**ABCD-EARS Application Data Collection, Cleaning, and Processing**

**Keyboard**

**Data collection.** Whenever a participant opened the keyboard, a timestamp was recorded for each keystroke, along with the identifier for the application hosting the text box. The release of iOS 16 prevented the application identifier from being collected, so only data collected before this release included the application identifier for iOS users.

**Daily features.** Keystroke data were aggregated into daily metrics with the following steps. First, data were aggregated into sessions based on application (when available) and temporal proximity. A session was defined as a sequence of keystrokes with the same application, with each consecutive keystroke being no more than 60 seconds apart. The length of each session was calculated as the difference between the first and last timestamp of the derived session. Finally, daily metrics were aggregated by counting all keystrokes and sessions per day and summing all session durations for each day. Sessions were assigned to the date of the final keystroke in each session.

**Summary metrics.** Data were aggregated further to derive metrics spanning the entire duration of the study. The category for each application that appeared in the keyboard data was scraped from the App Store (iOS) and the Google Play Store (Android), when available. Then, for each participant, all keyboard session data were aggregated to calculate number of keystrokes, sessions, and keyboard usage duration across two dimensions: day of week (weekday, weekend, all days) and application category. In addition, the total number of unique applications used was totaled across the entire study. Finally, average daily usage metrics were calculated by dividing the above metrics by the number of weekdays, weekend days, and total days that the participant used the EARS application. The period of EARS application usage was defined as the total number of days with at least one keyboard session assigned to that day.

**App usage**

**Data collection.** Every 15 minutes, EARS queried the Android UsageStats API, which returns aggregated information about the last week of application usage. For each application used, the API returned the duration each application was in the foreground, binned into approximately 24-hour windows, with start and end times arbitrarily defined by the API. The final window always ended at the time of the query, and started at some point in the last 24 hours, such that the final windows of successive queries could be subtracted from each other to deduce the amount of application usage between two consecutive queries (i.e. application usage during that 15-minute window). This accumulation would continue for approximately 24 hours until the start time of the query window reset, and then the accumulation would begin again.

**Data cleaning.** Before the raw data could be subtracted to derive application foreground durations during smaller windows (“non-cumulative” durations), data cleaning needed to occur to ensure that all assumptions needed for subtraction were met.

First, duplicate historical windows, which were expected to be collected due to the repeated one-week queries, were discarded.

Next, the consecutive usage windows that remained needed to have the same start time, until the accumulation reset for the next day. However, the API sometimes generated multiple records offset by several seconds, creating overlapping windows with duplicate information, structured such that they could not be subtracted from one another. The distribution of start times was thus explored to reduce the dataset to a set of usage windows where all consecutive start times were either the same or at least 60 seconds apart.

Finally, non-cumulative foreground durations were derived by subtracting consecutive foreground durations for a given application and usage window start time. Although logically this method should never return negative values, the API occasionally returned information that resulted in negative values for non-cumulative durations. Without access to how the API calculates these inconsistent values, we cannot deduce why this happens; however, in order to only keep sensical data, negative values were recoded as zeros.

**Daily features.** To create daily metrics, non-cumulative foreground durations were summed for each day, for each application. Usage windows were assigned to the usage window’s end date. Daily durations greater than 20 hours were removed, as it was discovered that certain system applications, for example home screen tools, resulted in inflated usage (often around 24 hours) that do not represent actual participant usage.

**Summary metrics.** Data were aggregated further to derive metrics spanning the entire duration of the study. The category for each application that appeared in the application usage data was scraped from the Google Play Store, when available. Then, for each participant, all non-cumulative foreground durations were aggregated to calculate durations across two dimensions: day of week (weekday, weekend, all days) and application category. In addition, the total number of unique applications used was totaled across the entire study. Finally, average daily usage metrics were calculated by dividing the above metrics by the number of weekdays, weekend days, and total days that the participant used the EARS application. The period of EARS application usage was defined as the total number of days with at least one application foreground duration assigned to that day.

Some applications, such as home screen managers and other system applications, result in inflated foreground times per day (often around 24 hours). A list of applications to exclude was derived based on quality assessment of the data. An estimate of screen time excluding these applications was derived for each participant. These applications were not excluded from category-specific metrics, but most of them did not fall into categories of interest. Below is a list of the application identifiers excluded:

• com.android.systemui

• com.lge.qmemoplus

• com.google.android.gms

• com.sec.android.app.launcher

• com.sec.android.mimage.photoretouching

• us.ozteam.bigfoot

• com.pixel.art.coloring.color.number

• com.robtopx.geometryjumplite

• com.google.android.inputmethod.latin

• com.lge.clock

• com.pt.bark

• com.tct.launcher

• com.lge.launcher3

• royaln.Removeunwantedcontent

• com.samsung.android.contacts

• com.google.android.packageinstaller

• com.wssyncmldm

**Table S1.** Example Categories for Each App Category by Operating System

|  |  |
| --- | --- |
| **Android OS Categories** | **Example App** |
| Art and Design | Canva: Design, Photo & Video |
| Autos and Vehicles | Cars.com |
| Beauty | Ulta Beauty |
| Books and Reference | KJV Bible Now |
| Business | Zoom |
| Comics | WEBTOON |
| Communications | WhatsApp Messenger |
| Dating | Bumble: Dating App & Friends |
| Education | Duolingo: language lessons |
| Entertainment | Max: Stream HBO, TV, & Movies |
| Events | Ticketmaster |
| Finance | Cash App |
| Food and Drink | McDonald’s |
| Games (Action + Adventure + Arcade + Board + Card + Casino + Casual + Educational + Music + Puzzle + Racing + Role Playing + Simulation + Sports + Strategy + Trivia + Word) | Monopoly GO! |
| Health and Fitness | Health Tracker |
| House and Home | Zillow |
| Libraries and Demo | Mods Melon Playground Sandbox |
| Lifestyle | Life360: Live Location Sharing |
| Maps and Navigation | Uber – Request a Ride |
| Medical | MyChart |
| Music and Audio | Spotify |
| News and Magazines | NewsBreak |
| Parenting | Findmykids: Location Tracker |
| Personalization | Find My Phone By Clap, Whistle |
| Photography | Photo Maker – GIF Master |
| Productivity | AI Security |
| Shopping | Temu: Shop Like a Billionaire |
| Social | TikTok |
| Sports | MLB Ballpark |
| Tools | QR & Barcode Scanner |
| Travel and Local | Expedia |
| Video Players and Editors | CapCut – Video Editor |
| Weather | Live Weather |

|  |  |
| --- | --- |
| **Apple iOS Categories** | **Example App** |
| Book | Strong's Concordance with KJV |
| Business | Glassdoor | Jobs & Community |
| Developer Tools | Code - Compile & Run Program |
| Education | ASA's Sailing Challenge |
| Entertainment | Hulu: Watch TV shows & movies |
| Finance | Binance Smart Chain Explorer |
| Food & Drink | Sous Vide °Celsius |
| Games | Water Sort Puzzle: Get Color |
| Graphics & Design | ArtRage Vitae Mobile Painting |
| Health & Fitness | HitMeal・Food & Calorie Tracker |
| Lifestyle | Bumble: Dating & Friends App |
| Magazines and Newspapers | Making Jewellery Magazine |
| Medical | Huckleberry: Baby & Child |
| Music | FM Radio App |
| Navigation | Waze Navigation & Live Traffic |
| News | The Economist |
| Photo & Video | Body Tune - Photo Editor |
| Productivity | Wipr |
| Reference | Merriam-Webster Dictionary |
| Shopping | Poshmark: Buy & Sell Fashion |
| Social Networking | Instagram Feed |
| Sports | Formula 1® |
| Travel | U-Haul |
| Utilities | Remote for TCL Roku TVs |
| Weather | Zoom Earth - Live Weather Map |

Notes: Example apps are top listed free apps from Google Play Store for Android. For Apple, the top “Popular Apps” in the App Store were listed.

**Table S2. Overall Smartphone Use by Self-Report and Passive Sensing**

|  |  |  |  |
| --- | --- | --- | --- |
| Category | Passively Sensed Minutes | Self-Reported Minutes | t and p-values |
| Mean (SD)  *Median [IQR]* | Mean (SD)  *Median [IQR]* |
| Daily Average | 293.3 (172.8)  *277.2 [167.2]* | 160.6 (159.8)  *111.4 [60-214.3]* | t474 = -14.97, p < .001 |
| Entertainment | 20.4 (44.8)  *2 [0.02-18.86]* | 106.5 (129.4)  *68.57 [15-150]* | t494=14.86, *p* < .001 |
| Games | 30 (42.6)  *15.51 [1.86-42.37]* | 60.2 (125.6)  *10.71 [0-68.57]* | t494=5.32, *p* < .001 |
| Social | 132.1 (124.5)  *103.04 [27.23-204.12]* | 163.2 (226.1)  *94.29 (30-205.71)* | t494=3.58, *p* < .001 |

Notes: Data here are restricted to Android users only. Participants were queried separately on single- and multiplayer gaming on their phones, their streaming of videos and shows, text messaging, video chatting, and social media use. In order to better match overarching summary categories as created in Table 1, participants queried responses were collapsed as necessary (single and multiplayer into “Games”; texting, video chatting, and social media into “Social”; streaming matched “Entertainment”).

**Figure S1. Histogram of Average Daily Keystrokes Across All Participants**

A graph of a graph

Description automatically generated

The x-axis represents the number of average daily keystrokes, and the y-axis represents prevalence (frequency) of that rate of use. Displayed data is from both iOS and Android users.

**Figure S2. Histogram of Average Daily App Use in Android Users**

A graph of a graph

Description automatically generated

The x-axis represents the number of average daily app use (minutes), and the y-axis represents prevalence (frequency) of that rate of use. Displayed data is from Android users.

**Figure S3. Histogram of Average Self-Reported Smartphone Use (minutes) Across All Participants**

A graph of a number of gray bars

Description automatically generated

The x-axis represents the average time reported of daily smartphone use (minutes), and the y-axis represents prevalence (frequency) of that rate of use. Displayed data is from both Apple and Android users.

**Table S3. Reliability of Screen Time Measures.**

|  |  |  |
| --- | --- | --- |
| Measure | ICC | Cronbach’s α |
| Keystrokes | 0.58 (0.56,0.60) | 0.98 (0.97, 0.97) |
| Keyboard seconds | 0.55 (0.53,0.57) | 0.97 (0.97,0.98) |
| Passively measured Smartphone Use | 0.51 (0.48,0.54) | 0.96 (0.95,0.96) |

Notes: ICC = intraclass correlation coefficient (two-way single random raters)

**Table S4. Correlations between Self-Report and ABCD-EARS measures within Android Users**

|  |  |  |  |
| --- | --- | --- | --- |
| **Category** | **Average Daily Keystrokes: Average Daily App Use** | **Average Daily Keystrokes: Self-Reported Smartphone Use** | **Average Daily App Use: Self-Reported Smartphone Use** |
| Books | 0.25\*\*\* |  |  |
| Business | 0.34\*\*\* |  |  |
| Tools/Utilities | 0.12\*\* |  |  |
| Education | 0.74\*\*\* |  |  |
| Entertainment | 0.22\*\*\* | 0.04 | 0.17\*\*\* |
| Finance | 0.27\*\*\* |  |  |
| Food | 0.52\*\*\* |  |  |
| Games | 0.51\*\*\* | 0.04 | 0.12\* |
| Art | 0.42\*\*\* |  |  |
| Health | 0.23\*\*\* |  |  |
| Lifestyle | 0.33\*\*\* |  |  |
| Music | 0.23\*\*\* |  |  |
| Maps | 0.25\*\*\* |  |  |
| News | 0.20\*\*\* |  |  |
| Medical | 0.07 |  |  |
| Photography | 0.31\*\*\* |  |  |
| Productivity | 0.13\*\* |  |  |
| Shopping | 0.80\*\*\* |  |  |
| Social | 0.55\*\*\* | 0.25\*\*\* | 0.48\*\*\* |
| Sports | 0.70\*\*\* |  |  |
| Travel | 0.15\*\*\* |  |  |
| Weather | 0.10\* |  |  |
| Total Use | 0.33\*\*\* | 0.21\*\*\* | 0.35\*\*\* |

Correlations between alternative measures of smartphone use by category in Android users. Keystrokes = average daily keystrokes, Self-Reported Smartphone Use = self-reported daily average minutes of smartphone use, Average Daily App Use = average minutes of passively measured smartphone application use.

\* = *p <* .05; \*\* = *p <* .01; \*\*\* = *p <* .001

**Table S5. Correlations between Self-Report and ABCD-EARS measures within Apple Users**

|  |  |
| --- | --- |
| **Category** | **Average Daily Keystrokes: Self-Reported Smartphone Use** |
| Entertainment | 0.10\*\* |
| Games | 0.08\* |
| Social | 0.02 |
| Total Use: | 0.13\*\* |

Correlations between alternative measures of smartphone use by category in iOS users. Keystrokes = average daily keystrokes, Self-Reported Smartphone Use = self-reported daily average minutes of smartphone use. Average Daily App Use was unavailable for iOS users due to restrictions on data collection by third party applications.

\* = *p <* .05; \*\* = *p <* .01; \*\*\* = *p <* .001

**Figure S4. Bland-Altman plot of the relationship between Average Daily App Usage and Self-Reported Smartphone Use.**

A graph with black dots

Description automatically generated

Bland-Altman plot displaying the mean of Average Daily App Use and Self-Reported Smartphone Use on the X-axis and their difference on the Y axis. Marginal histograms represent the number of observations at each value of mean (S1,S2) and S1 – S2.

**Table S6. Average App Use by Sex**

|  |  |  |  |
| --- | --- | --- | --- |
| **Category** | **Females**  **Mean (SD)** | **Males**  **Mean (SD)** | **p-value** |
| Social | 02:39:40 (02:17:02) | 01:51:38 (01:50:18) | <.001 |
| Photography | 00:56:36 (01:14:18) | 01:15:13 (01:29:53) | .02 |
| Games | 00:28:28 (00:48:25) | 00:31:12 (00:37:57) | .48 |
| Entertainment | 00:25:53 (00:53:53) | 00:16:25 (00:36:33) | .02 |
| Tools/Utilities | 00:12:22 (00:15:44) | 00:13:43 (00:36:48) | .05 |
| Books | 00:11:42 (00:47:07) | 00:00:46 (00:04:53) | <.001 |
| Music | 00:07:24 (00:21:05) | 00:05:20 (00:30:26) | .40 |
| Business | 00:00:45 (00:03:22) | 00:04:53 (00:03:35) | .86 |
| Productivity | 00:03:48 (00:26:25) | 00:00:37 (00:02:00) | .04 |
| Lifestyle | 00:03:17 (00:11:05) | 00:00:19 (00:02:03) | <.001 |
| Shopping | 00:01:28 (00:03:36) | 00:00:51 (00:02:30) | .02 |
| Sports | 00:00:01 (00:00:06) | 00:00:45 (00:04:43) | .03 |
| Art | 00:00:50 (00:03:06) | 00:00:05 (00:00:34) | <.001 |
| Medical | 00:00:23 (00:00:30) | 00:00:29 (00:01:13) | .23 |
| Travel | 00:00:27 (00:02:15) | 00:00:26 (00:02:51) | .99 |
| Food | 00:00:21 (00:02:06) | 00:00:10 (00:00:44) | .18 |
| News | 00:00:03 (00:00:26) | 00:00:12 (00:01:23) | .15 |
| Weather | 00:00:02 (00:00:07) | 00:00:04 (00:00:31) | .36 |
| Maps | 00:00:01 (00:00:02) | 00:00:03 (00:00:30) | .17 |
| Total App Use | 05:25:06 (02:56:06) | 04:29:54 (02:47:05) |  |
| **Category** | **Female, mean (SD)** | **Male, mean (SD)** |  |
| Unique Apps Used per Day | 2.95 (1.63) | 2.82 (1.39) |  |
| Days with at least one recorded App Use | 20.23 (4.36) | 19.85 (5.17) |  |

Average time per day spent using each application category recorded via the ABCD-EARS app usage data in male and female Android users. Times are in hour, minute, second format.

**Table S7. Average Daily Keystrokes by App Category and Operating System**

|  |  |  |  |
| --- | --- | --- | --- |
| **Category** | **Android Users, Mean (SD)** | | **iOS Users, Mean (SD)** |
| Social | | 1062.20 (1976.47) | 519.66 (995.08) |
| Photography | | 22.86 (53.30) | 387.87 (976.75) |
| Tools/Utilities | | 32.17 (43.48) | 54.78 (73.98) |
| Games | | 38.88 (363.37) | 14.23 (71.83) |
| Entertainment | | 7.29 (23.09) | 38.62 (111.23) |
| Productivity | | 15.25 (109.01) | 28.09 (127.43) |
| Music | | 8.05 (78.68) | 6.15 (17.65) |
| News | | 0.02 (0.23) | 5.83 (70.85) |
| Lifestyle | | 5.63 (46.16) | 2.29 (14.15) |
| Books | | 2.99 (32.54) | 4.92 (78.02) |
| Shopping | | 4.37 (13.46) | 3.77 (24.34) |
| Business | | 1.36 (9.60) | 0.57 (5.83) |
| Travel | | 0.70 (4.54) | 0.09 (1.02) |
| Maps | | 0.003 (0.08) | 0.56 (2.29) |
| Food | | 0.49 (2.33) | 0.21 (1.39) |
| Sports | | 0.27 (2.34) | 0.28 (3.09) |
| Art | | 0.16 (1.75) | 0.11 (2.24) |
| Medical | | 0.03 (0.39) | 0.13 (3.87) |
| Weather | | 0.01 (0.12) | 0.08 (0.50) |
| **Category** | | **Android Users, Mean (SD)** | **iOS Users, Mean (SD)** |
| Unique Apps Used per Day | | 1.28 (0.93) | 1.52 (1.24) |
| Days with at least one recorded Keyboard Use | | 17.42 (6.98) | 10.43 (7.2) |

Average keystrokes per day spent using each application category recorded via the ABCD-EARS keyboard data in Apple iOS and Android users.