

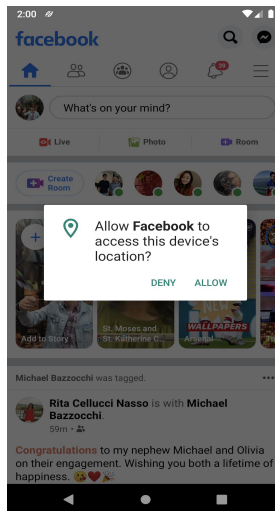
A Large Scale Study of User Behavior, Expectations and Engagement with Android Permissions

Weicheng Cao (U. Toronto) **Chunqiu Xia** (U. Toronto) **Sai Teja Peddinti** (Google)

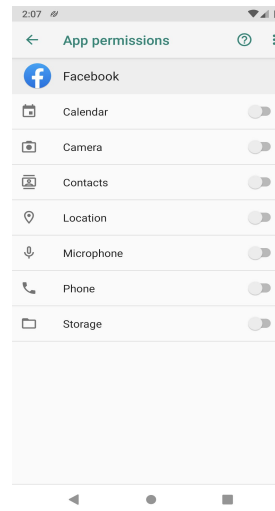
David Lie (U. Toronto) **Nina Taft** (Google) **Lisa M. Austin** (U. Toronto)

Controlling private data sharing with Android Permissions

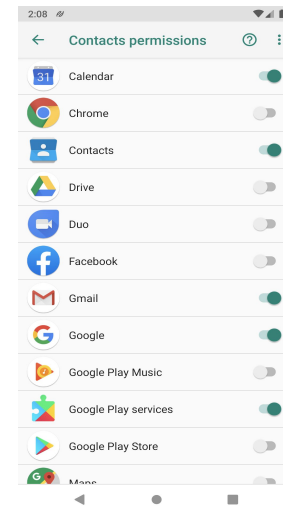
Users choose what **private data** to share with app via **Android permission system**



Runtime permission request



Android Settings menu

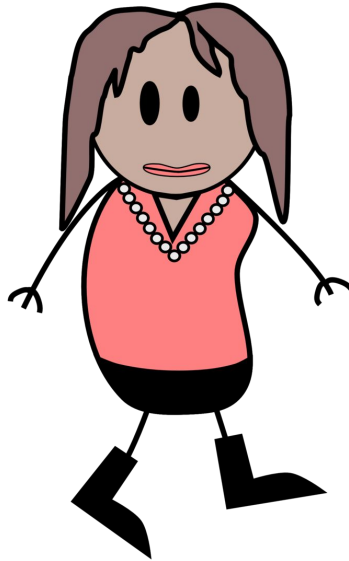


Many factors affect user's decision to deny a permission

Behaviors

Demographic

Expectations



Attitudes

Explanations

Goal: Study the **interplay** of all these factors;
study the **effect of one factor while
controlling for others**

Challenge: collect these disparate types of data from
the same individuals

Challenge: collect data from large, international set of
participants

PrivaDroid as experiment tool

Become a participant by installing Android App

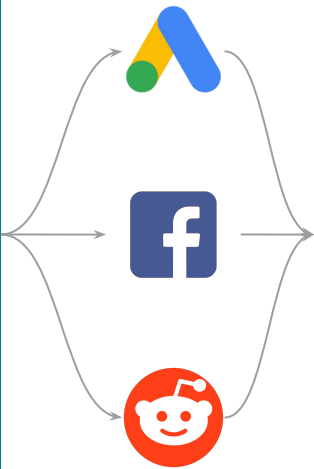
Stay for 30 Days

\$10 Reward

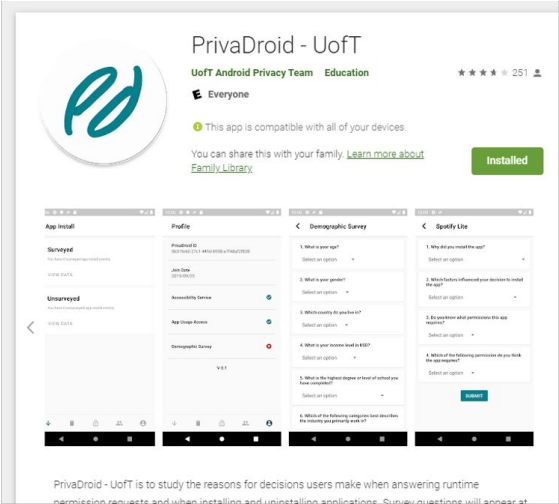
Experiment sponsored by the University of Toronto



Online mobile Ad



Platforms

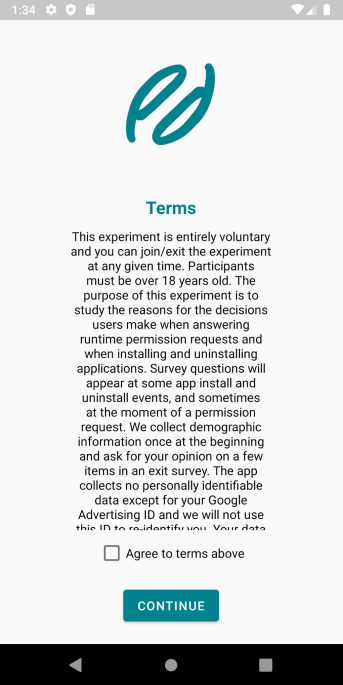


PrivaDroid - UoFT
UoFT Android Privacy Team Education
Everyone
This app is compatible with all of your devices.
You can share this with your family. [Learn more about Family Library](#) **Installed**

App Install, Profile, Demographic Survey, Spicy Life

PrivaDroid - UoFT is to study the reasons for decisions users make when answering runtime permission requests and when installing and uninstalling applications. Survey questions will appear at

Google Play Store



1:34

Terms

This experiment is entirely voluntary and you can join/exit the experiment at any given time. Participants must be over 18 years old. The purpose of this experiment is to study the reasons for the decisions users make when answering runtime permission requests and when installing and uninstalling applications. Survey questions will appear at some app install and uninstall events, and sometimes at the moment of a permission request. We collect demographic information once at the beginning and ask for your opinion on a few items in an exit survey. The app collects no personally identifiable data except for your Google Advertising ID and we will not use this ID to re-identify you. Your data

Agree to terms above

CONTINUE

PrivaDroid App

What do we collect

Demographics:

Gender, age, education,
country/region

Behavior:

Grant/Deny decisions
Apps installed

Expectations:

Whether participants expected
the permission request

Rationales:

Why participants granted or
denied a permission

Explanations:

Apps' explanations in
pre-prompts, for permissions

Attitudes:

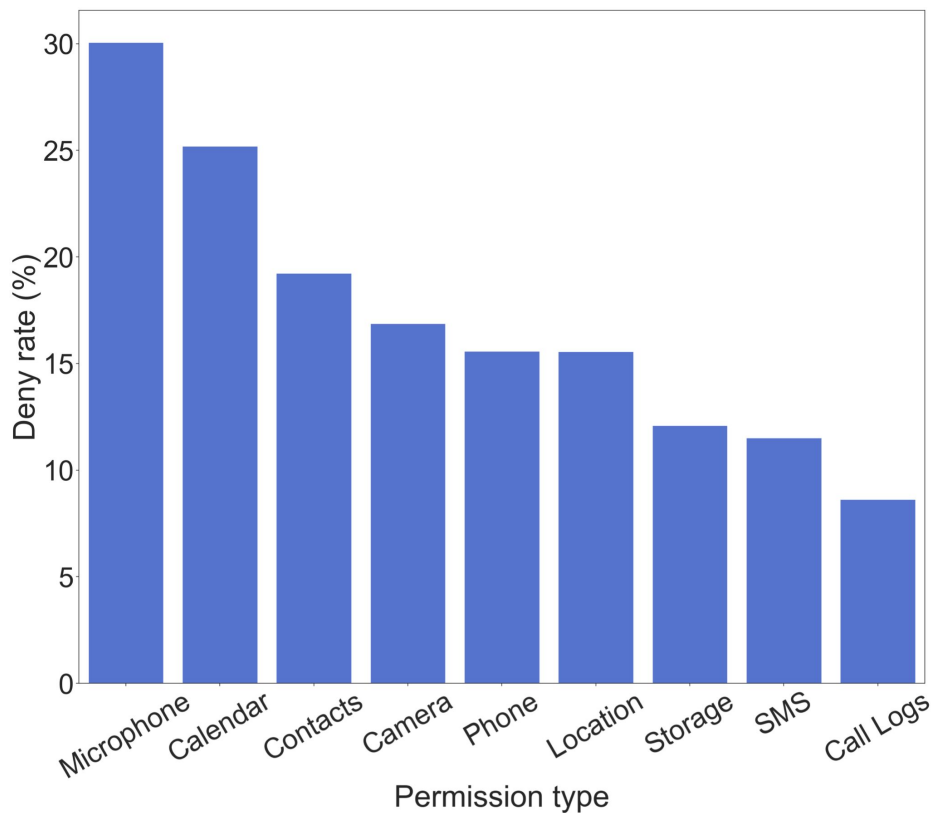
Privacy sensitivity scores

Permission data summary

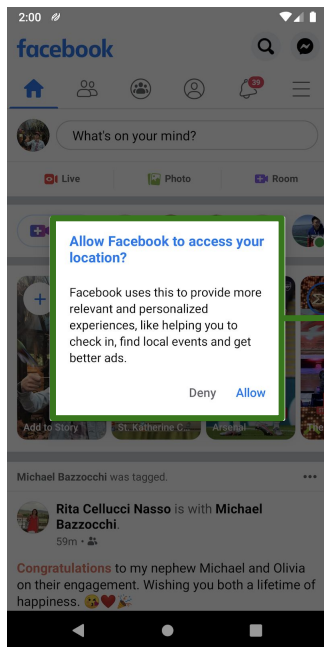
Study ran from Nov 2019 to May 2020

10 countries and regions, 1,719 participants

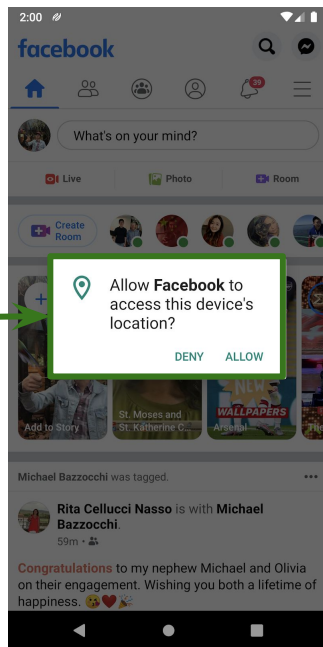
~36K permission decision events (30% surveyed) and overall 16.7% deny rate



Explanations



Explanation



Permission request

Explanation must have:

- A keyword about **data collection**, e.g. access, collect, etc.
- A keyword about a **permission/resource type**, e.g. camera, photos, etc.

Deny rate **15.4%** without explanation -> **7.1%** with explanation

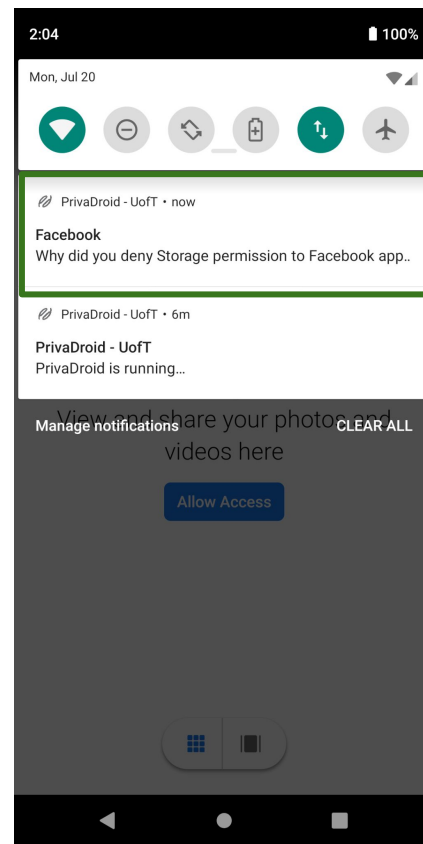
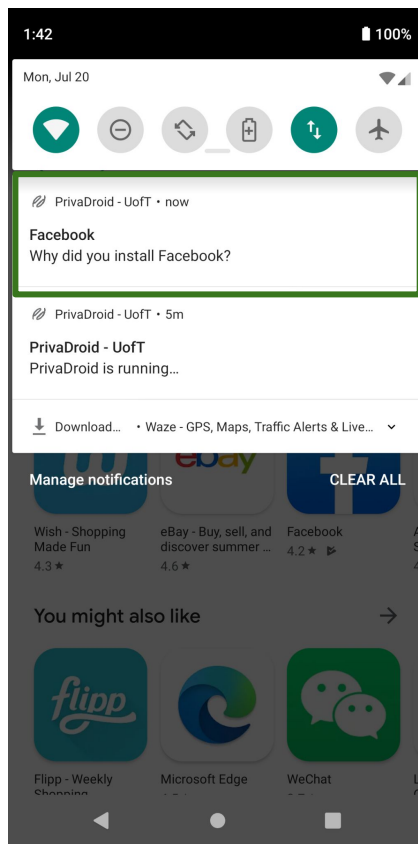
Mixed effects logistic regression (MELR) shows presence of explanation reduces deny rate

Expectations

Unexpected requests deny rate: 26.9%

Expected requests deny rate: 12.2%

MELR model shows unexpected runtime requests significantly increase likelihood that a user denies a permission. Model shows this is true even when controlling for other factors.

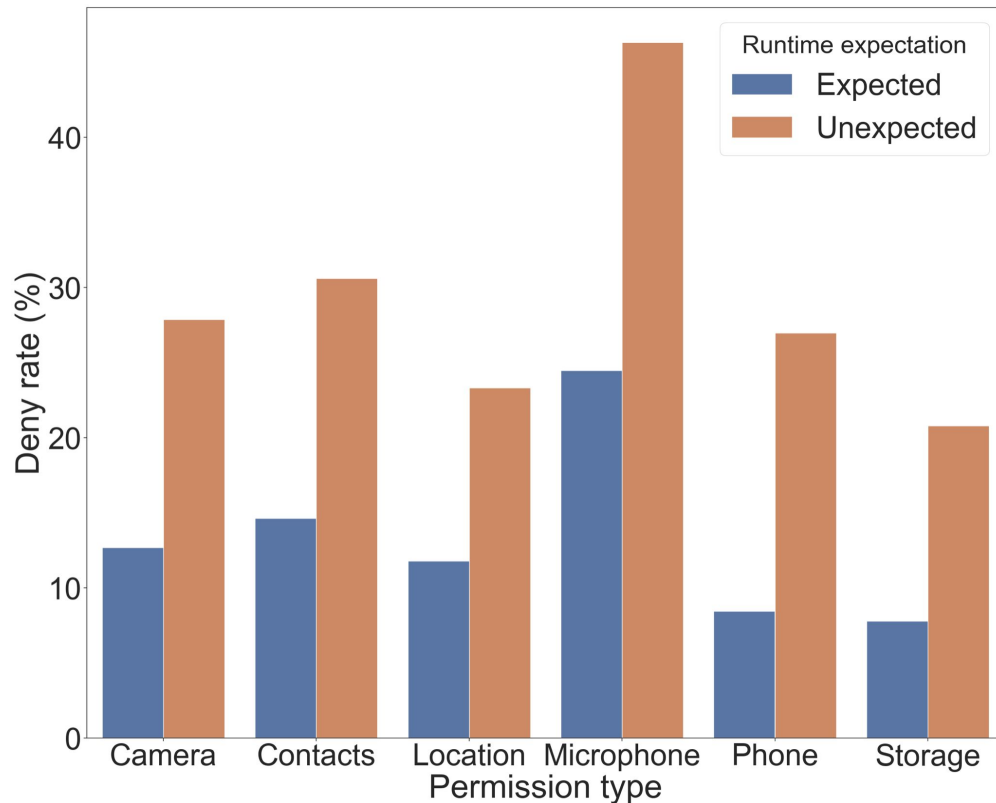


Expectations

Unexpected requests deny rate: 26.9%

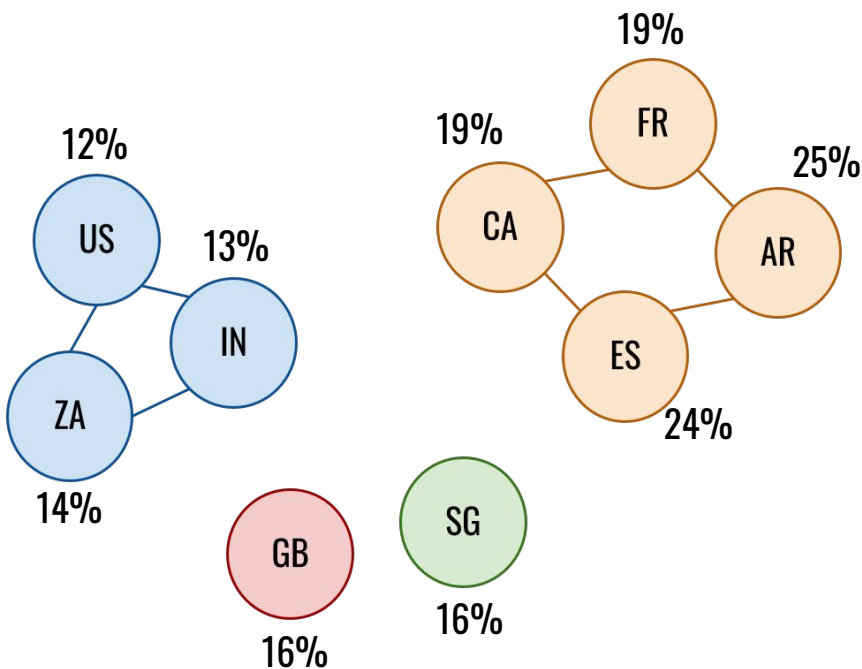
Expected requests deny rate: 12.2%

MELR model shows unexpected runtime requests significantly increase likelihood that a user denies a permission. Model shows this is true even when controlling for other factors.



Cross country analysis

- Challenging to understanding country to country comparison
 - Privacy attitudes, cultural values, regulatory frameworks, etc.
 - Only observations about the participants in our study
- Deny rates and distribution
 - **2 distinct cliques of countries** found via pairwise ANOVA tests on the deny rate distributions
 - Participants from countries in the same clique are drawn from populations with the **same mean deny rates**



HK is excluded because of not enough female participants

Factors influencing deny rate

- Mixed effects logistic regression model with 12 features
 - Privacy sensitivity (4)
 - Explanation (1)
 - Runtime expectation (1)
 - Whether permission decision is in Settings menu or runtime (1)
 - Demographic variables (4)
 - Permission type (1)
- Participant and app are included as random effects

Variable	Values	β Coefficient (p-value)
control awareness	[-2, 2]	-0.044
collection	[-2, 2]	0.109
secondary_use	[-2, 2]	0.404 (***)
has_explanation	Binary	-0.725 (***)
settings_menu	Binary	2.04 (***)
country/region (reference: US)	Canada	0.870 (***)
	Argentina	0.555 (***)
	UK	0.567 (***)
	France	0.795 (***)
	Spain	0.883 (***)
	South Africa	0.068
	India	0.118
	Singapore	0.42 (.)
gender (reference: Male)	Female	0.299 (**)

Variable	Values	β Coefficient (p-value)
age (reference: Below 30 years)	Between 30 and 50	-0.104
	Above 50	-0.006
education (reference: Bachelor's degree)	Less than high school	-0.249 (*)
	High school or equivalent	-0.193
permission (reference: Location)	Calendar	0.259
	Camera	0.011
	Contacts	0.258 (**)
	Microphone	0.606 (***)
	Phone	-0.093
	SMS	-0.265
	Storage	-0.379 (***)
runtime_expected (reference: Yes)	No	1.216 (***)
	Not surveyed	0.306 (***)

Random Effect	Variance
App (intercept)	1.889
User (intercept)	1.785

Significance codes:
 $p < 0.001$ (***)
 $p < 0.01$ (**)
 $p < 0.05$ (*)
 $p < 0.1$ (.)

Limitations

- **Selection Bias: Participants more likely to**
 - Respond to mobile advertising
 - Be tolerant to data collection by a mobile app
 - Be incentivised by financial rewards
- **Incomplete visibility:**
 - Can't see events for apps before study period, such as pre-installed or popular apps
 - Not enough data to analyze behaviors of individual apps

Conclusions

- Mobile advertising effective in recruiting participants
- Including rationales for permissions benefits the apps by reducing deny rate by more than half (7.1% vs 15.4%)
- Both install-time and runtime expectations affect users permission decisions
 - **this is true regardless of demographics and permission type**
- Participant demographics, their privacy attitudes, expectations, explanations and permission types all play a role in permission denial decision

Thank you!