The IAB-SMART Study:

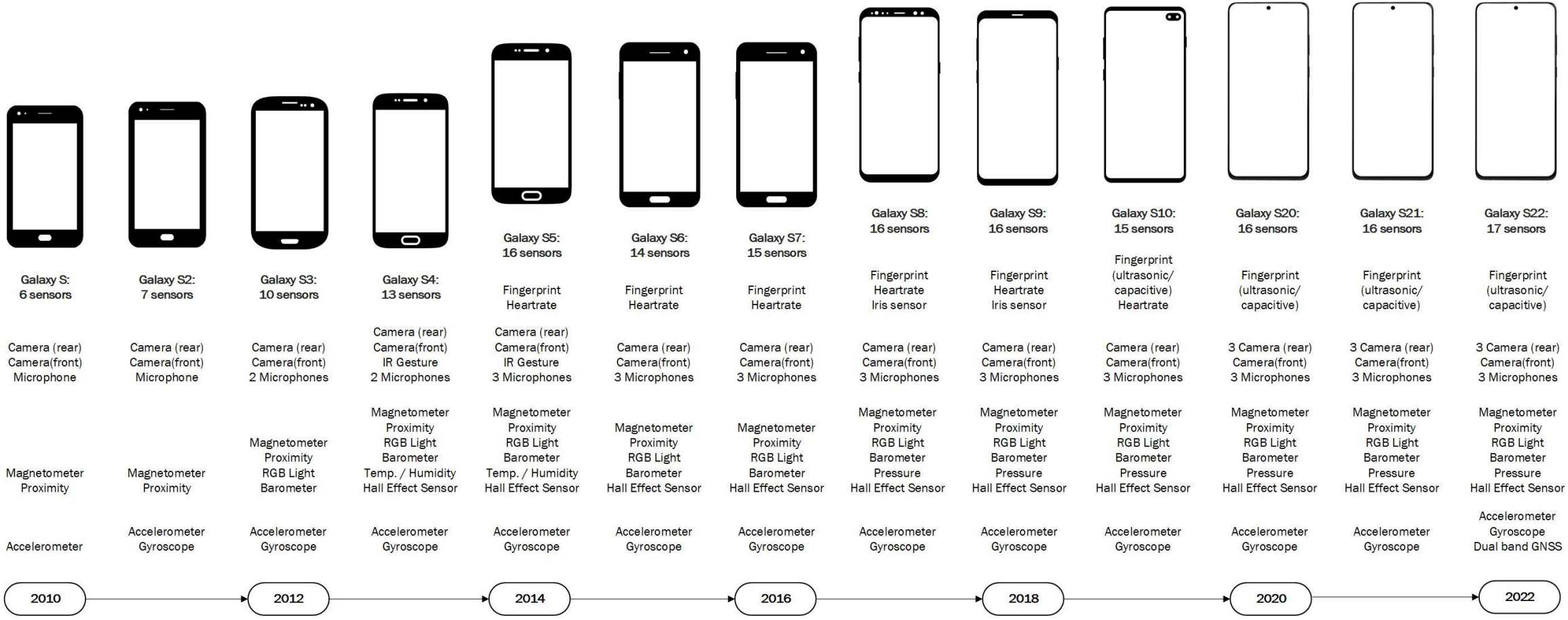
Collecting Behavioral Smartphone Sensor Data for Social Research

IAB-SMART Webinar Series, BERD Academy

June 28th 2023

Georg-Christoph Haas

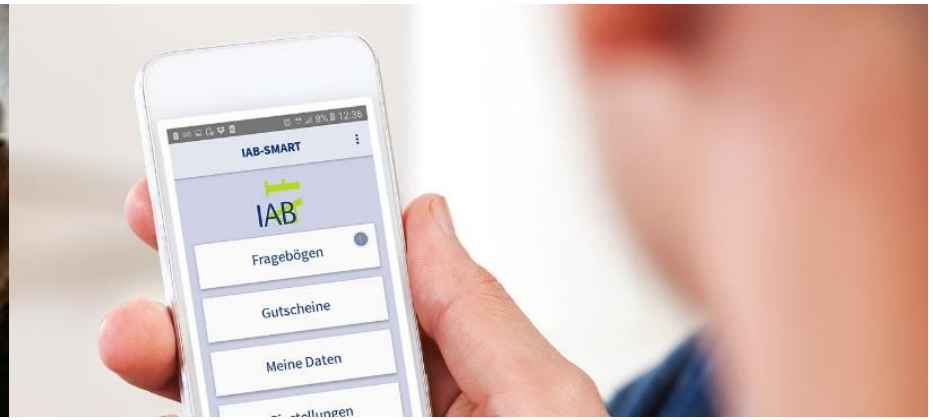
From 6 sensors in 2010 to 17 sensors in 2022



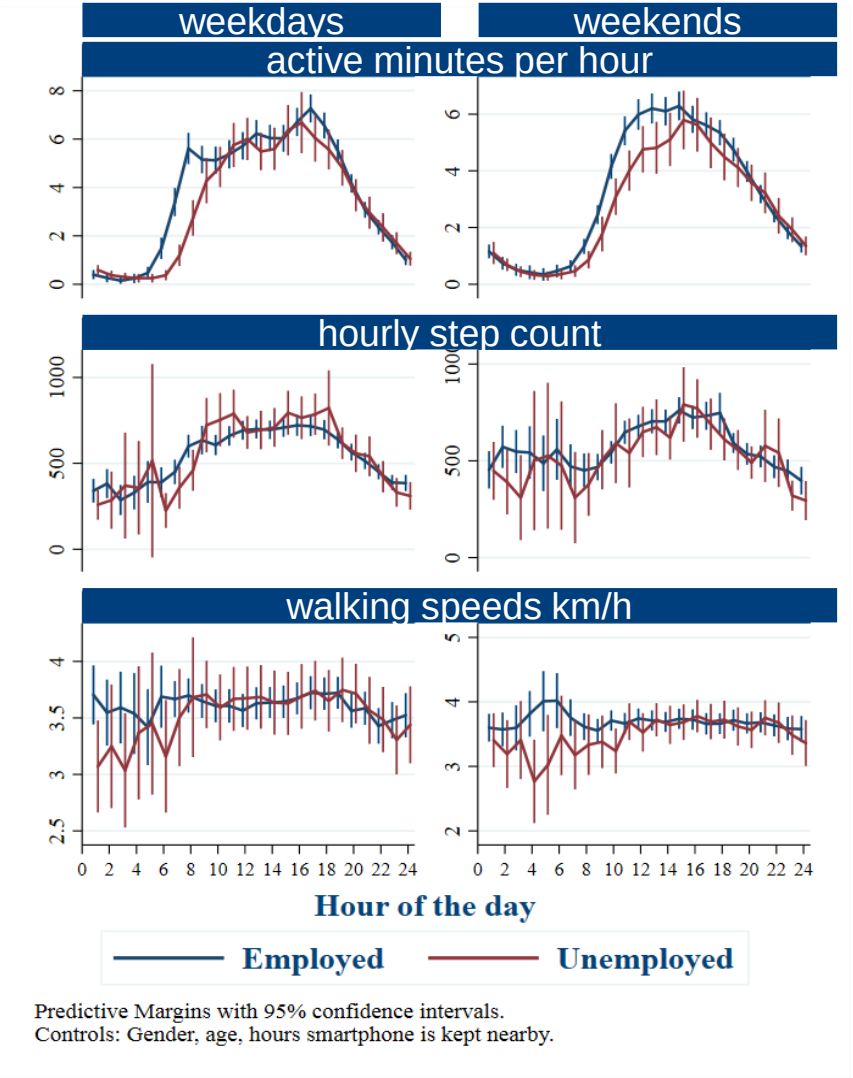
Source: Keusch, Florian, Bella Struminskaya, Stephanie Eckman, and Heidi Guyer. forthcoming. *Data Collection with Wearables, Apps, and Sensors. https://bookdown.org/wasbook_feedback/was/Intro1.html#WhyWAS1.3*

Unemployment research

1933 1980er Today



Loss of day structure

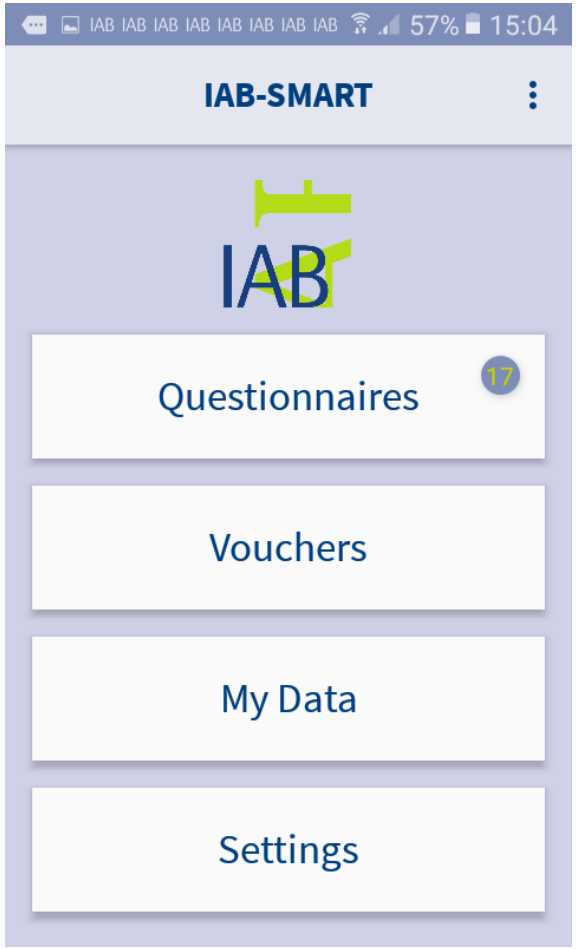


Predictive Margins with 95% confidence intervals.
Controls: Gender, age, hours smartphone is kept nearby.

- Over a range of indicators for activity we see only small differences between employed and unemployed
- Employed are more active in the mornings
- Differences are more pronounced at the weekdays
- No sign of different walking speeds between both groups

IAB-SMART App

- An app, that …
  - … launches surveys.
  - … passively collects smartphone data
- Collected data can be combined with…
  - … German panel data
  - … administrative data
- Over six months of data collection



Acknowledgement

The presentation presented here is result of a team effort with:

Sebastian Bähr, Florian Keusch, Mark Trapmann and Frauke Kreuter

Participants will learn…

About the IAB-SMART study.

How the recruitment process may be designed for a smartphone app study.

Which error sources may likely occur in smartphone app data collections.

Outline

- Recruitment
  - Invitation
  - Consent process
  - Incentives
- Error sources
  - Coverage Error
  - Nonparticipation Error
  - Measurement Error

Recruitment: Invitation

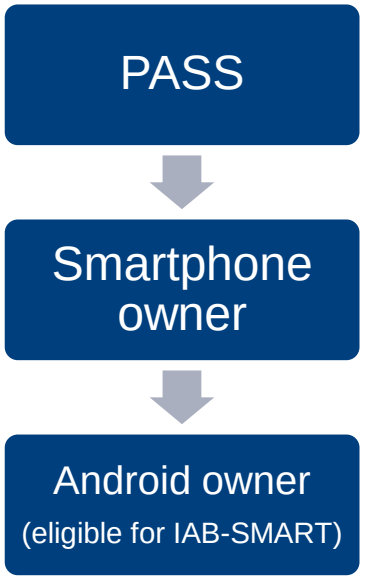
Kreuter, F.; Haas, G.-C.; Keusch, F.; Bähr, S.; Trappmann, M. (2020): Collecting survey and smartphone sensor data with an app: opportunities and challenges around privacy and informed consent. In: Social Science Computer Review, Vol. 38, No. 5, S. 533-549. https://doi.org/10.1177/0894439318816389

The PASS panel survey (Trappmann et al. 2013)

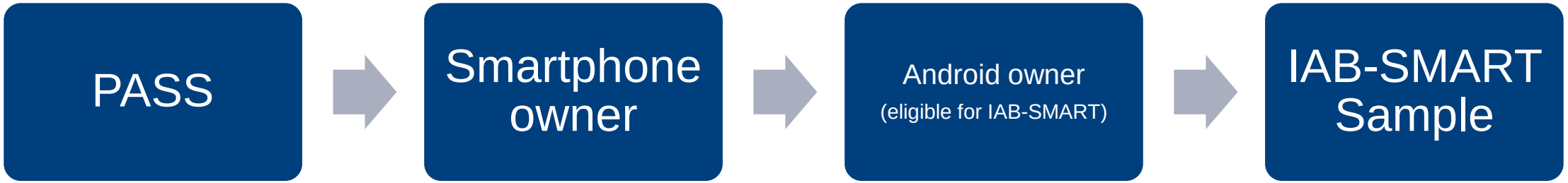
- Panel study ‘Labour Market and Social Security‘ (PASS)
  - Household panel survey by IAB
  - Major data source for research into unemployment & poverty
- Dual frame
  - Welfare recipients from national registers: Refreshed yearly by new entries
  - General population sample from municipal registers
- ~15.000 persons in ~10.000 households each year since 2007
- Sequential mixed-mode design: CAPI -> CATI
- Main topics include: Labor market participation, job search, benefit receipt, active labor market programs, social inclusion, health, income, deprivation

Sample

- Sampling from PASS panel participants (aged 18-64)
  - Wave 11, 2017:
  - Do you own a smartphone?: **83.9% YES**
  - Which operating system do you use? **70.3% use Android**
- Limited to smartphone owners with Android operating system
- Passive access to sensor data only possible with Android
- Benefits using PASS
  - Higher willingness for cooperation
  - Evaluation and separation of coverage-, nonresponse-, and measurement error



Sample


PASS
Smartphone owner
Android owner
(eligible for IAB-SMART)
IAB-SMART Sample

Communication with participants

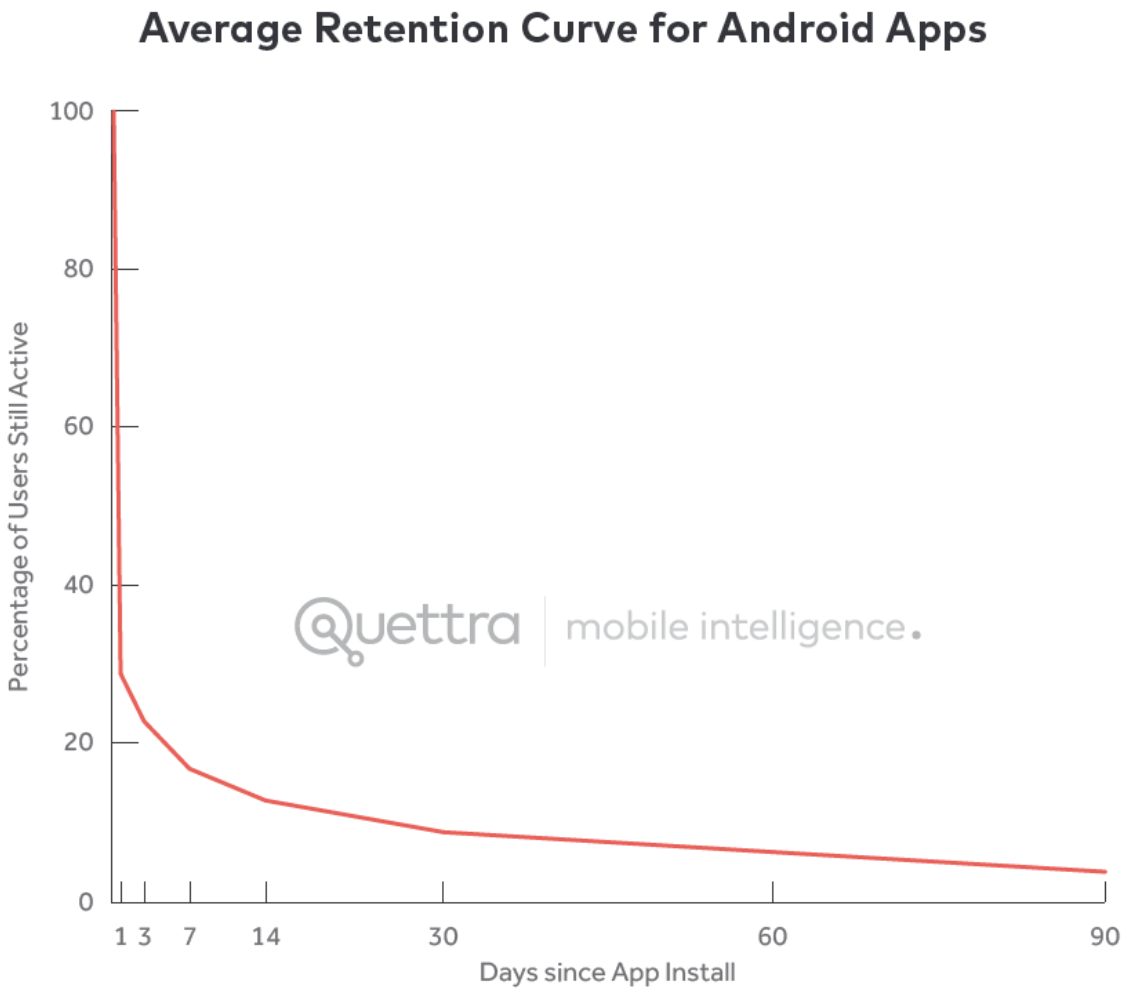
- Cover letter
  - Invitation letter
  - Data protection sheet
  - Voucher flyer
  - Function flyer
  - Installation booklet
- Website with information (www.iab.de/smart)
  - Frequently asked questions
- E-mail
- Hotline

Cover of the installation booklet

Field

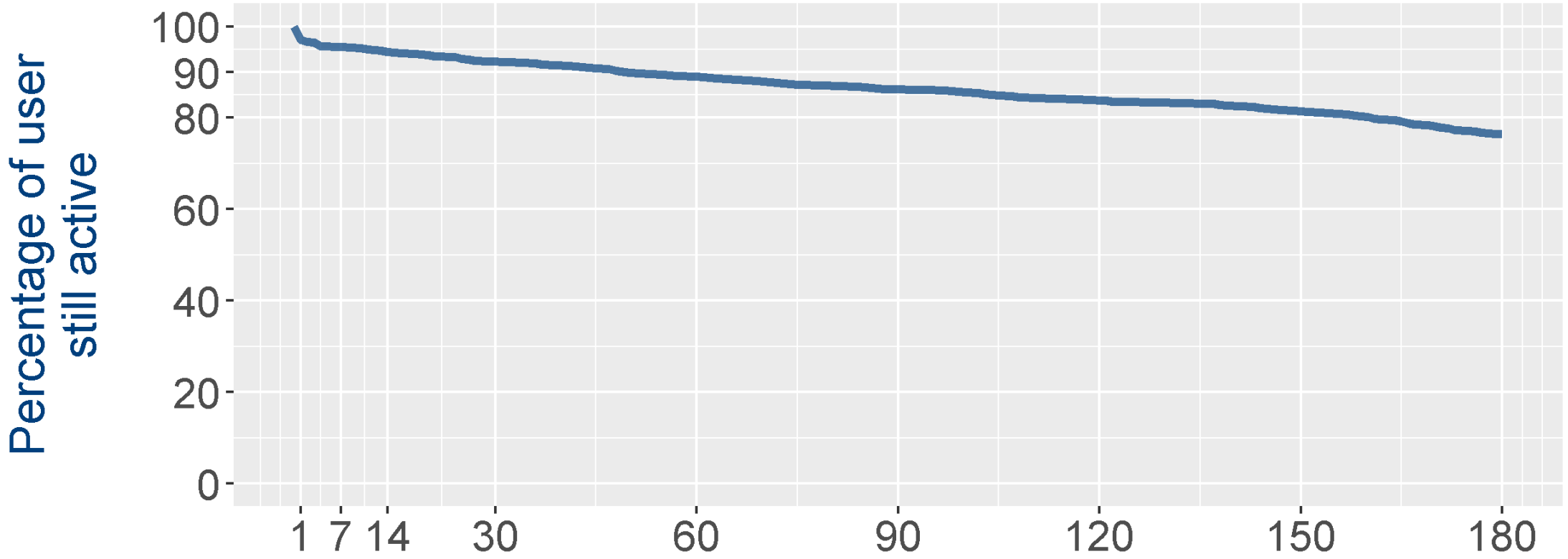
- Planned data collection: 6 months (180 days)
- Invitation: January 8th 2018 (4,293 Android smartphone owner)
- End of data collection: September 1st 2018
- 687 (16.7%) installed app

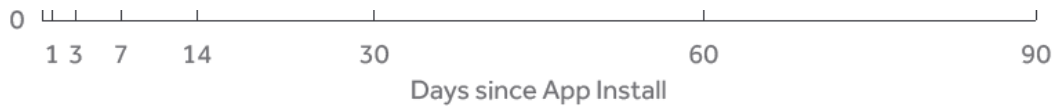
Retention



Source: http://andrewchen.com/wp-content/uploads/2015/06/retention_graph_average.png

Retention





Source: http://andrewchen.com/wp-content/uploads/2015/06/retention_graph_average.png

Consent process

Kreuter, F.; Haas, G.-C.; Keusch, F.; Bähr, S.; Trappmann, M. (2020): Collecting survey and smartphone sensor data with an app: opportunities and challenges around privacy and informed consent. In: Social Science Computer Review, Vol. 38, No. 5, S. 533-549. https://doi.org/10.1177/0894439318816389

Consent requests to data linkage and collection

- Linkage of app and panel data
- General data processing
- Five passive data collection functions
- Linkage of app and administrative data

- GDPR Principles (Article 7, recitals 32, 33)

(1) Demonstrate consent: who, when, what, and how.

(2) Emphasis requirement: distinguish consent from other subject matter

(3) Withdrawal: revocation of consent must be as simple as consent itself

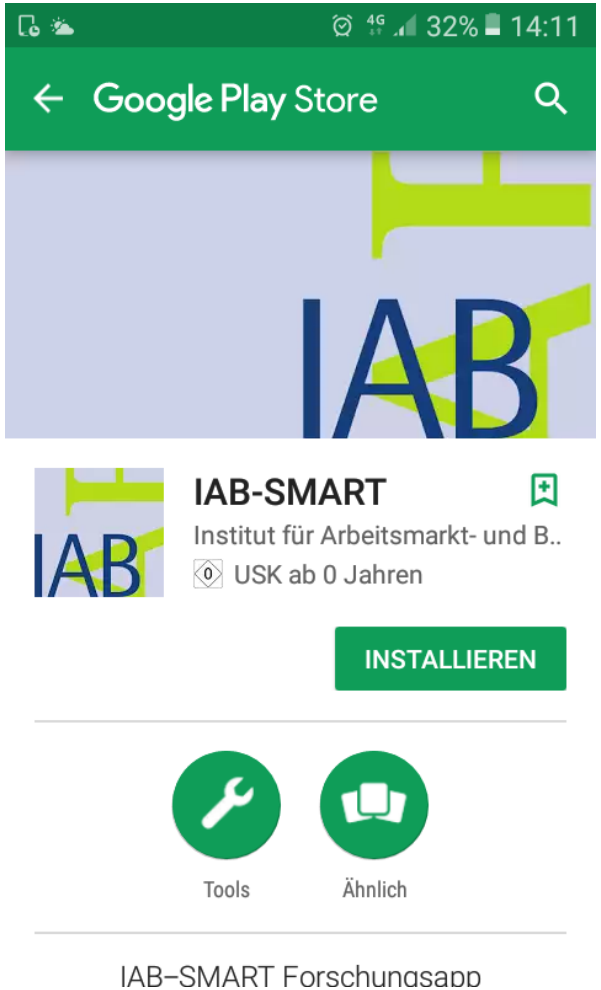
(4) Transparency: use clear and simple language

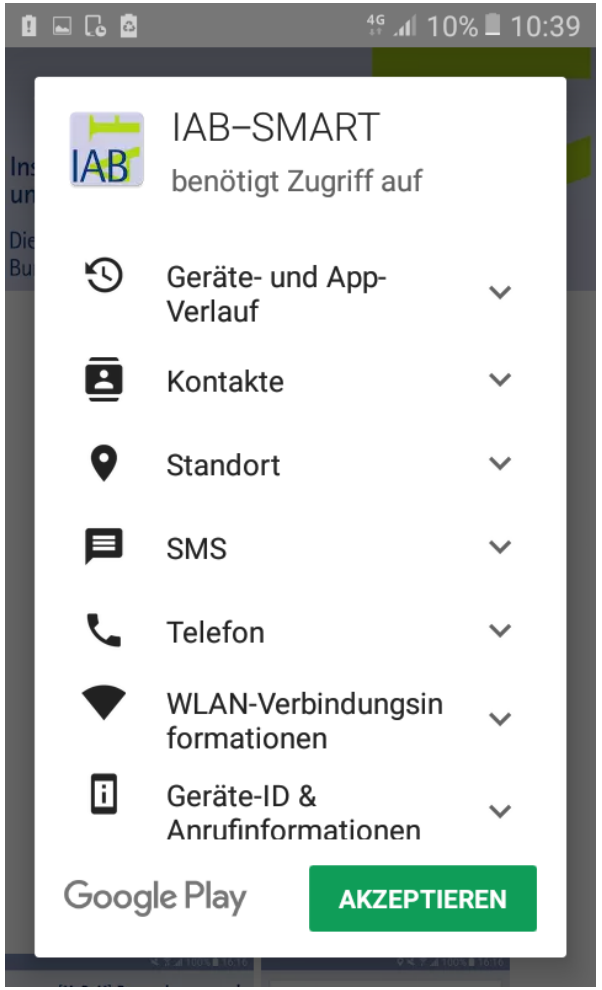
(5) Opt-in: consent must be active

(6) Purpose: data should only be collected for a specific purpose; multiple purposes = multiple requests

(7) Broad consent: consent can be transferred to similar purposes

Onboarding


32% 14:11
Google Play Store
IAB
IAB-SMART
Institut für Arbeitsmarkt- und B..
USK ab 0 Jahren
INSTALLIEREN
Tools
Ähnlich
IAB–SMART Forschungsapp


10% 10:39
IAB–SMART
benötigt Zugriff auf
Geräte- und App-Verlauf
Kontakte
Standort
SMS
Telefon
WLAN-Verbindungsinformationen
Geräte-ID & Anrufinformationen
Google Play
AKZEPTIEREN


30% 14:23
IAB
IAB-SMART
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USK ab 0 Jahren
DEINSTALLIEREN
ÖFFNEN
Tools
Ähnlich
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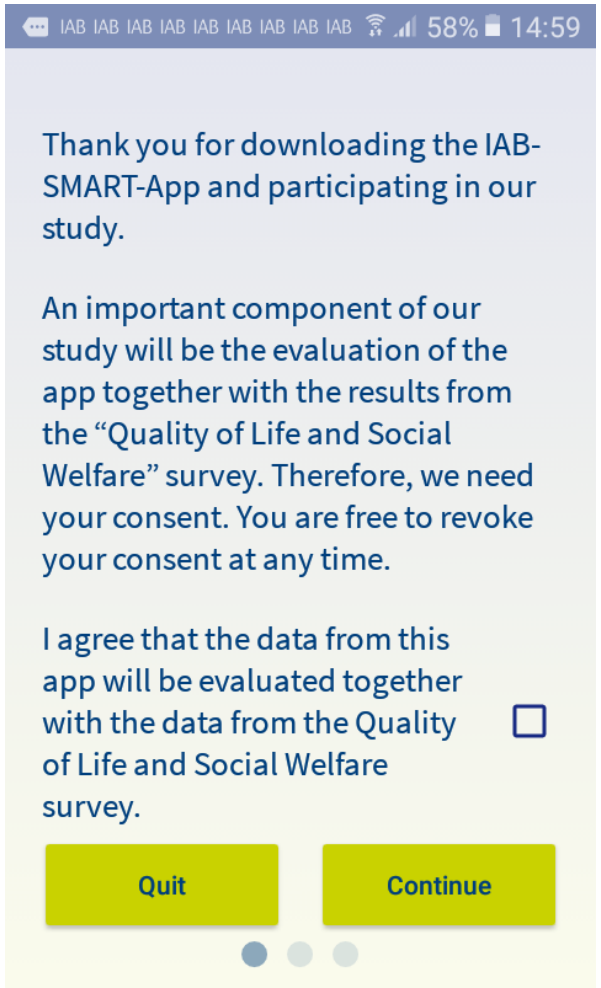
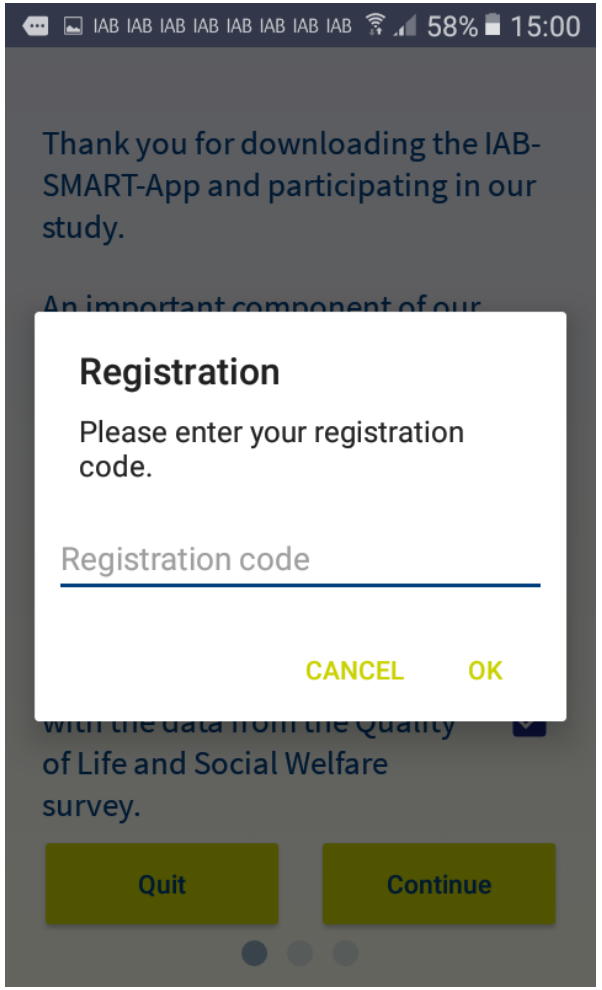
WEITERLESEN

Onboarding

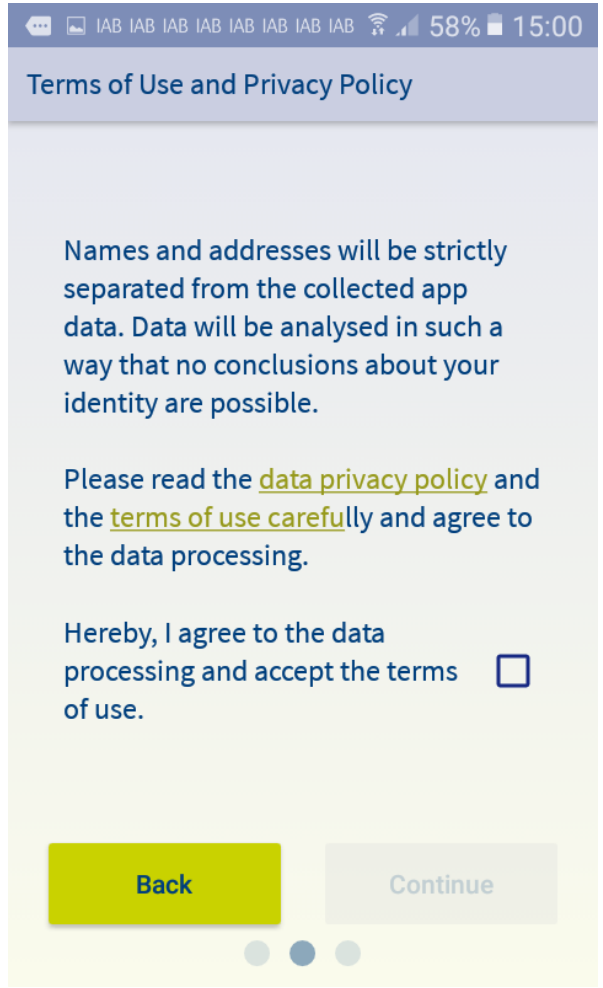
Linkage of app and panel data



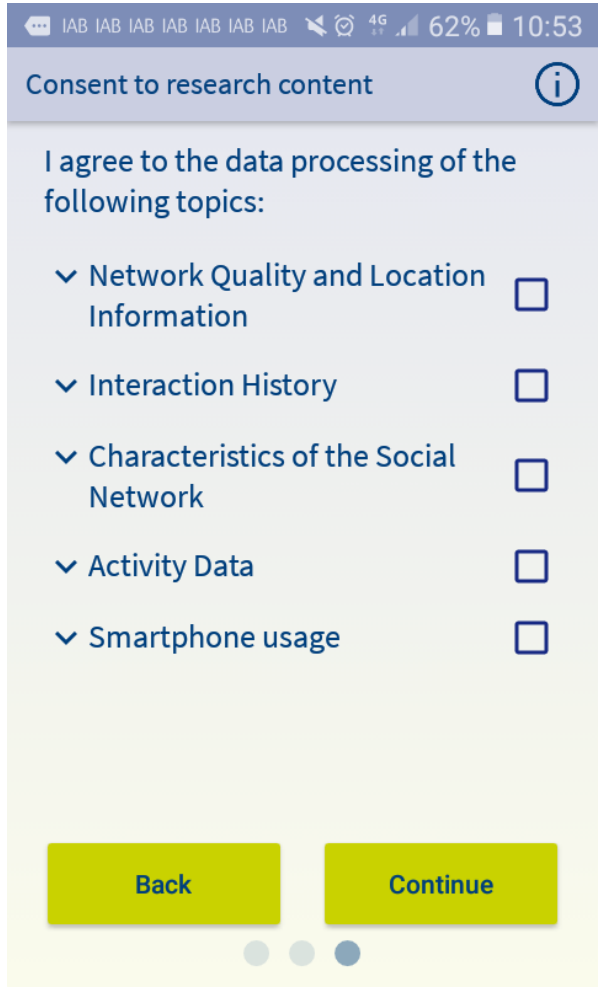
Registration



General data processing

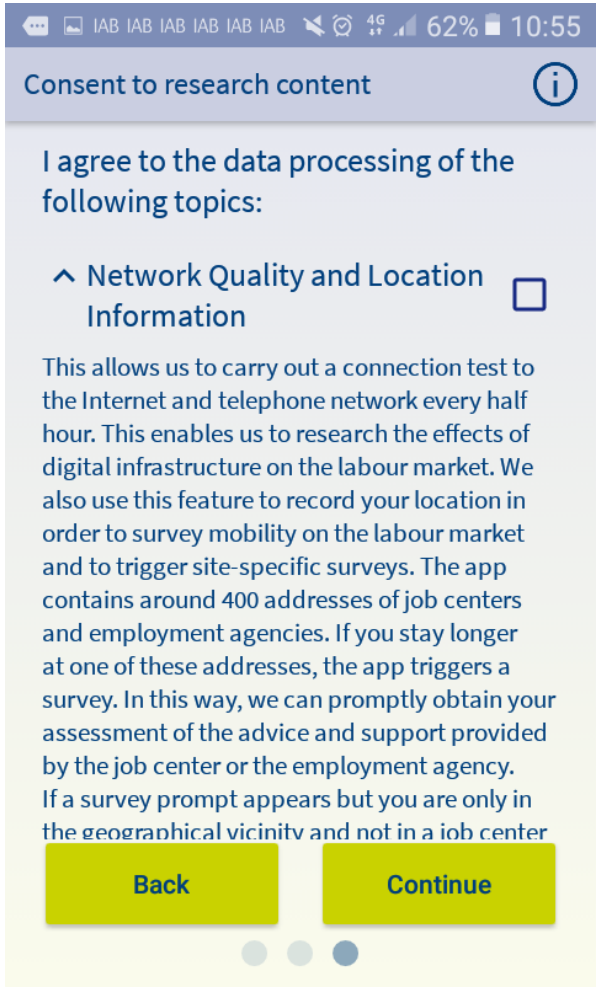


Asking for Consent



- Network quality and location information (every half hour)
- Interaction history
- Characteristics of the social network
- Activity data (every two minutes)
- Smartphone usage

Asking for Consent



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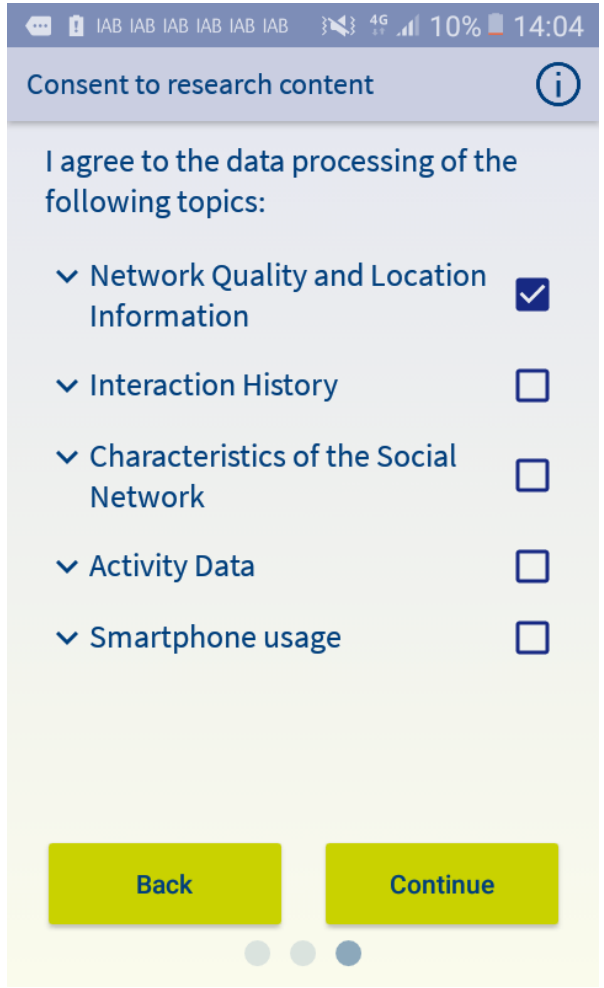

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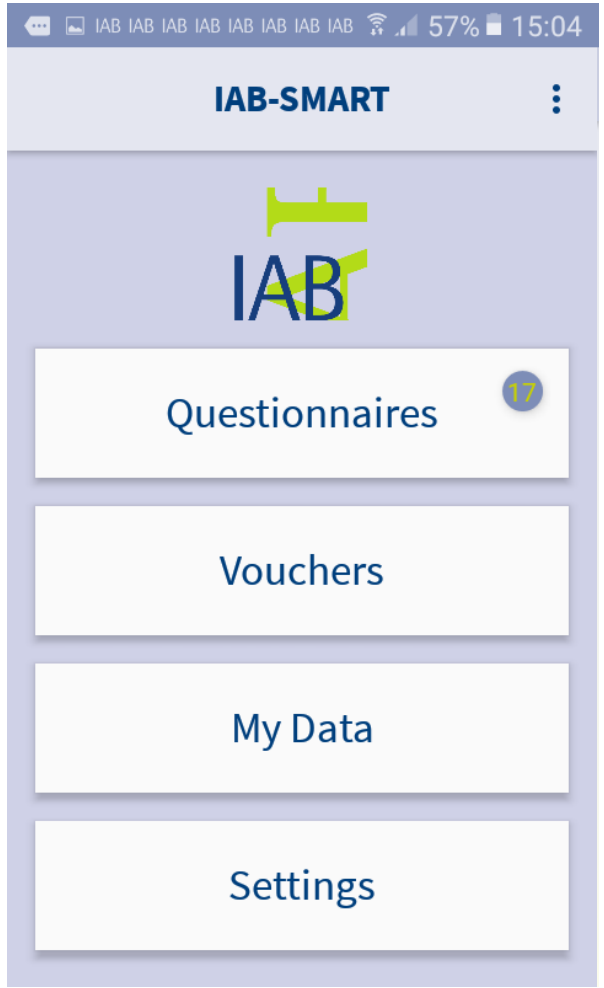

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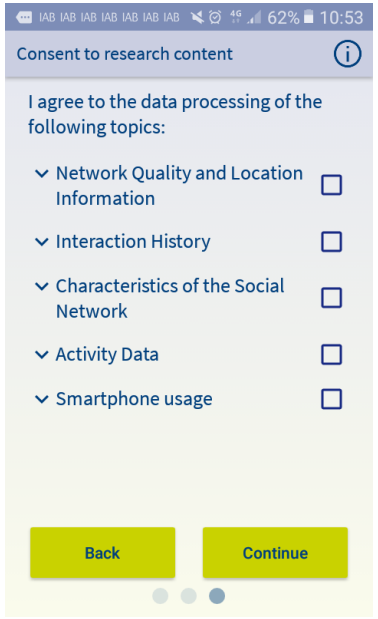
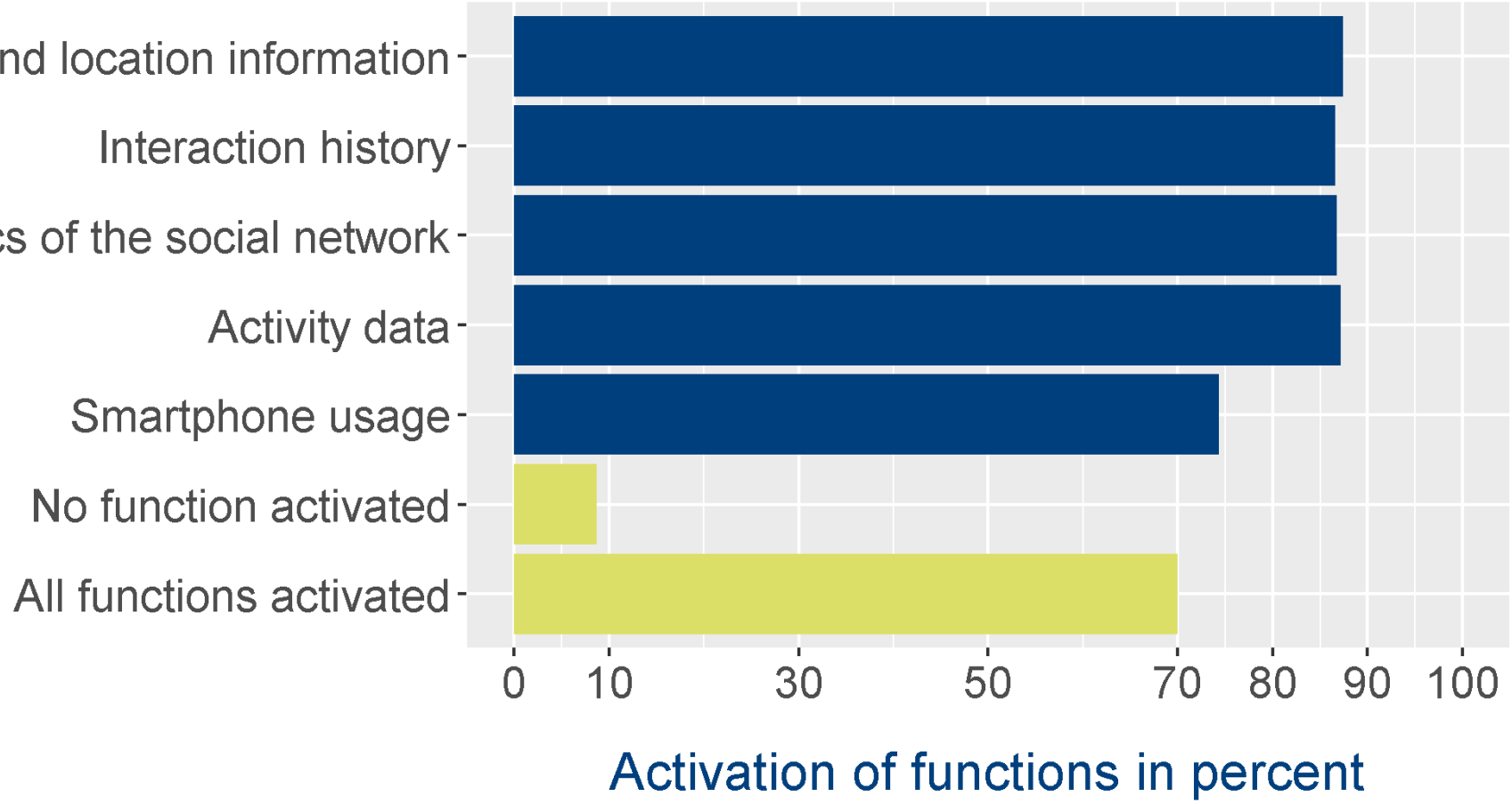
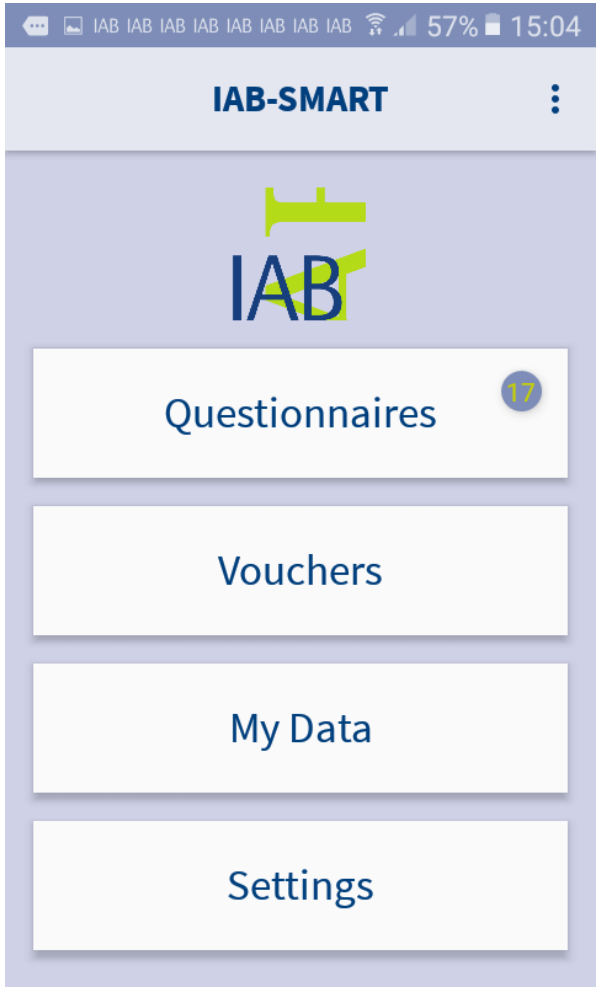
Which functions get activated?





Withdrawing consent



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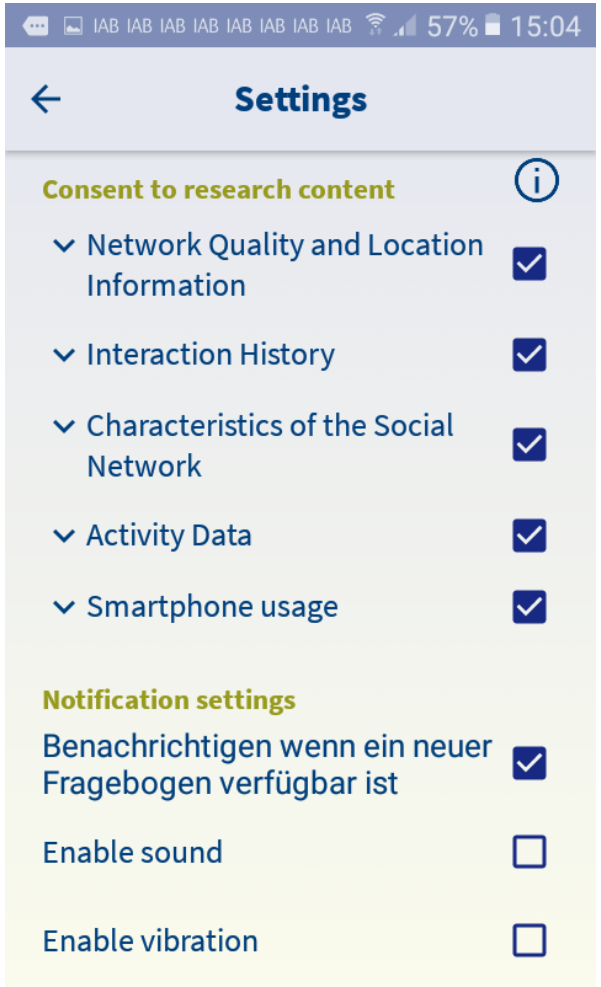

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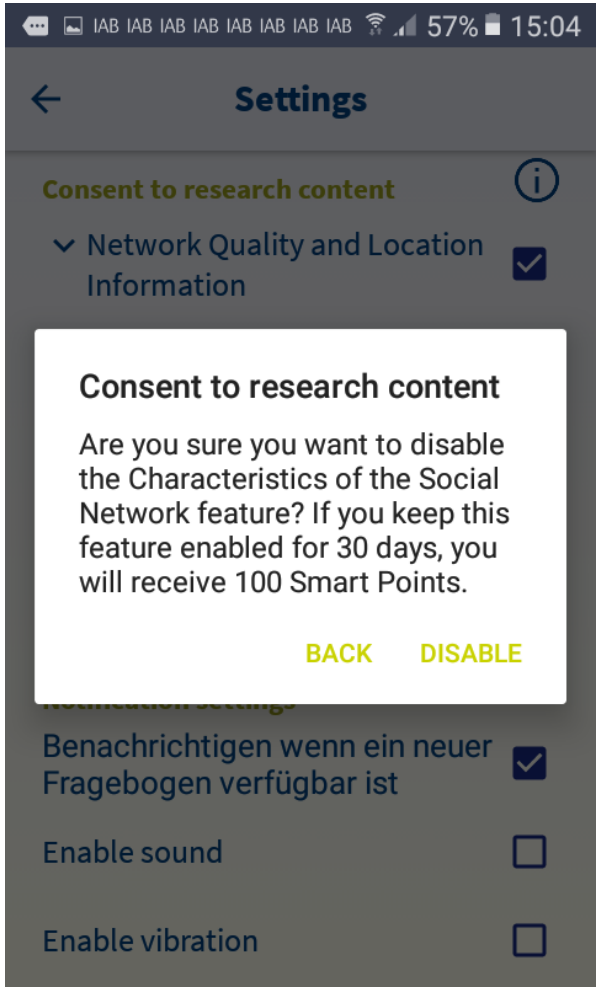

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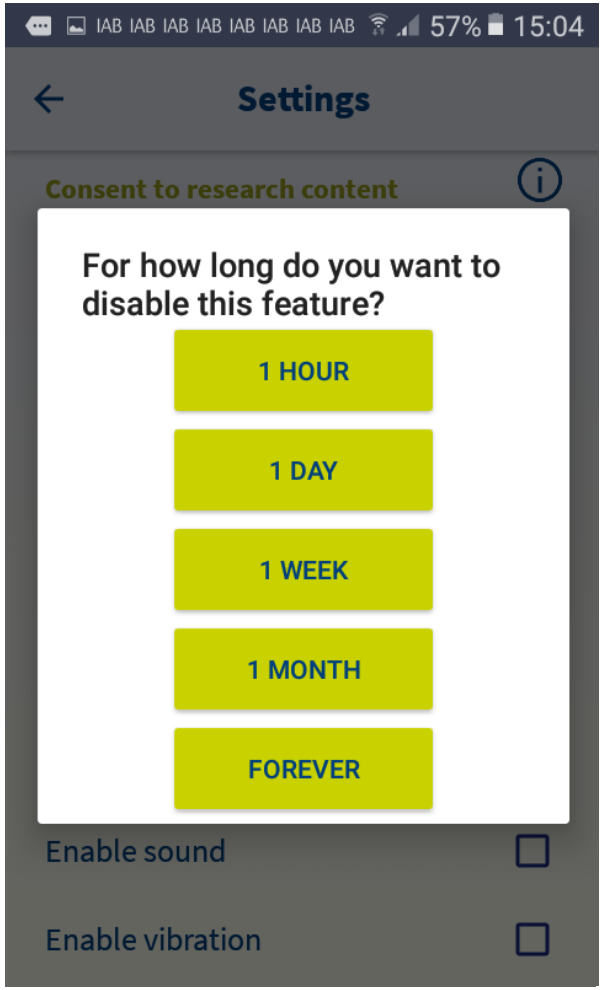

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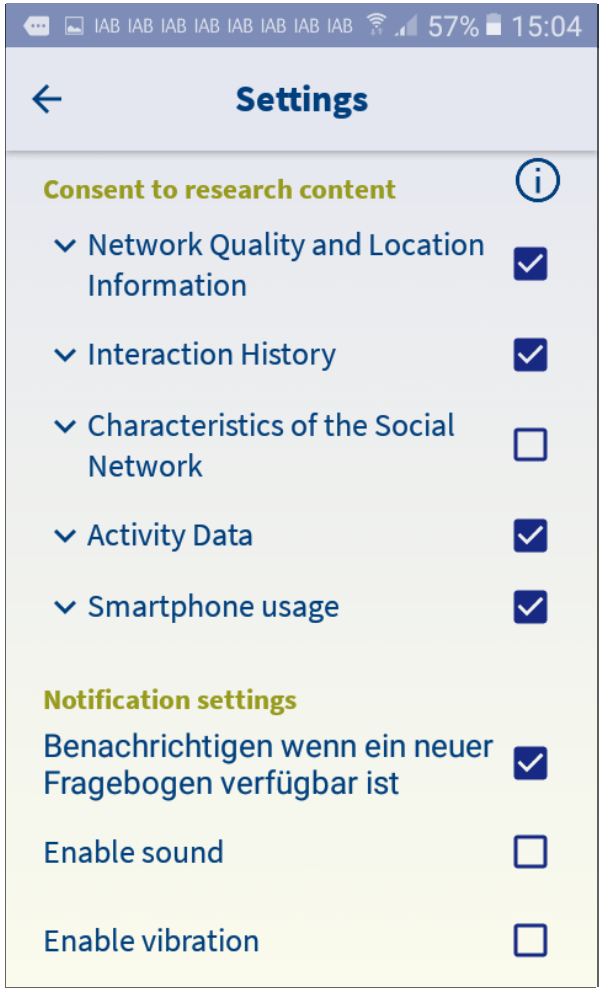

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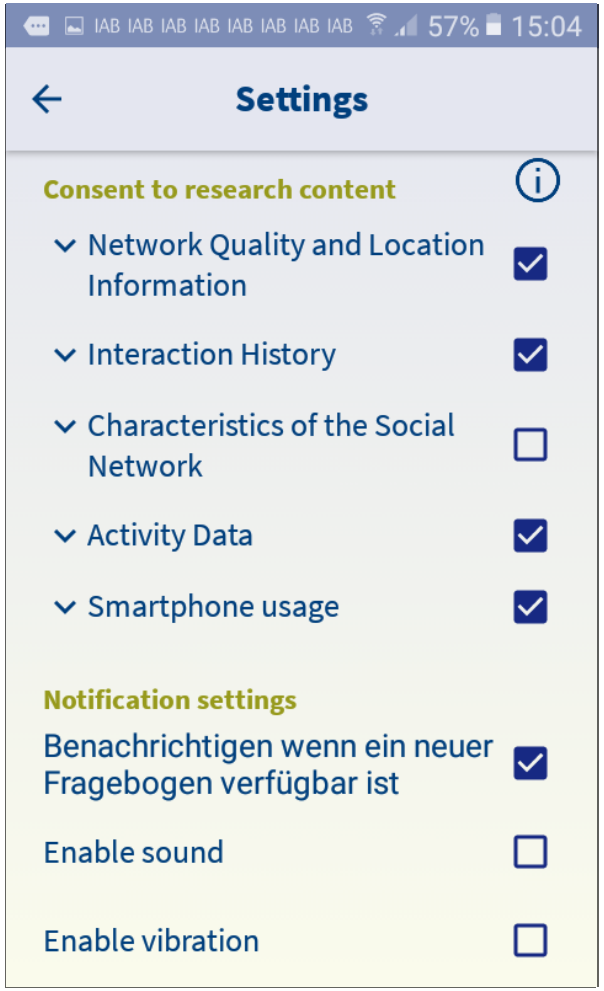

Overall, 129 (18.8%) individuals have made 590 changes

- 201 deactivations
- 389 activations

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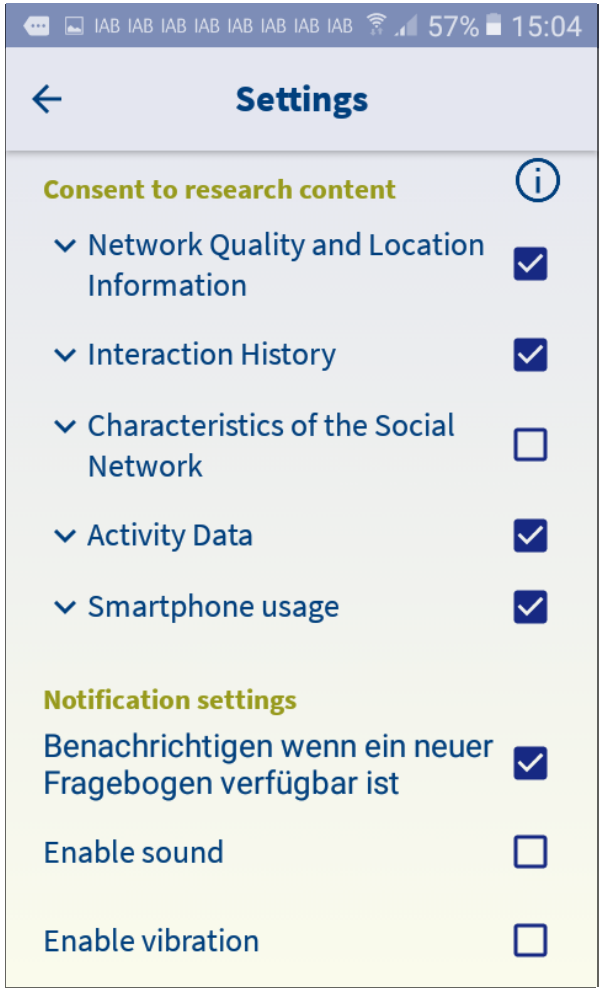

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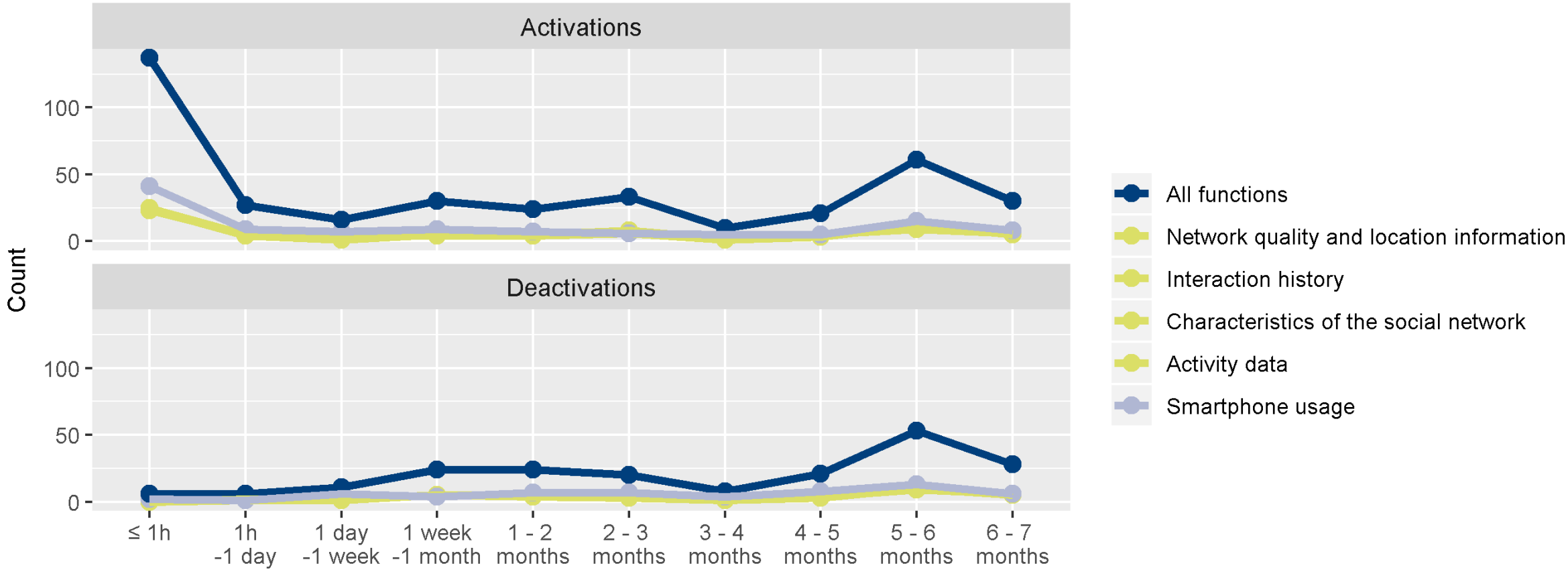
Fun fact: 1 person made 169 changes

Number of function (de-)activations within settings

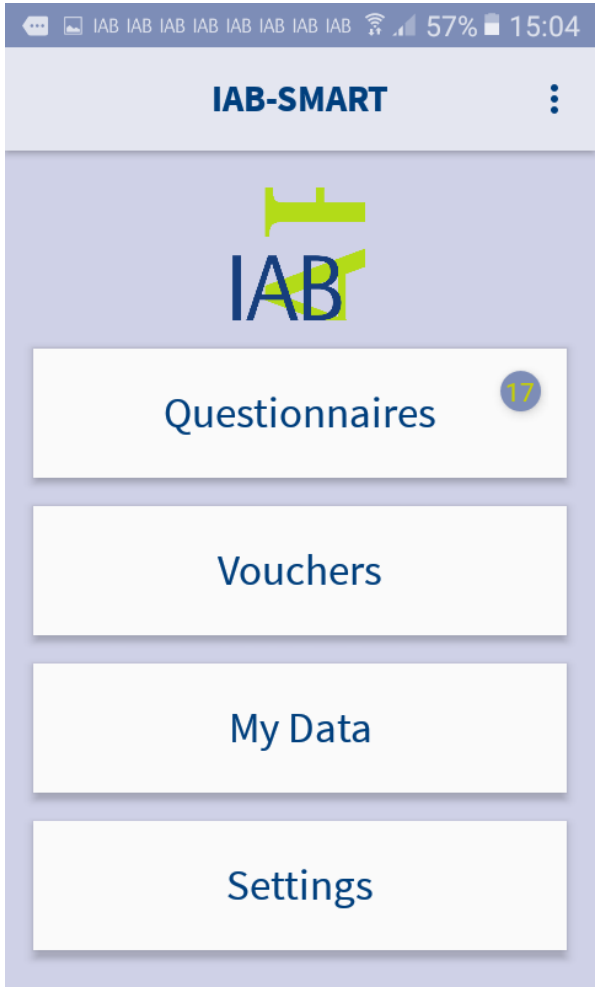


Incentives

Haas, G.-C.; Kreuter, F.; Keusch, F.; Trappmann, M.; Bähr, S. (2020): Effects of incentives in smartphone data collection. In: C. A. Hill et al. (Hrsg.), Big Data Meets Survey Science: A Collection of Innovative Methods, S. 387-414. https://doi.org/10.1002/9781118976357.ch13

Incentives: SMART-Points

- 100 points = 1 Euro
- Points can be converted into 5 or 10 Euro amazon.de vouchers
- How to collect points?
  - Installing the app (1000/2000 points)
  - Activating functions (100 points per function/ 100 points per function + 500 points if all functions are activated)
  - Answering survey questions (10 points per question)



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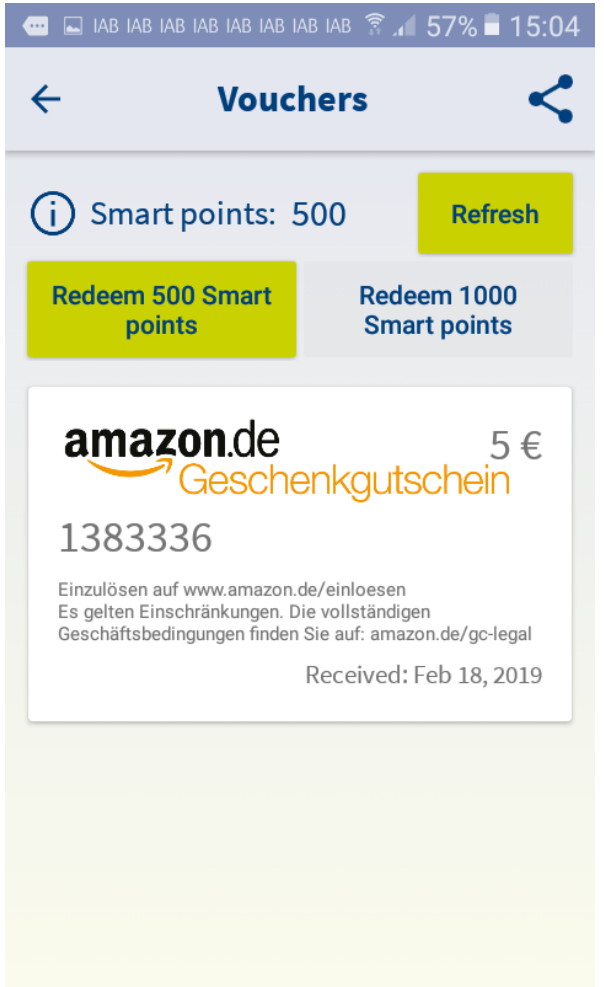
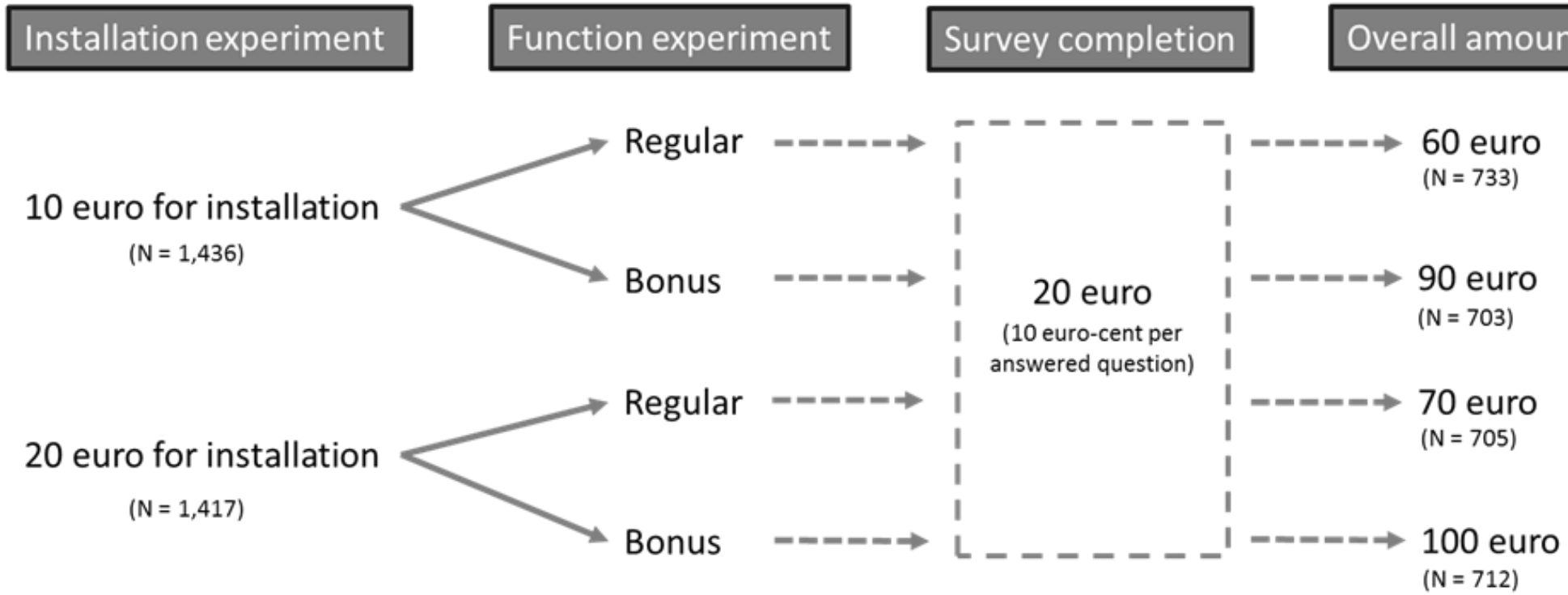
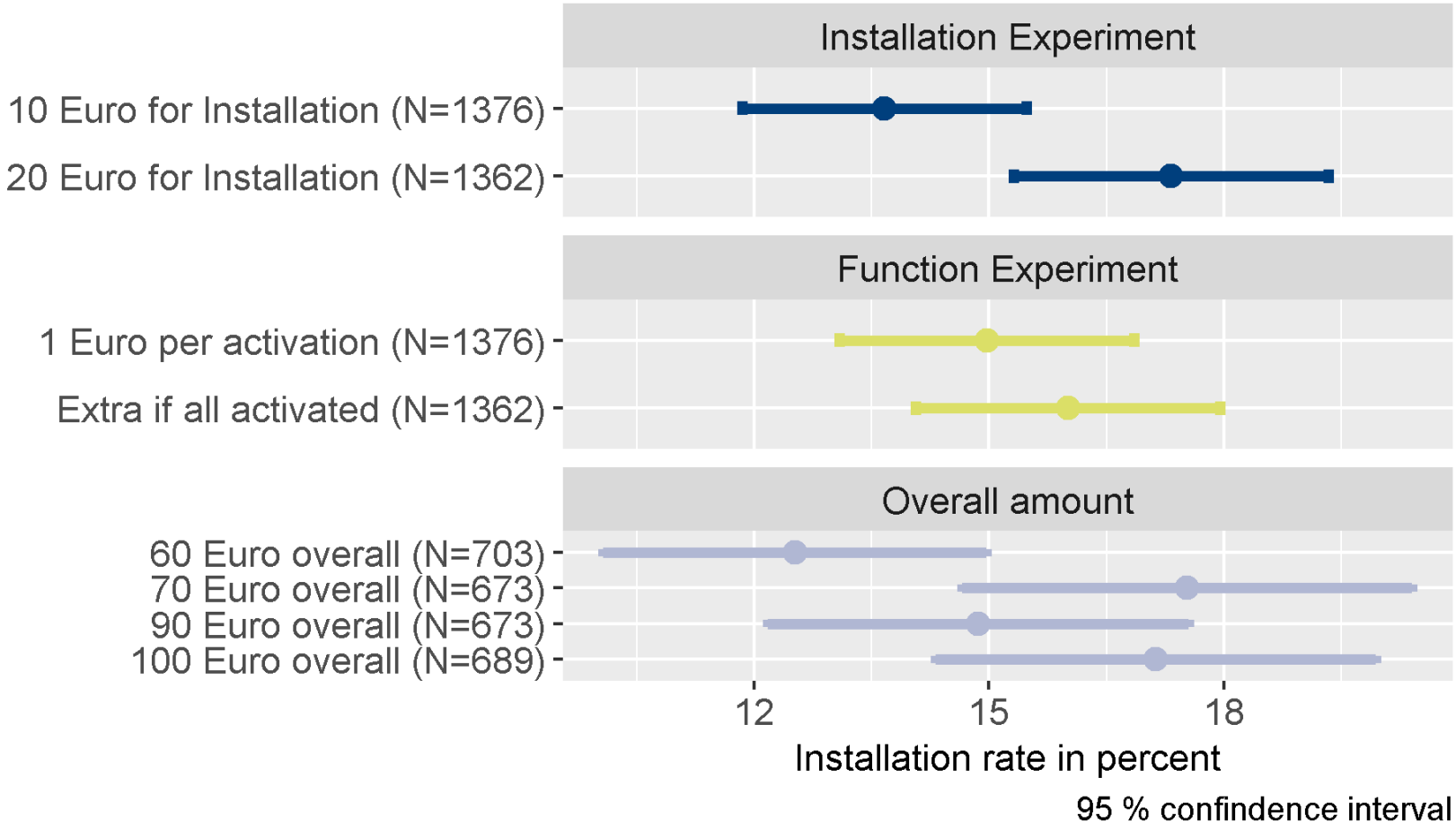


Experimental Factors



Effect on installation rate



We find no further effects of incentives

- No effects on
  - Mean number of initially activated functions
  - Deactivating functions
  - Retention
  - Average percent of points redeemed by participants

- No difference between vulnerable and non-vulnerable groups

Incentive strategy may lead to a forced participation

- Incentive strategy may lead to a forced participation because the incentive is too high.
  - Could not be evaluated upfront but in project

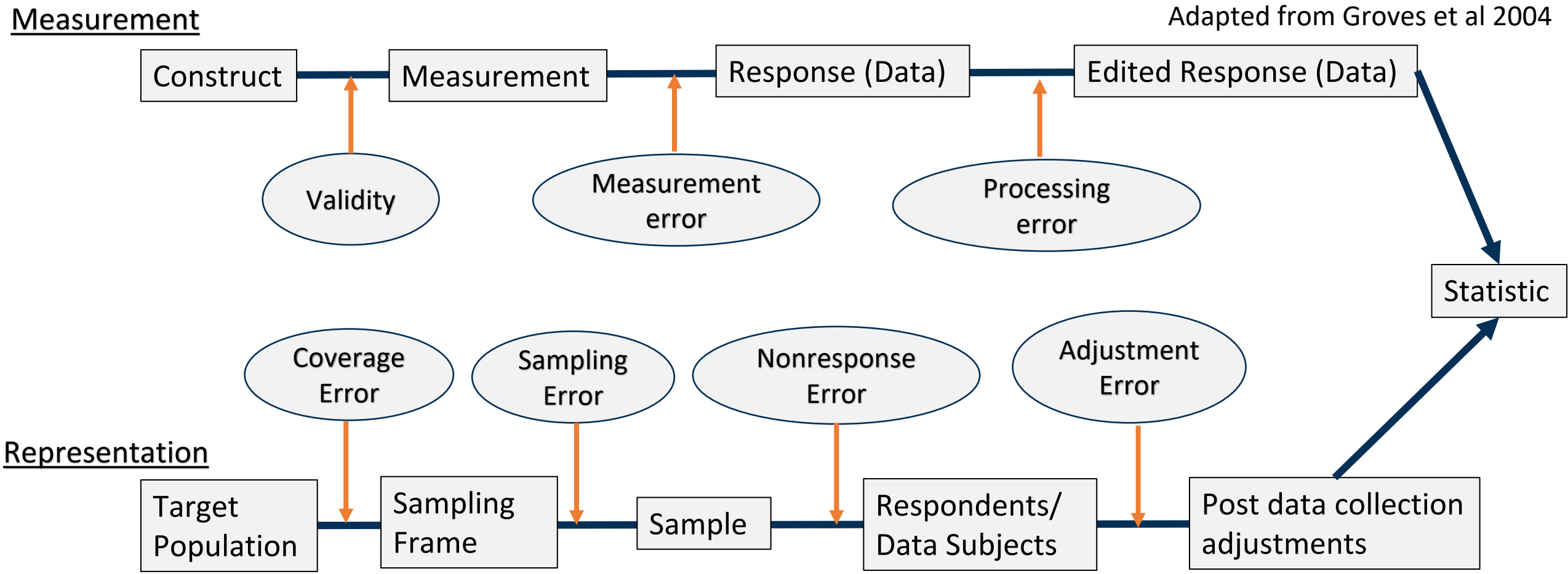
  Hypothesis:

  - If incentives force vulnerable groups to participation, we should see a higher participation rate for vulnerable than for non-vulnerable groups.
  - Comparison: Welfare recipients vs Non-welfare recipients (no difference found)
  - No effects found does not mean that nobody felt forced to participate

Conclusion Recruitment

- If possible, recruit from an already existing project.
  - A trusting relationship is already established
  - You are able to evaluate different error sources
- Using ethical or legal guidelines to design your recruitment
  - Think of it as an asset not as an obstacle
  - The IAB-SMART project used GDPR guidelines
  - There are other ethical guidelines, that may fell more intuitive (e.g., Belmont Report 1979, AAPOR Code of Professional Ethics and Practices 2021)
- Bonus incentive does is not effective
  - Continuous incentives during the field period are probably good idea

Error Sources

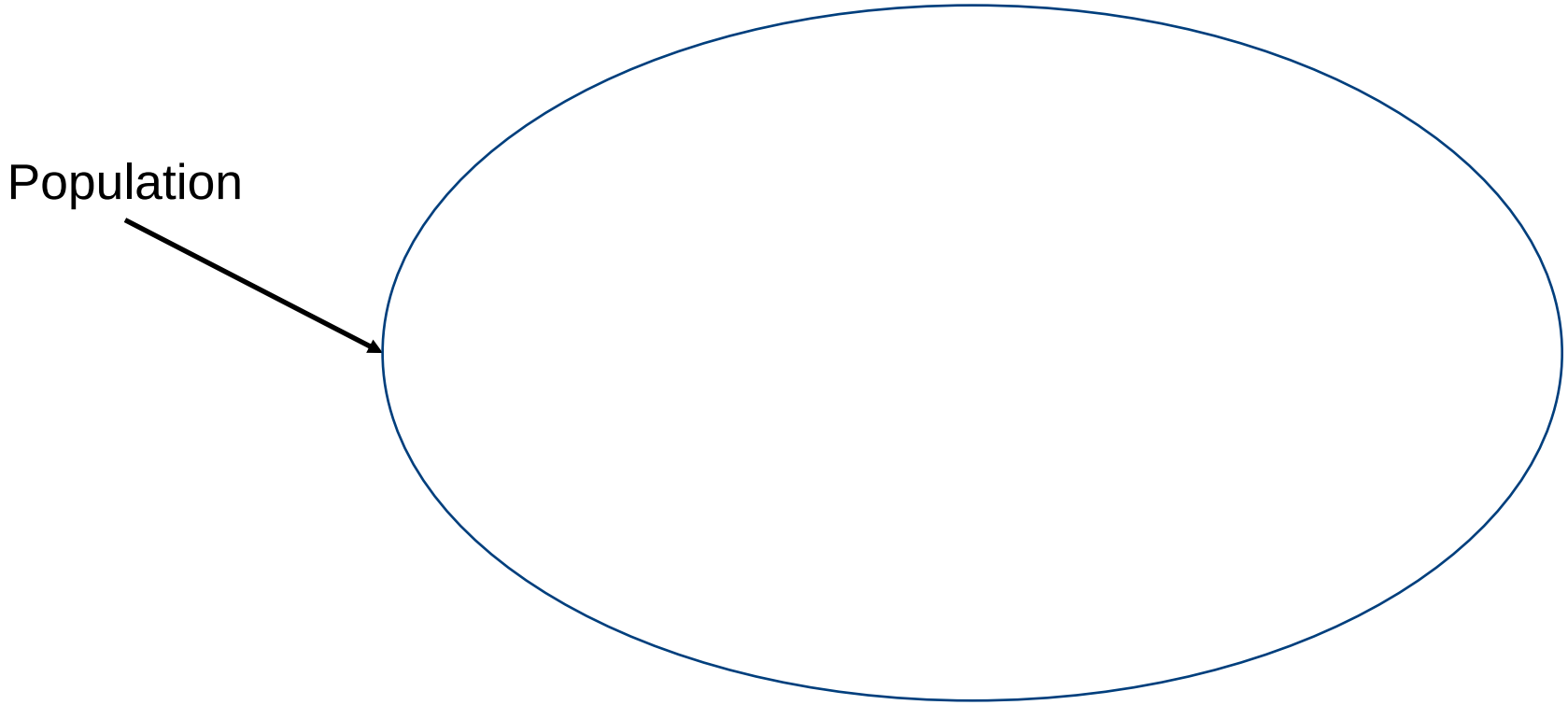

Measurement
Adapted from Groves et al 2004
Construct
Measurement
Response (Data)
Edited Response (Data)
Validity
Measurement error
Processing error
Statistic
Coverage Error
Sampling Error
Nonresponse Error
Adjustment Error
Representation
Target Population
Sampling Frame
Sample
Respondents/ Data Subjects
Post data collection adjustments

Coverage Error

*Keusch, F.; Bähr, S.; Haas, G.-C.; Kreuter, F.; Trappmann, M. (2020): Coverage error in data collection combining mobile surveys with passive measurement using apps * data from a German national survey. In: Sociological Methods & Research, online first, S. 1-38. https://doi.org/10.1177/0049124120914924*

Downloading a Research App Requires…

- …owning a (specific) smartphone



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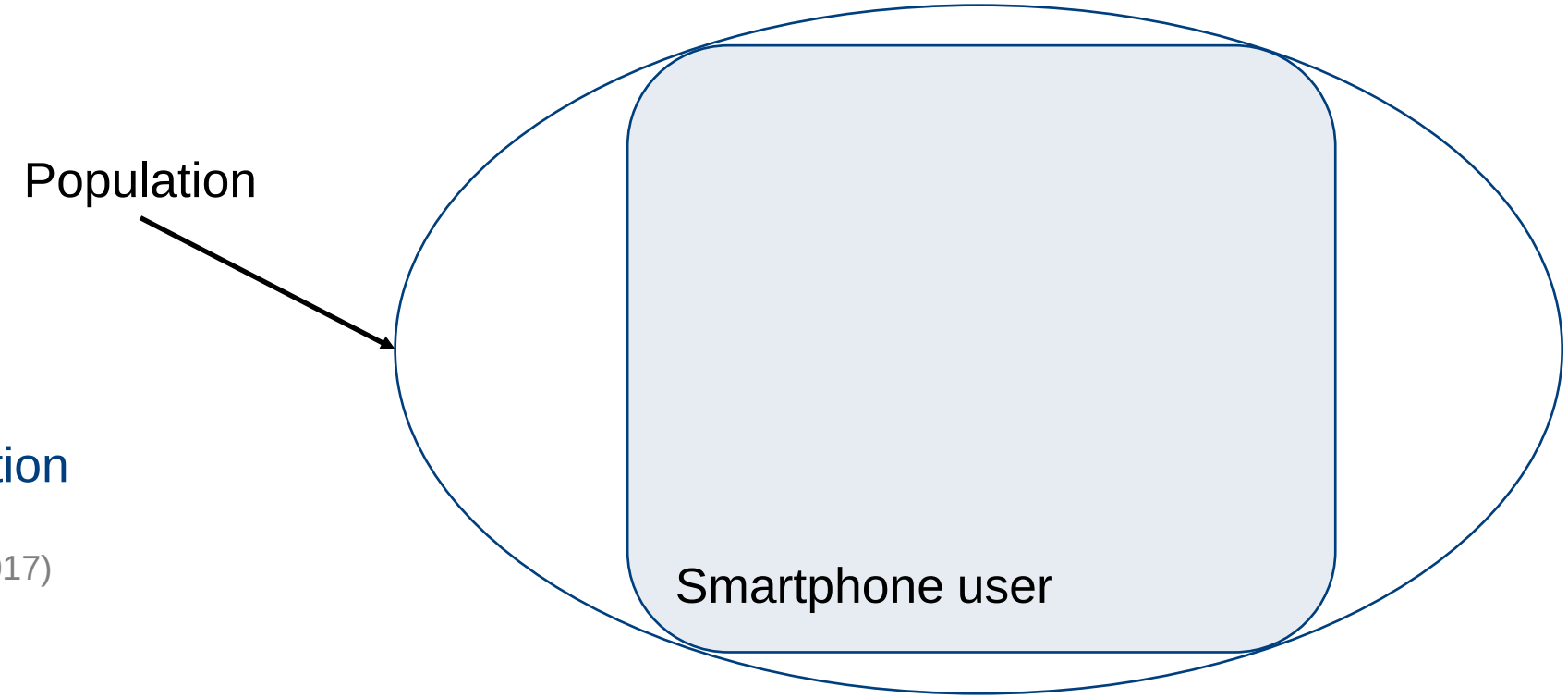

Smartphone penetration

- US: 77%
  (Pew Research Center 2017)
- GER: 73%
  (Eurostat 2018)

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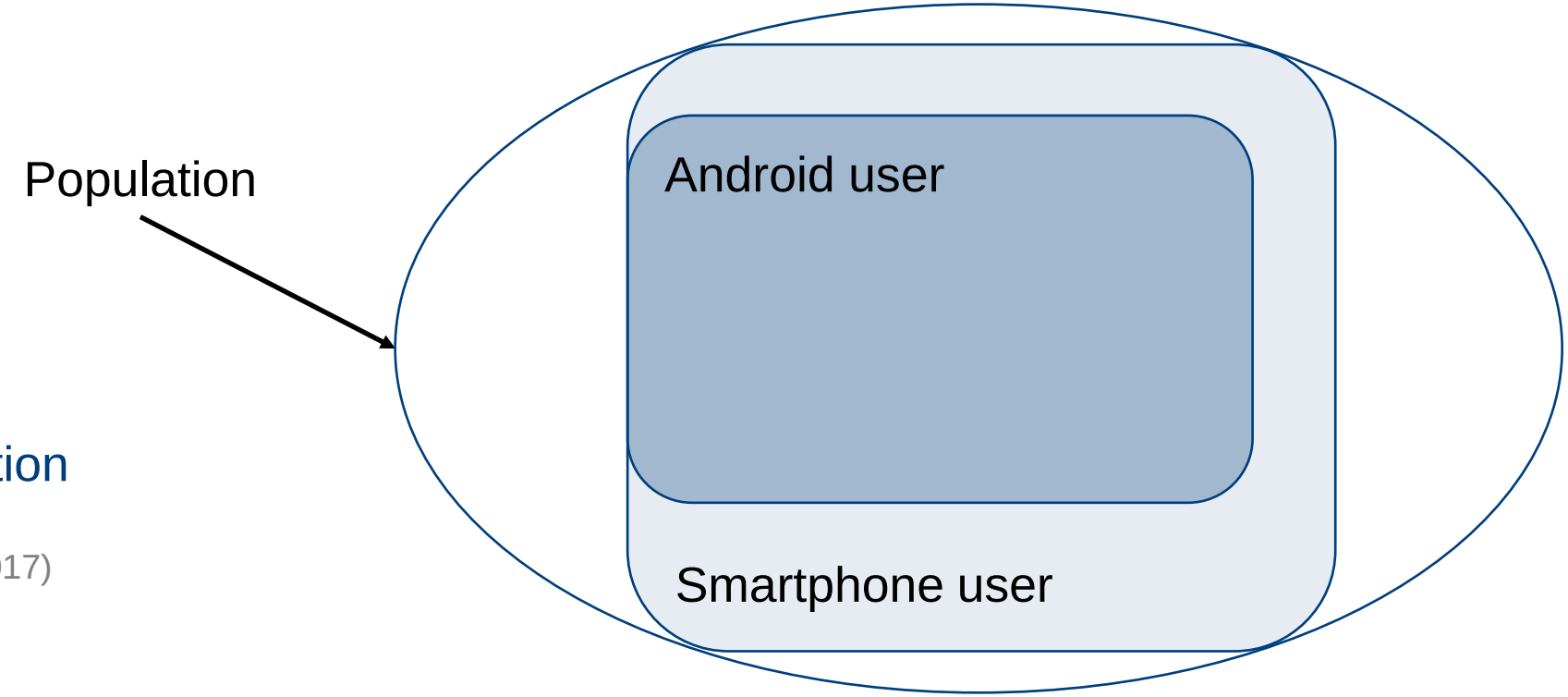

Smartphone penetration

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  (Pew Research Center 2017)
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  (Eurostat 2018)

Coverage Error in IAB-SMART

- 75.8% of German residents age 15+ own smartphone
  - 49.0% Android
  - 16.7% iOS
  - 5.4% Windows
  - 0.7% something else

Estimates based on weighted PASS data for Wave 11; unweighted n = 13,703

Coverage Error in IAB-SMART

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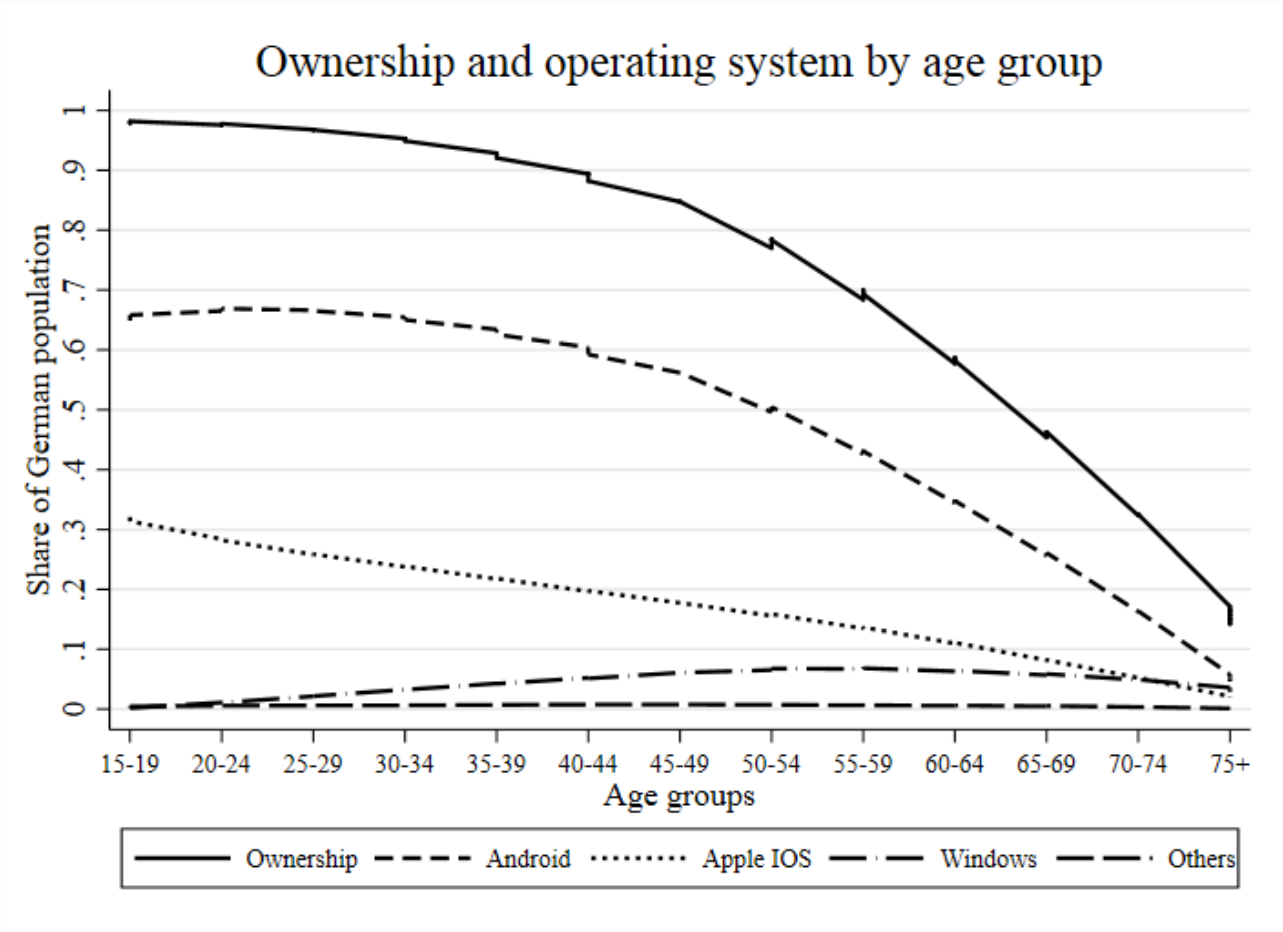

Estimates based on weighted PASS data for Wave 11; unweighted n = 13,703

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- Smartphone ownership also correlates with educational attainment, immigrant status, region, & community size

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- Absolute bias in many substantive measures of PASS for smartphone ownership relatively small (<6 p.p.), especially once limiting population to people <67 years (<2 p.p.)

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- Bias produced by Android smartphone coverage generally not much higher than general smartphone coverage bias

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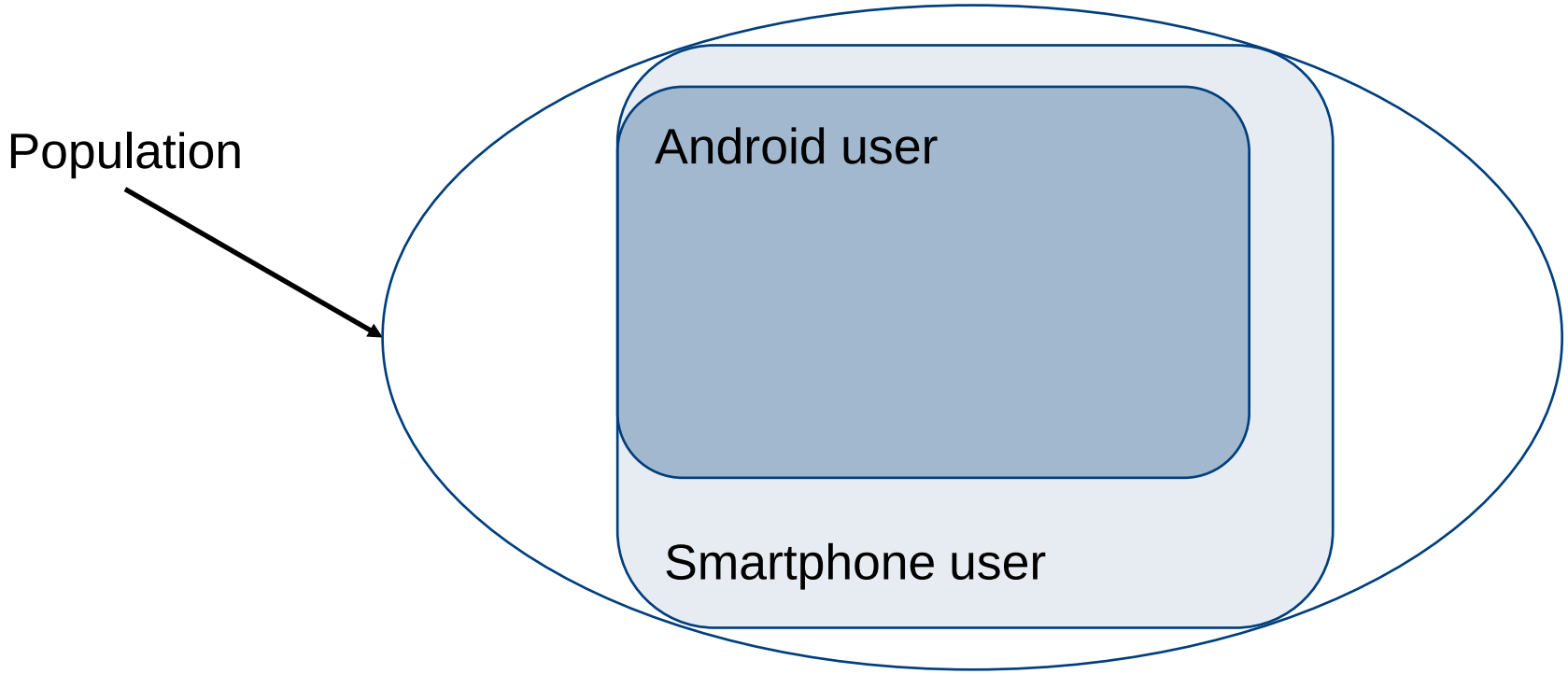
- Absolute bias in many substantive measures of PASS for smartphone ownership relatively small (<6 p.p.), especially once limiting population to people <67 years (<2 p.p.)
- Bias produced by Android smartphone coverage generally not much higher than general smartphone coverage bias
- Large iPhone coverage bias (up to 14 p.p.), even when controlling for age (up to 12 p.p.)
  - Especially for measures of life satisfaction and deprivation

Nonparticipation Error

Keusch, F., Bähr, S., Haas, G.-C., Kreuter, F., Trappmann, M., & Eckman, S. (2022). Nonparticipation in smartphone data collection using research apps. Journal of the Royal Statistical Society. Series A. https://doi.org/10.1111/rssa.12827

Downloading a Research App Requires…

- …owning a (specific) smartphone ⟶ Coverage error



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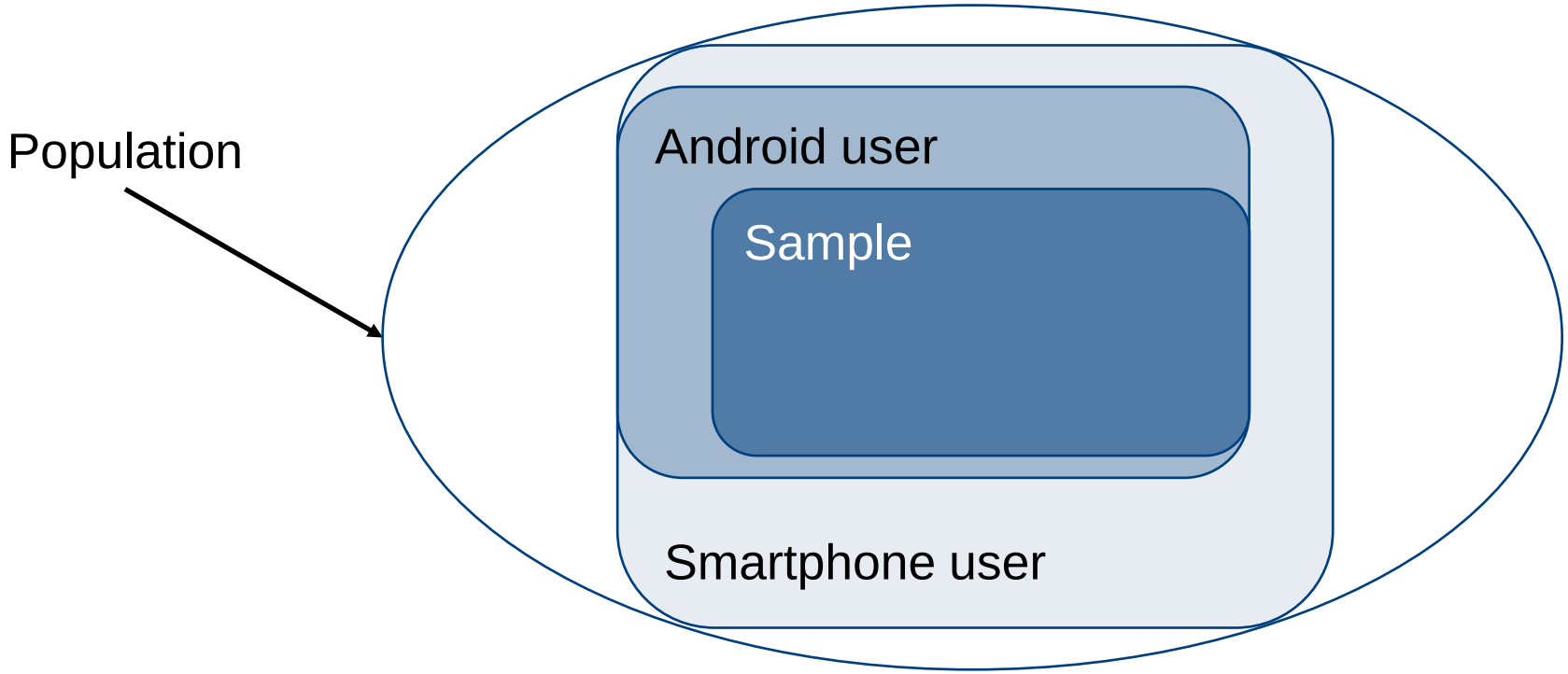
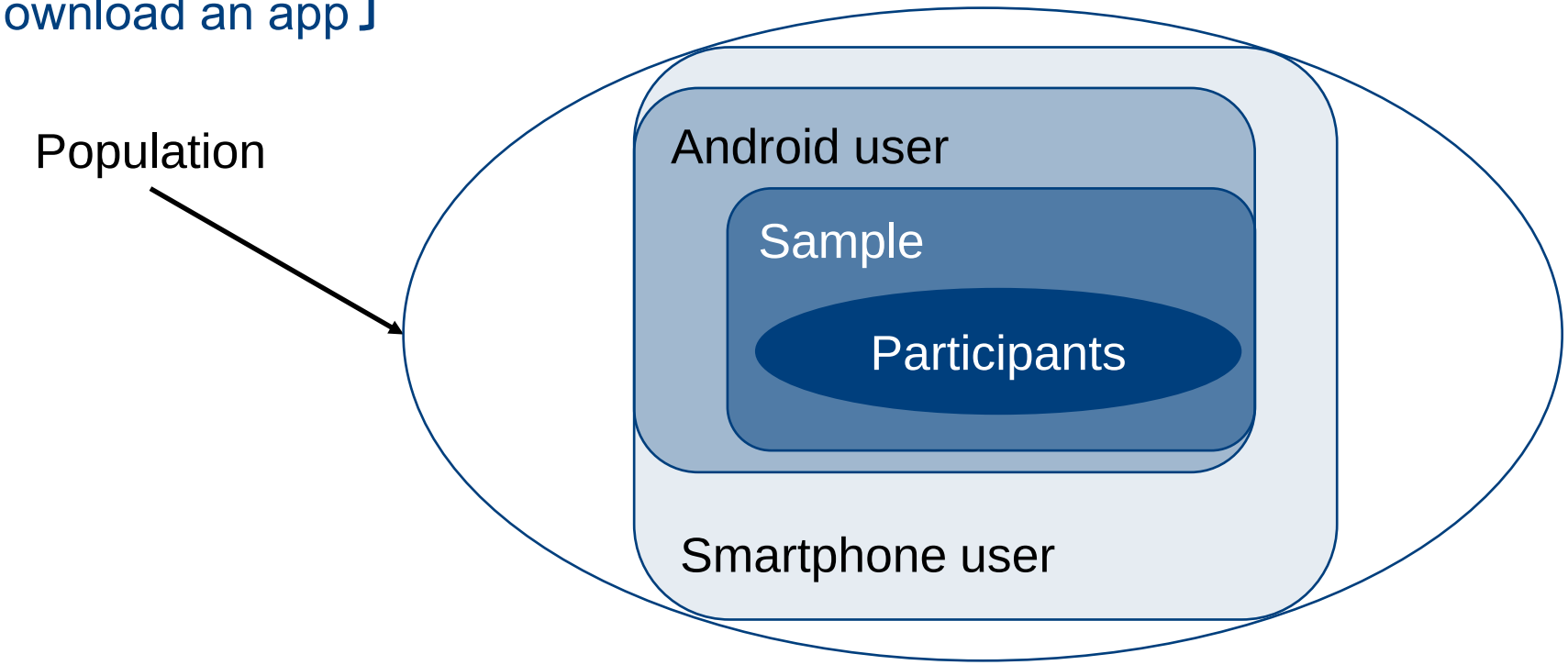


Downloading a Research App Requires…

- …owning a (specific) smartphone → Coverage error
- …being able to download an app
- …being willing to download an app

} Nonparticipation error



Who Counts as a Participant in IAB-SMART?

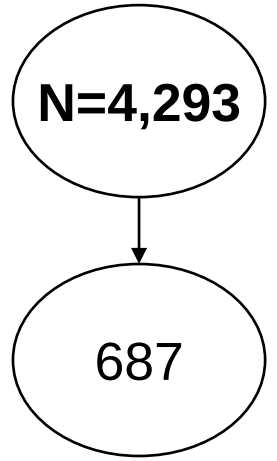
- Invited W11 PASS participants with Android smartphone

N=4,293

Who Counts as a Participant in IAB-SMART?

- Invited W11 PASS participants with Android smartphone

- App installations
  - Valid registration code entered in app



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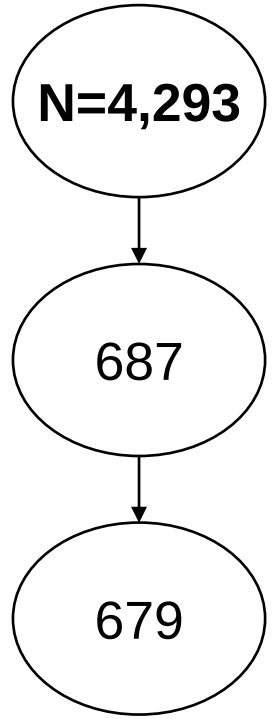
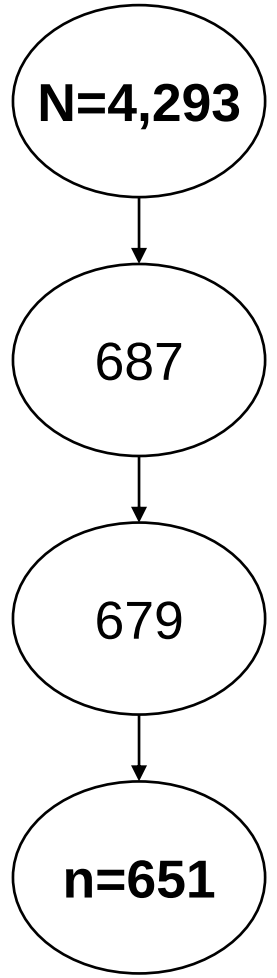
  - Any passive measure or answered at least one survey question

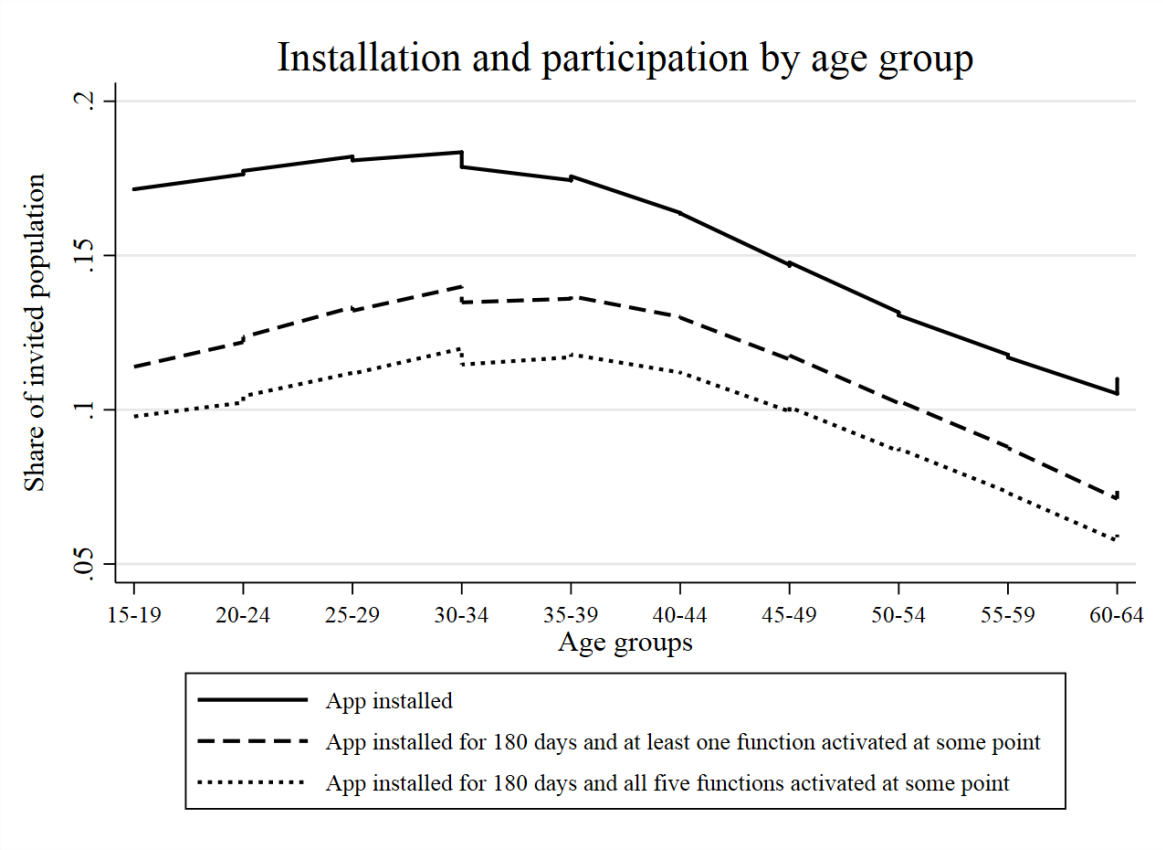


Who Counts as a Participant in IAB-SMART?

- Invited W11 PASS participants with Android smartphone
- App installations
  - Valid registration code entered in app
- Any data submitted
  - Any passive measure or answered at least one survey question
- Data from correct person
  - Age and gender in app align with PASS W11 data

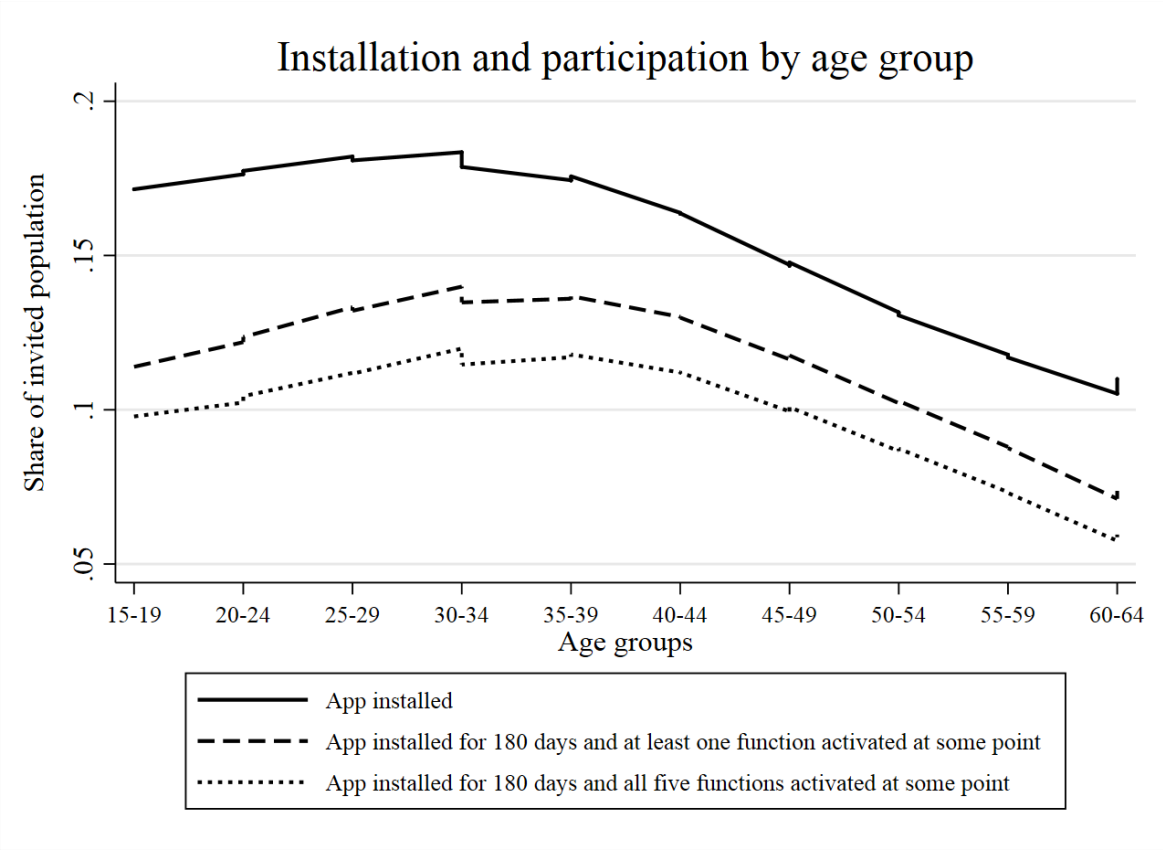


Participation by Sociodemographic Groups



Locally weighted scatter-plot smoother (LOWESS) regression

Participation by Sociodemographic Groups



- Installation sign. higher among…
  - Men
  - Higher educated
  - Non-immigrants
  - People living in „new“ states

Locally weighted scatter-plot smoother (LOWESS) regression

Non-Participation Bias in Percentage Points

	Variable	App installed
Overestimation	Personal network size: 3-9	+4.9
	High sat. /w living standards	+4.4
	>2,000 Euro HH income	+3.5
	No deprivation	+3.4
	>40 work hours/week	+2.9
	Employed	+2.8
	…	…
Underestimation	Inactive	-1.6
	Welfare receipt	-2.4
	Medium sat. /w living standards	-4.1
	High deprivation	-4.7
	<35 work hours/week	-4.7
	<1,000 Euro HH income	-4.9

Non-Participation in IAB-SMART

- Initial app installation rate (15%) comparable to web surveys in PASS
  - Participation rates in cross-sectional studies might be (much) lower
- Bias from differential nonparticipation is concern, and some effects of coverage and nonparticipation add up
  - e.g., age, education, income, employment, deprivation
- For other variables, nonresponse bias seems to be less of a problem
  - e.g., satisfaction

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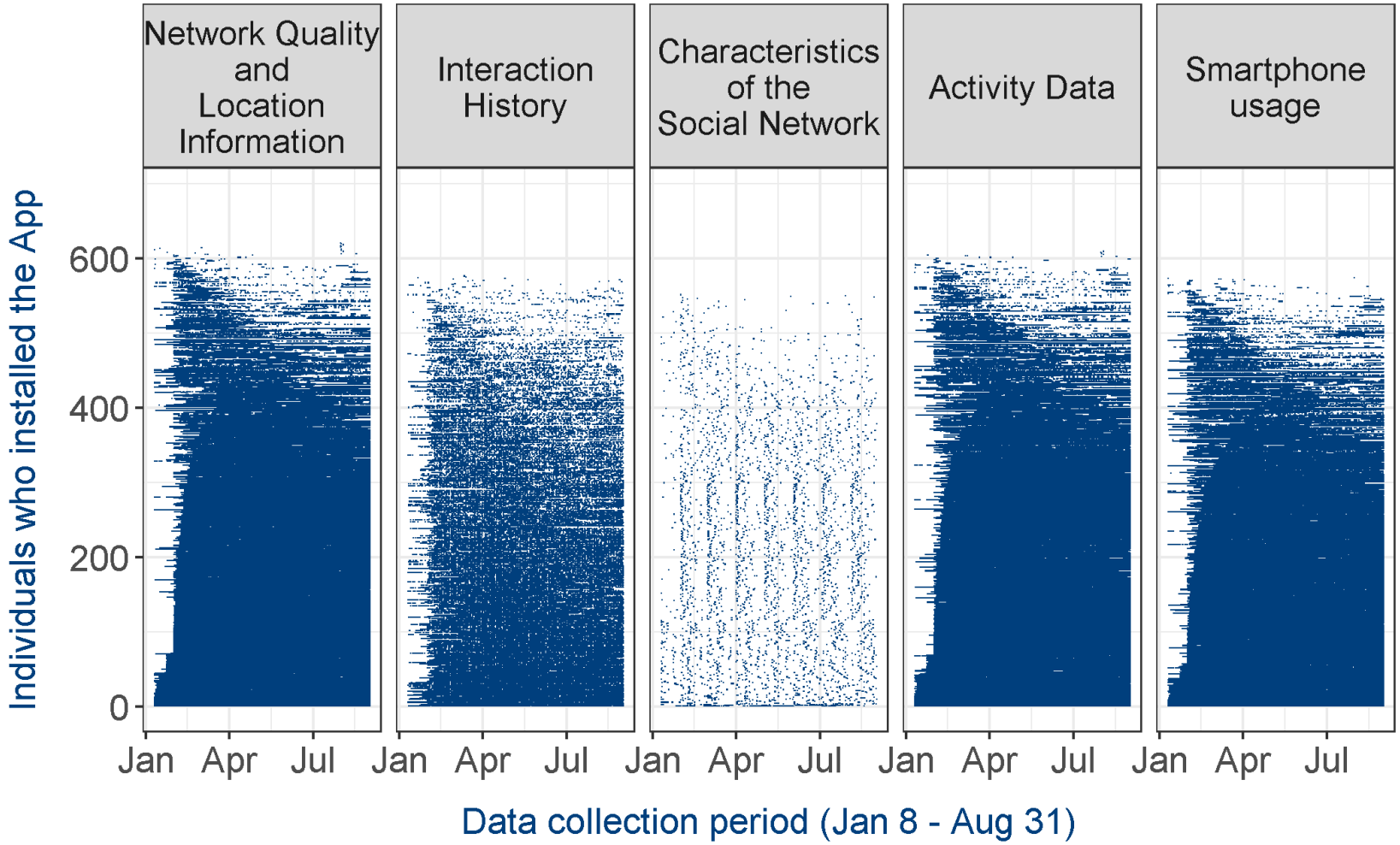
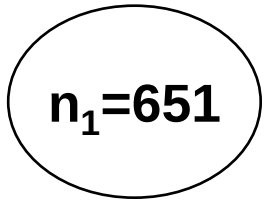
➢ But, does downloading app and sending some data constitute participation?

Missing Data Over Time



What If We Use “80%-rule” from AAPOR Standard Definitions?



Data from correct person

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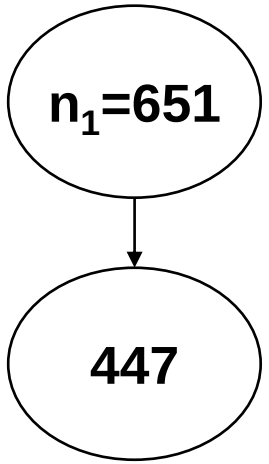
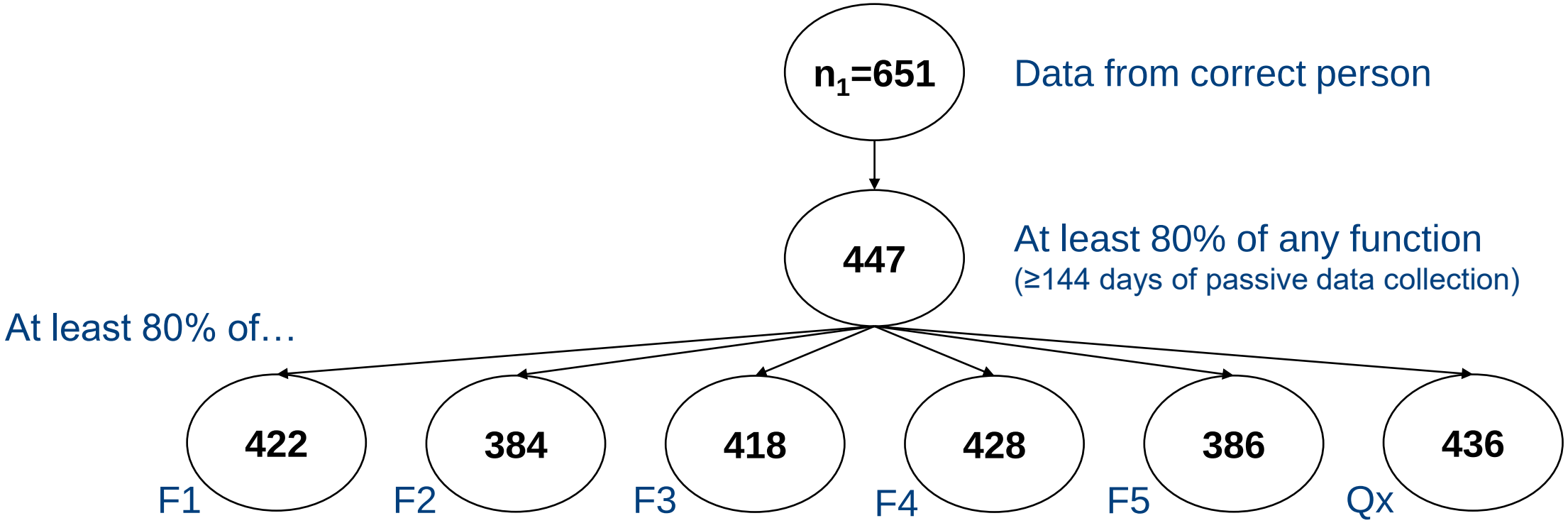


Data from correct person

At least 80% of any function
(≥144 days of passive data collection)

What If We Use “80%-rule” from AAPOR Standard Definitions?



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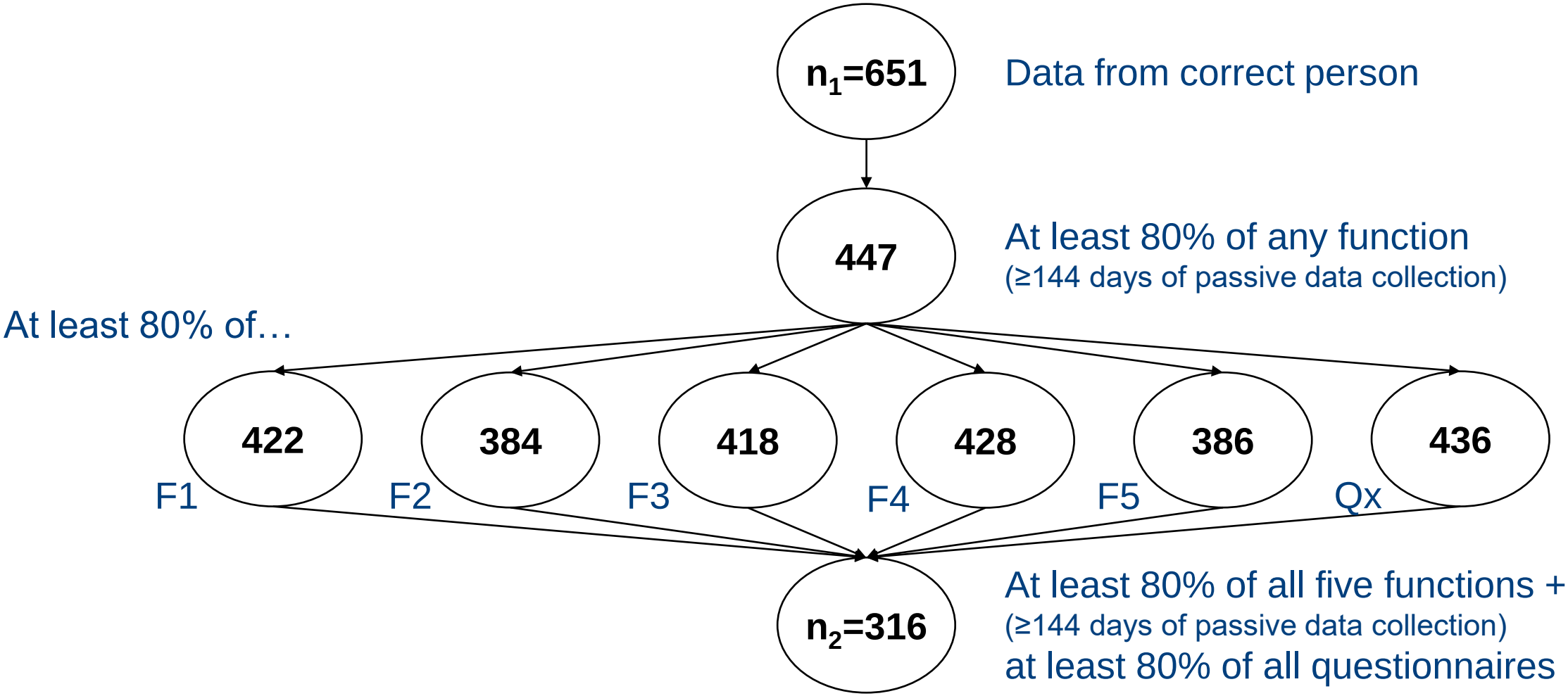


So What Should Be Reported?

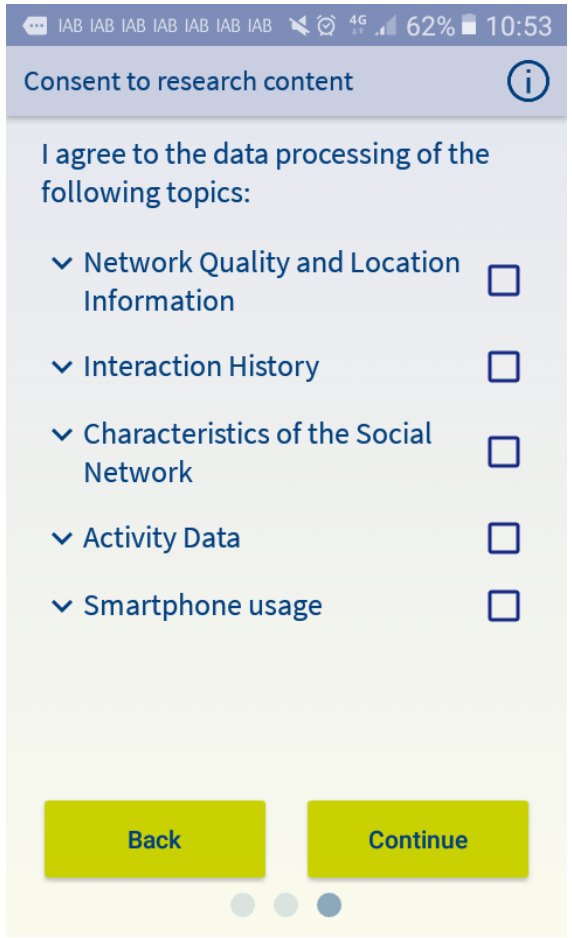
- App data collecting of various types of data over longer period of time provides rich data that can be used in different ways
  - Sometimes even short field periods might reveal patterns (e.g., repetitive behaviors)
  - Sometimes long, uninterrupted measurement is necessary (e.g., to understand changes over time)
  - Same person might be counted as participant for some types of data and as non-participant for other types of data
- Pragmatic view: take what makes sense for specific analysis
- However, we need to define standards for reporting meta data in such studies
  - Journal articles, reports, repositories, etc.
  - Might look at panel data where other types of data collected over longer periods of time (e.g., biomarkers)
  - E.g., see Müller et al 2022: Analyzing GPS Data for Psychological Research: A Tutorial, Fig. 3.

Measurement Error

Measurement Error: Interaction history data

Haas, G.-C., Malich S., Keusch, F., Bähr, S., Kreuter, F., Trappmann, M. Challenges of Measuring Social Interaction with Smartphone App Data. General Online Research 22, Berlin, September.

When did IAB-SMART collect social interactions?



Interactions History:

1. On demand: each time a phone call is made or received
2. In retrospect: from the phone log data

Compared to on demand, **in retrospect** collects additional data

id	time_stamp_start	time_stamp_end	call_type
1	*2018-01-09 16:01:23*	*2018-01-09 16:03:54*	*incoming*
1	*2018-01-09 18:10:40*	*2018-01-09 20:19:05*	*outgoing*
1	*2018-01-09 23:40:29*	*2018-01-09 23:40:29*	*missed*
1	*2018-01-11 17:00:45*	*2018-01-11 18:27:12*	*incoming*

On demand

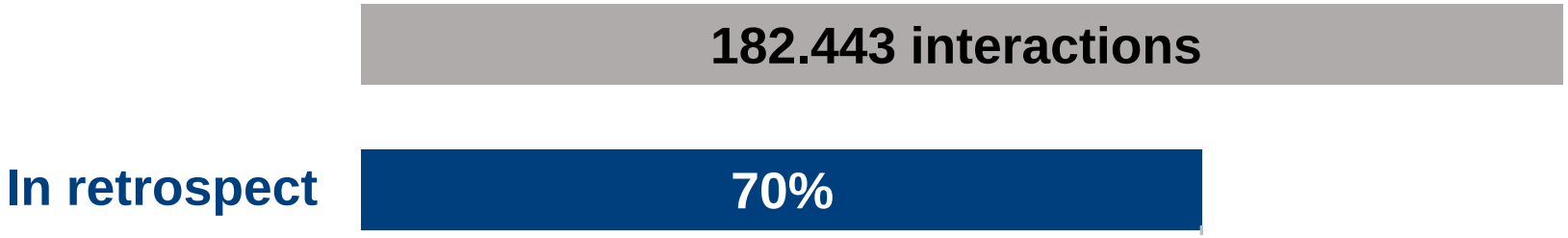
Compared to on demand, **in retrospect** collects additional data

id	time_stamp_start	time_stamp_end	call_type	masked_who	date_collect
1	*2018-01-09 16:01:23*	*2018-01-09 16:03:54*	*incoming*	*684z23234*	*2018-01-13*
1	*2018-01-09 18:10:40*	*2018-01-09 20:19:05*	*outgoing*	*09087eee43*	*2018-01-13*
1	*2018-01-09 23:40:29*	*2018-01-09 23:40:29*	*missed*	*684z23234*	*2018-01-13*
1	*2018-01-11 17:00:45*	*2018-01-11 18:27:12*	*incoming*	*090876343*	*2018-01-13*

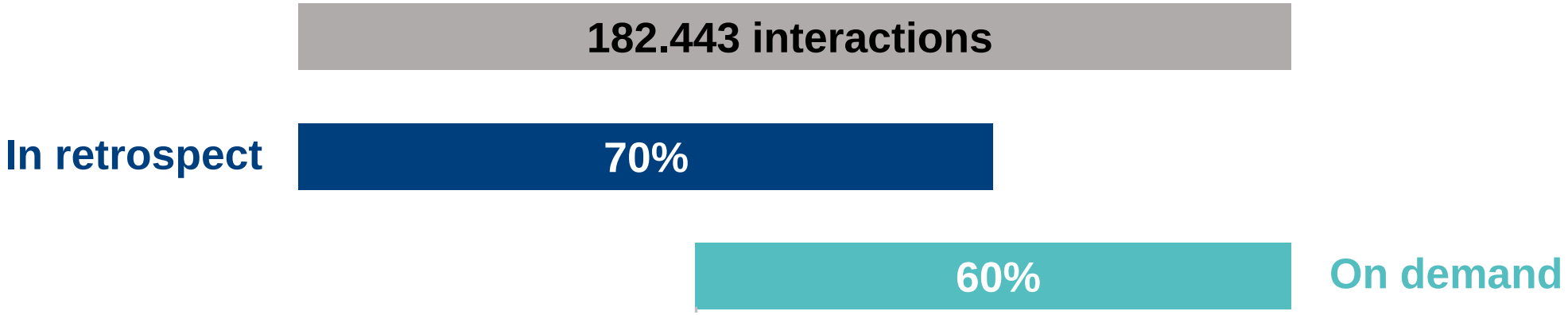
Alone **In retrospect** and **On demand** do not capture all interactions

182.443 interactions

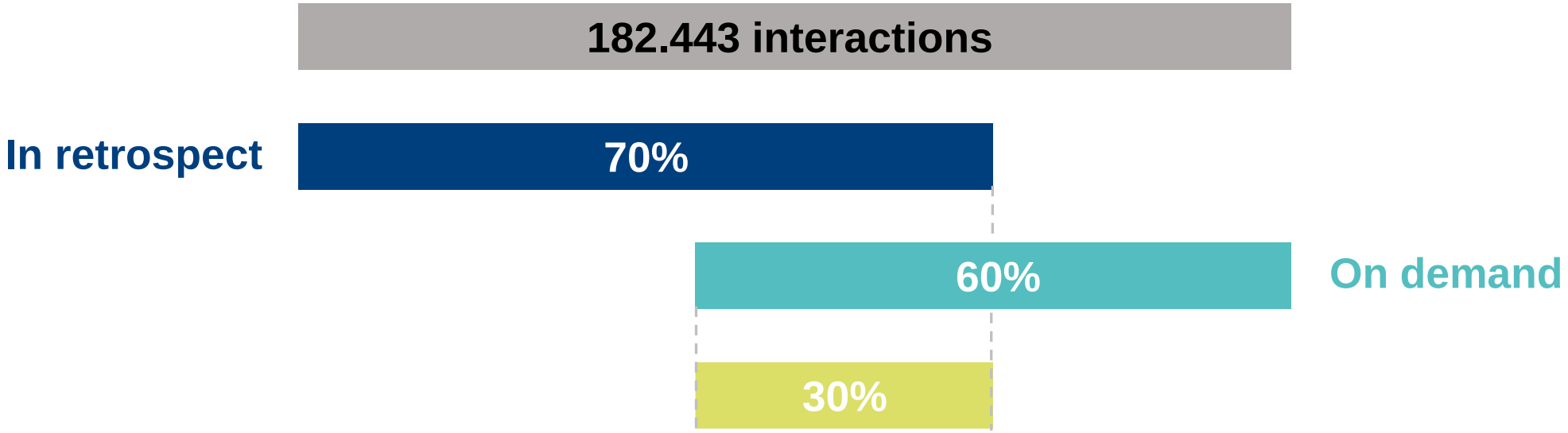
In retrospect captured **70%** of all measured interactions



On demand captured 60% of all measured interactions



Overlap between both data is 30%



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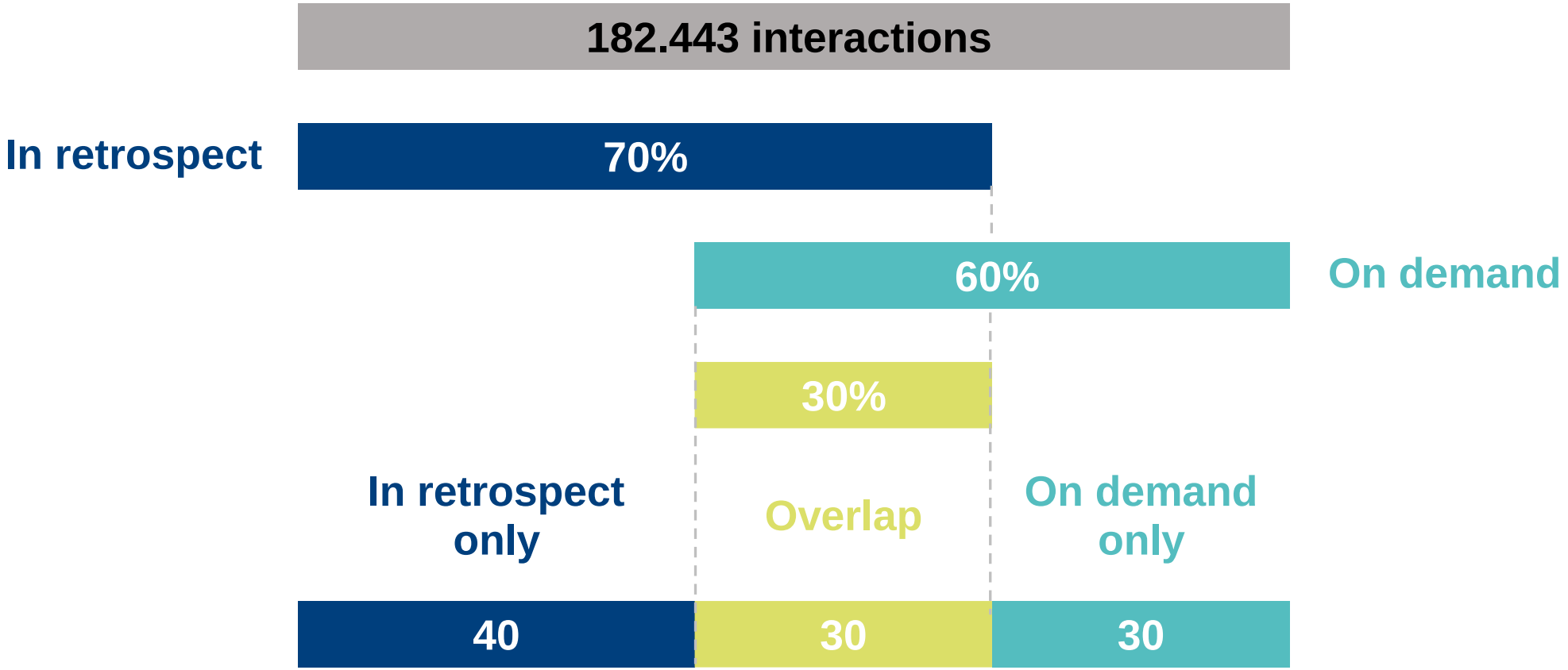
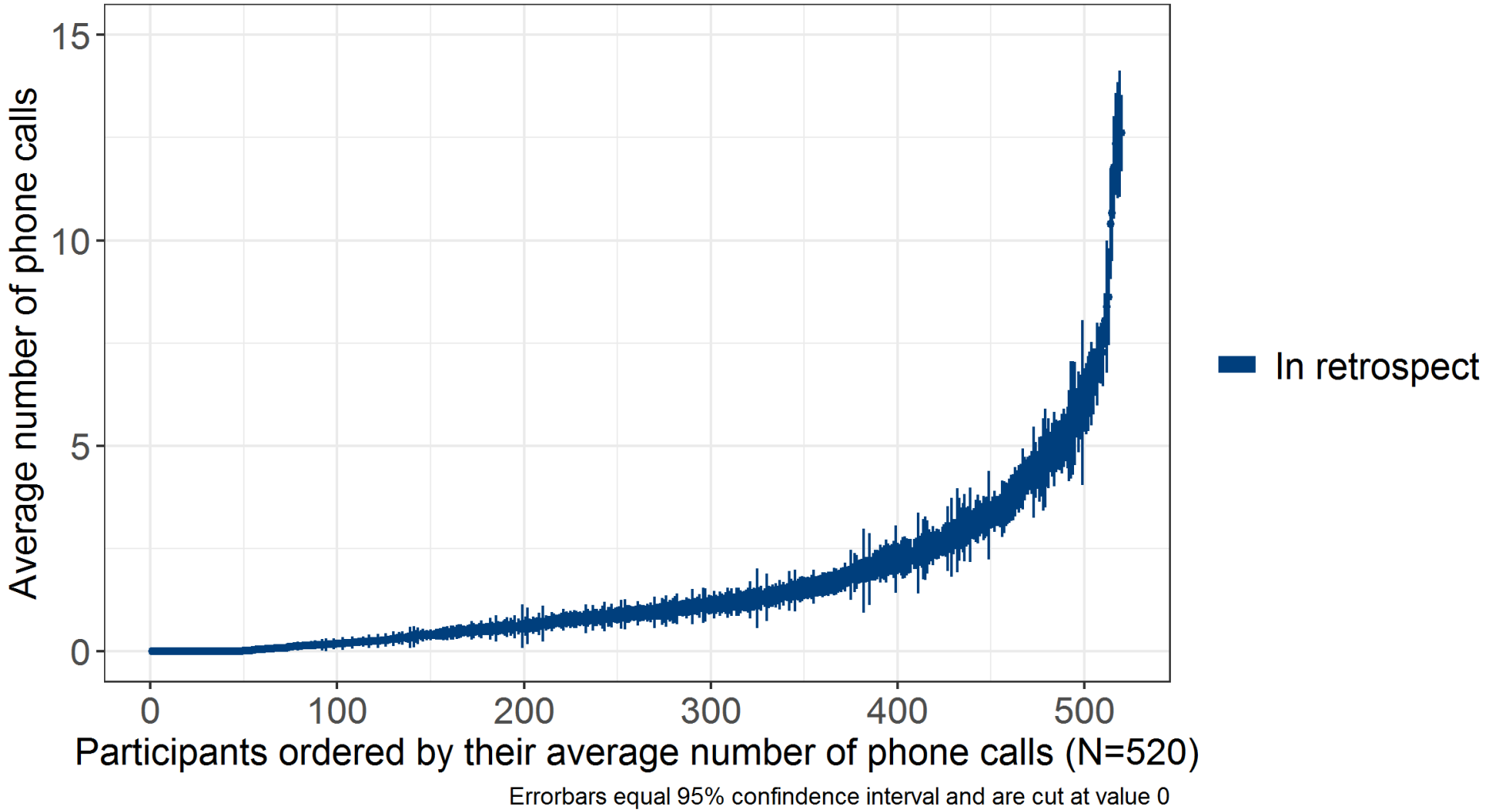
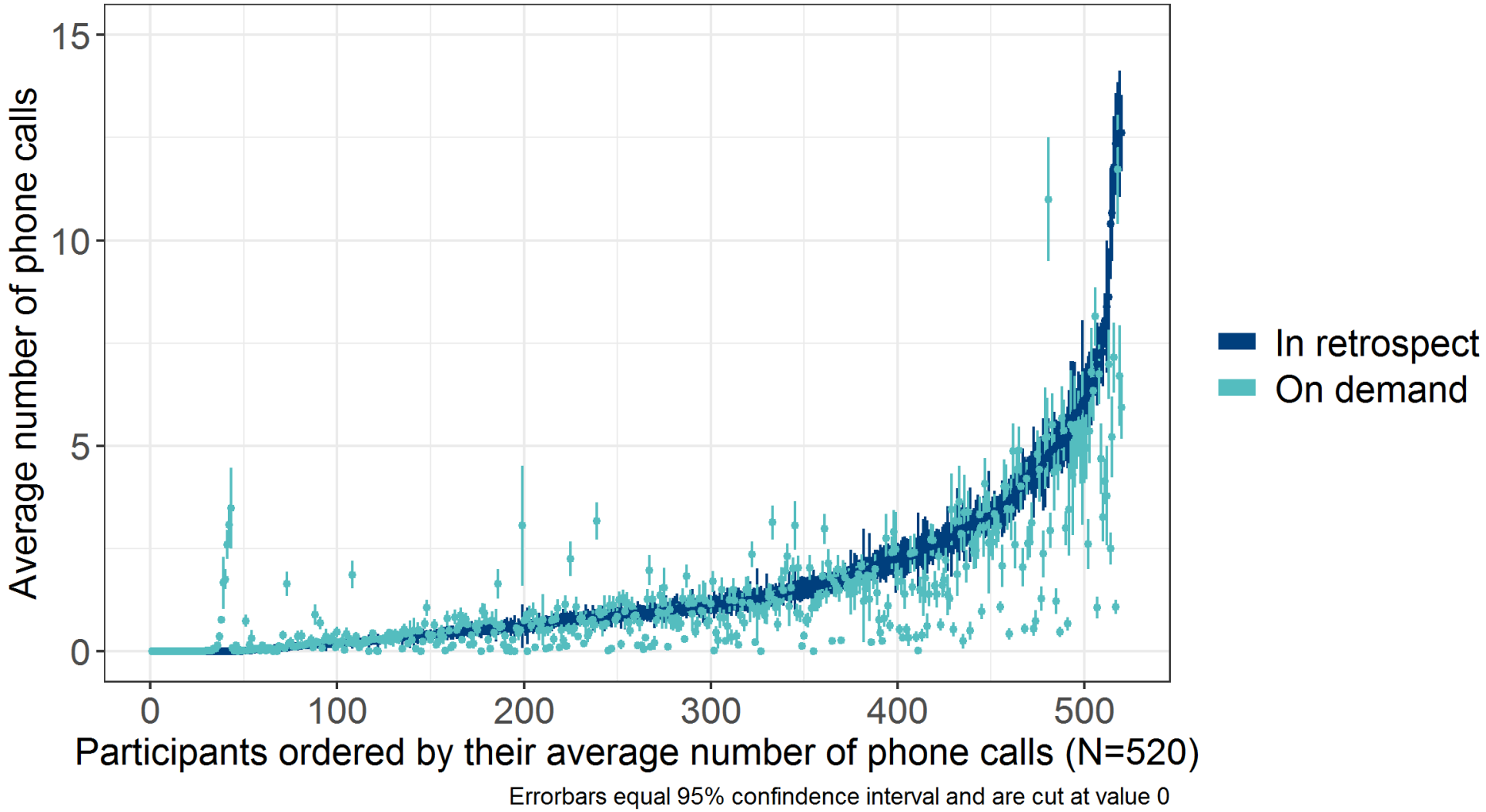


Do **In retrospect** and **On demand** measure the same average number of phone calls?



For a fair share of participants, the data does not match



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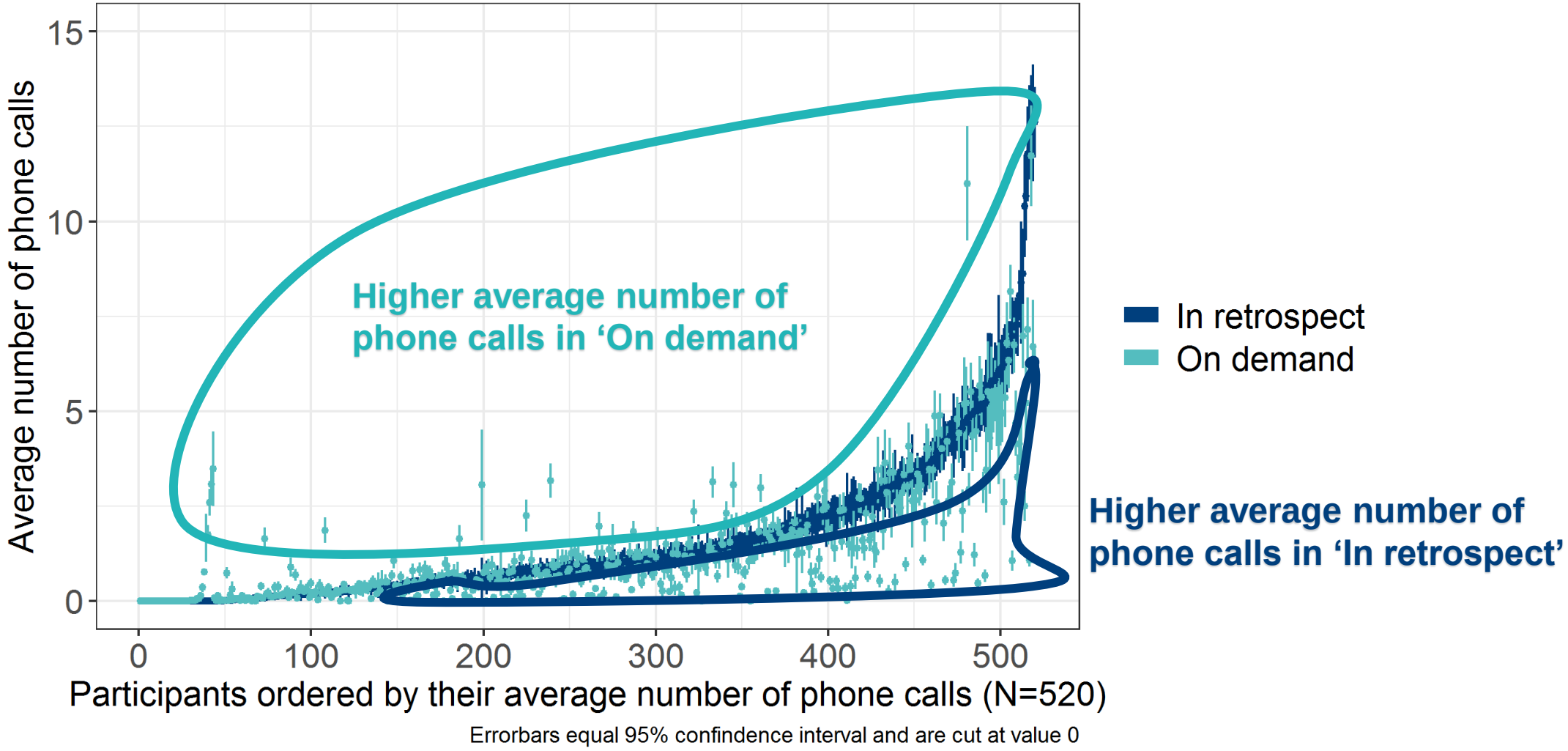
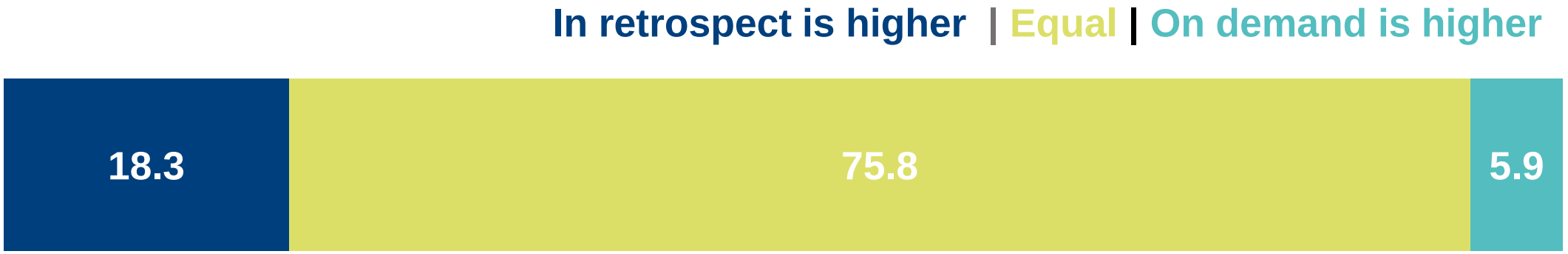


For Only 76% of participants the average number of phone calls is statistically equal between **In retrospect** and On demand

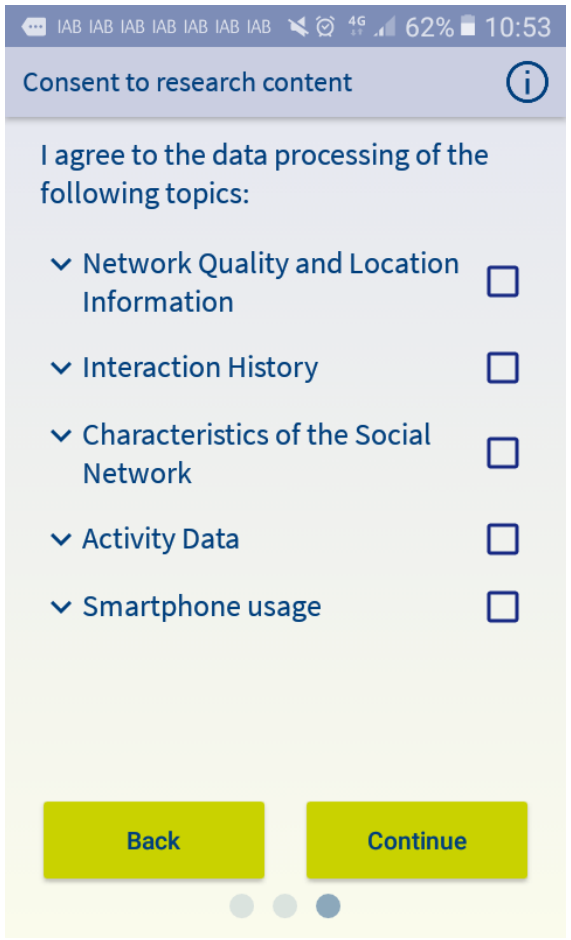


N = 492;
Selection: At least one interaction during the field period;
Statistical equality between indicators was tested with a two-sided t-test using a Bonferroni adjusted p-value, i.e.,
p = 0.0001 = 0.05/492

Measurement Error: Geodata

Bähr, S., Haas, G.-C., Keusch, F., Kreuter, F., Trappmann, M. (2022): Missing Data and Other Measurement Quality Issues in Mobile Geolocation Sensor Data. In: Social science computer review, Vol. 40, No. 1, S. 212-235. https://doi.org/10.1177/0894439320944118

Passive Data: Geolocation



Location sensor data

- Every 30 Minutes
- Geolocation from GPS, mobile carrier network, Wi-Fi (Fused-API)
- Precision (vertically and horizontally) in meters
- Precise timestamps for start and end of each measurement

Device related – Measurement Error / Processing Error

Manufacturer Settings	Device specific doze-/battery saving modes inhibit data collection
Operating System Settings	Data collection may be inhibited by the Operating System (OS) OS versions may vary in their rights management
Research App Settings	How the research app collects the data (what, when, where, for how long, at which interval, from whom) Interacts with device / OS / user: battery and RAM/CPU drain
Third Party Apps	Battery saving apps, Task-killer apps, GPS faker apps
Participant behavior	Fake data, kill / de-install battery-draining apps, selectively turn off data collection

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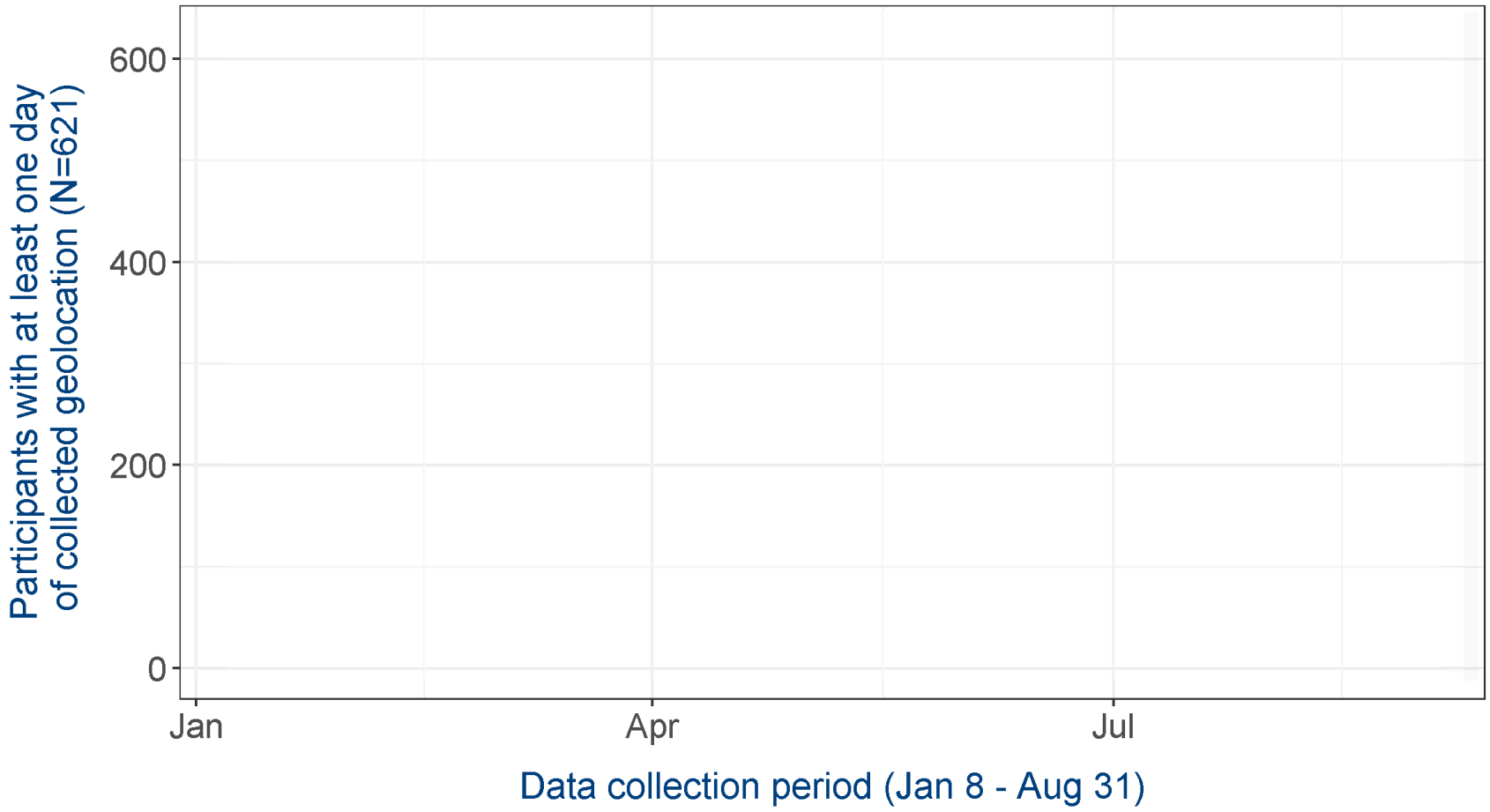
Third Party Apps

Participant behavior

Completeness of data over time



Of all participants who permitted collection of their geolocation:

- 73.9% provided at least 180 **cumulative** days of geolocation
- 73,7% provided at least 180 **consecutive** days of geolocation
- Mean Participation: 202 days

Participants sorted by number of days with geolocation measurement

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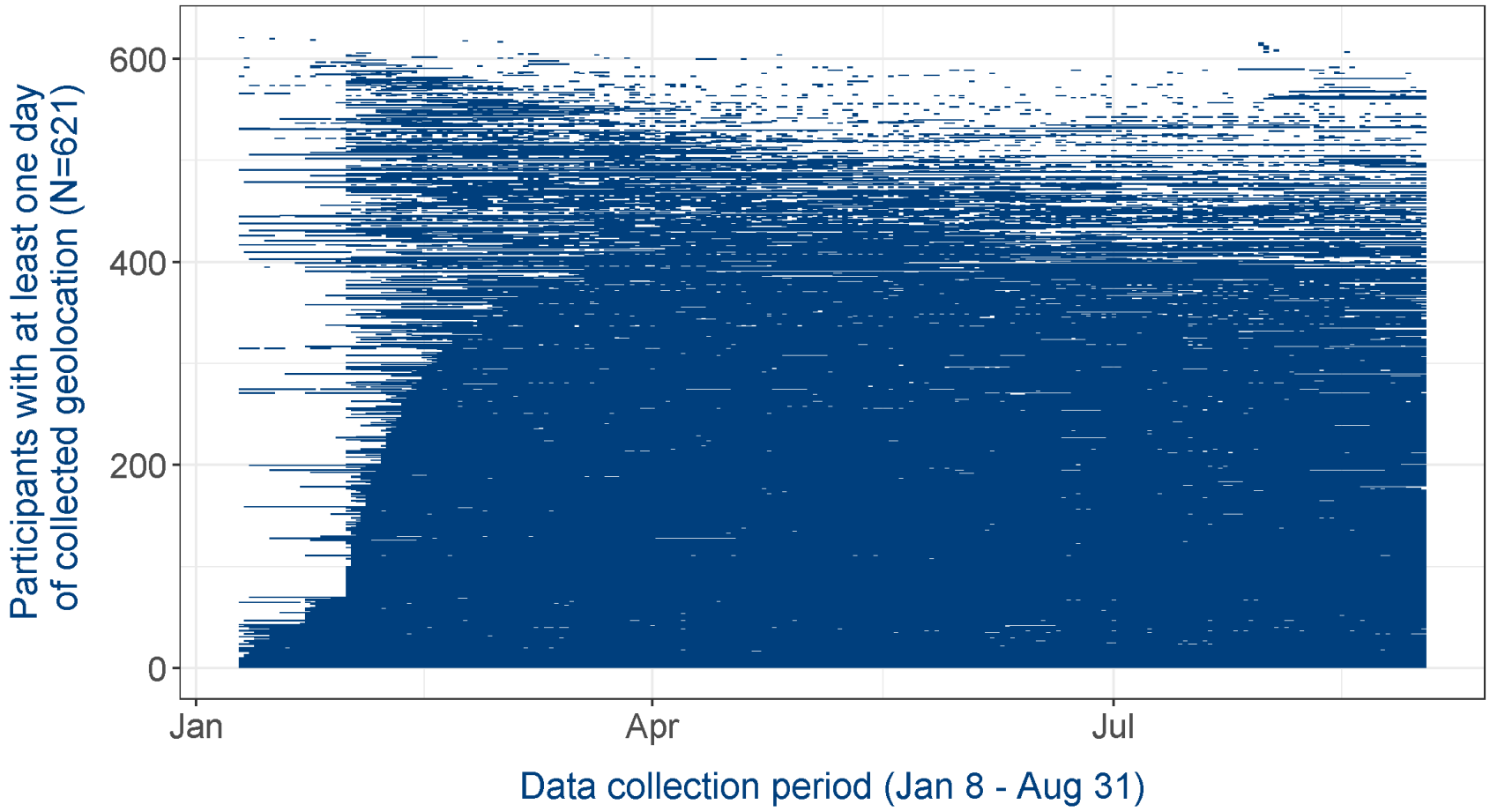

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	Obs	Mean	Std. Dev.	Min	Max
Days with geodata measurement	483	**158.2**	39.0	8	180
Days without geodata measurement	483	**21.7**	38.9	0	172
Number of gaps in measurement	483	**5.1**	8.6	0	45
Gap duration in days	303	**5.4**	12.3	1	170

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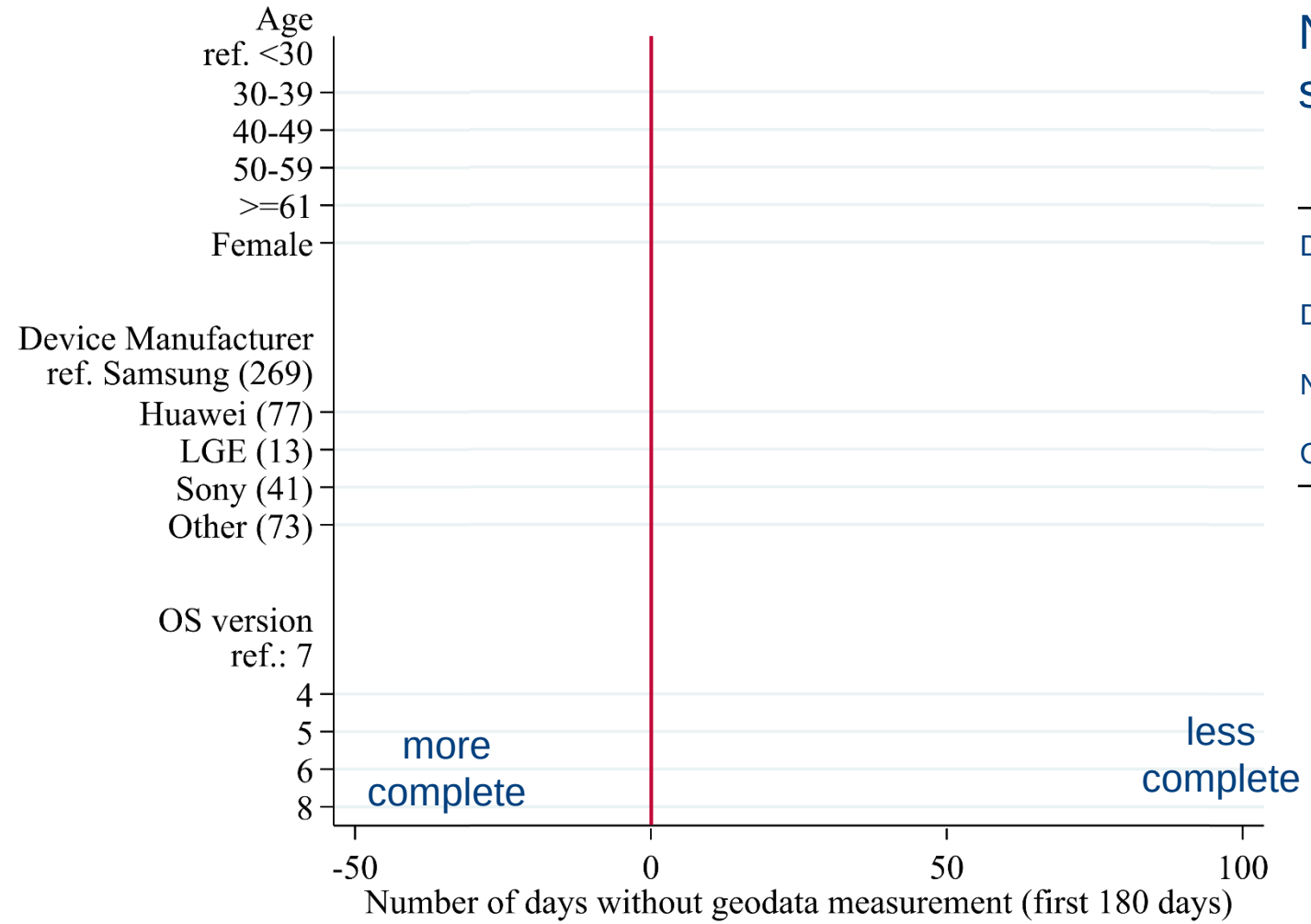

AME (with 95% CI) based on negative binomial count regression with robust standard errors.

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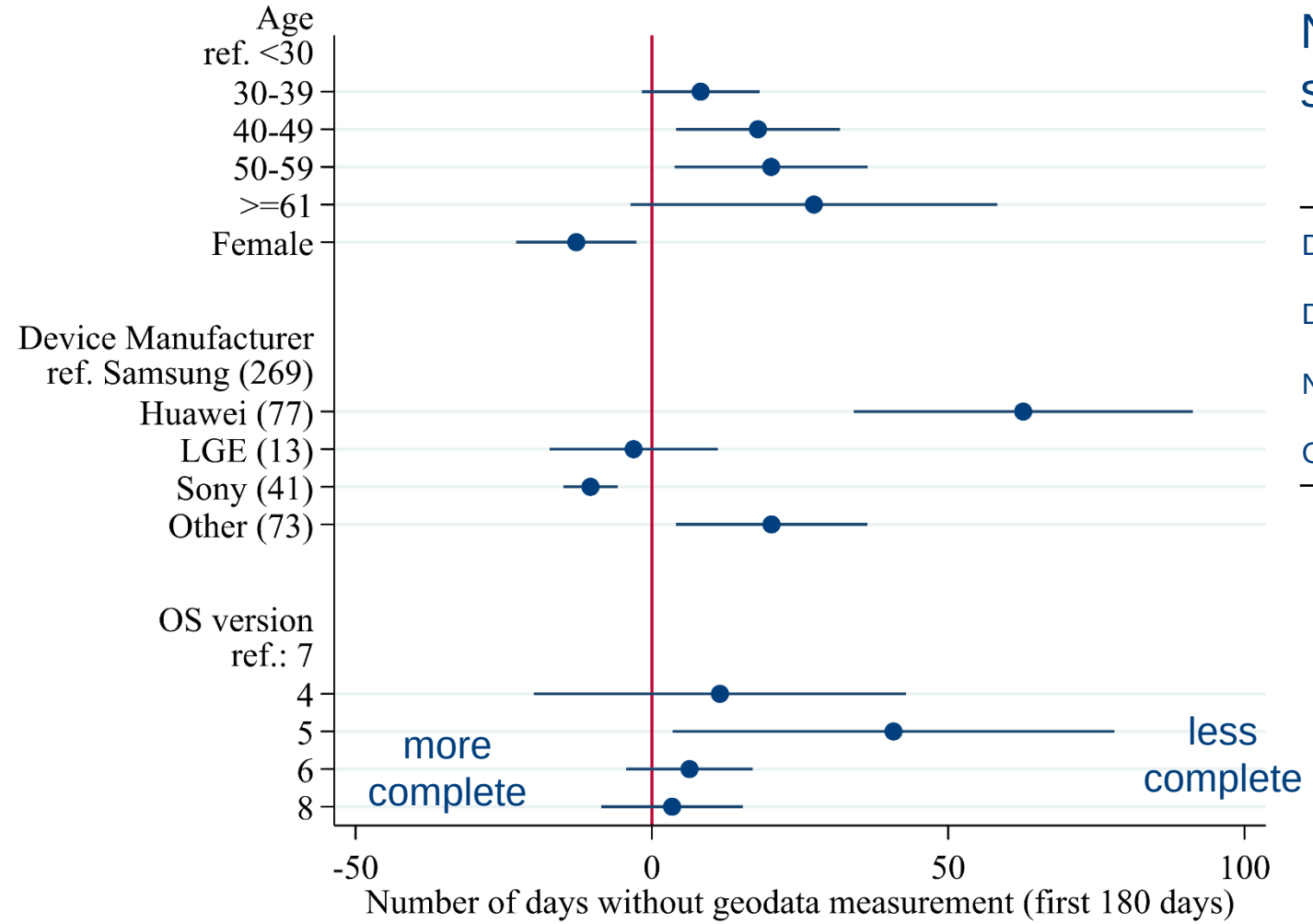

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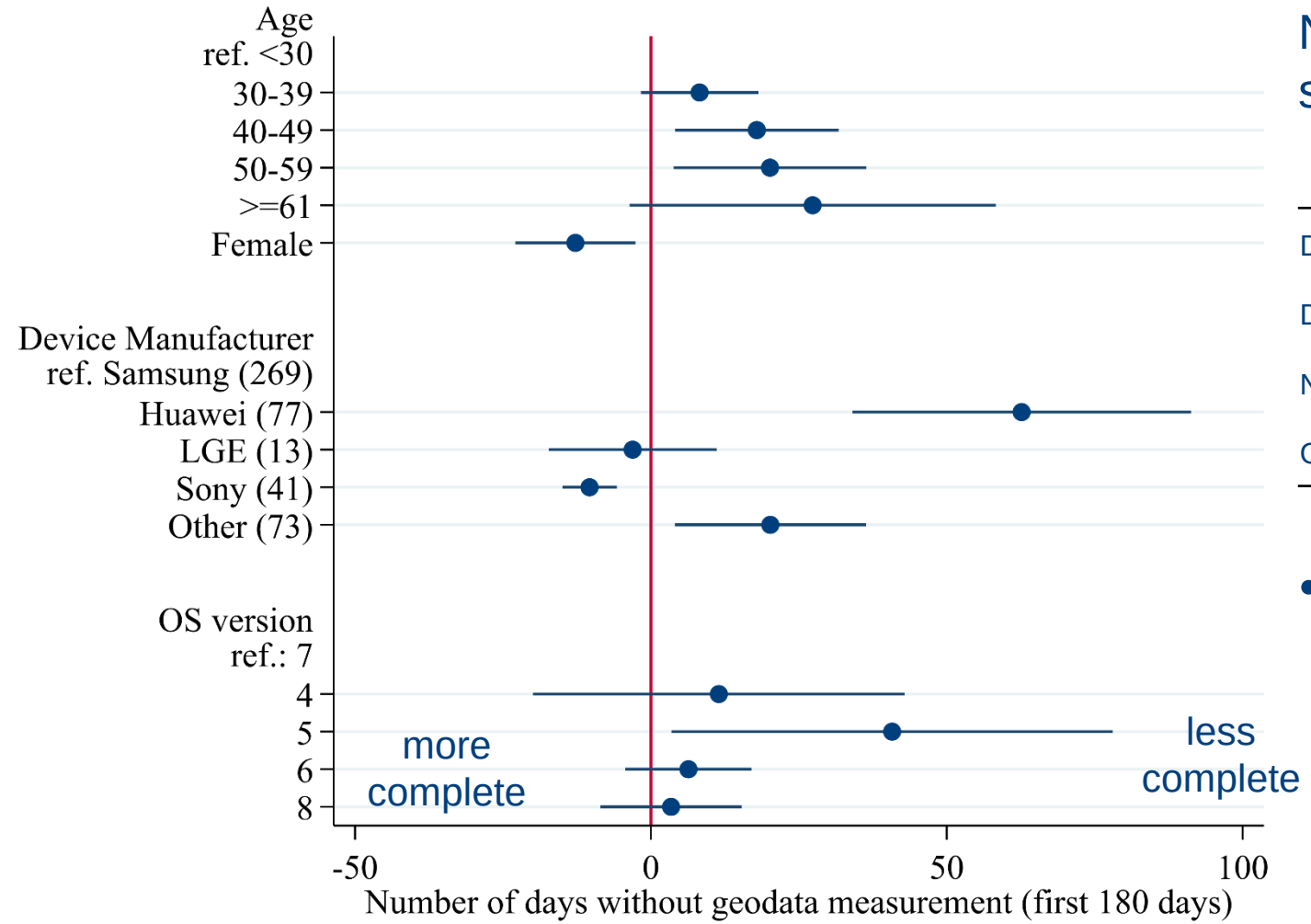

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- Older participants and men more gaps

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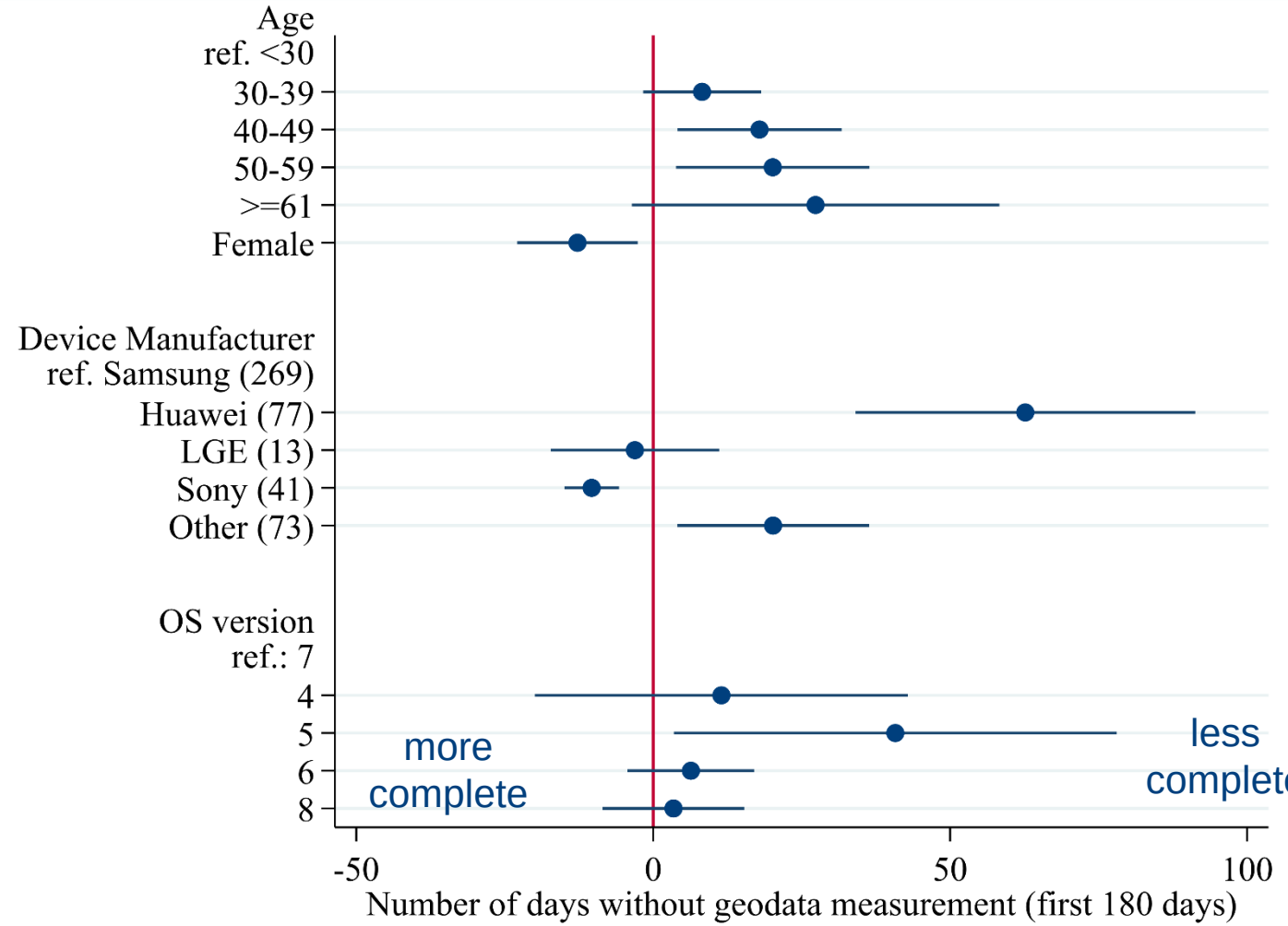

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- Older participants and men more gaps
- Device specific effects
- Older OS versions more prone to gaps

Device related – Measurement Error / Processing Error

Manufacturer Settings

Operating System Settings

Research App Settings

Third Party Apps — Battery saving apps, Task-killer apps, GPS faker apps

Participant behavior — Fake data, kill / de-install battery-draining apps, selectively turn off data collection

Plausibility Checks

codestring	timestamp	latitude	longit~e	country
dfeh7r4v2v	05aug2018 10:28:48	52.2	8.6	Germany
dfeh7r4v2v	05aug2018 11:43:38	52.2	8.6	Germany
dfeh7r4v2v	05aug2018 12:22:50	8.6	52.2	
dfeh7r4v2v	05aug2018 12:52:49	8.6	52.2	

Plausibility Checks

codestring	timestamp	latitude	longit~e	country
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- Apps falsify geolocation
- Aim: Privacy, access location-specific content

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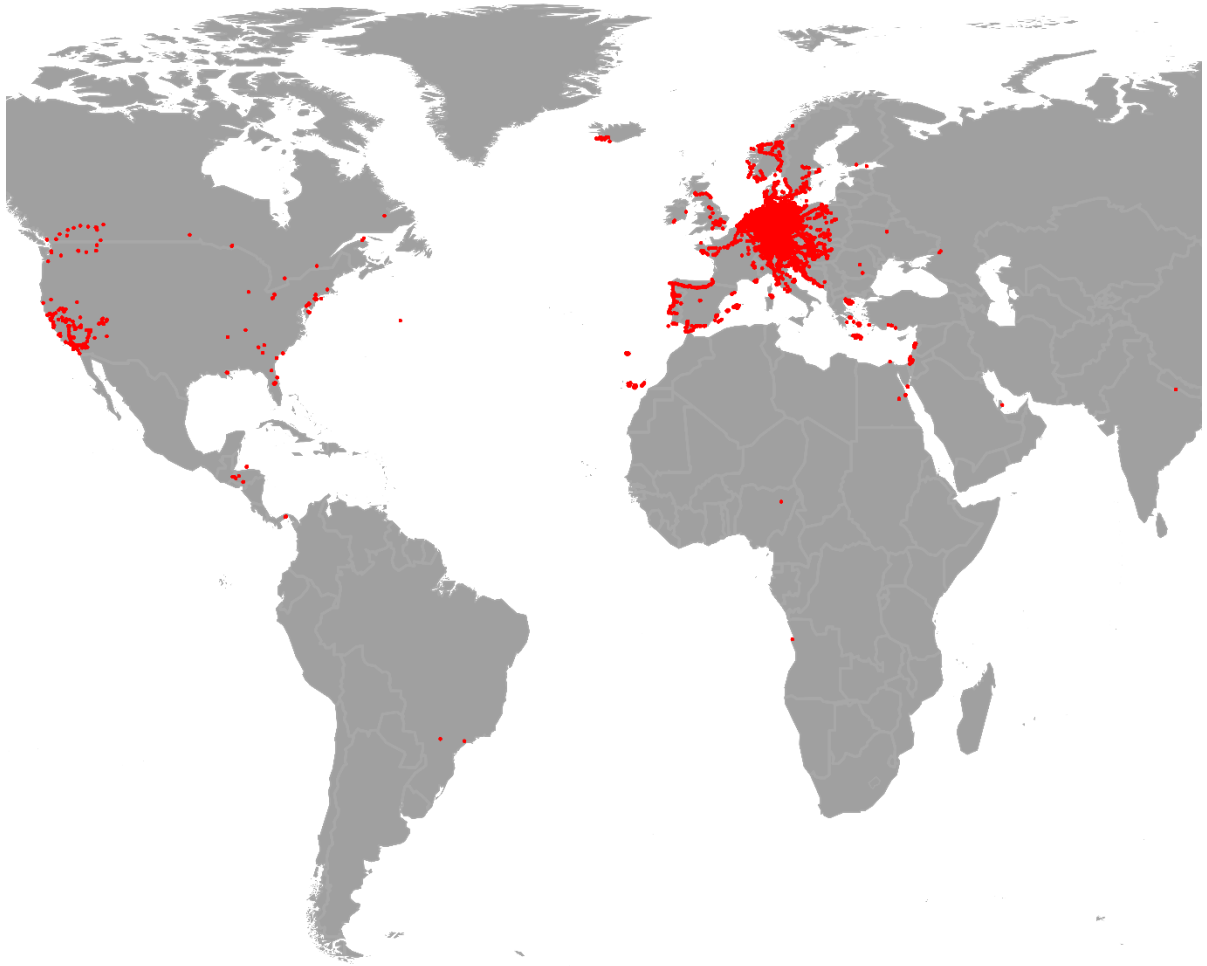
dfeh7r4v2v	05aug2018 12:52:49	8.6	52.2	

- Apps falsify geolocation
- Aim: Privacy, access location-specific content
- Validation with app usage data
- 4 / 621 participants had such apps installed

→ Replace false geo-positions with data from immediately before the app use

codestring	AppName	timestamp_start	timestamp_end
dfeh7r4v2v	Fake GPS with Joystick	05aug2018 12:11:21	05aug2018 12:11:32
dfeh7r4v2v	Fake GPS with Joystick	05aug2018 12:12:31	05aug2018 12:16:11
dfeh7r4v2v	Fake GPS with Joystick	05aug2018 12:18:31	05aug2018 12:18:40
dfeh7r4v2v	Fake GPS with Joystick	05aug2018 12:19:00	05aug2018 12:19:03

Plausibility Checks



Worldwide distribution of geolocations

Non-ordinary mobility patterns

- Continuous observation over 180 days vs. annual survey
- Mobility of participants outside the everyday pattern (holidays, business trips)
- Whether to keep observations outside the normal daily patterns depends on the research question
- Everyday pattern (work home, commuting) needs identification

Quality assessment from In-App surveys

- End of study survey includes rating questions

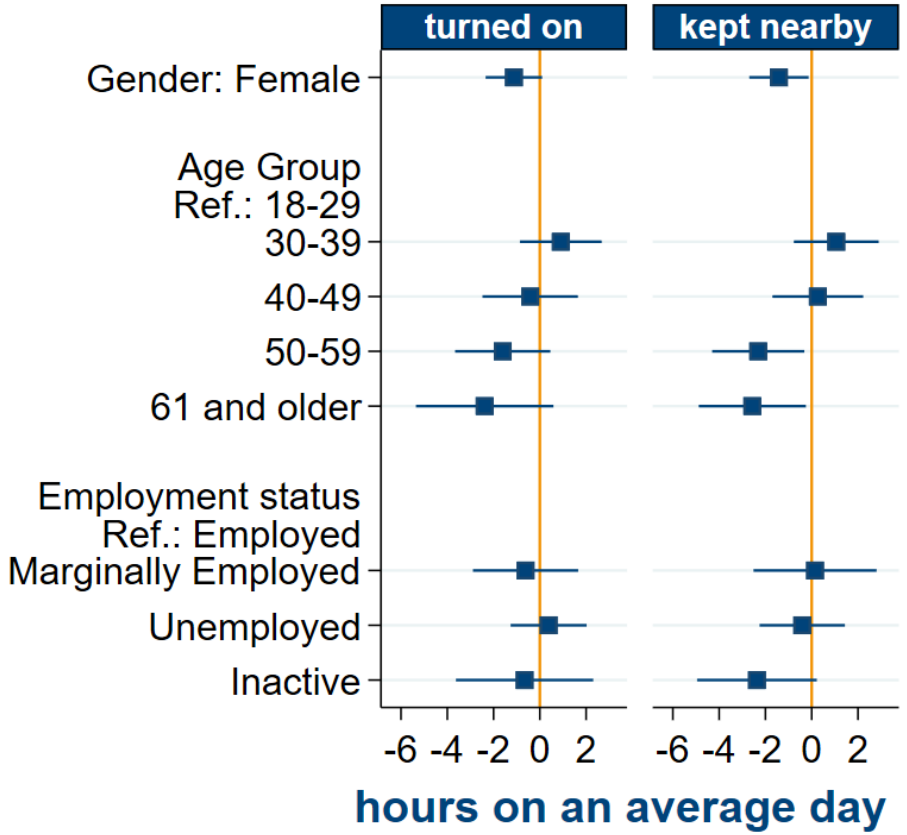
Quality assessment from In-App surveys

- End of study survey includes rating questions

Hours	Obs	Mean	Std. Dev.	Min	Max
turned on	462	**20.9**	5.8	1	24
kept nearby	462	**11.3**	6.2	0	24

Turned on - On average, how many hours per day is your smartphone turned on?
Kept nearby - How many hours is the smartphone in your immediate vicinity (i.e. on your body, in the same building / car)?

Quality assessment from In-App surveys



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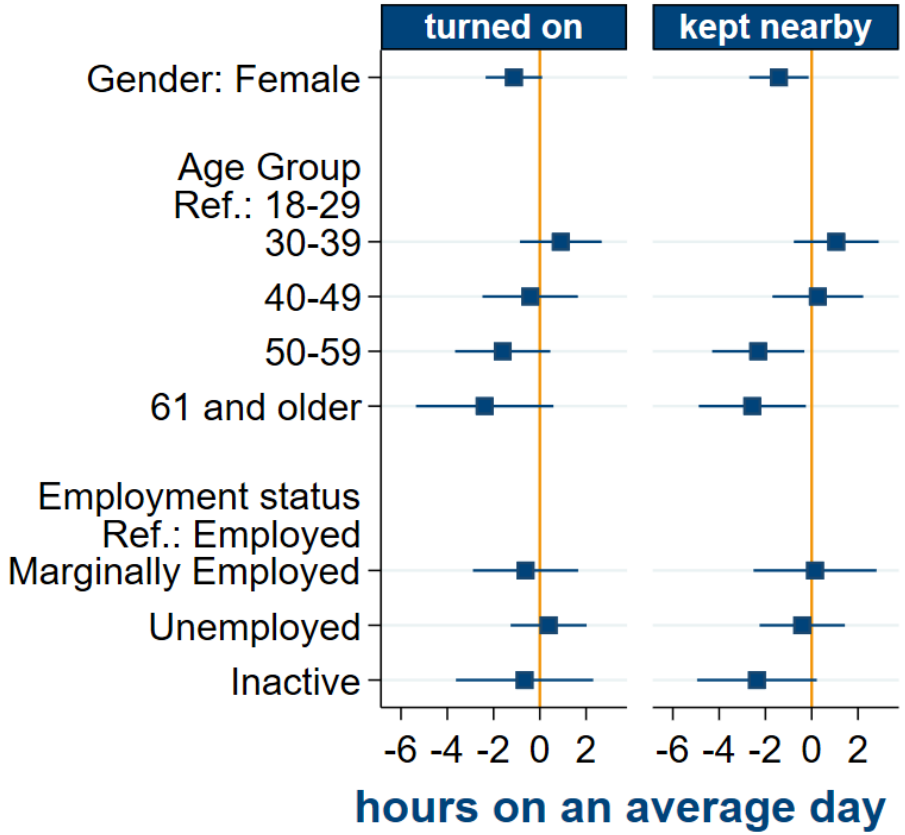

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- Women tend to use their smartphone less than men
- Smartphone use drops at about 50 years of age
- There is no difference in use between employed and unemployed persons
- These characteristics and the usage information itself can be controlled in the models

Quality assessment from In-App surveys

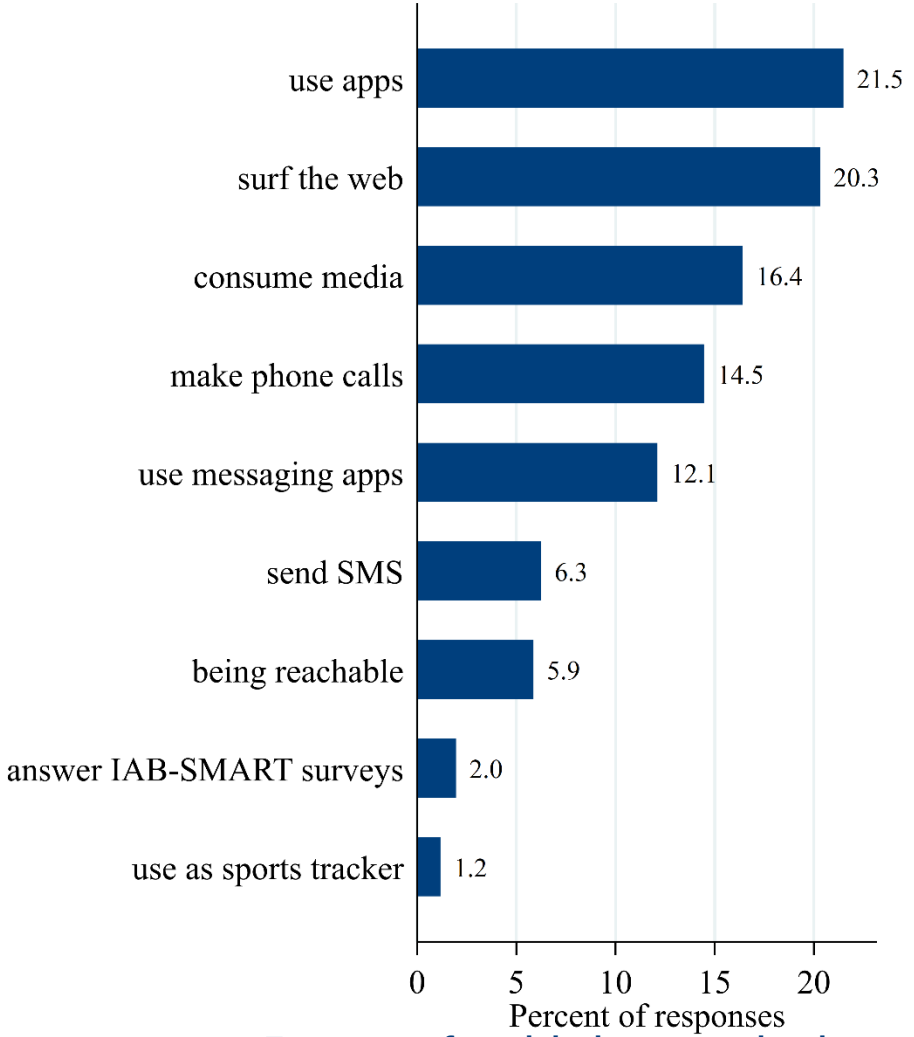
- End of study survey includes questions about **third-party device use (3pdu)**

Quality assessment from In-App surveys

- End of study survey includes questions about **third-party device use (3pdu)**

	Obs	Mean	Std. Dev.	Min	Max
Any 3pdu	465	**0.16**	0.4	0	1
Days with 3pdu	71	**11.03**	27.3	0	180
3pdu >10 days	471	**0.03**	0.2	0	1

Quality assessment from In-App surveys



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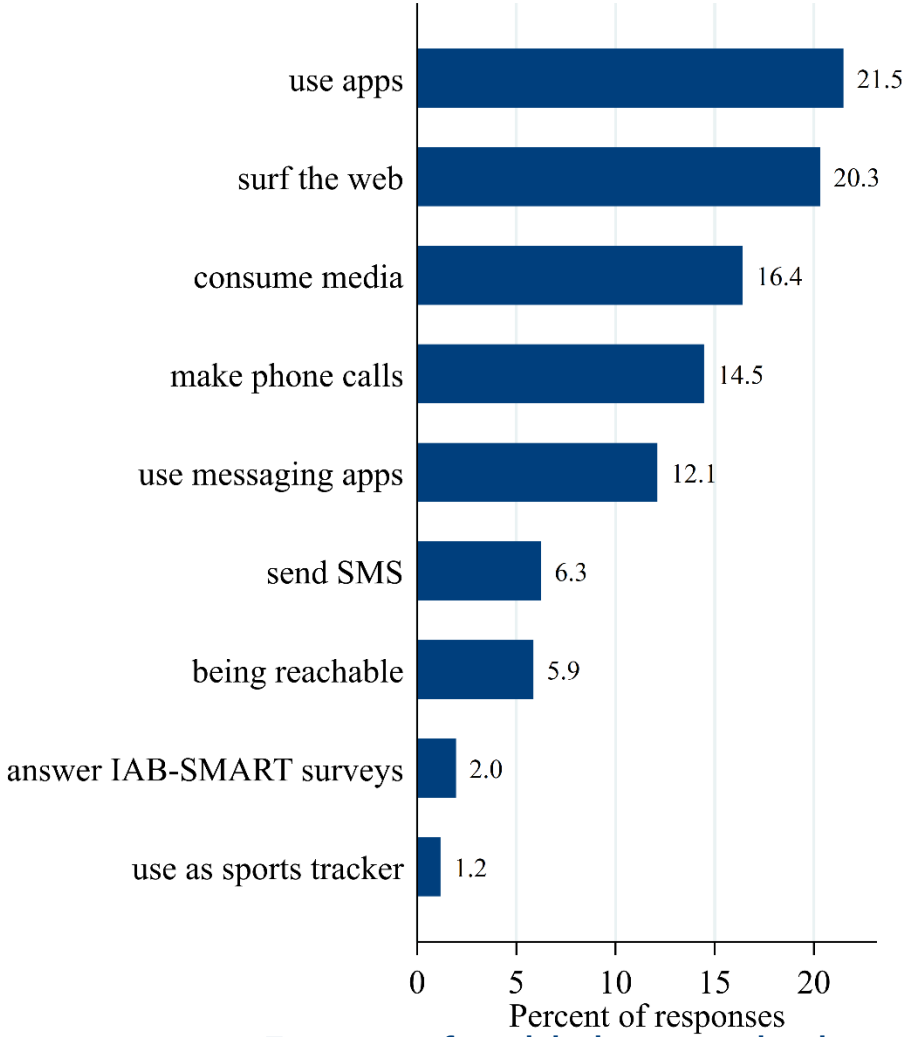

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- Reason for and extent of 3pdu determine scope of problem
- Depends on specific research questions

Conclusion Error Sources

- Coverage Error
  - Smartphone ownership correlates with educational attainment, immigrant status, region, & community size
  - Small bias for smartphone and Android ownership
  - Large bias for iPhone ownership
- Nonparticipation Error
  - Lead question: when can you consider a participation
  - Medium to small bias for personal network size, satisfaction, income, deprivation, employment status
- Measurement Error
  - Be aware of possible differences in In-App data collection methods.
  - Manufacturer, Operating System, App settings, third party apps and user behavior can affect your measurements

You made till the end. Thank you.

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