UNITED STATES DEPARTMENT OF COMMERCE
U.S. Census Bureau
Washington, DC 20233-0001

March 31, 2022

2021 AMERICAN COMMUNITY SURVEY RESEARCH AND EVALUATION REPORT MEMORANDUM SERIES #ACS21-RER-03

DSSD 2021 AMERICAN COMMUNITY SURVEY MEMORANDUM SERIES #ACS21-MP-04

MEMORANDUM FOR American Community Survey Research and Evaluation Workgroup

From: Donna M. Daily DONNA DAILY Digitally signed by DONNA DAILY Date: 2022.03.31 18:34:08 -04'00'
Chief, American Community Survey Office

Patrick J. Cantwell *P. Cantwell*
Chief, Decennial Statistical Studies Division

Prepared by: Gregory J. Mills *GJM*
Survey Analytics and Measures Branch
American Community Survey Office

Lindsay Longsine *LL*
American Community Survey Experiments Branch
Decennial Statistical Studies Division

R. Chase Sawyer *RCS*
Chief, Survey Analytics and Measures Branch
American Community Survey Office

Subject: Respondent Device Analysis for the Internet Instrument on the American Community Survey

Attached is the American Community Survey (ACS) Research and Evaluation report, "Respondent Device Analysis for the Internet Instrument on the American Community Survey." This report first examines device usage over time on the ACS internet instrument, focusing on

PCs, mobile phones, and tablets. It then looks at how certain respondent behaviors, such as multiple logins or device switching, as well as demographic characteristics, might be associated with device type usage. Implications for future ACS planning and research are then discussed.

If you have any questions about this report, please contact Gregory Mills at 301-763-6172 or Lindsay Longsine at 301-763-0364.

Attachment
cc:
ACSO HUSR Branch List
ACSO Methods Panel Coordination List
ACSO Survey Analytics and Measures Branch List

Joanna Fane Lineback	CBSM
Mathew Virgile	
Dorothy Barth	DSSD
Julia Coombs	
Broderick Oliver	
Michael Risley	
Samantha Spiers	
Rachel Horwitz	DSMD
Courtney Reiser	
Jennifer Tancreto	
Christine Flanagan Borman	POP
Colleen Keating	

December 2, 2021

Respondent Device Analysis for the Internet Instrument on the American Community Survey

FINAL REPORT

Gregory J. Mills
American Community Survey Office

Lindsay Longsine
Decennial Statistical Studies Division

R. Chase Sawyer
Social, Economic, and Housing Statistics Division

Intentionally Blank

TABLE OF CONTENTS

List of Tables

List of Appendix Tables

EXECUTIVE SUMMARY

The American Community Survey (ACS) introduced an internet data collection instrument for respondents in 2013. At that time, around 95 percent of internet respondents were using personal computers (PC) and thus the instrument was mostly designed for PC (desktop and laptop) users. A mobile-friendly version of the instrument was introduced in 2016. As mobile phone and tablet usage has grown considerably since that time, we expected more ACS respondents to have utilized those devices to respond using the internet instrument. This report aims to help us better understand these usage trends, and the characteristics of people using these different devices, which will facilitate the planning and implementation of future iterations of the ACS internet instrument.

In particular for this report, we analyzed:

- internet response rates over time
- the breakdown of internet responses by device type and operating system
- the number of logins by device type and operating system
- the timing of response by device type and operating system
- whether or not a respondent switched device types
- the outcome of login attempts by device type
- the characteristics of those who respond by device type

Analyzing data from ACS cases sampled from 2013 through 2019, we found that internet responses increased over time. PC users still made up the largest group of internet logins in 2019 but decreased over time (90.3 percent to 73.1 percent).[1] Mobile phone usage increased over time from 2.2 percent to 18.3 percent, and tablet usage increased from 7.4 percent to 8.6 percent.

The internet instrument allows users to log in more than once and pick up where they left off. Most users only logged in once, but some logged in multiple times. The percentage of PC users and tablet users with a single login held relatively steady between 77 and 80 percent for all years analyzed. However, the percentage of mobile phone users with a single login has increased from 73.5 to 81.6 percent from 2013 to 2019. Also, while PCs made up the majority of logins at each data collection stage, the share of logins from mobile phone increased somewhat after the third mailing and during CAPI.

While about 22 percent of all users had multiple logins, most that had multiple logins used the same device type for the first and last logins. Among those who logged in multiple times, users

[1] In this report, the term "users" after "PC," "mobile phone," or "tablet" refers generally to the cases that were classified as using a PC, mobile phone, or tablet, respectively, for the specific context or research question being discussed.

that initially used a mobile device were most likely to subsequently change devices (16.0 percent), followed by tablet users (12.3 percent), and then PC users (1.9 percent). Mobile phone and tablet users that changed devices tended to change to a PC.

Mobile phone users were less likely than PC and tablet users to provide a completed response (both in the initial login and overall). However, the percentage of completed responses by mobile phone improved over time. The percentage of mobile phone users with a completed response in a single session increased from 53.7 percent to 69.2 percent. The percentage of mobile phone users with a completed response at panel closeout increased from 91.7 percent to 95.9 percent.

Some characteristics positively associated with mobile phone usage included younger people, Hispanics, most self-reported non-White races (except those reporting as Asian and more than one race), renters, people who have never been married, and people who live in larger households. Some characteristics positively associated with PC usage included males, Asians, people who are White or more than one race, and those with a higher level of education. This is not a complete list of characteristics associated (positively or negatively) with the different device types. For more information, see the results section.

1. INTRODUCTION

The American Community Survey (ACS) introduced an internet data collection instrument for respondents in 2013. Leading up to the implementation of the internet instrument, research was done at the Census Bureau to better understand the general utility of the instrument and take stock of potential problems. At that time, around 95 percent of respondents accessing the instrument were using PCs. Thus, since its inception, the instrument has mostly catered to PC users, though a mobile-friendly version of the instrument was introduced in 2016. As mobile phone and tablet usage has grown considerably since that time, we expected more ACS respondents to have utilized those devices to respond using the internet instrument.

This report is the first of a larger project titled The ACS Respndent Device Analysis Project, which will examine various aspects of internet response – including response rates, user traits, and quality measures by device type (and sometimes operating system). This report focuses on basic information about respondents and aims to help us better understand usage trends and the characteristics of people using difference devices. The results will facilitate the planning and implementation of future iterations of the ACS internet instrument. Other aspects of internet response will be covered in other reports.

The first purpose of this report is to document historical trends of the ACS internet instrument usage overall, as well as by device type and operating system. Mobile phone usage in general in the United States has increased since the launching of the internet instrument (Pew Research Center, 2019), and internal reporting shows that usage of the internet instrument has also

increased over time. A second purpose of this research is to document how various behaviors in the internet instrument are related to device type, such as number of logins, switching devices, timing of response, and case disposition trends. With this information we can make better informed decisions regarding targeted usability and functionality for future iterations of the internet instrument.

A third purpose of this research is to examine how social and demographic characteristics are related to device type usage. This type of analysis is challenging particularly considering the overall evolution in device usage in recent years. It stands to reason that as overall device usage increases over time, characteristics related to particular device types may also change. Thus, for this analysis we will focus our attention on the most recent year of internet data collection included in this report.

The idea of pushing the respondent to respond using their phones has been proposed in hopes of increasing response rates by lowering the barrier to respond. This push would require understanding how current users interact with the internet instrument on those devices.

2. BACKGROUND

The ACS is an ongoing, nationwide survey conducted by the Census Bureau to collect detailed social, economic, housing, and demographic information from the population living in housing units and group quarters. The ACS uses a mail contact strategy to encourage residents in sampled addresses to self-respond by internet or mail; however, there are two additional ways to respond – Telephone Questionnaire Assistance (TQA) or a Computer-Assisted Personal Interview (CAPI).[2]

2.1 ACS Data Collection

Every year, the Census Bureau contacts over 3.5 million households across the country to participate in the ACS. The yearly sample for the ACS is distributed evenly across the calendar year, into monthly samples (or panels), with approximately 290,000 new households being contacted at the beginning of each month.

To encourage self-response in the ACS, the Census Bureau sends up to five mailings to a sample address. The initial mailing is sent to all mailable addresses in the sample. It includes an invitation to respond to the ACS online and states that a paper questionnaire will be sent in a few weeks to those unable to respond online. About seven days later, the same addresses are

[2] Telephone Questionnaire Assistance (TQA) is provided to respondents that call our telephone centers for assistance. Operators provide answers to questions about the survey. If the respondent is interested, the operator can complete the interview with them via a computer-assisted telephone interview.

sent a reminder letter, which repeats the instructions to either respond online, wait for a paper questionnaire, or call with questions.

Respondents are removed from the address file after this second mailing to create a new mailing universe of nonresponders. This new universe will be sent the third and fourth mailings. The third mailing includes a paper questionnaire. Recipients are given a new response option (paper) but are still able to respond online as well. About four days later, these addresses are sent a fourth mailing in the form of a reminder postcard.

After the fourth mailing, respondents are again removed from the address file to create a new mailing universe of nonresponders. This new universe of nonresponders are sent an additional reminder (fifth mailing) as a last attempt to collect a self-response. Two to three weeks later, a sample of nonrespondents are selected for the CAPI nonresponse followup operation. Field representatives visit those addresses to conduct in-person interviews.[3] During this time, it is still possible for people to self-respond by internet or paper questionnaire.

Additional information about the ACS can be found in the ACS Design and Methodology Report (U.S. Census Bureau 2014).

2.2 Internet Instrument

The internet instrument was added as a response mode in 2013. Previously, data were collected by paper questionnaire, TQA, Computer-Assisted Telephone Interview (CATI), and CAPI, with the paper questionnaire being the only self-response mode.[4] An internet instrument was developed as another self-response mode that, in addition to being convenient to respondents, could lower the operational costs for the ACS.

The instrument for the internet response mode was designed to be similar to the set-up of the mail, TQA, and CAPI modes to control for any mode effects on response, while also taking advantage of the technology used in the TQA and CAPI modes to improve data quality (Horwitz et al., 2013a). Consistent with the other modes, the internet instrument was developed with four sections of questions: the first section creates the roster, the second section asks basic demographic questions, the third section includes questions about housing characteristics, and the fourth section asks detailed questions about each person in the household. The instrument follows a linear path with typically one question per screen. This is to help the respondent navigate skip patterns, which are automatically executed whenever possible, as in TQA and CAPI. The respondent is also able to review the responses prior to submitting, to submit without review, or to save their progress in the instrument and return at a later time to complete their response.

[3] CAPI interviewers also attempt to conduct interviews by phone when possible.
[4] CATI was phased out of ACS data collection in October 2017.

In 2016 the internet instrument was updated to be more compatible with mobile phones. This included moving some elements such as FAQs and instructions to a drop down menu on the top right of the screen for conserving space and layout optimization, as well as creating mobile and tablet optimized renderings of the instrument that would initiate based on screen width pixelage.

2.3 Device Types and Operating Systems

Recent research into web surveys and device types often compares respondent behavior and data quality metrics amongst mobile phones, tablets, and personal computers. An issue arises in that terms are somewhat loosely defined. The term "PC" typically includes both desktop and laptop computers in the survey research literature (using a variety of operating systems, including Windows, MacOS, and Chrome), and we use the term similarly throughout this report. The term "mobile device" contrarily can refer to smartphones only (as in Antoun et al., 2017), or a combination of smartphones and tablets (as in Schlosser and Mays, 2018), depending on the paper or researcher. In this report, we analyze tablets and smartphones separately, referring to them separately as "tablets" and "mobile phones", respectively.

Using a paradata parser created by the Census Bureau's Center for Behavioral Science Methods (CBSM), we used information received from the device upon logging in to the instrument to categorize each device, which we go further into detail when describing the research questions. For the analysis in this report, the device types we defined are:

1. PCs (includes both desktop and laptop computers)
2. Tablets
3. Mobile phones

There are also a relatively small number of devices that do not fit into any of these categories (e.g., Smart TV, Sony PlayStation, etc.).[5] For most of our analysis we removed these devices. Otherwise, we grouped such devices into a separate "other" category.

We also analyzed data by operating system (sometimes referred to as "OS" in the report) for some of the research questions in this report. The paradata parser mentioned above provides an operating system family and version for each device. Operating systems were analyzed within device types, for more granularity and to better control for operating system differences across device types (e.g., Windows on mobile phones vs. Windows on a desktop computer). Some of the most common operating systems seen in the paradata are:

[5] The number of cases with uncategorized device types amounted to around 100 cases per year, out of close to one million logins per year, which is about one-hundredth of one percent of all cases. Often, these were irregular devices such as game console systems or cases where information was blocked from being captured by Census Bureau paradata systems.

- Android
- Chrome OS
- Linux
- Mac OS X
- Windows
- iOS

Cases where the operating system information was not present, or where an operating system made up less than one half of a percent of the cases for a particular device type for any year, thus being too small to meaningfully analyze, were grouped together into an "other" category for operating systems within each device type.[6] For 2019, these amounted to less than 0.1 percent of cases for both mobile phones and tablets, and about 0.2 percent of cases for PCs.

LITERATURE REVIEW

Leading up to the introduction of the ACS internet instrument in 2013, research was done at the Census Bureau to better understand the general utility of the internet instrument, and to help evaluate and identify problematic questions, screens, or features specific to the internet instrument (Horwitz et al., 2013a, 2013b). This research found no evidence of major issues with particular screens or questions, and found that other instrument features such as help screens and reentry procedures for breakoffs functioned at a satisfactory level. While the vast majority of logins were from PCs, tablets accounted for 3.6 percent of all logins and mobile phones accounted for 0.9 percent. Even though there was a limited sample size of mobile phones and tablets, and the instrument was not mobile-optimized[7], researchers found relatively consistent levels of breakoff rates across device types.

Since the time of this earlier research, smartphone and tablet usage has dramatically grown in the U.S. (Pew Research Center, 2019), and for many people, they have taken over key tasks once performed by desktop computers (Toepoel and Lugtig, 2018). Even though most survey researchers find personal computers still lead mobile phones and tablets in terms of aggregate web-based survey response (Couper et al., 2017; Tourangeau et al. 2017), there is a wide consensus that smartphone and tablet devices are rapidly increasing in use among survey respondents. Horwitz et al. (2013a, 2013b) found between three and four percent of internet instrument respondents used tablets, and slightly less than one percent used a mobile phone. In 2018, internal research suggested that tablet usage on the ACS had grown to about 10

[6] The one exception to this is Windows-based mobile phones, which made up about one percent of mobile phone cases in 2013, but by 2019 made up about one-hundredth of one percent. Due to their relative disappearance from the paradata in recent years, we did not analyze Windows-based mobile phones separately.

[7] Generally, mobile optimization of web surveys is a process where the size and layout of survey questions and response options are dynamically adjusted to better fit the screen size of a tablet or mobile phone (Liebe et al., 2015).

percent and mobile phone usage to 15 percent (Dileo, 2018). Many web-based surveys have created mobile-optimized versions to cater to this increase in mobile phone and tablet usage (Gummer, Quoß & Roßmann, 2019; Struminskaya, Weyandt & Bosnjak, 2015).

While this shift from PC-optimized to mobile-optimized surveys can be framed as being attuned to respondent preferences, some researchers have raised the concern that data quality could suffer with an influx of mobile phone and tablet users. One of the main issues survey researchers have long debated is the smaller screen size of mobile phones, potentially making navigation difficult or requiring more frequent scrolling (Liebe et al., 2015). This could in turn decrease data quality, it is argued, by increasing the time spent completing the survey, leading to higher item nonresponse rates, shorter responses to open-ended questions, or more breakoffs.

However, research into the effects of mobile phone and tablet use in survey response has been somewhat mixed. Some work has found higher item nonresponse among mobile phone users in experiments (Keusch and Yan, 2017), while other work has refuted this claim (Tourangeau et al., 2018). A mitigating factor hypothesized by Tourangeau et al. (2018) is that tablets and more advanced smartphone models, with larger screens and more advanced hardware would perhaps be less likely to have the negative effects associated with smartphones found in previous work.

There is a stronger consensus that completing web-based surveys on a smartphone takes more time than on a PC (Antoun and Cernat, 2019; Antoun et al., 2017; Liebe et al., 2015; Schlosser and Mays, 2018; Sommer et al., 2017). Across a set of 26 studies, Couper and Peterson (2017) found smartphone users took a median of 1.4 times longer to complete a survey than PC users, a finding supported by Antoun and Cernat (2019). This additional time appears to be at least somewhat related to the extra time needed to scroll through multiple-item questions, and the fact that smartphones have smaller screens than personal computers. As such, this particular issue may be less evident for larger smartphones or tablets. Additionally, Gummer and Roßmann (2015) found that interview duration of tablets appeared more consistent with PCs than with smartphones, lending support to the theory that devices with smaller screens may take more time to complete a survey. Antoun and Cernant (2019) also found that this difference was reduced for individuals who were more adept at using smartphones, which suggests that these differences could decline over time as smartphone use becomes more prevalent.

One of the problems with longer completion times is its association with higher breakoff rates, where respondents exit a survey prior to finishing. Much of the literature shows a baseline increase of breakoff rates among smartphone users compared to those using a PC (Couper and Peterson, 2017; Mavletova and Couper, 2015; Sommer et al., 2017). A meta-analysis by Couper et al. (2017) suggests that smartphones breakoff at a rate of about 2.8 times higher than PCs. However, there have been some studies that suggest these differences can be minimized in

certain situations. Mavletova and Couper (2015) found that mobile optimization, email invitations, and a large number of reminders were all associated with a decreased odds for breakoff. They also found that surveys that take more than 30 minutes in time, or that have complex questions with grids, sliders, or drop-downs had an increased odds of breakoff. There have also been some differences found within smartphone users in terms of breakoff rates. Mavletova and Couper (2013, 2014) found that Apple iOS users are least likely to breakoff, while Symbian-based users were most likely.[8] There is also evidence that smartphones with wider screens as well as tablets have lower breakoff rates (Mavletova and Couper, 2014, 2016).

While longer completion times and higher breakoff rates have been associated with smartphone responses, there is also evidence that overall data quality for the data provided across devices is relatively consistent. Sommer et al. (2017) found higher breakoff rates for smartphone devices but saw no difference when comparing internal data consistency and validity between device types. This study was conducted in Germany using members of a research panel, so the results are not necessarily applicable to ACS respondents. Antoun et al. (2017) found that smartphone responders were more likely to report distractions and need multiple sessions to complete their survey. On average smartphone responders took around 17 minutes to complete the survey, while PC users only needed around 10 minutes. In addition, they found that smartphone users recorded less accurate answers than PC users (96 percent accuracy for the former versus 98.9 percent for the latter). Interestingly mobile phone users tended to provide longer answers to the write-in questions than PC users. This goes against the common assumption that mobile users would find typing long answers more difficult. However, the text-box sizes provided for the surveys were not the same size for mobile users and PC users (the mobile text box was larger). This has been shown to have an effect on the length on the write-in answers (Smyth et al., 2009). Once again, this study took place in Europe (the Netherlands) and the participants were experienced survey takers, so the outcomes seen may not translate to the general U.S. population. There is some work showing that predictive text for open-ended questions may enable a faster response time for the respondent but may also be correlated with responses with fewer words and decreased response variation (Arnold, et al., 2020).

Schlosser and Mays (2018) found no difference in breakoff rates, item nonresponse, or length of response to open-ended questions when comparing PCs to all mobile devices. They did see significantly longer total response times for mobile devices, but this difference disappeared after controlling for internet connection speeds. Again, this study was conducted in another country (Germany) and the participants were university students, so the results may not be transferrable to the ACS target population.

[8] Symbian is a discontinued operating system for smartphones used most extensively by Nokia mobile phones.

3. RESEARCH QUESTIONS AND METHODOLOGY

3.1 Research Questions

This paper focuses on answering basic questions about the effect of device type and operating system on response and the relationships between device type and respondent characteristics.

Basic Questions/Demographic Information

1. What was the internet self-response rate over time (both overall and by device type)?
2. Among cases that logged into the internet instrument, what percentage came from each device and operating system (OS)? How did this change over time? What percent of internet cases used the Spanish internet instrument?
3. How many times did users log into the instrument by device type and how did this change over time?
4. Was there a difference in the first device or OS used by phase of data collection? What about the last device if there were multiple logins?
5. How many users switched device types? When they did switch, what was the combination of devices used?
6. Were there differences in the internet interview outcomes for each device type?
7. Were there differences in the demographic, housing, and socioeconomic traits of the respondent by device type?
8. How did household size compare between device types?

3.2 Data Sources

3.2.1 ACS Internet Paradata

Paradata are the data collected during the internet response process that do not include the responses themselves. Paradata can be used to understand how respondents interact with the instrument and potentially identify problems with the survey instrument and questions as well as measure survey burden.

Internet paradata can include a lot of information. There is information specific to the respondent, such as a user identification or location. There is information pertaining to the session itself, such as login times, screens visited, error messages received, etc. Then there is also information about the environment, such as the device type and OS. In the ACS paradata this environment information is captured in what is called a user agent string. This string can tell if the respondent used a mobile device or PC, for instance. To determine the device type and OS from the user agent string we use a parser.

Parsing the ACS internet paradata involves multiple steps. First a generic parser is run on XML files. This parser separates the paradata out into readable columns, including a column for the

user agent string, and outputs to a txt file. Then there is a second parser specific to parsing out information from the user agent string. This parser will output the device type, OS, and browser used for the session. The txt files can then be read into SAS for data analysis purposes.

3.2.2 ACS Responses

We used ACS response data to determine demographic, socioeconomic, and housing characteristics of respondents using each type of device. These traits included:

- age
- sex
- race
- Hispanic origin
- educational attainment
- marital status
- internet access
- smartphone use
- tenure
- household size

3.2.3 Control Files

Research questions 1 and 6 involved looking at response outcomes. For these questions we used data from the 2013 to 2019 control files. The control file is a file created to help facilitate the processing of the ACS operations, and it contains information about the status of each case in each data collection mode.

3.3 Analysis Metrics

Many of the above research questions looked at change over time. For this research, we included data from 2013 to 2019.

3.3.1 Response Rates

Research question 1 examined the distribution of the final self-response at the closeout of each panel.[9]

[9] The data for the first part of this research question came from an internal report called "Response rates – summary", by Stephanie K. Baumgardner (2021), which continually tracks the official ACS response rate overall and by mode, and is used for public reporting of the ACS response rate.

$$\text{Self} - \text{Response} = \frac{\begin{array}{c}\text{Number of eligible sample addresses that} \\ \text{provided a complete} \\ \text{or sufficient partial response in one of the self-response modes}^{10}\end{array}}{\begin{array}{c}\text{Total number of mailable, nonvacant sample addresses} \\ \text{eligible to reply} \\ \text{to the survey and not sampled out of CAPI}\end{array}} * 100$$

The distribution of internet self-response was also calculated by device type at the end of each panel using the formula:

$$\text{Device Type Response} = \frac{\begin{array}{c}\text{Number of eligible sample addresses that} \\ \text{provided a complete} \\ \text{or sufficient partial response by internet} \\ \text{for given device type}\end{array}}{\begin{array}{c}\text{Total number of sample addresses} \\ \text{that provided an internet response}\end{array}} * 100$$

3.3.2 Distribution of Device Type and Operating System by Year

Research question 2 examined the distribution of device type and operating system (OS) among internet logins by year. The distribution of operating systems within each device type was looked at as well. The number of "other" device type logins are provided as part of this analysis (in Table 2 of Section 6), but we excluded this category for all other analyses in the report. This is because it is an extremely small category, often with characteristics that make these devices difficult to categorize.[11]

The percentage for each device type was calculated by year using the following formula:

$$\text{Device Type Percentage} = \frac{\begin{array}{c}\text{Number of final internet} \\ \text{logins with } x \text{ device type}\end{array}}{\text{Number of unduplicated internet logins}} * 100$$

where *x* is the device type. We unduplicate logins by case, and in cases where there is more than one login, we select the final login. The operating system percentages were calculated within each device type rate using the following formula:

[10] Sufficient partials are only considered a response for the internet mode. In general, a sufficient partial internet response is one that has at least minimal information, which indicates an attempt to respond. The specific definition of a sufficient partial internet response is sensitive and for Census Bureau internal use only.

[11] These "other" devices are often gaming consoles, smart television sets, or individuals who have hidden or masked their device information.

$$\text{Operating System Percentage} = \frac{\begin{array}{c}\text{Number of final internet}\\ \text{logins with } y \text{ operating system}\end{array}}{\begin{array}{c}\text{Number of unduplicated internet}\\ \text{logins with } x \text{ device type}\end{array}} * 100$$

where *x* is the device type and *y* is the operating system.

On the first screen of the internet instrument, there is a link in Spanish for respondents to complete the survey in Spanish. Language is chosen upon logging in, thus users are unable to toggle back and forth between languages. But they can logout and choose another language upon reentry. We used the language selected upon interview submission, or the last language chosen in the case that there were multiple selections. We calculated the percentage of usage for the Spanish instrument by device type, using the following formula:

$$\text{Spanish instrument usage} = \frac{\begin{array}{c}\text{Number of final logins that used}\\ \text{the Spanish language instrument}\end{array}}{\text{Number of unduplicated internet logins}} * 100$$

3.3.3 Number of Logins

For research question 3 we determined the number of logins by device type by year.

$$\text{Number of Logins Rate} = \frac{\begin{array}{c}\text{Number of responses}\\ \text{with } x \text{ number of logins}\end{array}}{\begin{array}{c}\text{Number of unduplicated internet}\\ \text{responses with } y \text{ device type}\end{array}} * 100$$

The categories for number of logins are 1 login, 2 logins, 3 logins, and 4 or more logins.

The number of logins by operating system were calculated using the following formula:

$$\text{Number of Logins Rate} = \frac{\begin{array}{c}\text{Number of responses}\\ \text{with } x \text{ number of logins}\end{array}}{\begin{array}{c}\text{Number of unduplicated internet}\\ \text{responses with } y \text{ device type}\\ \text{and } z \text{ operating system}\end{array}} * 100$$

where *x* is the number of logins, *y* is the device type, and *z* is the operating system. We calculated these rates for 2019 but did not calculate these rates over time because operating systems have changed rapidly over time.

3.3.4 First Login Device Type and Operating System by Data Collection Stage

Research question 4 examines device types by data collection stage for cases sampled in 2019. When an address is sampled for the ACS, the Census Bureau first mails an invitation to respond, followed by several followup mailings designed to induce self-response. Finally, a subsample of nonresponding cases from each panel are sent to CAPI for further followup. Looking at each case's "first login", we calculated the distribution of device type and operating system usage in response to several mailings and in the CAPI data collection period. We split each panel into stages of data collection based on the most recent mailing or start of CAPI. Thus, we included four data collection stages: (1) between the first and second mailings, (2) between the second and third mailings, (3) between the third mailing and the start of CAPI, and (4) during CAPI data collection.[12] We used the following formula to report data collection stage:

$$\text{Data Collection State Rate} = \frac{\begin{array}{c}\text{Number of cases sampled} \\ \text{in 2019 with the first login} \\ \text{from } x \text{ data collection stage}\end{array}}{\begin{array}{c}\text{Number of cases sampled} \\ \text{in 2019 with at least} \\ \text{one login with } y \text{ device type} \\ \text{and } z \text{ operating system}\end{array}} * 100$$

where *x* is the data collection stage, *y* is the device type, and *z* is the operating system.

3.3.5 Device Switching

For research question 5 we looked at the prevalence and characteristics of cases changing device over the course of responding to the survey, for cases sampled in 2019. Most internet returns have a single login action, which leads to all progress made for a particular case. However, respondents have the option of saving their progress and logging in at a later time, potentially using a different device.

This analysis included all cases with at least two logins and tracked the device use from the first login to the last login. Specifically, we were interested in the distribution of last device types for each first login device type. The formula we used is as follows:

[12] These points in time were chosen to balance time periods of interest and allowing comparable volume of self-response across response phases.

$$\text{Last Device Type Rate} = \frac{\begin{array}{c}\text{Number of cases sampled} \\ \text{in 2019 with the last login} \\ \text{using device type } x\end{array}}{\begin{array}{c}\text{Number of cases sampled} \\ \text{in 2019 with at} \\ \text{least two logins, and first login} \\ \text{as device type } y\end{array}} * 100$$

where *y* is the device type of the first login, and *x* is the device type of the last login.

3.3.6 Distribution of Outcomes

For research question 6 we calculated the distribution of internet outcome codes by device type for both the initial outcome (how far through the instrument the respondent got on the first attempt) and the final outcome of the internet response. In most of these cases, the outcomes were the same, as roughly 80 percent of respondents finish the interview in their first attempt.

Outcomes were categorized as shown in Table 1.

Table 1. Internet Outcome Types

Initial Outcomes[13]	Final Outcomes[14]
Complete Interview	Complete Interview
Sufficient Partial Interview	Vacant
Vacant	Blank[15]
Roster Started[16]	
Other	

The numerator for these calculations was all valid responses for each outcome type within device type. The denominator included all cases with a valid internet response for each device type.

Rao-Scott chi-square tests of independence were used to determine if there are statistical differences in outcome across device type/operating system at the 0.1 level of significance (Rao & Scott, 1987).

[13] This is the outcome of the respondent's first login and is set by the internet instrument.
[14] This is the outcome created during processing. This variable represents the final outcome.
[15] Blank outcomes are cases where the household is not vacant, but the number of people is zero.
[16] This is the outcome where at least one name has been provided, but there is not enough information for a sufficient partial.

3.3.7 Demographic Distributions

For research question 7, demographic distributions were analyzed from the following response categories: age, sex, Hispanic origin, and race. We calculated person characteristics at the household level using the householder's response information. We also reviewed a number of socioeconomic and housing traits such as marital status, internet access, having a smartphone in the home, educational attainment, and tenure. Finally, for research question 8, the average household size for each device type was calculated and compared.

Rao-Scott chi-square tests of independence were used to determine if there are statistical differences in demographic variables across device type at the 0.1 level of significance (Rao & Scott, 1987).

3.3.7.1 Modeling for Demographic Questions

Determining what demographic, socioeconomic, and housing characteristics play a role in device usage can be a complex endeavor. A number of demographic characteristics can be correlated with device usage and could cause us to incorrectly conclude that there is a difference in data due to the device used rather than underlying differences in demographics. To attempt to dampen the effect of these confounding influences, we used logistic regression modeling to attempt to determine what characteristics are related to responses for each of the three device types.

3.4 Weighting and Standard Errors

All variances were estimated using the Successive Differences Replication method with replicate weights. The variance for each rate and difference was calculated using the formula below.

$$\mathrm{Var}(X_0) = \frac{4}{80}\sum_{r=1}^{80}(X_r - X_0)^2$$

Where:

X_r = the estimate calculated using the r^{th} replicate

X_0 = the estimate calculated using the full sample

The standard error of the estimate (X_0) is the square root of the variance.

For this report, we divided the weights (base weight and replicate weights) by the base weight. This allows for the weight of each observation to be equal to one, but still utilizes the replicate weights for the Successive Differences Replication method for the calculation of variance. The one exception was for the distribution of ACS self-response in research question 1. For this

question, we used the final housing unit weight, which is used in the published ACS datasets and matches other external publications of ACS response rates.

4. ASSUMPTIONS AND LIMITATIONS

There are a few limitations associated with our analysis. As described in section 2.2, users have the ability to save their progress and log in multiple times. This means it is possible to have logins from more than one device on a single case. In this report, we used details about the final login to the instrument in our response and usage metrics of devices and operating systems (unless otherwise specified). We did this to simplify our analysis and make the results easier to understand. We have little reason to believe this affected the findings, as the vast majority of respondents only logged in once, and the vast majority of those who logged in more than once did so with the same device type. We made exceptions to this rule for research questions 4, 5, and 6. Research question 4 reported the device type and operating system of the first login by data collection phase, in order to capture how respondents first interacted with the survey. Research question 5 analyzed device switching specifically, and considered the devices used for the first and last logins. For research question 6 we looked at the distribution of internet outcome codes for the first login and the final outcome determined at the end of the panel. For the analysis of the first login, we used the first login device type. For the final outcome, we used the last login device type.

Another limitation of our analysis is that the parser was unable to determine the device type for a small number of logins. Some of this can be attributed to unusual devices such as gaming consoles. The respondent can also mask their information, in which case we are unable to determine the device that was used. For these cases, we created an "other" category so they can be included in the analysis for research question 2. However, these cases were excluded from all other research questions.

We used unedited data from the respondents to determine the demographic, socioeconomic, and housing distributions. This was done to determine what the respondent indicated to us instead of the instances that responses are edited or imputed. Future reports will assess data quality and examine item nonresponse in more detail. For the person-level variables we chose the response of the householder, which was also the first person rostered for the vast majority of cases. But there were some cases where the householder was not the first person on the roster, and we cannot be sure that the householder was the person using the device or providing the information.

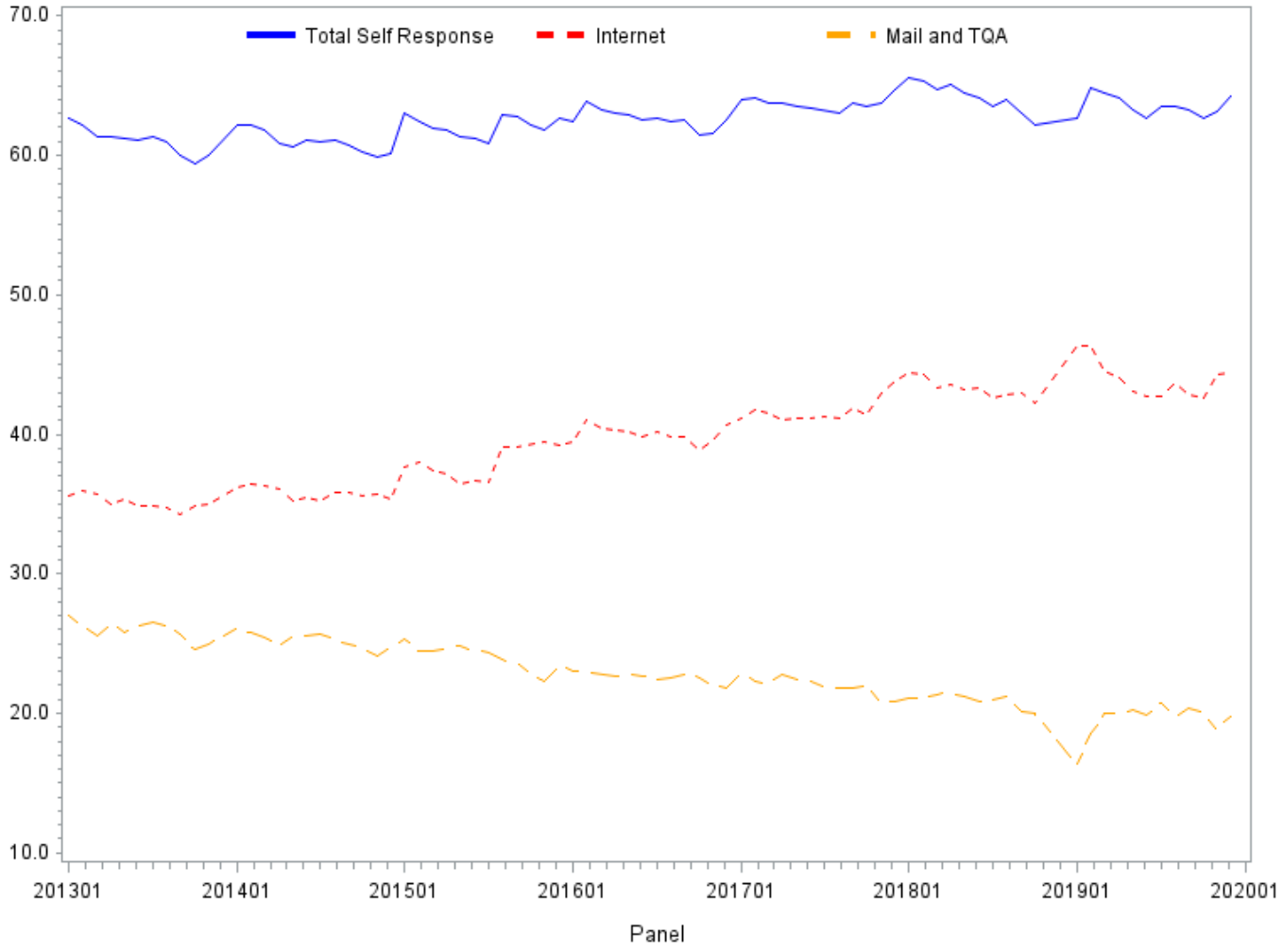
5. RESULTS

Research Question 1: What was the internet self-response over time (both overall and by device type)?

Figure 1 shows the breakdown of the final self-response rates, by mode, for each panel from 2013 through 2019.[17] In January 2013, the self-response rate was 62.6 percent (35.6 percent internet and 27.0 percent non-internet). Mail and TQA are collapsed together as we wanted to show the change in internet response over time. When the internet mode was first introduced in 2013, 56.8 percent of self-responses (35.6/62.6) came from the internet. By the end of 2019, 69.3 (44.5/64.2) percent of self-responses came from the internet.

[17] As described in Section 3, the data for Figure 1 came from an internal report showing the calculation of response rates (Baumgardner, 2021).

Figure 1. ACS Self Response 2013-2019

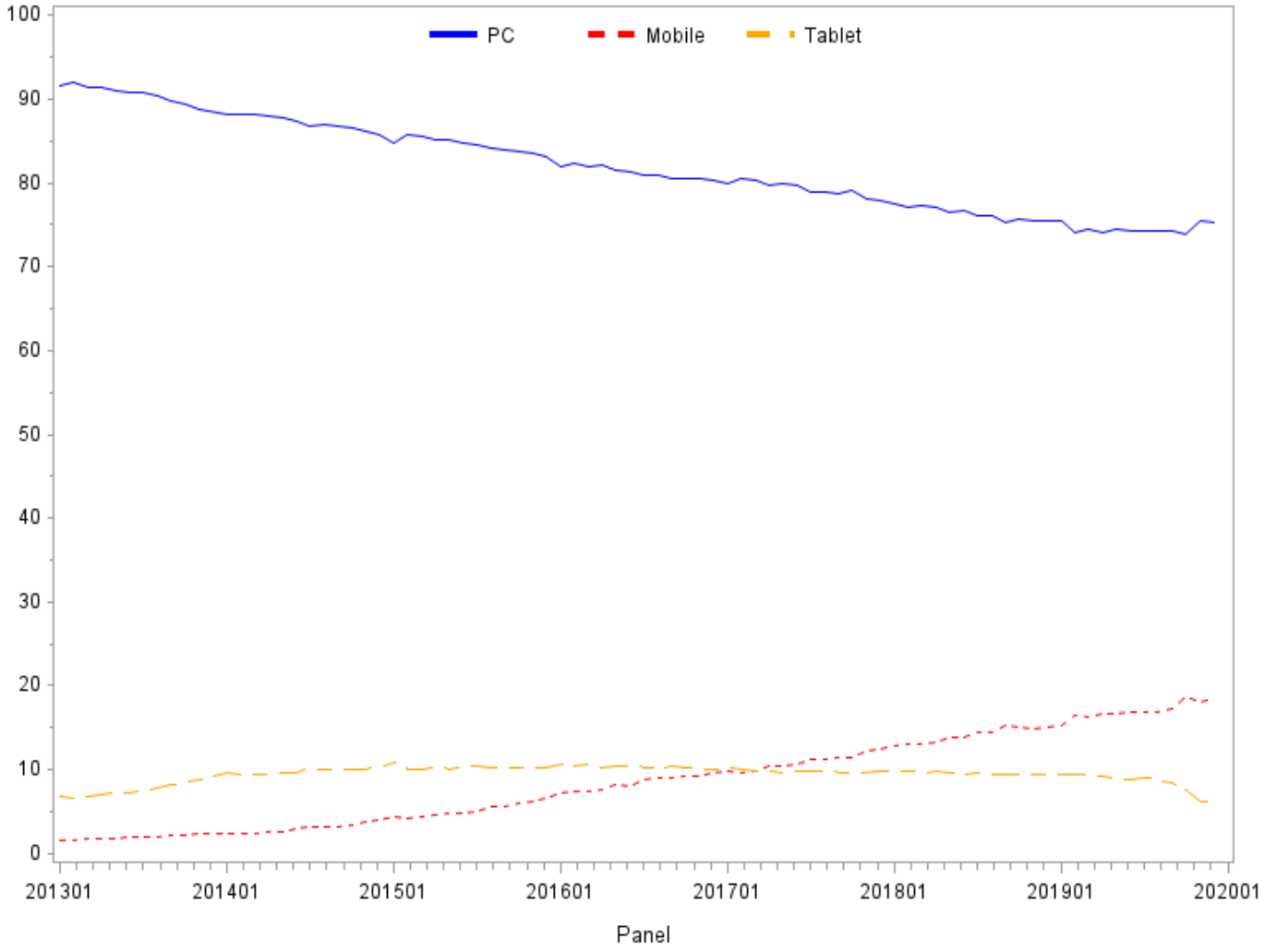


Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.
Note: Panels substantially affected by government shutdowns are not included.

As seen in the graph, the percentage of responses that came from the internet went up over time, while the percentage from non-internet self-response decreased.

With internet responses increasing over time, we must take into account the different ways a person can respond online. Figure 2 shows the internet responses only, broken down by device type.

Figure 2. Distribution of Internet Response by Device Type, 2013-2019



Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

The majority of internet responses came from PC users; however, that percentage decreased over time. Mobile phone respondents steadily increased during this time period and tablet users remained relatively constant. Because Figure 2 only shows completed interviews, this distribution may not accurately reflect how people would have preferred to respond online (e.g., a respondent may have wanted to respond on their mobile phone but found it too difficult and switched to another device type).

Research Question 2: Among cases that log into the internet instrument, what percentage came from each device and operating system (OS)? How did this change over time? What percent of internet cases used the Spanish internet instrument?

As mentioned, 2013 was the first year that the ACS collected data for final data product tabulation using an internet instrument. And as Figure 1 shows, the usage of the internet instrument increased over time. Table 2 shows the distribution of device and OS usage among cases with at least one login to the ACS internet instrument by sample year, between 2013 and 2019. As mentioned above, percentages were calculated by using the final login device type for each case. The relative distribution of each device and OS combination from 2019 was statistically tested against the corresponding distribution from 2013 to show if that rate increased or decreased over time. All differences tested in Table 2 were statistically significant.

In 2013, 90.3 percent of cases used a PC. These were mostly with Windows and Mac OS X operating systems, at 85.2 and 14.3 percent of PC cases, respectively. By 2019, the percentage of PC cases had fallen to 73.1 percent, or a decrease of 17.2 percentage points. Additionally, the relative usage of Chrome OS and Linux operating systems among PC cases had increased in that time, from 0.2 to 2.3 percent, and from 0.2 to 0.3 percent, respectively. Windows operating system usage, while still making up the majority of operating systems among PC cases, decreased from 85.2 to 75.3 percent.

By contrast, rates of mobile phone usage for cases with a login to the internet instrument increased from 2.2 percent in 2013 to 18.3 percent in 2019. Usage of mobile phones was relatively evenly split by iOS and Android operating systems over this time, with iOS usage increasing from 48.8 to 54.3 percent, and Android decreasing from 49.5 to 45.7 percent. Tablet usage was 7.4 percent in 2013 and 8.6 percent in 2019. It is interesting to note that the highest nominal rate of tablet usage was in 2015 and 2016 at 10.5 percent. OS usage among tablets was dominated by iOS, but Android usage among tablets increased from 12.5 to 19.0 percent, and Windows OS usage among tablets also increased from 0.8 to 8.4 percent.

Table 2. Percentage of Device Type and Operating System for all Internet Cases by Year

Categories	2013	2014	2015	2016	2017	2018	2019	2019-2013	P-value
PC	**90.3 (<0.1)**	**86.6 (<0.1)**	**83.6 (<0.1)**	**80.3 (0.1)**	**78.2 (0.1)**	**75.0 (0.1)**	**73.1 (0.1)**	**-17.2 (0.1)**	**<0.01**
Windows	85.2 (<0.1)	82.8 (<0.1)	80.9 (<0.1)	79.5 (<0.1)	78.3 (<0.1)	77.3 (<0.1)	75.3 (<0.1)	-9.9 (0.1)	<0.01
Mac OS X	14.3 (<0.1)	16.3 (<0.1)	17.9 (<0.1)	18.9 (<0.1)	19.9 (<0.1)	20.4 (<0.1)	21.9 (<0.1)	7.7 (0.1)	<0.01
Chrome OS	0.2 (<0.1)	0.5 (<0.1)	0.8 (<0.1)	1.1 (<0.1)	1.3 (<0.1)	1.8 (<0.1)	2.3 (<0.1)	2.1 (<0.1)	<0.01
Linux	0.2 (<0.1)	0.2 (<0.1)	0.2 (<0.1)	0.2 (<0.1)	0.2 (<0.1)	0.2 (<0.1)	0.3 (<0.1)	0.1 (<0.1)	<0.01
Other PC	0.2 (<0.1)	0.2 (<0.1)	0.2 (<0.1)	0.2 (<0.1)	0.2 (<0.1)	0.2 (<0.1)	0.2 (<0.1)	>-0.1 (<0.1)	0.02
Mobile	**2.2 (<0.1)**	**3.5 (<0.1)**	**5.9 (<0.1)**	**9.2 (<0.1)**	**11.8 (<0.1)**	**15.1 (<0.1)**	**18.3 (<0.1)**	**16.1 (<0.1)**	**<0.01**
iOS	48.8 (0.4)	44.3 (0.3)	45.2 (0.2)	47.8 (0.1)	51.7 (0.2)	52.2 (0.1)	54.3 (0.1)	5.5 (0.4)	<0.01
Android	49.5 (0.4)	54.1 (0.3)	53.6 (0.2)	51.6 (0.1)	48.1 (0.2)	47.7 (0.1)	45.7 (0.1)	-3.8 (0.4)	<0.01
Other Mobile	1.7 (0.1)	1.7 (0.1)	1.2 (<0.1)	0.6 (<0.1)	0.2 (<0.1)	0.1 (<0.1)	<0.1 (<0.1)	-1.7 (0.1)	<0.01
Tablet	**7.4 (<0.1)**	**9.8 (<0.1)**	**10.5 (<0.1)**	**10.5 (<0.1)**	**10.0 (<0.1)**	**9.8 (<0.1)**	**8.6 (<0.1)**	**1.2 (<0.1)**	**<0.01**
iOS	86.5 (0.1)	80.4 (0.1)	75.6 (0.1)	71.2 (0.2)	71.0 (0.1)	71.4 (0.1)	72.6 (0.2)	-13.9 (0.2)	<0.01
Android	12.5 (0.1)	17.2 (0.1)	21.3 (0.1)	20.9 (0.1)	20.3 (0.1)	20.1 (0.1)	19.0 (0.1)	6.6 (0.2)	<0.01
Windows	0.8 (<0.1)	2.3 (0.1)	3.0 (<0.1)	7.8 (0.1)	8.7 (0.1)	8.5 (0.1)	8.4 (0.1)	7.6 (0.1)	<0.01
Other Tablet	0.3 (<0.1)	0.1 (<0.1)	0.1 (<0.1)	<0.1 (<0.1)	<0.1 (<0.1)	<0.1 (<0.1)	<0.1 (<0.1)	-0.2 (<0.1)	<0.01
Other	**<0.1 (<0.1)**	**<0.1 (<0.1)**	**<0.1 (<0.1)**	**<0.1 (<0.1)**	**<0.1 (<0.1)**	**<0.1 (<0.1)**	**<0.1 (<0.1)**	**>-0.1 (<0.1)**	**<0.01**

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.
Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a two-tailed t-test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.

We also looked at how often the Spanish instrument was used. Table 3 shows the rate of Spanish language instrument usage overall and by device type, out of all instrument logins for the particular device type. This is in order to compare the relative prevalence of Spanish instrument usage across device types.

Table 3. Spanish Internet Instrument Usage in 2019 by Device Type, with Comparisons

Device Type	Spanish Instrument Usage Rate by Device Type		Spanish Instrument Usage by Device Type	
Total	0.4 (<0.1)		--	
PC	0.2 (<0.1)		48.5 (1.4)	
Mobile	0.8 (<0.1)		43.6 (1.4)	
Tablet	0.3 (<0.1)		8.0 (0.7)	
Comparison	**Difference**	**p-value**	**Difference**	**p-value**
PC vs Mobile	-0.6 (<0.1)	<0.01	4.9 (2.7)	<0.01
PC vs Tablet	-0.1 (<0.1)	<0.01	40.5 (1.7)	<0.01
Tablet vs Mobile	-0.5 (<0.1)	<0.01	-35.6 (1.7)	<0.01

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.
Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses.
Significance was tested based on a two-tailed t-test at the α=0.1 level

Overall, the rate of usage for the Spanish internet instrument in 2019 was 0.4 percent, or about one out of 250 logins. However, there were differences in usage across device types. For PCs, 0.2 percent of all logins accessed the Spanish instrument, compared to 0.8 and 0.3 percent for mobile phones and tablets, respectively. Within Spanish instrument users, 48.5 percent used a PC, 43.6 percent used a mobile phone, and 8.0 percent used a tablet. PC users had the lowest rate of Spanish language instrument usage, but the highest overall number of users. Mobile phones had the highest rate of Spanish instrument usage across device types, but had slightly fewer overall users than PCs.

Research Question 3: How many times did respondents log into the instrument by device type and how did this change over time?

Table 4 shows the distribution of the number of logins overall and for each device type by year. As mentioned above, percentages were calculated by using the final login device type for each case. Multiple login cases are further analyzed in Research Question 5.

Overall, although the differences in the number of logins were statistically significant, the number of logins did not show a clear directional shift over time and remained relatively stable on a practical level. In 2013, 78.2 percent of cases only logged in once, versus 78.1 percent in 2019. In 2013, 15.3 percent of cases logged in twice, 4.1 percent logged in three times, and 2.3 logged in four or more times; compared to 15.5 percent, 4.2 percent, and 2.2 percent in 2019, respectively. Notably, these comparisons while significant were easily within a half percentage point of each other.

For respondents using a PC or tablet, like for cases overall, the share of single-login cases did not appear to follow a clear trend. Across all years for both device types, between 77 and 80 percent of cases had only a single login. However, single-login cases for respondents using a mobile phone increased from 73.5 percent in 2013 to 81.6 percent in 2019. For mobile phones, all categories of multiple logins decreased across time between two and four percentage points.

In summary, there were some small changes to the proportion of cases that have one, two, three or four or more logins between 2013 and 2019, but it is unclear which direction these will move going forward. The number of logins for PCs and tablets seemed to align for the most part. Perhaps the most notable change over time was that mobile users had a growing tendency to have a single login. This may have reflected a growing ease for smartphone users to interact with the internet instrument.

Table 4. Number Logins by Year and Device Type

Categories	2013	2014	2015	2016	2017	2018	2019	2019-2013	p-value
Total									
1 login	78.2 (<0.1)	78.1 (0.1)	78.1 (<0.1)	79.8 (0.1)	80.0 (0.1)	79.9 (0.1)	78.1 (0.1)	-0.1 (0.1)	0.08
2 logins	15.3 (<0.1)	15.3 (<0.1)	15.4 (<0.1)	14.6 (<0.1)	14.5 (<0.1)	14.5 (<0.1)	15.5 (<0.1)	0.3 (0.1)	<0.01
3 logins	4.1 (<0.1)	4.2 (<0.1)	4.2 (<0.1)	3.8 (<0.1)	3.7 (<0.1)	3.7 (<0.1)	4.2 (<0.1)	<0.1 (<0.1)	0.15
4+ logins	2.3 (<0.1)	2.4 (<0.1)	2.3 (<0.1)	1.9 (<0.1)	1.9 (<0.1)	1.9 (<0.1)	2.2 (<0.1)	-0.1 (<0.1)	<0.01
PC									
1 login	78.4 (<0.1)	78.3 (0.1)	78.0 (<0.1)	79.3 (<0.1)	79.4 (<0.1)	79.4 (<0.1)	77.1 (<0.1)	-1.2 (0.1)	<0.01
2 logins	15.3 (<0.1)	15.3 (<0.1)	15.5 (<0.1)	14.9 (<0.1)	14.9 (<0.1)	14.8 (<0.1)	16.0 (<0.1)	0.8 (0.1)	<0.01
3 logins	4.1 (<0.1)	4.1 (<0.1)	4.2 (<0.1)	3.9 (<0.1)	3.8 (<0.1)	3.8 (<0.1)	4.4 (<0.1)	0.3 (<0.1)	<0.01
4+ logins	2.3 (<0.1)	2.3 (<0.1)	2.3 (<0.1)	1.9 (<0.1)	1.9 (<0.1)	2.0 (<0.1)	2.4 (<0.1)	0.1 (<0.1)	<0.01
Mobile									
1 login	73.5 (0.3)	76.4 (0.2)	80.2 (0.2)	83.6 (0.1)	83.3 (0.1)	82.5 (0.1)	81.6 (0.1)	8.1 (0.3)	<0.01
2 logins	16.2 (0.2)	14.2 (0.2)	13.4 (0.1)	11.9 (0.1)	12.1 (0.1)	12.9 (0.1)	13.7 (0.1)	-2.5 (0.2)	<0.01
3 logins	5.6 (0.2)	5.0 (0.1)	3.9 (0.1)	2.9 (0.1)	2.9 (<0.1)	3.0 (<0.1)	3.2 (<0.1)	-2.3 (0.2)	<0.01
4+ logins	4.8 (0.2)	4.4 (0.1)	2.5 (0.1)	1.7 (<0.1)	1.6 (<0.1)	1.6 (<0.1)	1.5 (<0.1)	-3.3 (0.2)	<0.01
Tablet									
1 login	78.3 (0.2)	77.1 (0.1)	77.7 (0.1)	79.7 (0.1)	79.9 (0.1)	79.8 (0.1)	79.2 (0.1)	0.9 (0.2)	<0.01
2 logins	15.2 (0.1)	16.0 (0.1)	15.7 (0.1)	14.6 (0.1)	14.5 (0.1)	14.5 (0.1)	15.0 (0.1)	-0.2 (0.2)	0.29
3 logins	4.1 (0.1)	4.3 (0.1)	4.3 (0.1)	3.7 (0.1)	3.7 (0.1)	3.7 (<0.1)	3.9 (0.1)	-0.2 (0.1)	0.03
4+ logins	2.4 (0.1)	2.5 (0.1)	2.3 (0.1)	2.0 (<0.1)	1.9 (<0.1)	2.0 (<0.1)	2.0 (<0.1)	-0.4 (0.1)	<0.01

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.
Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a two-tailed t-test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.

Table 5 shows the distribution of the number of logins by device and operating system for cases sampled in 2019. These figures add more detail to the 2019 column of Table 4. Most operating system subgroups appeared to show similar trends as the overall device type.

Table 5. Total Number of Logins by Device Type and Operating System, 2019

Categories	1 Login	2 Logins	3 Logins	4+ Logins
PC	**77.1 (<0.1)**	**16.0 (<0.1)**	**4.4 (<0.1)**	**2.4 (<0.1)**
Windows	76.9 (0.1)	16.2 (0.1)	4.5 (<0.1)	2.5 (<0.1)
Mac OS X	77.9 (0.1)	15.7 (0.1)	4.2 (0.1)	2.2 (<0.1)
Chrome OS	77.2 (0.3)	16.1 (0.3)	4.4 (0.1)	2.3 (0.1)
Linux	76.8 (0.8)	16.2 (0.6)	4.6 (0.3)	2.4 (0.3)
Other PC	77.8 (0.9)	14.9 (0.8)	3.9 (0.5)	3.4 (0.5)
Mobile	**81.6 (0.1)**	**13.7 (0.1)**	**3.2 (<0.1)**	**1.5 (<0.1)**
iOS	83.4 (0.1)	12.4 (0.1)	2.8 (0.1)	1.4 (<0.1)
Android	79.4 (0.1)	15.2 (0.1)	3.7 (0.1)	1.7 (<0.1)
Other Mobile	86.8 (6.2)	10.5 (4.8)	2.6 (3.8)	<0.1 (<0.1)
Tablet	**79.2 (0.1)**	**15.0 (0.1)**	**3.9 (0.1)**	**2.0 (<0.1)**
iOS	79.8 (0.2)	14.5 (0.1)	3.8 (0.1)	1.9 (0.1)
Android	77.0 (0.3)	16.6 (0.3)	4.1 (0.1)	2.3 (0.1)
Windows	78.7 (0.5)	15.3 (0.4)	4.1 (0.2)	1.9 (0.1)
Other Tablet	100.0 (<0.1)	0.0 (<0.1)	0.0 (<0.1)	0.0 (<0.1)
Total	**78.1 (0.1)**	**15.5 (<0.1)**	**4.2 (<0.1)**	**2.2 (<0.1)**

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses.

Research Question 4. Was there a difference in the first device or OS used by phase of data collection? What about the last device if there were multiple logins?

The typical ACS mailout schedule has several phases, where cases for which we have received a response are removed from the mailout list. For this research question, we first classified responses based on when the case initially logged in and looked to see if there were any device type trends across data collection phases. For the purposes of this report, we called the time between the first and second mailings the "First Phase," the time between the second and third mailings the "Second Phase," the time between the third mailing and the start of CAPI the "Third Phase," and the time during or after CAPI the "Fourth Phase." Table 6 shows the results from this analysis.

PCs made up 73.3 percent of cases that logged in for the first time during the first phase, and 75.4 percent of cases that logged in for the first time during the second phase. This compares to 67.9 percent of cases that logged in for the first time during the third phase, and 67.8 percent of cases that logged in for the first time during the fourth phase. Mobile phones comprised 17.2 percent of cases that logged in for the first time in the first phase and 16.9 percent of cases for the second phase. This compares to 24.9 percent for the third phase and 25.0 percent for the fourth phase. Tablets comprised 9.5 percent of cases that logged into the instrument for the first time during the first phase of data collection, 7.7 percent for the second phase, 7.2 percent for the third phase, and 7.2 percent for the fourth phase.

In sum, mobile phone usage nominally increased after the third mailing and remained higher during CAPI while PC usage decreased somewhat in these later phases. Tablet use was highest in the first phase and relatively similar after the third mailing.

Table 6. Device Type and OS of Initial Login by Phase of 2019 Data Collection

Categories	Between First and Second Mailings (First Phase)	Between Second and Third Mailings (Second Phase)	Between Third Mailing and CAPI (Third Phase)	During or after CAPI (Fourth Phase)
PC	**73.3 (0.1)**	**75.4 (0.1)**	**67.9 (0.2)**	**67.8 (0.2)**
Windows	76.9 (0.1)	73.5 (0.1)	73.6 (0.2)	72.1 (0.1)
Mac OS X	20.4 (0.1)	23.8 (0.1)	23.4 (0.2)	24.8 (0.2)
Chrome OS	2.2 (<0.1)	2.2 (<0.1)	2.6 (0.1)	2.7 (0.1)
Linux	0.3 (<0.1)	0.3 (<0.1)	0.3 (<0.1)	0.2 (<0.1)
Other PC	0.2 (<0.1)	0.2 (<0.1)	0.2 (<0.1)	0.2 (<0.1)
Mobile	**17.2 (<0.1)**	**16.9 (0.1)**	**24.9 (0.1)**	**25.0 (0.1)**
iOS	53.3 (0.2)	55.9 (0.3)	54.8 (0.3)	57.2 (0.3)
Android	46.7 (0.2)	44.1 (0.3)	45.2 (0.3)	42.8 (0.3)
Other Mobile	<0.1 (<0.1)	<0.1 (<0.1)	<0.1 (<0.1)	<0.1 (<0.1)
Tablet	**9.5 (<0.1)**	**7.7 (0.1)**	**7.2 (0.2)**	**7.2 (0.1)**
iOS	73.3 (0.2)	72.4 (0.3)	70.3 (0.6)	70.6 (0.5)
Android	19.2 (0.2)	17.6 (0.3)	20.1 (0.5)	19.7 (0.4)
Windows	7.5 (0.1)	10.0 (0.2)	9.5 (0.4)	9.8 (0.3)
Other Tablet	<0.1 (<0.1)	<0.1 (<0.1)	<0.1 (<0.1)	<0.1 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.
Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses.

Similar metrics are shown in Table 7 for the last login for cases that had more than one login. Table 5 showed that about 22 percent of cases sampled in 2019 had more than one login. Of cases with multiple logins where the final login was received in the first phase of data collection, 76.2 percent were from PCs, while 14.5 percent were from mobile phones, and 9.2 percent were from tablets. For those where the final login was in the second stage of data collection, 79.3 percent were from PCs, 13.3 percent from mobile phones, and 7.4 percent from tablets. In the third stage of data collection, 74.2 percent were from PCs, 19.1 percent were from mobile phones, and 7.0 percent were from tablets. Finally, in the fourth stage of data collection 72.1 percent were from PCs, 21.0 percent were from mobile phones, and 6.9 percent were from tablets.

Thus, the usage of mobile phones increased in later rounds of data collection also among cases with multiple logins. Additionally, there was a higher proportion of PC users among multiple

login cases (Table 7) than among cases overall (Table 6).[18] This may suggest that device switching that occurs among multiple login cases favored PC usage. We explore this more in the following research question.

Table 7. Device Type and OS of Final Login from Cases with Multiple Logins, by Phase of 2019 Data Collection

Categories	Between First and Second Mailings (First Phase)	Between Second and Third Mailings (Second Phase)	Between Third Mailing and CAPI (Third Phase)	During or after CAPI (Fourth Phase)
PC	**76.2 (0.1)**	**79.3 (0.1)**	**74.2 (0.3)**	**72.1 (0.2)**
Windows	78.1 (0.1)	74.7 (0.2)	74.2 (0.4)	72.8 (0.3)
Mac OS X	19.2 (0.1)	22.6 (0.2)	22.8 (0.3)	24.1 (0.3)
Chrome OS	2.2 (<0.1)	2.2 (0.1)	2.6 (0.2)	2.6 (0.1)
Linux	0.3 (<0.1)	0.3 (<0.1)	0.3 (<0.1)	0.3 (<0.1)
Other PC	0.2 (<0.1)	0.2 (<0.1)	0.2 (<0.1)	0.1 (<0.1)
Mobile	**14.5 (0.1)**	**13.3 (0.1)**	**19.1 (0.3)**	**21.0 (0.2)**
iOS	47.5 (0.4)	50.6 (0.5)	47.2 (0.8)	51.4 (0.6)
Android	52.5 (0.4)	49.4 (0.5)	52.8 (0.8)	48.6 (0.6)
Other Mobile	<0.1 (<0.1)	<0.1 (<0.1)	-	<0.1 (<0.1)
Tablet	**9.2 (0.1)**	**7.4 (0.1)**	**7.0 (0.2)**	**6.9 (0.2)**
iOS	70.6 (0.5)	71.1 (0.6)	67.8 (1.4)	69.1 (1.0)
Android	21.8 (0.4)	19.3 (0.6)	22.8 (1.1)	20.3 (0.8)
Windows	7.6 (0.2)	9.5 (0.4)	9.4 (0.7)	10.6 (0.7)
Other Tablet	-	-	-	-

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.
Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses.

Research Question 5: How many respondents switched device types? When they did switch, what was the combination of devices used?

In Table 7, device usage among cases with more than one login was examined, showing that PC usage appeared to be higher in the final login among multiple login cases than in the first login among all cases. Research question 5 more thoroughly analyzes device usage patterns of multiple login cases.

As can be seen in Table 8, most cases that logged in more than once used the same type of device for the first and final logins; 98.1 percent of those who started on a PC also used the same device type for the final login. Put another way, 1.9 percent of multiple login cases that

[18] In an unshown t-test comparison, the rate of PC usage at each phase of data collection was higher among multiple login cases than in cases overall, with p-values measuring less than 0.01 for all comparisons.

started on a PC changed to another device type for the final login. For mobile users, 84.0 percent who first logged in with a mobile phone stayed on a mobile phone for the final login, while 16.0 percent changed to another device. For tablet users, 87.7 percent remained on a tablet, while 12.3 percent changed to another device type.

Additionally, we wanted to know which devices were more likely to be used for the final login when a change in devices did occur. To do this analysis, for cases that began with a specific device type, we compared the percent of cases that changed to either of the other device types for the final login.

For those who start on a PC, 1.1 percent moved to a mobile phone, while 0.8 percent moved to a tablet, which is a statistically significant difference of 0.3 percent. For those who first logged in with a mobile phone, 14.2 percent finished on a PC, while 1.8 percent finished on a tablet, which was a statistically significant difference of 12.4 percent. Likewise, for those who first logged in with a tablet, 10.6 percent finished on a PC, while 1.8 percent finished on a mobile phone, which was a statistically significant difference of 8.8 percentage points. Thus, it can be said that for both cases that began on a mobile phone or tablet when there was a change in devices, it was more likely to be a change to a PC than to a tablet or mobile phone, respectively.

Table 8. Device Use Patterns for Internet Users with Multiple Logins, 2019

First Device	Final Login with PC	Final Login with Mobile Phone	Final Login with Tablet	Device Changers Comparison	*p-value*	Most Likely Changed to
PC	98.1 (<0.1)	1.1 (<0.1)	0.8 (<0.1)	0.3 (<0.1)	<0.01	Mobile
Mobile	14.2 (0.2)	84.0 (0.2)	1.8 (0.1)	12.4 (0.2)	<0.01	PC
Tablet	10.6 (0.2)	1.8 (0.1)	87.7 (0.3)	8.8 (0.3)	<0.01	PC

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a two-tailed t-test at the α=0.1 level

Table 9 lends additional support to the device switching patterns shown in Table 8 by statistically comparing the overall rate of device switching by device type. PC users were least likely to switch device types, followed by tablet users, with mobile phone users most likely to have switched device types. All three comparisons were statistically significant.

Table 9. Comparison of Multiple Login Cases with a Change in Device Type, 2019

Device Comparison	Percent that Change Devices	Difference	*p-value*	More Likely to Change Devices
PC versus Mobile	1.9 (<0.1) versus 16.0 (0.2)	14.0 (0.2)	<0.01	Mobile
PC versus Tablet	1.9 (<0.1) versus 12.3 (0.1)	10.4 (0.3)	<0.01	Tablet
Mobile versus Tablet	16.0 (0.2) versus 12.3 (0.1)	3.6 (0.3)	<0.01	Mobile

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a two-tailed t-test at the α=0.1 level

Research Question 6: Were there differences in the internet interview outcomes for each device type?

Interview outcomes, in general, indicate how far a respondent got through the interview. Internet outcomes for ACS are collected in multiple ways. One outcome variable records how far a respondent got through the instrument on their first login. There is another variable that reflects the most recent outcome, determined by the instrument. Finally, there is an outcome variable set as the final outcome through processing at panel closeout. Most respondents finish in their first login, but there are some that do not. We were interested in whether there was a difference amongst device types as to how far a respondent made it through the instrument on their first try. We analyzed this by looking at the distribution of internet outcomes for the initial login variable and the first device type that was used. We were also interested in the final distribution of internet outcomes. We analyzed this by looking at the distribution of the final outcome at panel closeout and the final device type used.

Table 10 shows the distribution of internet outcomes for the first login attempt. The universe for table 10 is all internet responses.

Table 10. Initial Outcome by Device Type for Internet Responses

Year	Outcome	PC	Mobile	Tablet	Chi-square	P-value
2013	Complete	74.1 (<0.1)	53.7 (0.4)	70.4 (0.2)	875.6	<0.01
	Sufficient Partial	16.4 (<0.1)	25.6 (0.3)	18.0 (0.2)		
	Vacant	1.8 (<0.1)	1.3 (0.1)	1.7 (<0.1)		
	Roster Started	5.1 (<0.1)	10.1 (0.2)	6.1 (0.1)		
	Other	2.6 (<0.1)	9.3 (0.2)	3.7 (0.1)		
2014	Complete	73.8 (0.1)	54.7 (0.2)	69.8 (0.2)	1121.2	<0.01
	Sufficient Partial	16.1 (<0.1)	25.3 (0.2)	18.2 (0.1)		
	Vacant	1.8 (<0.1)	1.1 (0.1)	1.7 (<0.1)		
	Roster Started	5.2 (<0.1)	9.5 (0.2)	6.4 (0.1)		
	Other	3.1 (<0.1)	9.3 (0.2)	4.0 (0.1)		
2015	Complete	73.4 (0.1)	57.4 (0.2)	70.9 (0.2)	1084.2	<0.01
	Sufficient Partial	16.2 (<0.1)	25.2 (0.2)	17.6 (0.1)		
	Vacant	1.8 (<0.1)	1.2 (<0.1)	1.8 (<0.1)		
	Roster Started	5.4 (<0.1)	9.4 (0.1)	6.1 (0.1)		
	Other	3.1 (<0.1)	6.8 (0.1)	3.6 (0.1)		
2016	Complete	74.8 (<0.1)	67.5 (0.1)	73.7 (0.2)	520.4	<0.01
	Sufficient Partial	15.0 (<0.1)	19.6 (0.1)	15.4 (0.1)		
	Vacant	1.9 (<0.1)	1.3 (<0.1)	1.9 (<0.1)		
	Roster Started	5.7 (<0.1)	6.9 (0.1)	5.9 (0.1)		
	Other	2.6 (<0.1)	4.8 (0.1)	3.0 (0.1)		
2017	Complete	75.9 (0.1)	69.3 (0.2)	75.6 (0.1)	517.1	<0.01
	Sufficient Partial	13.7 (<0.1)	17.5 (0.1)	13.3 (0.1)		
	Vacant	1.9 (<0.1)	1.2 (<0.1)	2.0 (<0.1)		
	Roster Started	5.9 (<0.1)	7.1 (0.1)	6.2 (0.1)		
	Other	2.6 (<0.1)	4.9 (0.1)	2.9 (0.1)		
2018	Complete	75.9 (0.1)	69.4 (0.1)	76.0 (0.2)	651.1	<0.01
	Sufficient Partial	13.6 (<0.1)	17.5 (0.1)	12.9 (0.1)		
	Vacant	1.9 (<0.1)	1.2 (<0.1)	2.1 (<0.1)		
	Roster Started	5.9 (<0.1)	7.3 (0.1)	6.1 (0.1)		
	Other	2.7 (<0.1)	4.6 (0.1)	3.0 (0.1)		
2019	Complete	75.4 (0.1)	69.2 (0.1)	76.2 (0.1)	619.1	<0.01
	Sufficient Partial	13.8 (<0.1)	17.6 (0.1)	13.1 (0.1)		
	Vacant	1.9 (<0.1)	1.2 (<0.1)	2.0 (<0.1)		
	Roster Started	6.1 (<0.1)	7.6 (0.1)	6.1 (0.1)		
	Other	2.8 (<0.1)	4.4 (0.1)	2.6 (0.1)		

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.

The relationship between initial internet outcome and device type was statistically significant. Each outcome type was also compared across device types using two-sided t-tests. For the years 2014 – 2017 there was no significant difference in the vacant rates between PC and tablet users. All other comparisons were significant.

The completion rate for mobile phones in 2013 was 53.7 percent. By 2019, the rate was 69.2 percent. The biggest jump was in 2016 when the internet instrument was optimized for mobile phones. The completion rates for PCs and tablets appear to have increased over time as well, but we did not statistically test to see if completion rates have increased with time (only the relationship of internet outcomes to device type).

Table 11 shows the distribution of final internet outcomes.

Table 11. Final Outcome by Device Type for Internet Responses

Year	Outcome	PC	Mobile	Tablet	Chi-square	P-value
2013	Complete	97.7 (<0.1)	91.7 (0.2)	96.9 (0.1)	956.6	<0.01
	Vacant	1.0 (<0.1)	2.0 (0.1)	1.1 (<0.1)		
	Blank	1.3 (<0.1)	6.3 (0.2)	2.0 (0.1)		
2014	Complete	97.8 (<0.1)	91.8 (0.2)	97.0 (0.1)	1537.7	<0.01
	Vacant	1.0 (<0.1)	2.0 (0.1)	1.2 (<0.1)		
	Blank	1.2 (<0.1)	6.2 (0.1)	1.8 (<0.1)		
2015	Complete	97.7 (<0.1)	93.7 (0.1)	97.1 (0.1)	931.4	<0.01
	Vacant	1.1 (<0.1)	2.1 (0.1)	1.2 (<0.1)		
	Blank	1.2 (<0.1)	4.2 (0.1)	1.7 (<0.1)		
2016	Complete	97.6 (<0.1)	95.4 (0.1)	97.0 (0.1)	421.1	<0.01
	Vacant	1.1 (<0.1)	1.9 (<0.1)	1.3 (<0.1)		
	Blank	1.2 (<0.1)	2.7 (0.1)	1.7 (<0.1)		
2017	Complete	97.6 (<0.1)	95.5 (0.1)	97.2 (0.2)	498.6	<0.01
	Vacant	1.1 (<0.1)	1.8 (<0.1)	1.3 (<0.1)		
	Blank	1.3 (<0.1)	2.7 (<0.1)	1.6 (<0.1)		
2018	Complete	97.4 (<0.1)	95.7 (0.1)	97.0 (0.1)	434.9	<0.01
	Vacant	1.2 (<0.1)	1.8 (<0.1)	1.5 (<0.1)		
	Blank	1.3 (<0.1)	2.4 (<0.1)	1.6 (<0.1)		
2019	Complete	97.3 (<0.1)	95.9 (0.1)	97.4 (<0.1)	251.5	<0.01
	Vacant	1.2 (<0.1)	1.9 (<0.1)	1.3 (<0.1)		
	Blank	1.5 (<0.1)	2.2 (<0.1)	1.4 (<0.1)		

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.

The relationship between final internet outcome and device type was statistically significant, with all three device types having a final completion rate over 90 percent. The percent complete and percent vacant were not statistically different between PC and tablet for 2019. All other comparisons were significantly different. The final completion rate for mobile phones improved over time but was nominally lower than the other device types. The percentage of blank responses was also nominally higher for mobile phones than the other two device types.

Research Question 7. Were there differences in the demographic, housing, and socioeconomic traits of the respondent by device type?

Tables 12 through 20 show the distributions by device type for age, sex, educational attainment, Hispanic origin, race, marital status, smartphone ownership, internet access, and tenure. These tables are for 2019 alone. Tables for 2013 – 2019 can be found in Appendix A. The universe for research question 7 is all internet logins.

Table 12 provides the distribution of respondent age by device type.

Table 12. Age of Respondent by Device Type for 2019

Age	PC	Mobile	Tablet	Chi-square	P-value	Total
Under 25	2.7 (<0.1)	6.5 (0.1)	0.8 (<0.1)	5149.7	<0.01	3.2 (<0.1)
25 to 34	12.7 (<0.1)	27.3 (0.1)	6.4 (0.1)			14.8 (<0.1)
35 to 44	15.6 (<0.1)	24.4 (0.1)	12.1 (0.1)			16.8 (<0.1)
45 to 54	18.4 (<0.1)	15.5 (0.1)	18.8 (0.1)			17.9 (<0.1)
55 to 64	21.5 (0.1)	12.1 (0.1)	26.4 (0.1)			20.2 (<0.1)
65 to 74	16.7 (<0.1)	5.8 (<0.1)	21.6 (0.1)			15.1 (<0.1)
75 to 84	6.2 (<0.1)	1.6 (<0.1)	7.0 (0.1)			5.4 (<0.1)
85 and over	1.7 (<0.1)	0.7 (<0.1)	1.9 (<0.1)			1.5 (<0.1)
Missing	4.4 (<0.1)	6.1 (0.1)	5.0 (0.1)			5.1 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level

The relationship between age and device type was statistically significant. The largest age group for PC users was 55 to 64, the largest age group for mobile phone users was 25 to 34 and the largest age group for tablet users was 55 to 64. Age was missing at a nominally higher rate for mobile phone users. Missing could mean more than one thing. A respondent may have seen the question and deliberately left it blank, or they may have broken off before getting to the question. If breakoffs were typically higher for a given mode (e.g., mobile phones), that could have been a possible explanation as to why the missing data rates appeared to be higher.

Table 13 provides the distribution of sex by device type.

Table 13. Sex of Respondent by Device Type for 2019

Sex	PC	Mobile	Tablet	Chi-square	P-value	Total
Male	50.9 (0.1)	41.0 (0.1)	43.1 (0.2)	1915.1	<0.01	48.3 (0.1)
Female	45.3 (0.1)	53.7 (0.1)	52.6 (0.2)			47.3 (0.1)
Missing	3.8 (<0.1)	5.2 (0.1)	4.3 (0.1)			4.4 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.
Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level.

The relationship between sex and device type was statistically significant. PC users had a higher percentage of males than females, while the opposite was true for mobile phone and tablet. Sex was missing at a nominally higher rate for mobile phone users.

Table 14 provides the distribution of educational attainment by device type.

Table 14. Educational Attainment of Respondent by Device Type for 2019

Education	PC	Mobile	Tablet	Chi-square	P-value	Total
Less than High School	2.9 (<0.1)	6.5 (0.1)	3.6 (0.1)	3777.3	<0.01	3.6 (<0.1)
High School or GED	13.9 (<0.1)	21.8 (0.1)	19.1 (0.1)			15.8 (<0.1)
Some college/AD	27.2 (<0.1)	32.2 (0.1)	29.9 (0.1)			28.3 (<0.1)
Bachelor's degree	27.6 (<0.1)	18.5 (0.1)	23.2 (0.1)			25.5 (<0.1)
Graduate degree	21.4 (<0.1)	9.8 (0.1)	16.4 (0.1)			18.8 (<0.1)
Missing	7.0 (<0.1)	11.3 (0.1)	7.7 (0.1)			8.1 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.
Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. AD=Associates degree.

The relationship between educational attainment and device type was statistically significant. The largest educational attainment group for PC users was Bachelor's degree, the largest educational attainment group for mobile phone users was some college or Associate's degree, and the largest educational attainment group for tablet users was some college or Associate's degree. Educational attainment was missing at a nominally higher rate for mobile phone users.

Table 15 provides the distribution of Hispanic origin by device type.

Table 15. Hispanic Origin of Respondent by Device Type for 2019

Hispanic Origin	PC	Mobile	Tablet	Chi-square	P-value	Total
Hispanic	7.1 (<0.1)	11.9 (0.1)	6.1 (0.1)	2073.4	<0.01	7.9 (<0.1)
Not Hispanic	88.1 (<0.1)	81.3 (0.1)	88.4 (0.1)			86.7 (0.1)
Missing	4.8 (<0.1)	6.8 (0.1)	5.5 (0.1)			5.5 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.
Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level.

The relationship between Hispanic origin and device type was statistically significant. Users for all three device types tended to not be Hispanic, but the percentage of Hispanic users was nominally larger for mobile phone than the other two device types. Hispanic origin was missing at a nominally higher rate for mobile phone users.

Table 16 provides the distribution of race by device type.

Table 16. Race of Respondent by Device Type for 2019

Race	PC	Mobile	Tablet	Chi-square	P-value	Total
White alone	79.9 (<0.1)	73.9 (0.1)	81.6 (0.1)	768.2	<0.01	78.8 (0.1)
Black alone	4.8 (<0.1)	8.3 (0.1)	5.6 (0.1)			5.5 (<0.1)
AIAN alone	0.4 (<0.1)	0.7 (<0.1)	0.4 (<0.1)			0.4 (<0.1)
Asian alone	6.0 (<0.1)	3.6 (<0.1)	3.8 (0.1)			5.4 (<0.1)
NHPI alone	0.1 (<0.1)	0.2 (<0.1)	0.1 (<0.1)			0.1 (<0.1)
Multiple races	1.8 (<0.1)	2.5 (<0.1)	1.3 (<0.1)			1.9 (<0.1)
Some other race	2.0 (<0.1)	3.4 (<0.1)	1.5 (<0.1)			2.2 (<0.1)
Missing	5.1 (<0.1)	7.3 (0.1)	5.7 (0.1)			5.8 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.
Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. AIAN=American Indian Alaska Native and NHPI=Native Hawaiian Pacific Islander.

The relationship between race and device type was statistically significant. The largest race group for all three device types was White alone. The mobile phone group had a nominally larger percentage of Black alone, some other race, and multiple races compared to the other device types. The PC group had a nominally larger percentage of Asian alone compared to the other two device types. Race was missing at a nominally higher rate for mobile phone users.

Table 17 provides the distribution of marital status by device type.

Table 17. Marital Status of Respondent by Device Type for 2019

Marital Status	PC	Mobile	Tablet	Chi-square	P-value	Total
Married	59.3 (0.1)	49.0 (0.1)	60.1 (0.1)	1890.5	<0.01	57.3 (0.1)
Widowed	5.7 (<0.1)	3.6 (<0.1)	8.1 (0.1)			5.5 (<0.1)
Divorced	12.6 (<0.1)	12.8 (0.1)	13.4 (0.1)			12.6 (<0.1)
Separated	1.2 (<0.1)	2.3 (<0.1)	1.3 (<0.1)			1.4 (<0.1)
Never married	15.6 (<0.1)	23.1 (0.1)	11.1 (0.1)			16.5 (<0.1)
Missing	5.7 (<0.1)	9.2 (0.1)	6.0 (0.1)			6.6 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.
Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level.

The relationship between marital status and device type was statistically significant. The largest marital status group for all three device types was married, however the percentage for mobile

phone users was less than half. The mobile phone distribution had a nominally larger percentage of respondents that had never married. Marital status was missing at a nominally higher rate for mobile phone users.

Table 18 provides the distribution of smartphone ownership by device type.

Table 18. Smartphone Ownership of Respondent by Device Type for 2019

Smartphone	PC	Mobile	Tablet	Chi-square	P-value	Total
Yes	87.9 (<0.1)	89.3 (0.1)	86.5 (0.1)	476.0	<0.01	87.8 (0.1)
No[19]	4.2 (<0.1)	2.2 (<0.1)	4.2 (0.1)			3.8 (<0.1)
Missing	7.9 (<0.1)	8.4 (0.1)	9.3 (0.1)			8.4 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level.

The relationship between smartphone ownership and device type was statistically significant. Smartphone owners were the largest group for all three device types. The percentage was nominally higher for mobile phone users. Smartphone ownership was missing at a nominally higher rate for tablet users.

Table 19 provides the distribution of internet access by device type.

Table 19. Internet Access by Device Type for 2019

Internet Access	PC	Mobile	Tablet	Chi-square	P-value	Total
Yes, with subscription	91.6 (<0.1)	87.3 (0.1)	91.0 (0.1)	685.3	<0.01	90.5 (0.1)
Yes, w/o subscription	1.6 (<0.1)	1.7 (<0.1)	1.7 (<0.1)			1.6 (<0.1)
No[20]	1.6 (<0.1)	3.2 (<0.1)	1.5 (<0.1)			1.9 (<0.1)
Missing	5.3 (<0.1)	7.7 (0.1)	5.8 (0.1)			6.0 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. Sub=subscription.

The relationship between internet access and device type was statistically significant. The largest internet access group for all three device types was yes with a subscription, however the percentage was nominally smaller for mobile phone users. The percent of users without an internet subscription was also nominally higher for mobile phones. Internet access was missing at a nominally higher rate for mobile phone users.

Table 20 provides the distribution of tenure by device type.

[19] There could be a variety of reasons why a respondent answered 'no' to this question when it appears they responded using a mobile device. The mobile phone used to respond may not belong to the user, it may be a mobile phone that is not a smartphone, or the response may be a mistake.

[20] While a 'no internet access' response seems unusual for a response that was received in the internet instrument, the respondent may be using public internet (library, café, etc.). A 'no' response could also be an error.

Table 20. Tenure by Device Type for 2019

Tenure	PC	Mobile	Tablet	Chi-square	P-value	Total
Owned	73.4 (0.1)	56.3 (0.1)	77.8 (0.1)	7170.7	<0.01	70.5 (0.1)
Rented	21.2 (<0.1)	35.5 (0.1)	16.2 (0.1)			23.3 (<0.1)
Missing	5.4 (<0.1)	8.1 (0.1)	6.0 (0.1)			6.3 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level.

The relationship between tenure and device type was statistically significant. The largest tenure group for all three device types was owners, however the percentage owners was around 20 percentage points lower for mobile phone users. The percentage of renters was nominally larger for mobile phone users. Tenure was missing at a nominally higher rate for mobile phone users.

Tables 12 through 20 show that there were relationships between device type and the demographic, housing, and socioeconomic variables we looked at.

With the exception of the smartphone ownership question, the mobile phone distributions also had nominally larger percentages of missing data, but this was not statistically tested for this report. The percent of missing data for mobile phones, looking through all years, appeared to decrease in 2016 when ACS was made more mobile-friendly (see Appendix A, Tables A1-A9). This was also somewhat true for tablets but was not observed for PCs. This suggests that changes made in 2016 to make the internet instrument more mobile friendly improved item nonresponse rates. Item missing data rates will be more thoroughly examined in more detail in a future report.

The above tables may show an incomplete picture. Chi-square testing provides the relationship between two variables but does not take into account the likelihood that many of these demographic variables could be working in conjunction. We built logistic regression models to control for the effect other demographic variables (and other variables as well) to get a better understanding of the relationships of demographic characteristics and device type. A separate logistic regression model was created for each device type using only the data from 2019.

Table 21 provides the odds ratios for our logistic regression models. An odds ratio greater than one indicates that as the explanatory variable increased, the odds of a response for the given device type increased. An odds ratio less than one indicates that as the explanatory variable increased, the odds of a response decreased for that device type.

This interpretation is more straightforward with numeric explanatory variables. Looking at the table we see that as age increased, the odds of a PC or tablet response increased, while the odds of a mobile phone response decreased. For the categorical variables, there was a reference category to which the remaining categories were compared. For example, the

reference category for sex was male. Thus, for females, the odds of a PC response decreased (compared to males) but increased for mobile phone and tablet.

There were a handful of comparisons that were not significant. Those are marked with (NS) next to the odds ratio.

Table 21. Estimated Odds Ratios from a Logistic Regression of Device Type

Variable	PC	Mobile	Tablet
Age	1.025	0.952	1.021
Educational Attainment	1.145	0.846	0.968
Household Size	0.944	1.123	0.925
Number of Logins	1.111	0.880	0.944
Sex – Female vs Male	0.729	1.338	1.338
Hispanic Origin – Hispanic vs Not Hispanic	0.977	1.042	0.937
Tenure – Renter vs Owner	0.896	1.206	0.778
Internet Access – No vs Yes	0.733	1.684	0.802
Smartphone Ownership – No vs Yes	1.447	0.672	0.739
Race – Black vs White	0.694	1.601	1.101
Race – Asian vs White	1.543	0.628	0.821 (NS)
Race – AIAN vs White	0.790	1.365	0.970
Race – NHPI vs White	0.705	1.429	1.201 (NS)
Race – SOR vs White	0.977 (NS)	1.090	0.832
Race – Multiple Races vs White	1.038	0.998 (NS)	0.873
Marital Status – Never Married vs Married	0.994 (NS)	1.034	0.811
Marital Status – Divorced vs Married	0.833	1.525	0.846
Marital Status – Separated vs Married	0.725	1.698	0.843
Marital Status – Widowed vs Married	0.729	1.814	0.816

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Notes: Significance was determined based on the analysis of effects in a logistic regression model at the α=0.1 level. The reference category is the category listed to the right of 'vs' (e.g., White is the reference category for Race). All three models also controlled for stage of data collection.

In order to get a true measure of the relationships these demographic characteristics to each other and to device type, a more thorough analysis would need to be done. These models were meant to give us a descriptive snapshot of how device type usage may be related to some demographic characteristics, while controlling for other demographic characteristics. The results of these models should not be interpreted as truth or used to try and predict which device type an individual would use based on their demographic characteristics. However, we were able to observe the following trends using these logistic regression models :

The odds of a PC response increase with:

- more educated respondents
- males

- Whites, Asians, and respondents who are multiple races
- respondents who do not own smartphones

The odds of a mobile phone response increase with:

- younger respondents
- larger households
- Hispanic respondents
- non-White respondents (except Asians and multiple races)
- renters
- respondents who are not married

The odds of a tablet response increase with:

- older respondents
- Black respondents
- respondents who are married
- homeowners

The results of these models mostly align with what we saw in research question 7 – that device type is related to many demographic characteristics. Again, a more thorough analysis would be necessary in order to predict how an individual might pick a device based on their characteristics.

Research Question 8. How did household size compare between device types?

Table 22 shows the household size for all internet logins by device type and operating system (OS) in 2019.

Table 22. 2019 Household Size by Device Type and OS

Categories	1 person	2 persons	3 persons	4 persons	5 persons	6+ persons	0 persons	Missing	Average
PC	**21.2 (<0.1)**	**38.4 (0.1)**	**15.4 (<0.1)**	**12.9 (<0.1)**	**5.4 (<0.1)**	**3.1 (<0.1)**	**2.5 (<0.1)**	**1.1 (<0.1)**	**2.5 (<0.1)**
Windows	21.5 (0.1)	38.9 (0.1)	15.4 (0.1)	12.4 (<0.1)	5.2 (<0.1)	3.0 (<0.1)	2.5 (<0.1)	1.1 (<0.1)	2.5 (<0.1)
Mac OS X	20.3 (0.1)	37.6 (0.1)	15.5 (0.1)	14.0 (0.1)	5.7 (0.1)	3.1 (<0.1)	2.6 (<0.1)	1.2 (<0.1)	2.6 (<0.1)
Chrome	19.3 (0.3)	32.6 (0.3)	16.4 (0.3)	16.5 (0.2)	7.5 (0.2)	4.6 (0.1)	1.8 (0.1)	1.2 (0.1)	2.8 (<0.1)
Linux	28.3 (0.9)	33.4 (1.0)	13.2 (0.8)	13.3 (0.8)	5.4 (0.5)	2.2 (0.4)	2.2 (0.3)	1.5 (0.2)	2.4 (<0.1)
Other	28.0 (1.2)	38.2 (1.1)	13.5 (0.8)	10.9 (0.7)	3.5 (0.4)	3.1 (0.4)	2.2 (0.4)	0.6 (0.2)	2.3 (<0.1)
Mobile	**19.0 (0.1)**	**27.2 (0.1)**	**17.7 (0.1)**	**16.8 (0.1)**	**9.1 (0.1)**	**5.4 (0.1)**	**2.6 (<0.1)**	**2.2 (<0.1)**	**2.9 (<0.1)**
iOS	18.1 (0.1)	27.3 (0.1)	17.6 (0.1)	17.3 (0.1)	9.5 (0.1)	5.2 (0.1)	2.7 (0.1)	2.3 (0.1)	2.9 (<0.1)
Android	20.0 (0.1)	27.1 (0.1)	18.0 (0.1)	16.1 (0.1)	8.6 (0.1)	5.7 (0.1)	2.3 (<0.1)	2.1 (0.1)	2.9 (<0.1)
Other	34.3 (7.9)	20.0 (7.1)	14.3 (6.6)	11.4 (4.6)	11.4 (5.1)	<0.1 (<0.1)	<0.1 (<0.1)	8.6 (4.4)	2.4 (0.2)
Tablet	**22.3 (0.1)**	**42.3 (0.2)**	**14.0 (0.1)**	**10.4 (0.1)**	**4.8 (0.1)**	**2.3 (0.1)**	**2.6 (<0.1)**	**1.4 (<0.1)**	**2.4 (<0.1)**
iOS	22.0 (0.2)	43.0 (0.2)	13.7 (0.1)	10.2 (0.1)	4.9 (0.1)	2.2 (0.1)	2.7 (0.1)	1.3 (<0.1)	2.4 (<0.1)
Android	24.4 (0.3)	41.7 (0.3)	14.5 (0.3)	9.2 (0.2)	3.8 (0.1)	2.5 (0.1)	2.1 (0.1)	1.7 (0.1)	2.3 (<0.1)
Windows	20.2 (0.5)	37.8 (0.6)	15.8 (0.4)	14.1 (0.3)	5.5 (0.3)	2.8 (0.2)	2.8 (0.2)	1.0 (0.1)	2.6 (<0.1)
Other	30.0 (15.5)	30.0 (15.8)	30.0 (16.3)	10.0 (13.8)	<0.1 (<0.1)	<0.1 (<0.1)	<0.1 (<0.1)	<0.1 (<0.1)	2.2 (0.3)
Total	**20.8 (<0.1)**	**36.6 (<0.1)**	**15.7 (<0.1)**	**13.3 (<0.1)**	**6.0 (<0.1)**	**3.4 (<0.1)**	**2.5 (<0.1)**	**1.6 (<0.1)**	**2.6 (<0.1)**

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.
Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Typically, 0 persons means a vacant household, while missing means the question was not answered.

The most common household size across all device types was two persons. The average household size was somewhere between two and three persons for each device type and OS. Comparing the average household size across device types showed that mobile phone users tended to have larger households than both PC and tablet users (significant with a p-value <0.01). As seen from the results of research question 7, mobile phone users were more likely to be younger and not married. Paired with the fact that they were more likely to live in larger households, this suggests that perhaps mobile phone users were more likely to have roommates. This could account for the fact that mobile phone users had nominally higher missing data rates (a respondent may not know as much information about a roommate as they would a family member) – although the possible difficulties of using the internet instrument through a mobile phone could also explain the higher missing data rates.

6. CONCLUSIONS

This report was undertaken to understand more about how usage of the internet instrument has changed across time and among different device types, and to know more about the social and demographic characteristics of people that tend to use each device type to respond to the ACS. We analyzed internet instrument paradata and unedited response data collected from addresses sampled in the ACS from 2013 to 2019.

Our first main conclusion is that usage of the internet instrument increased between its launching in 2013 and 2019. As shown in Research Question 1, the weighted percentage of ACS self-responses that came from the internet instrument increased from 56.8 percent in January of 2013 to 69.3 percent in December of 2019.

Second, while the majority of cases that logged in used a PC for all years between 2013 and 2019, the proportion that came from mobile phones increased dramatically during this time, from 2.2 percent in 2013 to 18.3 percent in 2019. Cases that logged in with a tablet had also increased from 7.4 percent in 2013 to 8.6 percent in 2019. While Windows operating systems still accounted for the majority of cases that logged in with a PC, the share of PC logins with Mac OS, Linux, and Chrome OS had all increased. Mobile phone logins were roughly split evenly between Android and iOS devices between 2013 and 2019. Most tablet users used iOS devices across all years, but to a slightly lesser extent in 2019 versus 2013. It was also shown that 0.4 percent of all logins in 2019 were in the Spanish version of the ACS internet instrument. Most Spanish language internet returns came from PCs, but mobile phones had the highest rate of Spanish vs. English instrument usage.

The average number of logins by case for PCs and tablets stayed relatively consistent over time, with the percent of cases with only one login hovering between 77 and 80 percent for all years analyzed. However, it appears that mobile phone cases became somewhat more likely to log in only once, aligning with the other device types. This may reflect a growing ease of mobile phones in interacting with the internet instrument.

Of the roughly 22 percent of cases that logged in more than once, the vast majority did not switch devices. However, mobile phone users were most likely to switch devices, with 16 percent of mobile phone cases with multiple logins switching devices. The majority of mobile phone and tablet logins that did switch devices changed to a PC. This may have been due to the respondent preferring to continue on a PC due to screen size or functionality issues or could simply have been due to PC logins being more common overall.

There were also differences across device types in the likelihood of completing the instrument in the first login, and overall completion, which we examined in Research Question 6. While mobile phone users had nominally lower completion rates than PC and tablet, the mobile phone completion rates seemed to improve over time.

In research questions 7 and 8 we saw that there were strong relationships between device type and many demographic, housing, and socioeconomic variables. The model for mobile phone response showed higher odds for younger respondents and minority groups, and also renters and nonmarried respondents. The models for PC and tablet on the other hand had higher odds for older, married respondents, and homeowners; although they had different results for sex, race, and educational attainment.

When planning future data collection strategies, it is clear from this research that the internet instrument should occupy a prominent position. The number of responses from the internet instrument have continually outpaced those from the paper instrument and will likely continue to do so. It is also clear that future iterations of the internet instrument should adequately account for the increase in internet responses from mobile phones. While PCs still made up the majority of internet responses in 2019, the percent of internet responses coming from mobile phones increased every year from 2013 to 2019, and will likely continue to grow. Tablet usage is also growing and should be considered when doing an instrument redesign.

There is currently planning underway for additional research into device usage on the ACS, which will hopefully help guide changes to the internet instrument that will be considered. One area that future research will focus on is how device usage relates to instrument functionality. It would be beneficial to know, for example, if mobile phones or tablets trigger more error messages on particular screens compared to PCs, or if mobile phones or tablets tend to breakoff more frequently or take more time at particular screens compared to PCs. Another area of research will focus on how data quality might be affected by the growth of mobile phone usage. For example, it would be interesting to know if responses from mobile phones on open-ended questions are typically shorter than those from PCs, or if responses are able to be coded as frequently.

7. REFERENCES

Antoun, C., & Cernat, A. (2019). Factors Affecting Completion Times: A Comparative Analysis of Smartphone and PC Web Surveys. *Social Science Computer Review*, 1-13.

Antoun, C., Couper, M. P., & Conrad, F. G. (2017). Effects of mobile versus PC web on survey response quality: A crossover experiment in a probability web panel. *Public Opinion Quarterly*, *81*(S1), 280-306.

Arnold, K. C., Chauncey, K., & Gajos, K. Z. (2020) Predictive text encourages predictable writing. In *Proceedings of the 25th International Conference on Intelligent User Interfaces* (pp. 128-138). Retrieved from: https://dl.acm.org/doi/abs/10.1145/3377325.3377523

Baumgardner, S. K. (2021). *Response rates - summary.* Internal Census Bureau Report: unpublished.

Couper, M. P., Antoun, C., & Mavletova, A. (2017). Mobile Web Surveys. A Total Survey Error Perspective. In P. Biemer, E. de Leeuw, S. Eckman, B. Edwards, F. Kreuter, L.E. Lyberg, N.C. Tucker, B.T. West, et al. (Ed.), A Total Survey Error in Practice (pp. 133–154). Hoboken: John Wiley & Sons.

Couper, M. P., & Peterson, G. J. (2017). Why do Web Surveys Take Longer on Smartphones?. *Social Science Computer Review*, *35*(3), 357-377.

Dileo, D. (2018). *Devices Used in the Internet Mode of the American Community Survey.* Internal Census Bureau Report: unpublished.

Gummer, T., Quoß, F., & Roßmann, J. (2019). Does Increasing Mobile Device Coverage Reduce Heterogeneity in Completing Web Surveys on Smartphones? *Social Science Computer Review*, *37*(3), 371–384.

Gummer, T. & Roßmann, J. (2015). Explaining Interview Duration in Web Surveys: A Multilevel Approach. *Social Science Computer Review*, *33*(2), 217–234.

Horwitz, R., Tancreto, J. G., Zelenak, M. F., & Davis, M. (2013a). *Use of Paradata to Assess the Quality and Functionality of the American Community Survey Internet Instrument US Census Bureau*. ACS12-RER-26-R1. Retrieved from: https://www.census.gov/library/working-papers/2013/acs/2013_Horwitz_01.html.

Horwitz, R., Tancreto, J. G., Zelenak, M. F., & Davis, M. (2013b). *Using Paradata to Identify Potential Issues and Trends in the American Community Survey Internet Instrument*. ACS13-RER-02. Retrieved from: https://www.census.gov/library/working-papers/2013/acs/2013_Horwitz_02.html.

Keusch, F., & Yan, T. (2017). Web Versus Mobile Web: An Experimental Study of Device Effects and Self-Selection Effects. *Social Science Computer Review*, *35*(6), 751–769.

Liebe, U., Glenk, K., Oehlmann, M., & Meyerhoff, J. (2015). Does the use of mobile devices (tablets and smartphones) affect survey quality and choice behaviour in web surveys?. *Journal of Choice Modelling*, *14*, 17-31.

Mavletova, A., & Couper, M. P. (2013). Sensitive topics in PC web and mobile web surveys: is there a difference?. *Survey Research Methods*, *7*(3), 191-205.

Mavletova, A., & Couper, M. P. (2014). Mobile web survey design: scrolling versus paging, SMS versus e-mail invitations. *Journal of Survey Statistics and Methodology*, *2*(4), 498-518.

Mavletova, A., & Couper, M. P. (2015). A meta-analysis of breakoff rates in mobile web surveys. In D. Toninelli, R. Pinter, & P. de Pedraza (Eds.), Mobile research methods: Opportunities and challenges of mobile research methodologies (pp. 81–98). London, England: Ubiquity Press.

Mavletova, A., & Couper, M. P. (2016). Device use in Web Surveys: The effect of differential incentives. *International Journal of Market Research*, *58*(4), 523–544.

Pew Research Center (2019). Demographics of Mobile Device Ownership and Adoption in the United States. Retrieved from: https://www.pewresearch.org/internet/fact-sheet/mobile/#mobile-phone-ownership-over-time

Schlosser, S., & Mays, A. (2018). Mobile and Dirty: Does Using Mobile Devices Affect the Data Quality and the Response Process of Online Surveys? *Social Science Computer Review*, *36*(2), 212–230.

Smyth, J. D., Dillman, D. A., Christian, L. M., & McBride, M. (2009). Open-Ended Questions in Web Surveys: Can Increasing the Size of Answer Boxes and Providing Extra Verbal Instructions Improve Response Quality?. *Public Opinion Quarterly, 73*(2), 325-337.

Sommer, J., Diedenhofen, B., & Musch, J. (2017). Not to Be Considered Harmful: Mobile-Device Users Do Not Spoil Data Quality in Web Surveys. *Social Science Computer Review*, *35*(3), 378–387.

Struminskaya, B., Weyandt, K., & Bosnjak, M. (2015). The effects of questionnaire completion using mobile devices on data quality. Evidence from a probability-based general population panel. *Methods, Data, Analyses*, *9*(2), 261-292.

Tourangeau, R., Maitland, A., Rivero, G., Sun, H., Williams, D., & Yan, T. (2017). Web Surveys by Smartphone and Tablets. *Public Opinion Quarterly*, *81*(4), 896–929.

Tourangeau, R., Sun, H., Yan, T., Maitland, A., Rivero, G., & Williams, D. (2018). Web Surveys by Smartphones and Tablets: Effects on Data Quality. *Social Science Computer Review*, *36*(5), 542–556.

Toepoel, V., & Lugtig, P. (2018). Modularization in an Era of Mobile Web: Investigating the Effects of Cutting a Survey Into Smaller Pieces on Data Quality. *Social Science Computer Review*.

Appendix A. Demographic Tabulations by Year and Device Type

Table A1. Age by Device Type and Year

Year	Age	PC	Mobile	Tablet	Chi-square	P-value	Total
2013	Under 25	3.3 (<0.1)	9.7 (0.2)	2.8 (0.1)	1152.5	<0.01	3.4 (<0.1)
	25 to 34	13.7 (<0.1)	33.0 (0.3)	19.3 (0.1)			14.6 (<0.1)
	35 to 44	16.9 (<0.1)	22.0 (0.3)	22.3 (0.1)			17.4 (<0.1)
	45 to 54	21.2 (<0.1)	12.6 (0.3)	21.2 (0.2)			21.0 (<0.1)
	55 to 64	21.4 (<0.1)	7.8 (0.2)	17.7 (0.2)			20.8 (<0.1)
	65 to 74	13.2 (<0.1)	2.7 (0.1)	8.3 (0.1)			12.6 (<0.1)
	75 to 84	4.6 (<0.1)	1.1 (0.1)	2.4 (0.1)			4.3 (<0.1)
	85 and over	1.4 (<0.1)	0.7 (0.1)	0.9 (<0.1)			1.3 (<0.1)
	Missing	4.3 (<0.1)	10.3 (0.2)	5.2 (0.1)			4.5 (<0.1)
2014	Under 25	2.9 (<0.1)	9.0 (0.2)	2.3 (<0.1)	1548.3	<0.01	3.1 (<0.1)
	25 to 34	13.8 (<0.1)	32.8 (0.3)	17.2 (0.1)			14.8 (<0.1)
	35 to 44	16.7 (<0.1)	22.4 (0.3)	21.0 (0.1)			17.3 (<0.1)
	45 to 54	20.7 (<0.1)	12.8 (0.2)	21.1 (0.1)			20.5 (<0.1)
	55 to 64	21.4 (<0.1)	7.9 (0.1)	19.7 (0.1)			20.8 (<0.1)
	65 to 74	13.9 (<0.1)	3.0 (0.1)	9.8 (0.1)			13.1 (<0.1)
	75 to 84	4.8 (<0.1)	1.1 (0.1)	2.7 (0.1)			4.4 (<0.1)
	85 and over	1.4 (<0.1)	0.6 (<0.1)	1.0 (<0.1)			1.3 (<0.1)
	Missing	4.5 (<0.1)	10.4 (0.2)	5.2 (0.1)			4.7 (<0.1)
2015	Under 25	2.9 (<0.1)	8.5 (0.1)	1.9 (<0.1)	2177.7	<0.01	3.1 (<0.1)
	25 to 34	13.6 (<0.1)	32.3 (0.2)	14.0 (0.1)			14.8 (<0.1)
	35 to 44	16.3 (<0.1)	22.9 (0.2)	18.8 (0.1)			17.0 (<0.1)
	45 to 54	20.4 (<0.1)	14.0 (0.2)	21.4 (0.1)			20.2 (<0.1)
	55 to 64	21.4 (<0.1)	8.7 (0.1)	21.6 (0.2)			20.7 (<0.1)
	65 to 74	14.3 (<0.1)	3.2 (0.1)	12.4 (0.1)			13.4 (<0.1)
	75 to 84	4.9 (<0.1)	1.2 (<0.1)	3.5 (0.1)			4.6 (<0.1)
	85 and over	1.5 (<0.1)	0.7 (<0.1)	1.2 (<0.1)			1.4 (<0.1)
	Missing	4.6 (<0.1)	8.5 (0.1)	5.2 (0.1)			4.9 (<0.1)
2016	Under 25	2.9 (<0.1)	7.8 (0.1)	1.5 (<0.1)	3131.1	<0.01	3.2 (<0.1)
	25 to 34	13.7 (<0.1)	31.2 (0.1)	11.1 (0.1)			15.0 (<0.1)
	35 to 44	16.1 (<0.1)	23.8 (0.1)	16.6 (0.1)			16.9 (<0.1)
	45 to 54	20.1 (<0.1)	14.8 (0.1)	21.4 (0.1)			19.7 (<0.1)
	55 to 64	21.4 (0.1)	9.9 (0.1)	23.4 (0.1)			20.5 (<0.1)
	65 to 74	14.6 (<0.1)	4.0 (0.1)	15.1 (0.1)			13.7 (<0.1)
	75 to 84	5.0 (<0.1)	1.2 (<0.1)	4.3 (0.1)			4.6 (<0.1)
	85 and over	1.5 (<0.1)	0.7 (<0.1)	1.4 (<0.1)			1.4 (<0.1)
	Missing	4.7 (<0.1)	6.7 (0.1)	5.2 (0.1)			5.0 (<0.1)

2017	Under 25	2.9 (<0.1)	7.1 (0.1)	1.2 (<0.1)	3653.9	<0.01	3.2 (<0.1)
	25 to 34	13.5 (<0.1)	29.8 (0.1)	9.1 (0.1)			15.0 (<0.1)
	35 to 44	16.0 (<0.1)	24.3 (0.1)	14.9 (0.1)			16.9 (<0.1)
	45 to 54	19.6 (<0.1)	15.2 (0.1)	21.0 (0.1)			19.3 (<0.1)
	55 to 64	21.2 (<0.1)	10.5 (0.1)	24.7 (0.1)			20.3 (<0.1)
	65 to 74	15.2 (<0.1)	4.5 (0.1)	17.1 (0.1)			14.1 (<0.1)
	75 to 84	5.3 (<0.1)	1.3 (<0.1)	5.1 (0.1)			4.8 (<0.1)
	85 and over	1.6 (<0.1)	0.7 (<0.1)	1.6 (<0.1)			1.5 (<0.1)
	Missing	4.7 (<0.1)	6.6 (0.1)	5.3 (0.1)			5.0 (<0.1)
2018	Under 25	2.7 (<0.1)	6.6 (<0.1)	1.0 (<0.1)	4249.9	<0.01	3.2 (<0.1)
	25 to 34	12.9 (<0.1)	28.3 (0.1)	7.4 (0.1)			14.7 (<0.1)
	35 to 44	15.7 (<0.1)	24.1 (0.1)	13.2 (0.1)			16.7 (<0.1)
	45 to 54	18.8 (<0.1)	15.3 (0.1)	20.1 (0.1)			18.4 (<0.1)
	55 to 64	21.3 (<0.1)	11.8 (0.1)	25.5 (0.1)			20.3 (<0.1)
	65 to 74	16.2 (<0.1)	5.4 (0.1)	19.6 (0.1)			14.9 (<0.1)
	75 to 84	5.9 (<0.1)	1.6 (<0.1)	6.2 (0.1)			5.3 (<0.1)
	85 and over	1.7 (<0.1)	0.7 (<0.1)	1.7 (<0.1)			1.5 (<0.1)
	Missing	4.7 (<0.1)	6.3 (0.1)	5.3 (0.1)			5.0 (<0.1)
2019	Under 25	2.7 (<0.1)	6.5 (0.1)	0.8 (<0.1)	5270.0	<0.01	3.2 (<0.1)
	25 to 34	12.7 (<0.1)	27.3 (0.1)	6.4 (0.1)			14.8 (<0.1)
	35 to 44	15.6 (<0.1)	24.4 (0.1)	12.1 (0.1)			16.8 (<0.1)
	45 to 54	18.4 (<0.1)	15.5 (0.1)	18.8 (0.1)			17.9 (<0.1)
	55 to 64	21.5 (0.1)	12.1 (0.1)	26.4 (0.1)			20.2 (<0.1)
	65 to 74	16.7 (<0.1)	5.8 (<0.1)	21.6 (0.1)			15.1 (<0.1)
	75 to 84	6.2 (<0.1)	1.6 (<0.1)	7.0 (0.1)			5.4 (<0.1)
	85 and over	1.7 (<0.1)	0.7 (<0.1)	1.9 (<0.1)			1.5 (<0.1)
	Missing	4.4 (<0.1)	6.1 (0.1)	5.0 (0.1)			5.1 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.

Table A2. Sex by Device Type and Year

Year	Sex	PC	Mobile	Tablet	Chi-square	P-value	Total
2013	Male	49.9 (0.1)	38.8 (0.4)	43.0 (0.2)	862.8	<0.01	49.1 (0.1)
	Female	46.3 (0.1)	51.5 (0.4)	52.4 (0.2)			46.9 (0.1)
	Missing	3.8 (<0.1)	9.7 (0.2)	4.6 (0.1)			4.0 (<0.1)
2014	Male	50.3 (0.1)	39.7 (0.3)	42.4 (0.2)	1350.4	<0.01	49.1 (0.1)
	Female	46.0 (0.1)	50.9 (0.3)	53.1 (0.2)			46.9 (0.1)
	Missing	3.7 (<0.1)	9.4 (0.2)	4.5 (0.1)			4.0 (<0.1)
2015	Male	50.6 (0.1)	40.5 (0.2)	42.1 (0.1)	1394.4	<0.01	49.2 (<0.1)
	Female	45.5 (0.1)	52.0 (0.2)	53.4 (0.2)			46.7 (<0.1)
	Missing	3.8 (<0.1)	7.5 (0.1)	4.4 (0.1)			4.1 (<0.1)
2016	Male	50.5 (0.1)	40.8 (0.2)	42.6 (0.1)	1382.0	<0.01	48.8 (0.1)
	Female	45.5 (0.1)	53.5 (0.2)	52.9 (0.1)			47.1 (0.1)
	Missing	4.0 (<0.1)	5.7 (0.1)	4.5 (0.1)			4.2 (<0.1)
2017	Male	50.4 (0.1)	40.6 (0.1)	42.8 (0.2)	1482.6	<0.01	48.5 (0.1)
	Female	45.6 (0.1)	53.7 (0.1)	52.7 (0.1)			47.3 (0.1)
	Missing	4.0 (<0.1)	5.7 (0.1)	4.5 (0.1)			4.2 (<0.1)
2018	Male	50.6 (0.1)	40.8 (0.1)	42.8 (0.2)	1751.9	<0.01	48.4 (0.1)
	Female	45.3 (0.1)	53.9 (0.1)	52.6 (0.2)			47.4 (0.1)
	Missing	4.0 (<0.1)	5.3 (0.1)	4.6 (0.1)			4.3 (<0.1)
2019	Male	50.9 (0.1)	41.0 (0.1)	43.1 (0.2)	1828.8	<0.01	48.3 (0.1)
	Female	45.3 (0.1)	53.7 (0.1)	52.6 (0.2)			47.3 (0.1)
	Missing	3.8 (<0.1)	5.2 (0.1)	4.3 (0.1)			4.4 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.

Table A3. Educational Attainment by Device Type and Year

Year	Education	PC	Mobile	Tablet	Chi-square	P-value	Total
2013	Less than HS	3.6 (<0.1)	6.6 (0.2)	3.2 (0.1)	725.9	<0.01	3.6 (<0.1)
	HS or GED	16.2 (<0.1)	20.1 (0.3)	13.4 (0.1)			16.1 (<0.1)
	Some college/AD	29.3 (0.1)	30.3 (0.3)	27.0 (0.2)			29.1 (0.1)
	Bachelors deg	25.2 (0.1)	15.7 (0.3)	26.7 (0.1)			25.1 (0.1)
	Graduate deg	18.6 (0.1)	8.2 (0.2)	20.6 (0.1)			18.5 (<0.1)
	Missing	7.3 (<0.1)	19.2 (0.3)	9.1 (0.1)			7.7 (<0.1)
2014	Less than HS	3.4 (<0.1)	7.0 (0.1)	3.6 (0.1)	1078.3	<0.01	3.5 (<0.1)
	HS or GED	15.6 (<0.1)	20.9 (0.2)	15.4 (0.1)			15.7 (<0.1)
	Some college/AD	29.0 (<0.1)	30.4 (0.3)	28.1 (0.1)			28.9 (<0.1)
	Bachelors deg	25.8 (0.1)	15.4 (0.2)	25.5 (0.1)			25.4 (<0.1)
	Graduate deg	19.2 (<0.1)	7.7 (0.1)	18.5 (0.1)			18.8 (<0.1)
	Missing	7.0 (<0.1)	18.5 (0.2)	8.9 (0.1)			7.6 (<0.1)
2015	Less than HS	3.3 (<0.1)	7.2 (0.1)	4.0 (0.1)	1739.0	<0.01	3.6 (<0.1)
	HS or GED	15.2 (<0.1)	21.1 (0.2)	17.5 (0.1)			15.8 (<0.1)
	Some college/AD	28.5 (0.1)	30.9 (0.2)	29.3 (0.1)			28.7 (<0.1)
	Bachelors deg	26.2 (<0.1)	16.0 (0.1)	23.7 (0.1)			25.3 (<0.1)
	Graduate deg	19.6 (<0.1)	8.2 (0.1)	16.8 (0.1)			18.7 (<0.1)
	Missing	7.3 (<0.1)	16.6 (0.2)	8.6 (0.1)			8.0 (<0.1)
2016	Less than HS	3.3 (<0.1)	7.4 (0.1)	4.0 (0.1)	2061.5	<0.01	3.7 (<0.1)
	HS or GED	14.5 (<0.1)	21.7 (0.1)	18.2 (0.1)			15.5 (<0.1)
	Some college/AD	28.1 (0.1)	32.7 (0.1)	29.7 (0.1)			28.7 (0.1)
	Bachelors deg	26.7 (0.1)	17.1 (0.1)	23.3 (0.1)			25.5 (0.1)
	Graduate deg	20.2 (<0.1)	9.1 (0.1)	16.5 (0.1)			18.8 (<0.1)
	Missing	7.4 (<0.1)	12.1 (0.1)	8.3 (0.1)			7.9 (<0.1)
2017	Less than HS	3.1 (<0.1)	6.9 (0.1)	4.0 (0.1)	2525.8	<0.01	3.7 (<0.1)
	HS or GED	14.3 (<0.1)	21.8 (0.1)	18.6 (0.1)			15.6 (<0.1)
	Some college/AD	27.8 (0.1)	32.4 (0.1)	29.7 (0.1)			28.5 (0.1)
	Bachelors deg	27.0 (<0.1)	17.8 (0.1)	23.1 (0.1)			25.5 (<0.1)
	Graduate deg	20.6 (<0.1)	9.3 (0.1)	16.5 (0.1)			18.9 (<0.1)
	Missing	7.2 (<0.1)	11.7 (0.1)	8.2 (0.1)			7.8 (<0.1)
2018	Less than HS	3.1 (<0.1)	6.8 (0.1)	3.8 (0.1)	2936.4	<0.01	3.7 (<0.1)
	HS or GED	14.2 (<0.1)	22.2 (0.1)	19.2 (0.1)			15.9 (<0.1)
	Some college/AD	27.6 (0.1)	32.6 (0.1)	30.0 (0.1)			28.6 (0.1)
	Bachelors deg	27.1 (<0.1)	18.0 (0.1)	22.8 (0.1)			25.3 (<0.1)
	Graduate deg	20.9 (<0.1)	9.3 (0.1)	16.3 (0.1)			18.7 (<0.1)
	Missing	7.2 (<0.1)	11.3 (0.1)	8.0 (0.1)			7.9 (<0.1)

2019	Less than HS	2.9 (<0.1)	6.5 (0.1)	3.6 (0.1)	3720.7	<0.01	3.6 (<0.1)
	HS or GED	13.9 (<0.1)	21.8 (0.1)	19.1 (0.1)			15.8 (<0.1)
	Some college/AD	27.2 (<0.1)	32.2 (0.1)	29.9 (0.1)			28.3 (<0.1)
	Bachelors deg	27.6 (<0.1)	18.5 (0.1)	23.2 (0.1)			25.5 (<0.1)
	Graduate deg	21.4 (<0.1)	9.8 (0.1)	16.4 (0.1)			18.8 (<0.1)
	Missing	7.0 (<0.1)	11.3 (0.1)	7.7 (0.1)			8.1 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.

Table A4. Hispanic Origin by Device Type and Year

Year	Hispanic Origin	PC	Mobile	Tablet	Chi-square	P-value	Total
2013	Hispanic	6.0 (<0.1)	12.0 (0.2)	7.6 (0.1)	881.1	<0.01	6.2 (<0.1)
	Not Hispanic	89.1 (<0.1)	76.2 (0.3)	86.6 (0.1)			88.6 (<0.1)
	Missing	4.9 (<0.1)	11.8 (0.2)	5.8 (0.1)			5.1 (<0.1)
2014	Hispanic	6.1 (<0.1)	12.4 (0.2)	7.7 (0.1)	1460.0	<0.01	6.5 (<0.1)
	Not Hispanic	89.0 (<0.1)	76.1 (0.2)	86.5 (0.1)			88.3 (<0.1)
	Missing	4.8 (<0.1)	11.5 (0.2)	5.7 (0.1)			5.1 (<0.1)
2015	Hispanic	6.4 (<0.1)	12.9 (0.1)	7.3 (0.1)	1476.5	<0.01	6.9 (<0.1)
	Not Hispanic	88.6 (<0.1)	77.3 (0.2)	87.0 (0.1)			87.8 (<0.1)
	Missing	5.0 (<0.1)	9.8 (0.1)	5.7 (0.1)			5.3 (<0.1)
2016	Hispanic	6.7 (<0.1)	12.8 (0.1)	7.0 (0.1)	1421.3	<0.01	7.3 (<0.1)
	Not Hispanic	88.2 (<0.1)	79.7 (0.1)	87.2 (0.1)			87.3 (0.1)
	Missing	5.1 (<0.1)	7.5 (0.1)	5.7 (0.1)			5.4 (<0.1)
2017	Hispanic	6.9 (<0.1)	12.4 (0.1)	6.7 (0.1)	1468.4	<0.01	7.5 (<0.1)
	Not Hispanic	88.0 (<0.1)	80.2 (0.1)	87.5 (0.1)			87.1 (0.1)
	Missing	5.1 (<0.1)	7.4 (0.1)	5.8 (0.1)			5.4 (<0.1)
2018	Hispanic	6.9 (<0.1)	12.1 (0.1)	6.4 (0.1)	1808.1	<0.01	7.6 (<0.1)
	Not Hispanic	88.0 (<0.1)	80.9 (0.1)	87.7 (0.1)			86.9 (0.1)
	Missing	5.1 (<0.1)	7.0 (0.1)	5.9 (0.1)			5.5 (<0.1)
2019	Hispanic	7.1 (<0.1)	11.9 (0.1)	6.1 (0.1)	1961.8	<0.01	7.9 (<0.1)
	Not Hispanic	88.1 (<0.1)	81.3 (0.1)	88.4 (0.1)			86.7 (0.1)
	Missing	4.8 (<0.1)	6.8 (0.1)	5.5 (0.1)			5.5 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.

Table A5. Race by Device Type and Year

Year	Race	PC	Mobile	Tablet	Chi-square	P-value	Total
2013	White alone	81.2 (0.1)	67.5 (0.4)	79.2 (0.2)	291.5	<0.01	80.7 (<0.1)
	Black alone	5.0 (<0.1)	9.5 (0.2)	5.6 (0.1)			5.1 (<0.1)
	AIAN alone	0.4 (<0.1)	0.6 (0.1)	0.4 (<0.1)			0.4 (<0.1)
	Asian alone	4.9 (<0.1)	3.2 (0.1)	5.0 (0.1)			4.9 (<0.1)
	NHPI alone	0.1 (<0.1)	0.1 (<0.1)	0.1 (<0.1)			0.1 (<0.1)
	Multiple races	1.5 (<0.1)	2.5 (0.1)	1.5 (<0.1)			1.6 (<0.1)
	Some other race	1.9 (<0.1)	3.6 (0.1)	2.0 (0.1)			1.9 (<0.1)
	Missing	5.1 (<0.1)	13.0 (0.3)	6.2 (0.1)			5.3 (<0.1)
2014	White alone	81.0 (<0.1)	68.1 (0.3)	79.5 (0.1)	460.1	<0.01	80.4 (<0.1)
	Black alone	4.9 (<0.1)	9.4 (0.2)	5.9 (0.1)			5.2 (<0.1)
	AIAN alone	0.4 (<0.1)	0.7 (<0.1)	0.4 (<0.1)			0.4 (<0.1)
	Asian alone	5.2 (<0.1)	3.2 (0.1)	4.5 (0.1)			5.0 (<0.1)
	NHPI alone	0.1 (<0.1)	0.2 (<0.1)	0.1 (<0.1)			0.1 (<0.1)
	Multiple races	1.6 (<0.1)	2.3 (0.1)	1.5 (<0.1)			1.6 (<0.1)
	Some other race	1.9 (<0.1)	3.7 (0.1)	2.0 (<0.1)			2.0 (<0.1)
	Missing	5.0 (<0.1)	12.5 (0.2)	6.1 (0.1)			5.4 (<0.1)
2015	White alone	80.5 (<0.1)	69.4 (0.2)	79.8 (0.1)	566.0	<0.01	79.7 (<0.1)
	Black alone	4.9 (<0.1)	9.6 (0.1)	6.0 (0.1)			5.3 (<0.1)
	AIAN alone	0.4 (<0.1)	0.7 (<0.1)	0.4 (<0.1)			0.4 (<0.1)
	Asian alone	5.3 (<0.1)	3.3 (0.1)	4.1 (0.1)			5.1 (<0.1)
	NHPI alone	0.1 (<0.1)	0.2 (<0.1)	0.1 (<0.1)			0.1 (<0.1)
	Multiple races	1.7 (<0.1)	2.4 (0.1)	1.5 (<0.1)			1.7 (<0.1)
	Some other race	2.0 (<0.1)	3.8 (0.1)	2.0 (0.1)			2.1 (<0.1)
	Missing	5.2 (<0.1)	10.6 (0.1)	6.1 (0.1)			5.6 (<0.1)
2016	White alone	79.8 (<0.1)	71.7 (0.1)	80.4 (0.1)	590.4	<0.01	79.2 (0.1)
	Black alone	5.1 (<0.1)	9.2 (0.1)	5.9 (<0.1)			5.5 (<0.1)
	AIAN alone	0.4 (<0.1)	0.8 (<0.1)	0.4 (<0.1)			0.4 (<0.1)
	Asian alone	5.6 (<0.1)	3.7 (0.1)	4.0 (0.1)			5.3 (<0.1)
	NHPI alone	0.1 (<0.1)	0.2 (<0.1)	0.1 (<0.1)			0.1 (<0.1)
	Multiple races	1.7 (<0.1)	2.3 (<0.1)	1.4 (<0.1)			1.7 (<0.1)
	Some other race	1.9 (<0.1)	3.8 (0.1)	1.8 (<0.1)			2.1 (<0.1)
	Missing	5.3 (<0.1)	8.3 (0.1)	6.0 (0.1)			5.7 (<0.1)
2017	White alone	79.7 (<0.1)	72.6 (0.2)	80.7 (0.1)	624.2	<0.01	79.0 (0.1)
	Black alone	4.9 (<0.1)	8.6 (0.1)	5.6 (0.1)			5.4 (<0.1)
	AIAN alone	0.4 (<0.1)	0.7 (<0.1)	0.4 (<0.1)			0.4 (<0.1)
	Asian alone	5.8 (<0.1)	3.7 (0.1)	4.0 (0.1)			5.4 (<0.1)
	NHPI alone	0.1 (<0.1)	0.2 (<0.1)	0.1 (<0.1)			0.1 (<0.1)
	Multiple races	1.8 (<0.1)	2.3 (<0.1)	1.3 (<0.1)			1.8 (<0.1)
	Some other race	2.0 (<0.1)	3.7 (0.1)	1.6 (<0.1)			2.2 (<0.1)
	Missing	5.3 (<0.1)	8.1 (0.1)	6.1 (0.1)			5.7 (<0.1)

2018	White alone	79.9 (<0.1)	73.8 (0.1)	81.1 (0.2)	673.5	<0.01	79.1 (0.1)
	Black alone	4.8 (<0.1)	8.3 (0.1)	5.5 (0.1)			5.4 (<0.1)
	AIAN alone	0.4 (<0.1)	0.7 (<0.1)	0.4 (<0.1)			0.4 (<0.1)
	Asian alone	5.8 (<0.1)	3.5 (0.1)	3.8 (0.1)			5.2 (<0.1)
	NHPI alone	0.1 (<0.1)	0.2 (<0.1)	0.1 (<0.1)			0.1 (<0.1)
	Multiple races	1.8 (<0.1)	2.4 (<0.1)	1.4 (<0.1)			1.9 (<0.1)
	Some other race	1.9 (<0.1)	3.5 (<0.1)	1.6 (<0.1)			2.1 (<0.1)
	Missing	5.3 (<0.1)	7.6 (0.1)	6.1 (0.1)			5.8 (<0.1)
2019	White alone	79.9 (<0.1)	73.9 (0.1)	81.6 (0.1)	737.5	<0.01	78.8 (0.1)
	Black alone	4.8 (<0.1)	8.3 (0.1)	5.6 (0.1)			5.5 (<0.1)
	AIAN alone	0.4 (<0.1)	0.7 (<0.1)	0.4 (<0.1)			0.4 (<0.1)
	Asian alone	6.0 (<0.1)	3.6 (<0.1)	3.8 (0.1)			5.4 (<0.1)
	NHPI alone	0.1 (<0.1)	0.2 (<0.1)	0.1 (<0.1)			0.1 (<0.1)
	Multiple races	1.8 (<0.1)	2.5 (<0.1)	1.3 (<0.1)			1.9 (<0.1)
	Some other race	2.0 (<0.1)	3.4 (<0.1)	1.5 (<0.1)			2.2 (<0.1)
	Missing	5.1 (<0.1)	7.3 (0.1)	5.7 (0.1)			5.8 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.

Table A6. Marital Status by Device Type and Year

Year	Marital Status	PC	Mobile	Tablet	Chi-square	P-value	Total
2013	Married	60.1 (<0.1)	41.9 (0.3)	64.9 (0.2)	747.5	<0.01	60.0 (<0.1)
	Widowed	5.4 (<0.1)	2.6 (0.1)	4.0 (0.1)			5.2 (<0.1)
	Divorced	12.7 (<0.1)	11.8 (0.2)	9.6 (0.1)			12.4 (<0.1)
	Separated	1.5 (<0.1)	2.9 (0.1)	1.3 (<0.1)			1.5 (<0.1)
	Never married	14.7 (<0.1)	25.3 (0.3)	13.6 (0.2)			14.9 (<0.1)
	Missing	5.6 (<0.1)	15.5 (0.3)	6.6 (0.1)			5.9 (<0.1)
2014	Married	60.0 (0.1)	43.6 (0.2)	63.2 (0.1)	985.3	<0.01	59.7 (0.1)
	Widowed	5.4 (<0.1)	2.6 (0.1)	4.5 (0.1)			5.2 (<0.1)
	Divorced	12.7 (<0.1)	11.3 (0.2)	10.6 (0.1)			12.4 (<0.1)
	Separated	1.4 (<0.1)	2.7 (0.1)	1.4 (<0.1)			1.5 (<0.1)
	Never married	15.0 (<0.1)	24.7 (0.3)	13.7 (0.1)			15.2 (<0.1)
	Missing	5.5 (<0.1)	15.1 (0.2)	6.6 (0.1)			6.0 (<0.1)
2015	Married	59.8 (0.1)	45.2 (0.2)	61.7 (0.2)	1185.4	<0.01	59.1 (0.1)
	Widowed	5.4 (<0.1)	2.7 (0.1)	5.5 (0.1)			5.3 (<0.1)
	Divorced	12.6 (<0.1)	11.7 (0.2)	11.7 (0.1)			12.4 (<0.1)
	Separated	1.4 (<0.1)	2.6 (0.1)	1.5 (<0.1)			1.5 (<0.1)
	Never married	15.1 (<0.1)	24.5 (0.2)	13.0 (0.1)			15.4 (<0.1)
	Missing	5.7 (<0.1)	13.3 (0.2)	6.5 (0.1)			6.3 (<0.1)
2016	Married	59.2 (0.1)	47.5 (0.2)	61.1 (0.2)	1122.5	<0.01	58.4 (0.1)
	Widowed	5.4 (<0.1)	3.1 (0.1)	6.4 (0.1)			5.3 (<0.1)
	Divorced	12.6 (<0.1)	12.2 (0.1)	12.4 (0.1)			12.5 (<0.1)
	Separated	1.4 (<0.1)	2.6 (0.1)	1.4 (<0.1)			1.5 (<0.1)
	Never married	15.5 (<0.1)	24.7 (0.1)	12.3 (0.1)			16.0 (<0.1)
	Missing	5.9 (<0.1)	9.9 (0.1)	6.4 (0.1)			6.3 (<0.1)
2017	Married	59.3 (0.1)	48.4 (0.1)	60.6 (0.2)	1314.6	<0.01	58.2 (0.1)
	Widowed	5.4 (<0.1)	3.3 (0.1)	7.0 (0.1)			5.3 (<0.1)
	Divorced	12.5 (<0.1)	12.4 (0.1)	12.9 (0.1)			12.5 (<0.1)
	Separated	1.3 (<0.1)	2.5 (<0.1)	1.4 (<0.1)			1.5 (<0.1)
	Never married	15.5 (<0.1)	23.8 (0.1)	11.9 (0.1)			16.1 (<0.1)
	Missing	5.9 (<0.1)	9.6 (0.1)	6.3 (0.1)			6.4 (<0.1)
2018	Married	59.3 (0.1)	48.5 (0.1)	60.0 (0.2)	1692.6	<0.01	57.8 (0.1)
	Widowed	5.6 (<0.1)	3.6 (<0.1)	7.7 (0.1)			5.5 (<0.1)
	Divorced	12.5 (<0.1)	12.8 (0.1)	13.2 (0.1)			12.7 (<0.1)
	Separated	1.3 (<0.1)	2.5 (<0.1)	1.3 (<0.1)			1.4 (<0.1)
	Never married	15.4 (<0.1)	23.4 (0.1)	11.4 (0.1)			16.2 (<0.1)
	Missing	5.9 (<0.1)	9.2 (0.1)	6.4 (0.1)			6.5 (<0.1)

2019	Married	59.3 (0.1)	49.0 (0.1)	60.1 (0.1)	1824.4	<0.01	57.3 (0.1)
	Widowed	5.7 (<0.1)	3.6 (<0.1)	8.1 (0.1)			5.5 (<0.1)
	Divorced	12.6 (<0.1)	12.8 (0.1)	13.4 (0.1)			12.6 (<0.1)
	Separated	1.2 (<0.1)	2.3 (<0.1)	1.3 (<0.1)			1.4 (<0.1)
	Never married	15.6 (<0.1)	23.1 (0.1)	11.1 (0.1)			16.5 (<0.1)
	Missing	5.7 (<0.1)	9.2 (0.1)	6.0 (0.1)			6.6 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.

Table A7. Smartphone Ownership by Device Type and Year

Year	Smartphone	PC	Mobile	Tablet	Chi-square	P-value	Total
2016	Yes	82.3 (<0.1)	87.8 (0.1)	83.7 (0.1)	917.8	<0.01	83.0 (0.1)
	No	9.1 (<0.1)	3.4 (0.1)	6.9 (0.1)			8.3 (<0.1)
	Missing	8.6 (<0.1)	8.8 (0.1)	9.4 (0.1)			8.7 (<0.1)
2017	Yes	84.9 (<0.1)	88.4 (0.1)	84.8 (0.1)	788.9	<0.01	85.3 (0.1)
	No	7.0 (<0.1)	2.9 (<0.1)	6.0 (0.1)			6.5 (<0.1)
	Missing	8.1 (<0.1)	8.7 (0.1)	9.2 (0.1)			8.2 (<0.1)
2018	Yes	86.3 (<0.1)	89.0 (0.1)	85.6 (0.1)	708.6	<0.01	86.7 (0.1)
	No	5.9 (<0.1)	2.7 (<0.1)	5.3 (0.1)			5.4 (<0.1)
	Missing	7.8 (<0.1)	8.4 (0.1)	9.0 (0.1)			8.0 (<0.1)
2019	Yes	87.9 (<0.1)	89.3 (0.1)	86.5 (0.1)	448.5	<0.01	87.8 (0.1)
	No	4.2 (<0.1)	2.2 (<0.1)	4.2 (0.1)			3.8 (<0.1)
	Missing	7.9 (<0.1)	8.4 (0.1)	9.3 (0.1)			8.4 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.

Table A8. Internet Access by Device Type and Year

Year	Internet Access	PC	Mobile	Tablet	Chi-square	P-value	Total
2013	Yes, with subscription	88.8 (<0.1)	61.8 (0.3)	89.2 (0.1)	2587.6	<0.01	88.2 (<0.1)
	Yes, w/o subscription	2.3 (<0.1)	10.3 (0.2)	2.1 (0.1)			2.5 (<0.1)
	No	3.7 (<0.1)	14.7 (0.2)	2.5 (0.1)			3.9 (<0.1)
	Missing	5.2 (<0.1)	13.3 (0.3)	6.3 (0.1)			5.5 (<0.1)
2014	Yes, with subscription	89.1 (<0.1)	65.0 (0.2)	89.0 (0.1)	3259.7	<0.01	88.3 (<0.1)
	Yes, w/o subscription	2.2 (<0.1)	9.3 (0.2)	2.2 (<0.1)			2.5 (<0.1)
	No	3.5 (<0.1)	12.9 (0.2)	2.6 (<0.1)			3.7 (<0.1)
	Missing	5.2 (<0.1)	12.8 (0.2)	6.2 (0.1)			5.5 (<0.1)
2015	Yes, with subscription	89.1 (<0.1)	69.2 (0.2)	88.7 (0.1)	3925.8	<0.01	87.9 (<0.1)
	Yes, w/o subscription	2.2 (<0.1)	8.3 (0.1)	2.5 (<0.1)			2.6 (<0.1)
	No	3.3 (<0.1)	11.5 (0.1)	2.8 (0.1)			3.7 (<0.1)
	Missing	5.4 (<0.1)	10.9 (0.1)	6.0 (0.1)			5.7 (<0.1)
2016	Yes, with subscription	90.4 (<0.1)	85.4 (0.1)	90.3 (0.1)	453.0	<0.01	90.0 (0.1)
	Yes, w/o subscription	1.8 (<0.1)	2.1 (<0.1)	1.7 (<0.1)			1.8 (<0.1)
	No	2.3 (<0.1)	4.4 (0.1)	2.0 (<0.1)			2.5 (<0.1)
	Missing	5.5 (<0.1)	8.1 (0.1)	6.1 (0.1)			5.8 (<0.1)
2017	Yes, with subscription	90.8 (<0.1)	86.1 (0.1)	90.4 (0.1)	556.0	<0.01	90.2 (0.1)
	Yes, w/o subscription	1.7 (<0.1)	1.9 (<0.1)	1.7 (<0.1)			1.7 (<0.1)
	No	2.0 (<0.1)	3.9 (0.1)	1.8 (<0.1)			2.2 (<0.1)
	Missing	5.5 (<0.1)	8.1 (0.1)	6.1 (0.1)			5.8 (<0.1)
2018	Yes, with subscription	91.0 (<0.1)	86.8 (0.1)	90.4 (0.1)	537.4	<0.01	90.4 (0.1)
	Yes, w/o subscription	1.7 (<0.1)	1.8 (<0.1)	1.8 (<0.1)			1.7 (<0.1)
	No	1.9 (<0.1)	3.6 (<0.1)	1.7 (<0.1)			2.1 (<0.1)
	Missing	5.5 (<0.1)	7.7 (0.1)	6.2 (0.1)			5.9 (<0.1)
2019	Yes, with subscription	91.6 (<0.1)	87.3 (0.1)	91.0 (0.1)	609.8	<0.01	90.5 (0.1)
	Yes, w/o subscription	1.6 (<0.1)	1.7 (<0.1)	1.7 (<0.1)			1.6 (<0.1)
	No	1.6 (<0.1)	3.2 (<0.1)	1.5 (<0.1)			1.9 (<0.1)
	Missing	5.3 (<0.1)	7.7 (0.1)	5.8 (0.1)			6.0 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.

Table A9. Tenure by Device Type and Year

Year	Tenure	PC	Mobile	Tablet	Chi-square	P-value	Total
2013	Owned	72.7 (<0.1)	46.2 (0.3)	73.8 (0.1)	1979.5	<0.01	72.2 (<0.1)
	Rented	21.8 (<0.1)	39.5 (0.3)	19.6 (0.2)			22.0 (<0.1)
	Missing	5.5 (<0.1)	14.3 (0.3)	6.6 (0.1)			5.7 (<0.1)
2014	Owned	72.7 (0.1)	46.2 (0.2)	73.1 (0.1)	3290.5	<0.01	71.8 (<0.1)
	Rented	22.0 (<0.1)	40.1 (0.3)	20.4 (0.1)			22.5 (<0.1)
	Missing	5.3 (<0.1)	13.8 (0.2)	6.5 (0.1)			5.8 (<0.1)
2015	Owned	72.4 (0.1)	48.3 (0.2)	73.7 (0.1)	3657.9	<0.01	71.1 (<0.1)
	Rented	22.0 (0.1)	39.9 (0.2)	19.9 (0.1)			22.9 (<0.1)
	Missing	5.6 (<0.1)	11.9 (0.2)	6.4 (0.1)			6.0 (<0.1)
2016	Owned	72.0 (<0.1)	52.2 (0.2)	74.7 (0.1)	4308.3	<0.01	70.5 (0.1)
	Rented	22.3 (<0.1)	39.2 (0.2)	19.0 (0.1)			23.5 (<0.1)
	Missing	5.7 (<0.1)	8.7 (0.1)	6.3 (0.1)			6.1 (<0.1)
2017	Owned	72.5 (<0.1)	54.1 (0.2)	75.8 (0.1)	4797.3	<0.01	70.7 (0.1)
	Rented	21.8 (<0.1)	37.3 (0.1)	17.9 (0.1)			23.3 (<0.1)
	Missing	5.7 (<0.1)	8.5 (0.1)	6.3 (0.1)			6.1 (<0.1)
2018	Owned	73.1 (<0.1)	55.5 (0.1)	77.1 (0.1)	5732.4	<0.01	70.8 (0.1)
	Rented	21.3 (<0.1)	36.3 (0.1)	16.6 (0.1)			23.1 (<0.1)
	Missing	5.7 (<0.1)	8.2 (0.1)	6.3 (0.1)			6.1 (<0.1)
2019	Owned	73.4 (0.1)	56.3 (0.1)	77.8 (0.1)	7146.8	<0.01	70.5 (0.1)
	Rented	21.2 (<0.1)	35.5 (0.1)	16.2 (0.1)			23.3 (<0.1)
	Missing	5.4 (<0.1)	8.1 (0.1)	6.0 (0.1)			6.3 (<0.1)

Source: U.S. Census Bureau, American Community Survey, 2020 Respondent Device Analyses. DRB Approval Number: CBDRB-FY20-ACSO003-B0030.

Note: Minor additive discrepancies are due to rounding. Standard errors are in parentheses. Significance was tested based on a Chi-square test at the α=0.1 level. The p-values in the table are the original p-values. We adjusted for multiple comparisons, but the significance level did not change for any of the comparisons.