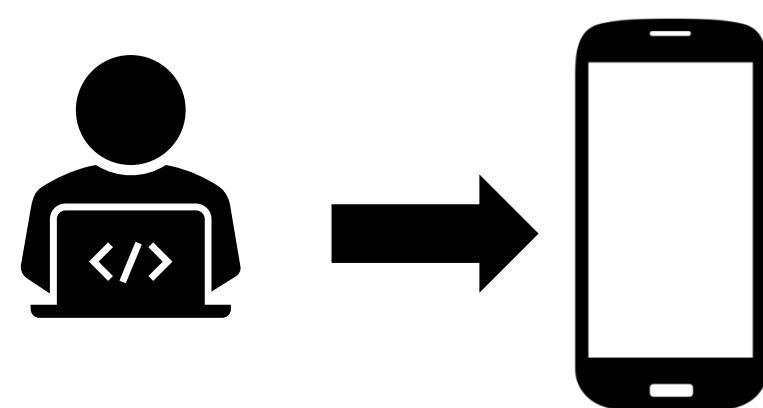
Beyond developer intervention.

Needed when:

Lack of timely repair

App not maintained

More personalized experiences



Interaction Proxies

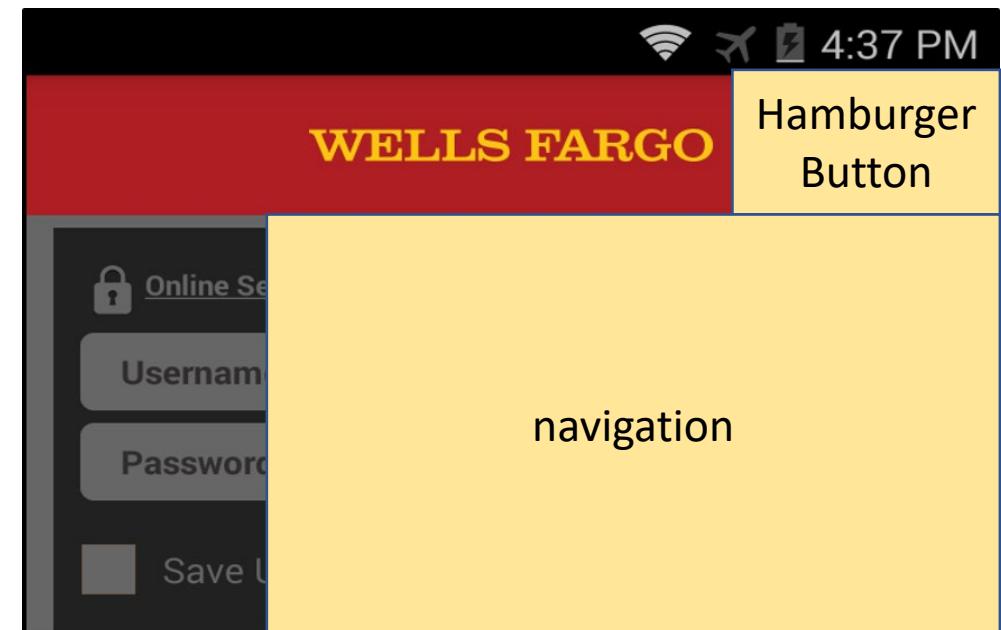
Xiaoyi Zhang, Anne Spencer Ross, Anat Caspi, James Fogarty, Jacob O. Wobbrock. CHI '17
[Interaction Proxies for Runtime Repair and Enhancement of Mobile Application Accessibility.](#)

Interaction Proxies

Original Interface



Screen Reader Manifest Interface



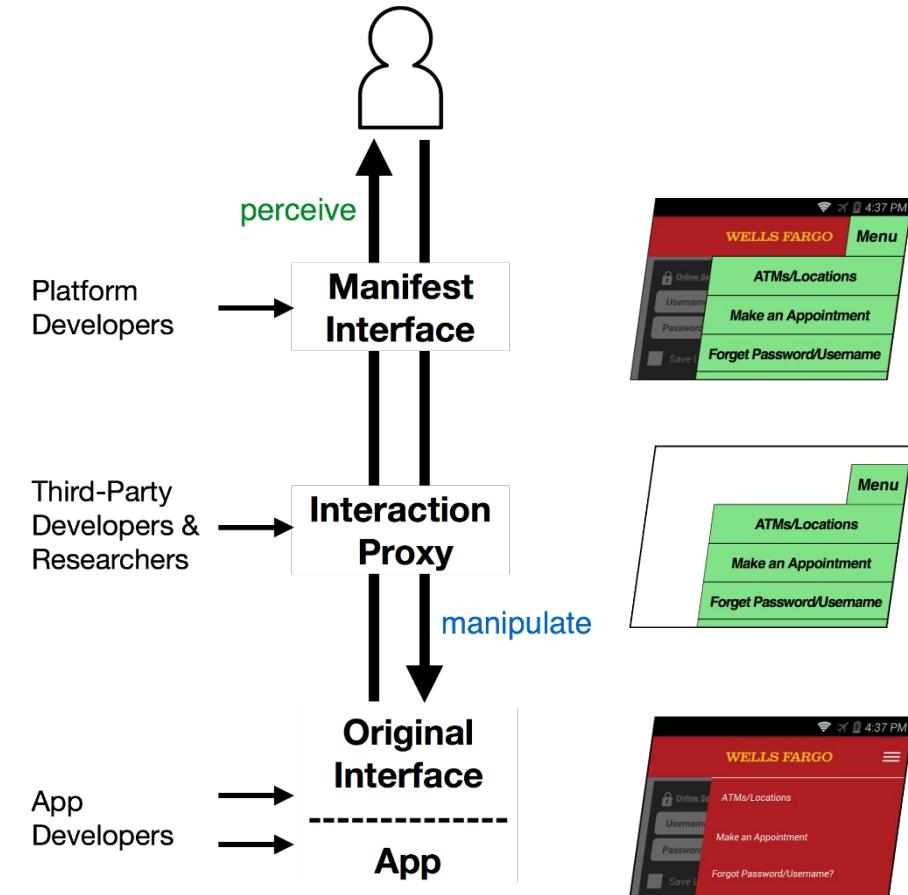
Interaction Proxies

Preserves

- App functionality
- Device services (like AT)
- Seamlessness of interaction

Does not need

- Source code
- Device modification

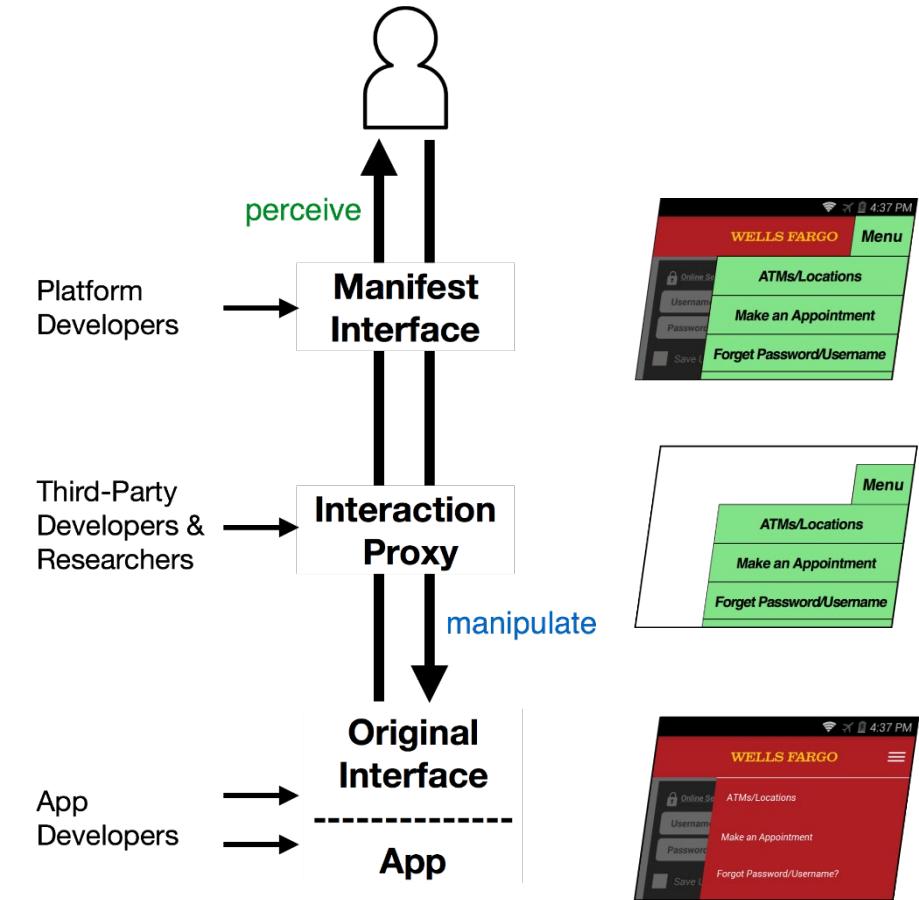


Interaction Proxies

Overall positive feedback

Ecosystem of deployment

- Co-create repairs
- Accessible creation tools
- Capacity for repairs to be produced
- Trust in third-party downloads



Outline

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Thesis Statement

In mobile app accessibility, applying an epidemiology-inspired framework that emphasizes multi-factor and large-scale analyses can:

- (T1) reveal population-level trends of accessibility failures;
- (T2) aid in identifying a range of intrinsic to extrinsic factors that can impact app accessibility; &
- (T3) inform the design of tools for identifying and repairing accessibility failures.

Research Contributions

In mobile app accessibility, applying an **epidemiology-inspired framework** that emphasizes multi-factor and large-scale analyses can:

- (T1) reveal population-level trends of accessibility failures;
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- (T3) inform the design of tools for identifying and repairing accessibility failures.

Epidemiology-Inspired Framework



Overview

Framework

Understand

Improve

Discuss

Research Contributions

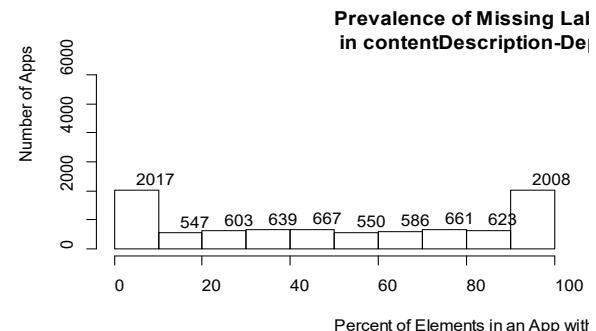
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Epidemiology-Inspired Framework



Population-Scale, Multi-Factor Analyses



Research Contributions

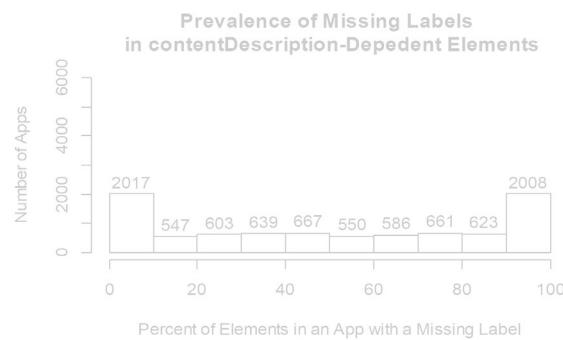
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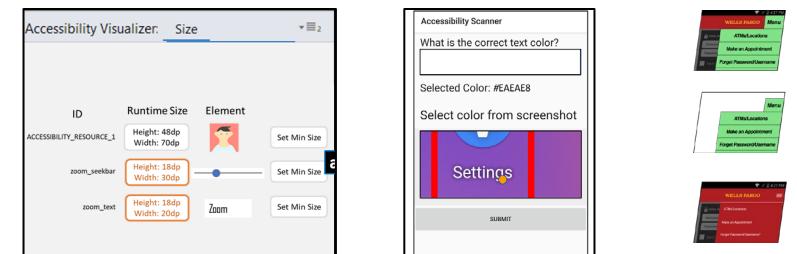
Epidemiology-Inspired Framework



Population-Scale, Multi-Factor Analyses



Tools for Developing, Testing, & Third-Party Repair



Research Contributions

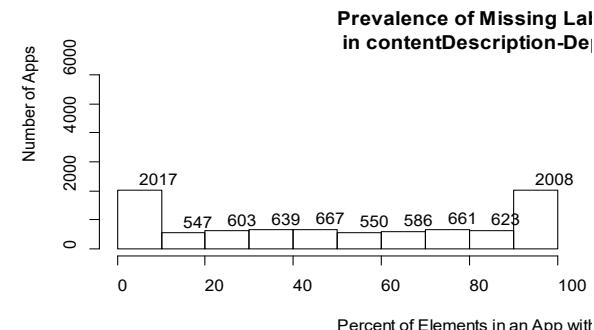
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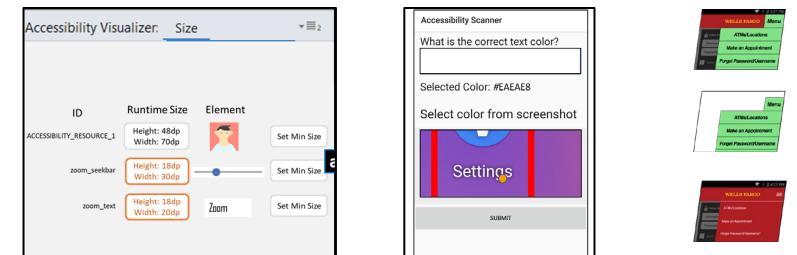
Epidemiology-Inspired Framework



Population-Scale, Multi-Factor Analyses



Tools for Developing, Testing, & Third-Party Repair



Applying the Framework

Prompts creative thinking

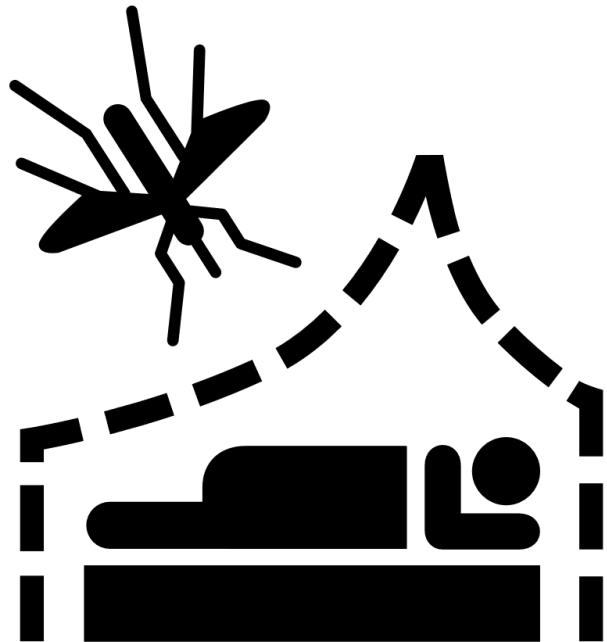
Colloquial epidemiology concepts → app accessibility

Applying the Framework

Prompts creative thinking

Colloquial epidemiology concepts → app accessibility

*What is equivalent
to a mosquito net?*



Inaccessible tool warnings
for developers

Filter app marketplaces by
accessibility support

Research Vision

I envision a world in which
**accessibility is integrated
into every facet of app creation**

from the low-level design and implementation details
to organization-level structures, incentives, and resources.

Acknowledgements

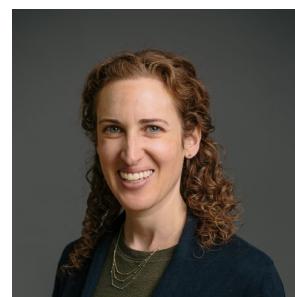
Family



Friends (I don't take a lot of pics, apparently!)



Collaborators



Funding



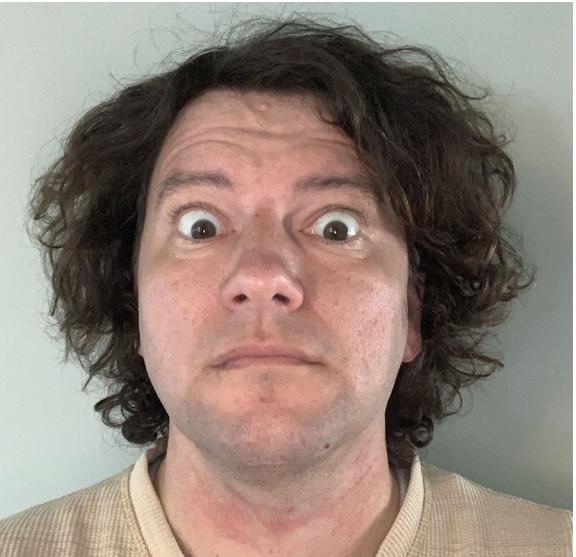
Mani
Charitable
Foundation

Wilma Bradley Endowed
Fellowship in Computer
Science & Engineering

Advisors



James Fogarty



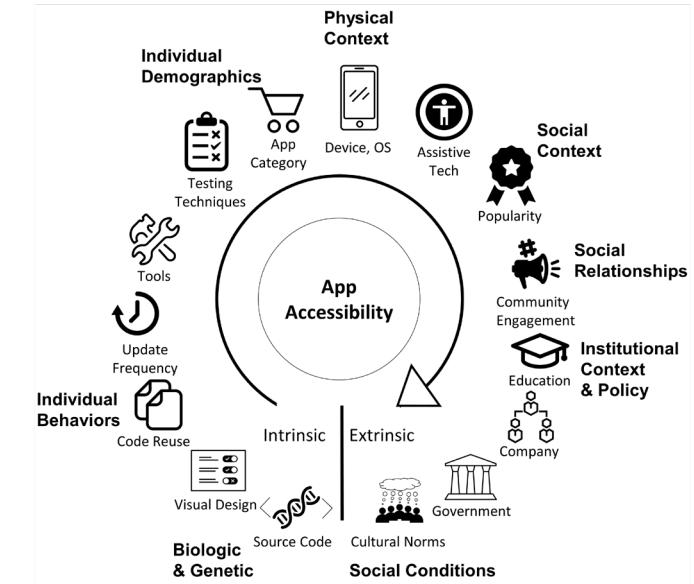
Jake Wobbrock



A Large-Scale, Multi-Factor Approach to Understanding and Improving Mobile Application Accessibility

In mobile app accessibility, applying an epidemiology-inspired framework can:

- (T1) reveal population-level trends of accessibility failures;
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