Digital Phenotyping

A Uniter Instead of Divider

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Fall ADRC Meeting

October 20, 2022

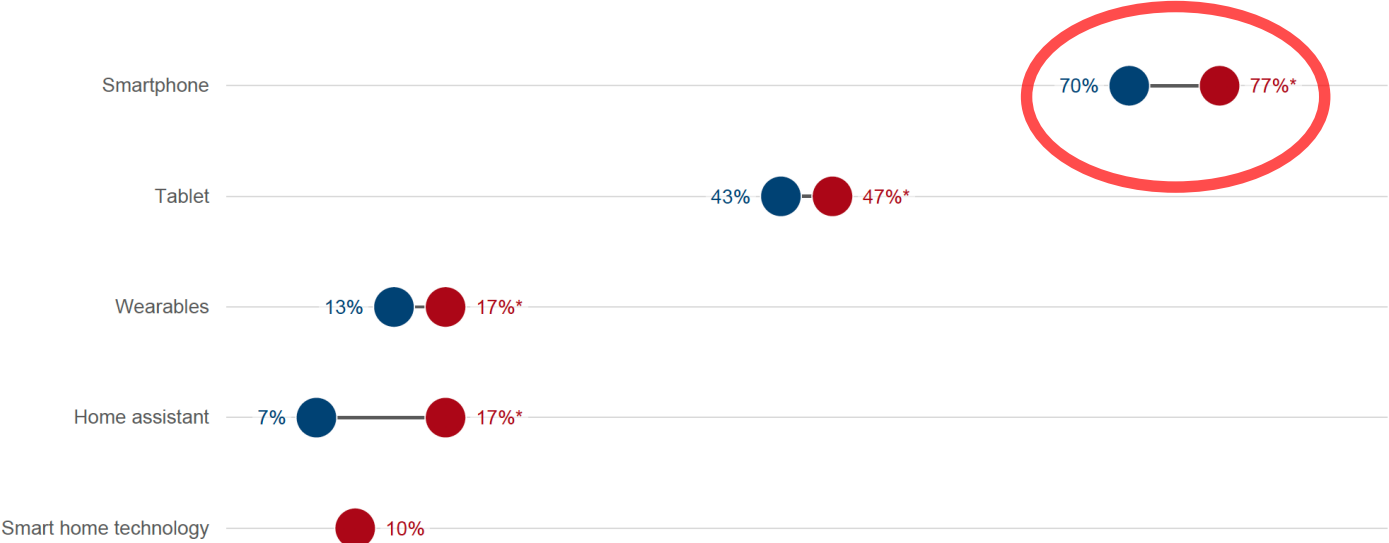# Myth or Reality?

Pre-Covid

Older adults continue to adopt all forms of modern technology devices.

Device adoption rates among adults ages 50 and older, *2017 (n=1,520)* and *2019 (n=2,597)*

Device	2017	2019
Smartphone	70%	77%*
Tablet	43%	47%*
Wearables	13%	17%*
Home assistant	7%	17%*
Smart home technology		10%

Base: Total Respondents
Q.Tech1 Which of the following items do you have?

* Indicates a significant difference at the 95% confidence level

Since Covid

More older adults (44%) view tech more positively that they did before Covid-19

TECHNOLOGY & INNOVATION • **APR 21, 2021**

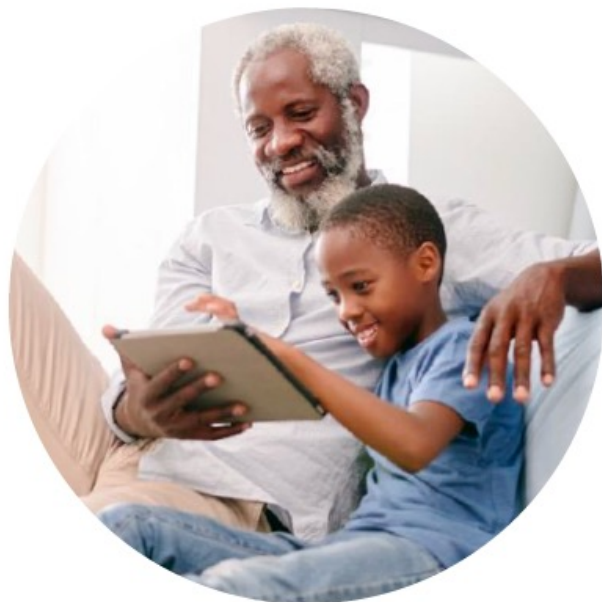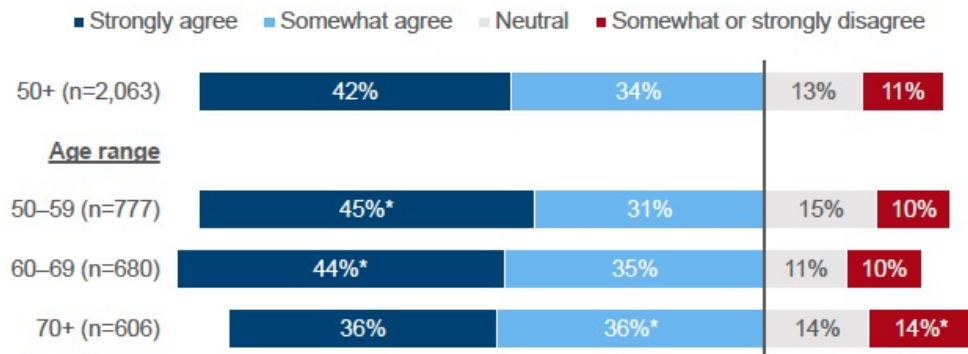# Tech Usage Among Older Adults Skyrockets During Pandemic

New AARP research report highlights rise in tech ownership, adoption, and usage, yet access to internet is still an issue for older Americans

WASHINGTON–In a year with a global pandemic significantly limiting social interaction, technology became more important than ever, especially for older adults. New research from AARP found that more older adults (44%) view tech more positively as a way to stay connected than they did before COVID-19. In addition, 4 out of 5 adults age 50+ rely on technology to stay connected and in touch with family and friends.

4 out of 5 adults age 50+ rely on technology to stay connected and in touch with family and friends

The reliance on technology to stay connected and in touch with friends and family remains a cornerstone with 76% of those 50-plus saying they rely on it, including three in four adults in their 50's (76%), 60's (79%), and 70's (72%).

Agreement with "I rely on technology to stay connected and in touch with friends and family"
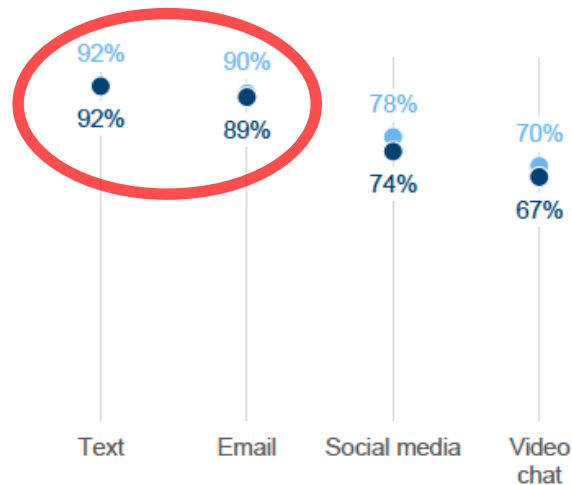*Among adults 50+ and by age range*

■ Strongly agree　■ Somewhat agree　■ Neutral　■ Somewhat or strongly disagree

	Strongly agree	Somewhat agree	Neutral	Somewhat or strongly disagree
50+ (n=2,063)	42%	34%	13%	11%

Age range

	Strongly agree	Somewhat agree	Neutral	Somewhat or strongly disagree
50–59 (n=777)	45%*	31%	15%	10%
60–69 (n=680)	44%*	35%	11%	10%
70+ (n=606)	36%	36%*	14%	14%*

Base: Total 50+ Respondents (n=2,063)
Q11. Please rate how much you agree or disagree with the following statement.
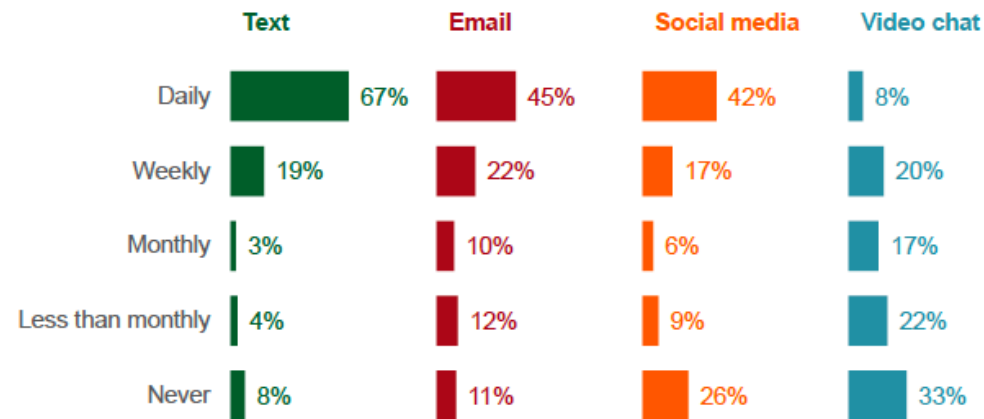
* Indicates a significant difference at a 95% confidence level

Older adults engage with multiple types of online communication to stay connected with others and report a year-over-year increase in the use of video chat, texting, and social media.

Methods used to stay connected
Among adults 50+, 2020 and 2021

	Text	Email	Social media	Video chat
2020	92%	90%	78%	70%
2021	92%	89%	74%	67%

Frequency of using the following methods to stay connected
Among adults 50+

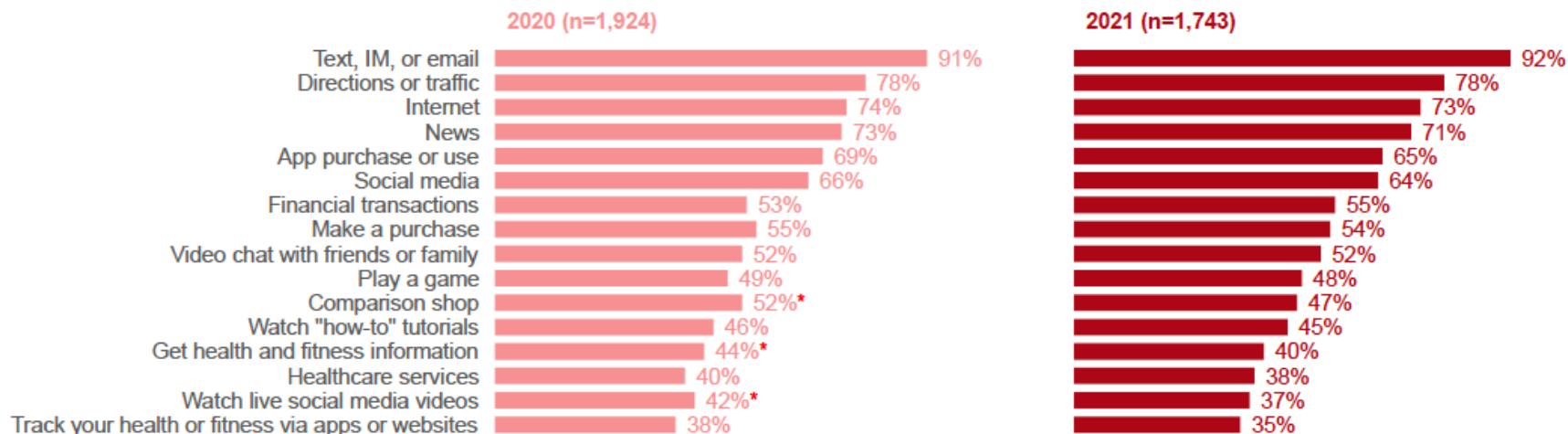|	Text	Email	Social media	Video chat
Daily	67%	45%	42%	8%
Weekly	19%	22%	17%	20%
Monthly	3%	10%	6%	17%
Less than monthly	4%	12%	9%	22%
Never	8%	11%	26%	33%

Base: Total 50+ Respondents (n=2,063)
Q12. How often do you use each of the following to communicate with and stay connected to friends and family?

* Indicates a significant difference at a 95% confidence level

Smartphone activities embraced during the pandemic such as making a purchase, banking, and telehealth services are more mainstream in 2021.

Most popular activities performed on a smartphone in the past three months, 2020 and 2021
Among adults 50+

2020 (n=1,924)

Activity	2020
Text, IM, or email	91%
Directions or traffic	78%
Internet	74%
News	73%
App purchase or use	69%
Social media	66%
Financial transactions	53%
Make a purchase	55%
Video chat with friends or family	52%
Play a game	49%
Comparison shop	52%*
Watch "how-to" tutorials	46%
Get health and fitness information	44%*
Healthcare services	40%
Watch live social media videos	42%*
Track your health or fitness via apps or websites	38%

2021 (n=1,743)

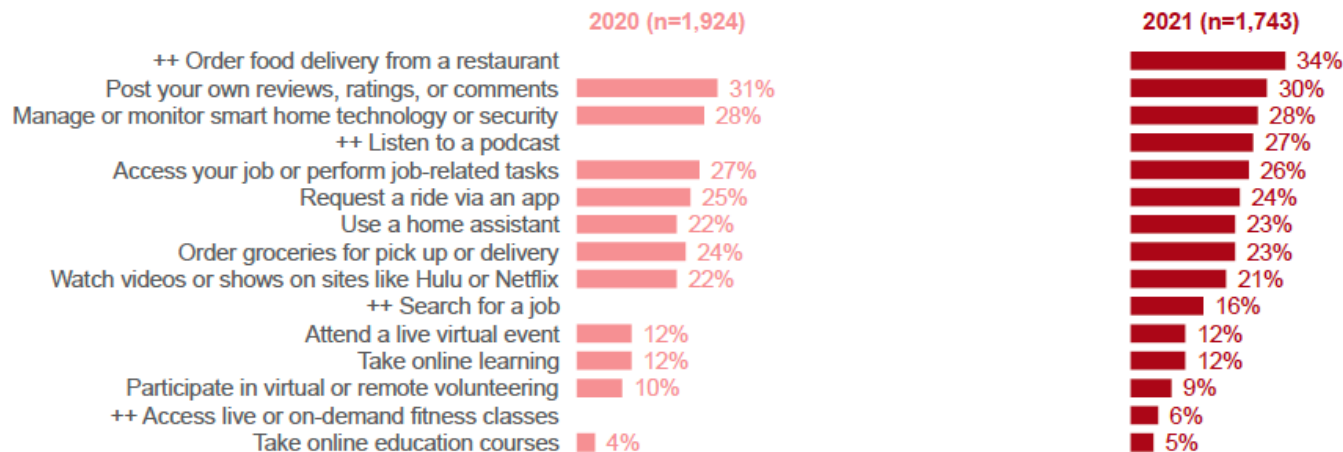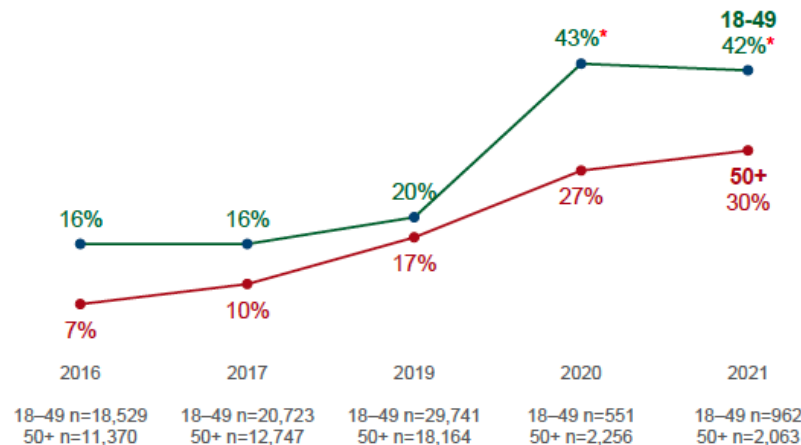| Activity	2021
Text, IM, or email	92%
Directions or traffic	78%
Internet	73%
News	71%
App purchase or use	65%
Social media	64%
Financial transactions	55%
Make a purchase	54%
Video chat with friends or family	52%
Play a game	48%
Comparison shop	47%
Watch "how-to" tutorials	45%
Get health and fitness information	40%
Healthcare services	38%
Watch live social media videos	37%
Track your health or fitness via apps or websites	35%

Base: Those who use a Smartphone
Q4. For each device listed below, please indicate the activities that you have used it for in the past 3 months?

*Indicates a significant difference at a 95% confidence level
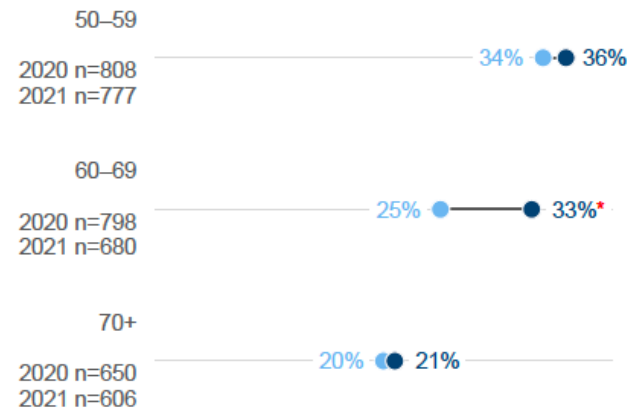++ indicates new item in 2021

Smartphones continue to be adopted in new ways to manage day to day living. One in three have ordered food delivery and one in four listen to podcasts on their smartphones.

Moderately popular activities performed on a smartphone in the past three months, 2020 and 2021
Among adults 50+

	2020 (n=1,924)	2021 (n=1,743)
++ Order food delivery from a restaurant		34%
Post your own reviews, ratings, or comments	31%	30%
Manage or monitor smart home technology or security	28%	28%
++ Listen to a podcast		27%
Access your job or perform job-related tasks	27%	26%
Request a ride via an app	25%	24%
Use a home assistant	22%	23%
Order groceries for pick up or delivery	24%	23%
Watch videos or shows on sites like Hulu or Netflix	22%	21%
++ Search for a job		16%
Attend a live virtual event	12%	12%
Take online learning	12%	12%
Participate in virtual or remote volunteering	10%	9%
++ Access live or on-demand fitness classes		6%
Take online education courses	4%	5%

Base: Those who use a Smartphone
Q4. For each device listed below, please indicate the activities that you have used it for in the past 3 months?

Indicates a significant difference at a 95% confidence level
++ indicates new item in 2021

Ownership of wearables has increased among adults 50-plus as both those in their 60's and 70's report increases in ownership year over year.

Wearable ownership rates
Among adults 18–49 and 50+

18-49
43%*
42%*

50+
27%
30%

16%   16%   20%
7%   10%   17%

2016	2017	2019	2020	2021
18–49 n=18,529	18–49 n=20,723	18–49 n=29,741	18–49 n=551	18–49 n=962
50+ n=11,370	50+ n=12,747	50+ n=18,164	50+ n=2,256	50+ n=2,063

* 2014-2019 Source: Forrester Analytics; Consumer Technographics Online Benchmark Survey (Part 2)
2020 Source: Q2. Which of the following items do have/own?

Wearable ownership rates, 2020 and 2021
Among adults 50–59, 60–69, and 70+

50–59
2020 n=808
2021 n=777
34%   36%

60–69
2020 n=798
2021 n=680
25%   33%*

70+
2020 n=650
2021 n=606
20%   21%

Base: Total 50+ Respondents
*Indicates a significant difference at a 95% confidence level

Among those who own a wearable, the majority use it on a daily basis, regardless of age.

Wearable daily use rates, 2020 and 2021
Among adults 18–49 and 50+

18–49
2020 n=241
2021 n=434
71% ●● 74%

50+
2020 n=641
2021 n=654
78% ●● 81%
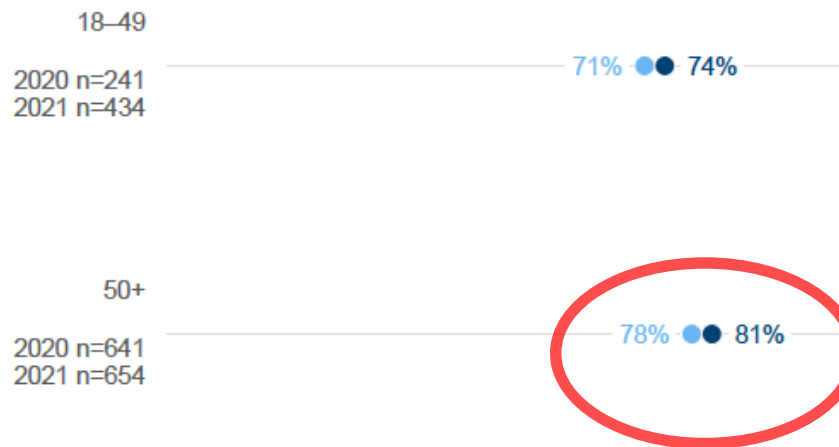
Wearable daily use rates, 2020 and 2021
Among adults 50+, by age range

50–59
2020 n=286
2021 n=302
77% ● 78%

60–69
2020 n=210
2021 n=203
76% ●—● 82%

70+
2020 n=145
2021 n=149
82% ●—● 86%
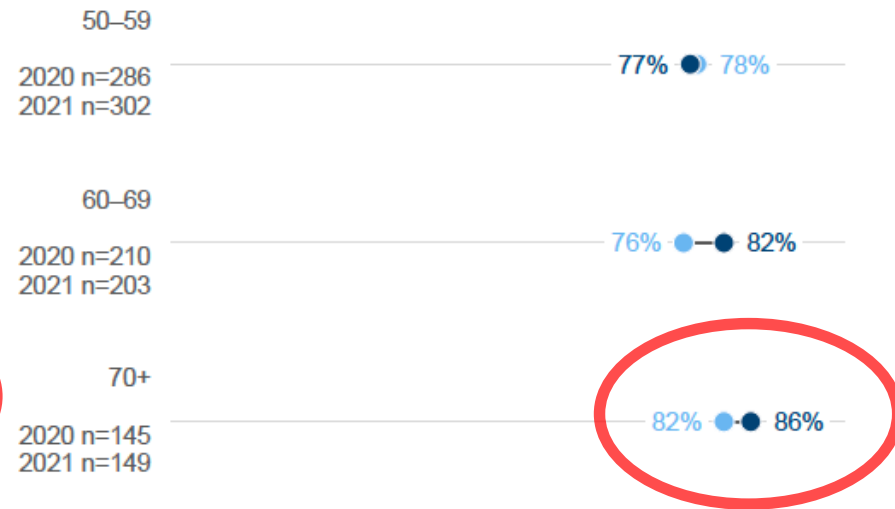
Base: Those who own a wearable
Q3. How often do you currently use the following?

* Indicates a significant difference at a 95% confidence level

Pre-Covid

Blacks and Hispanics own mobile devices at similar shares to whites

% of U.S. adults in each group who say they have the following

Smartphone
- White: 82
- Black: 80
- Hispanic: 79

Tablet computer
- White: 53
- Black: 58
- Hispanic: 43
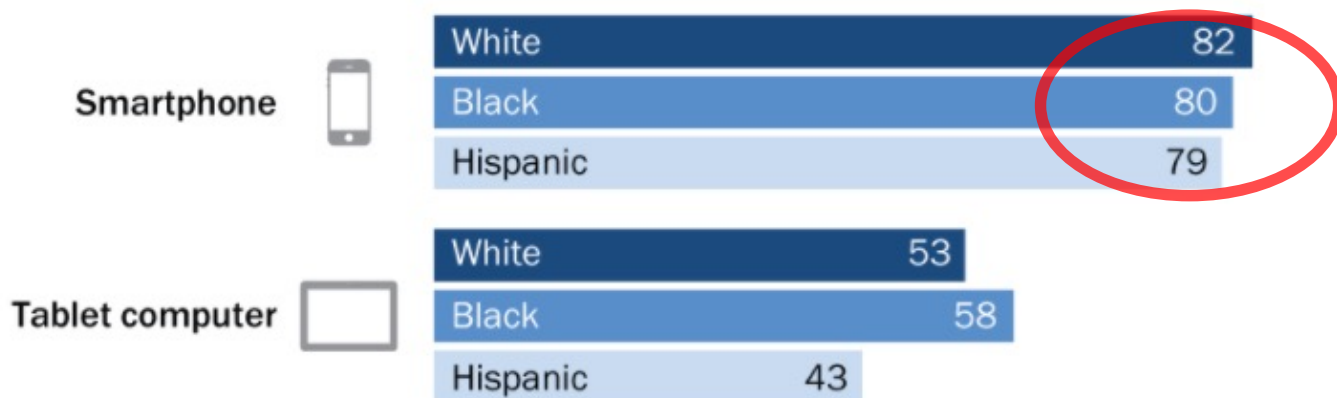
Since Covid

Black and Hispanic adults in U.S. are less likely than White adults to have a traditional computer, home broadband

% of U.S. adults who say they have the following

■ White ■ Black ■ Hispanic

	White	Black	Hispanic
Desktop or laptop computer	80	69	67
Home broadband	80	71	65
Smartphone	85	83	85
Tablet computer	53	54	53
All of the above	42	40	35

2022	2019
85	82
83	80
85	79
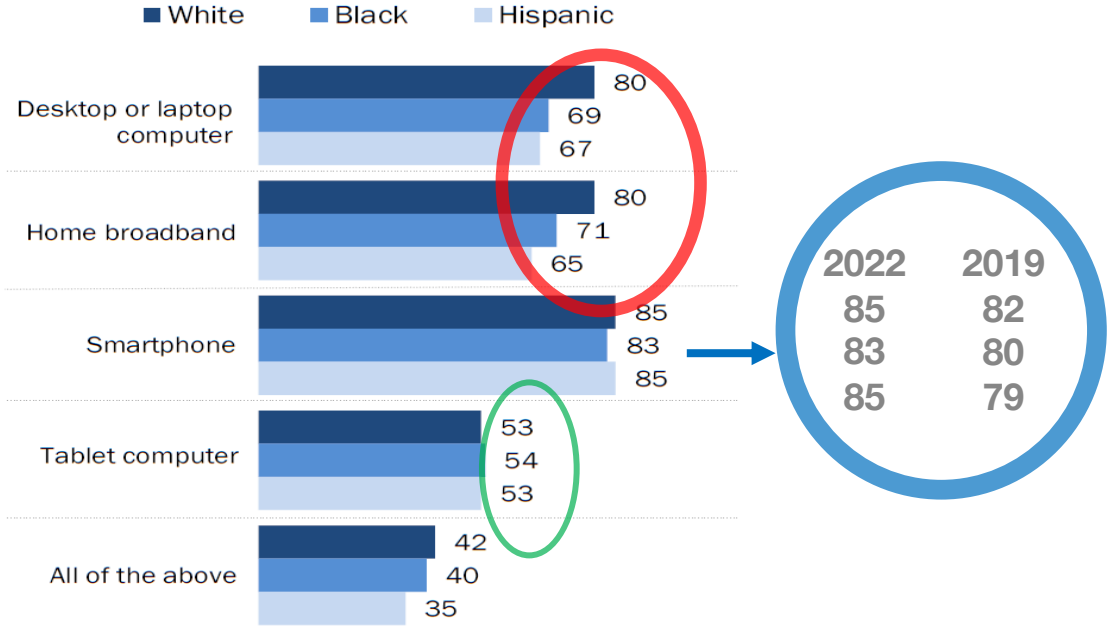
Note: Respondents who did not give an answer are not shown. White and Black adults include those who report being only one race and are not Hispanic. Hispanics are of any race.
Source: Survey of U.S. adults conducted Jan. 25-Feb. 8, 2021.

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Pre-Covid

Lower-income Americans have lower levels of technology adoption

% of U.S. adults who say they have the following ...

■ <$30K ■ $30K-$99,999 ■ $100K+

Smartphone
- 71
- 85
- 97

Desktop or laptop computer
- 54
- 83
- 94

Home broadband
- 56
- 81
- 94

Tablet computer
- 36
- 55
- 70
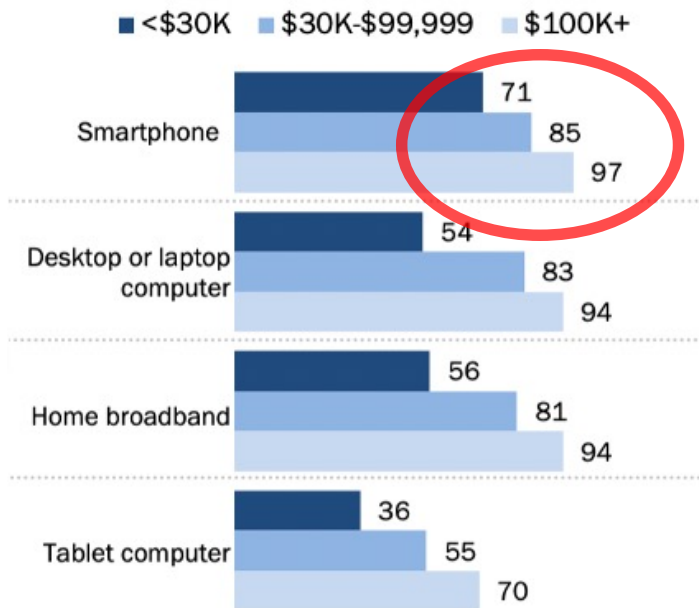
17% of Americans are "smartphone only" internet users

% of U.S. adults who say they own a smartphone, but do not have a high-speed internet connection at home

- HS or less — 26
- Some college — 16
- College+ — 4

- Less than $30,000 — 26
- $30,000-$74,999 — 15
- $75,000 or more — 6

- Urban — 17
- Suburban — 13
- Rural — 20

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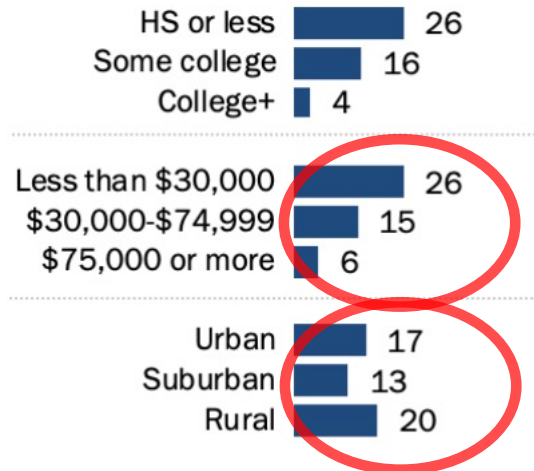
Since Covid

Americans with lower incomes have lower levels of technology adoption

% of U.S. adults who say they have each of the following, by household income
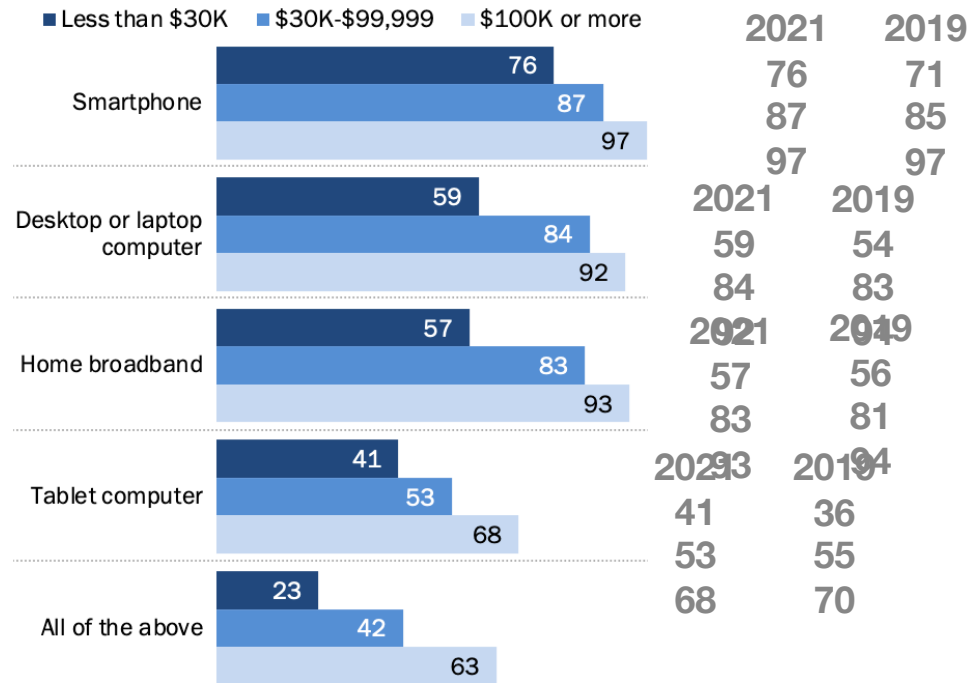
■ Less than $30K   ■ $30K-$99,999   ■ $100K or more

	2021	2019
Smartphone		
Less than $30K	76	71
$30K-$99,999	87	85
$100K or more	97	97
Desktop or laptop computer		
Less than $30K	59	54
$30K-$99,999	84	83
$100K or more	92	94
Home broadband		
Less than $30K	57	56
$30K-$99,999	83	81
$100K or more	93	94
Tablet computer		
Less than $30K	41	36
$30K-$99,999	53	55
$100K or more	68	70
All of the above		
Less than $30K	23	
$30K-$99,999	42	
$100K or more	63	

Note: Respondents who did not give an answer are not shown.
Source: Survey of U.S. adults conducted Jan. 25-Feb. 8, 2021.

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The share of Americans with lower incomes who rely on their smartphones for going online has roughly doubled since 2013

% of U.S. adults who say they have a smartphone but no broadband at home, by household income
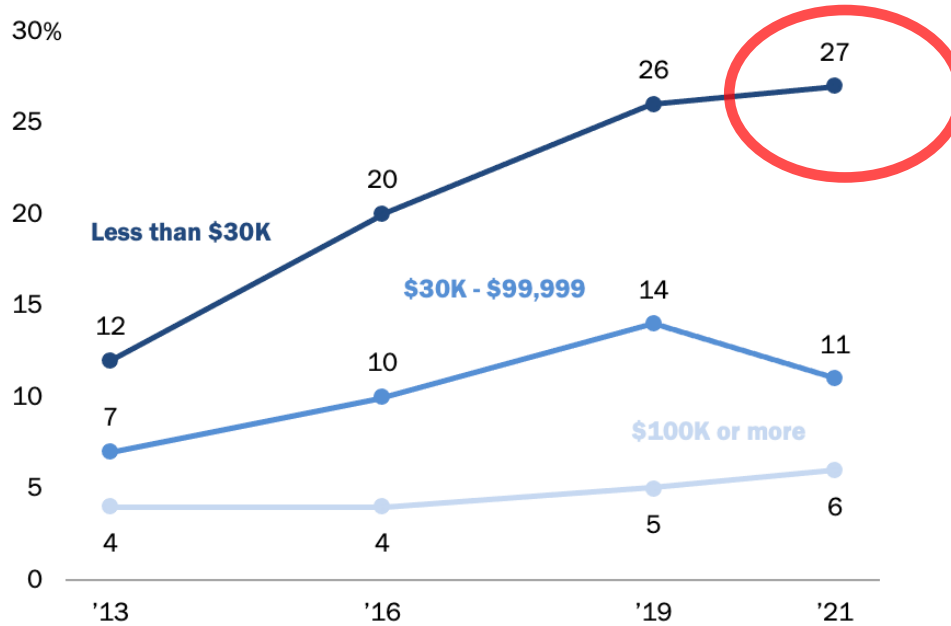
Note: Respondents who did not give an answer are not shown.
Source: Survey of U.S. adults conducted Jan. 25-Feb. 8, 2021.

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Despite growth, rural Americans have consistently lower levels of technology ownership than urbanites and lower broadband adoption than suburbanites

% of U.S. adults who say they have or own the following

Home broadband	Smartphone	Tablet	Desktop/laptop computer

Home broadband

100%

80 — 79
77
72

Suburban

60

Urban

40

Rural

1
1
0

'00 — '21

Smartphone

89
84
80

38
37

21

'00 — '11 — '21

Tablet

55
54
44

4
3
1

'00 — '10 — '21

Desktop/laptop computer

80
78
78
73
72
61

'00 — '08 — '21
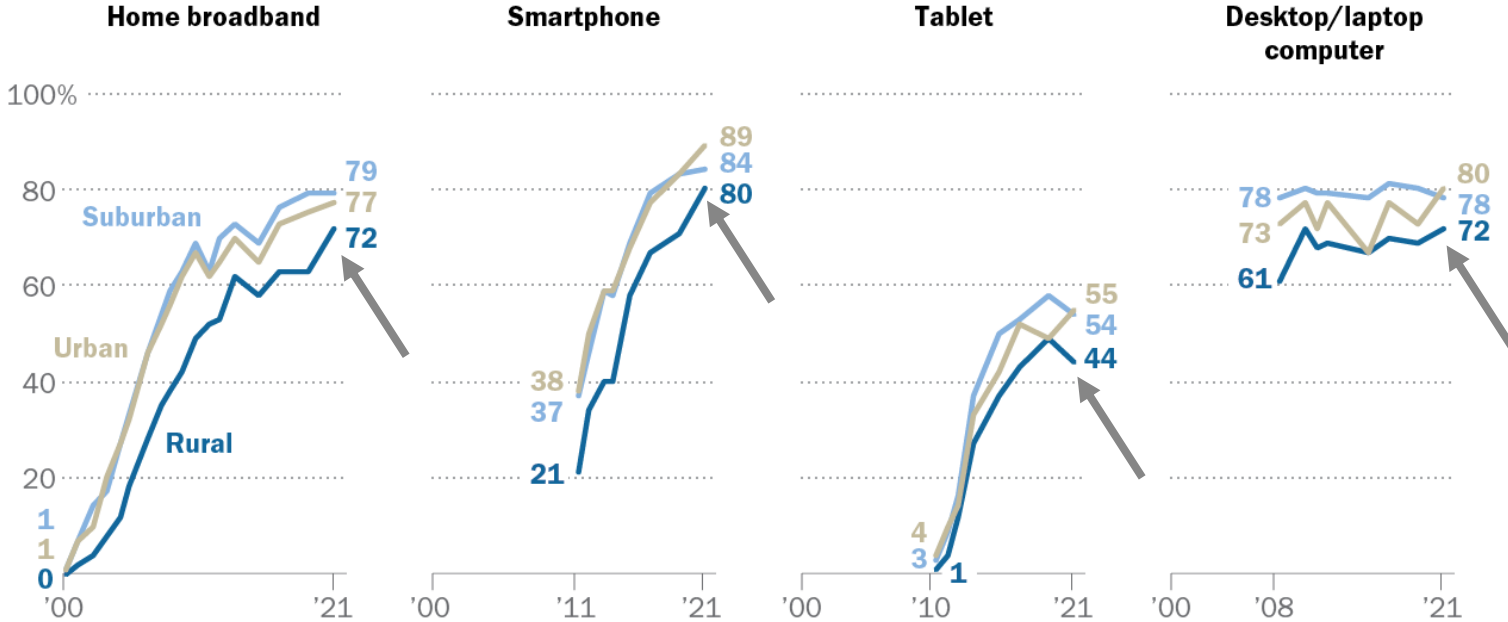
Source: Survey conducted Jan. 25-Feb. 8, 2021.

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Just A Reminder
This is Where We are At Now

Regions well covered with several studies of good methodological quality
Some studies but insufficient to derive regional estimates with confidence
Single epidemiological studies
No epidemiological studies
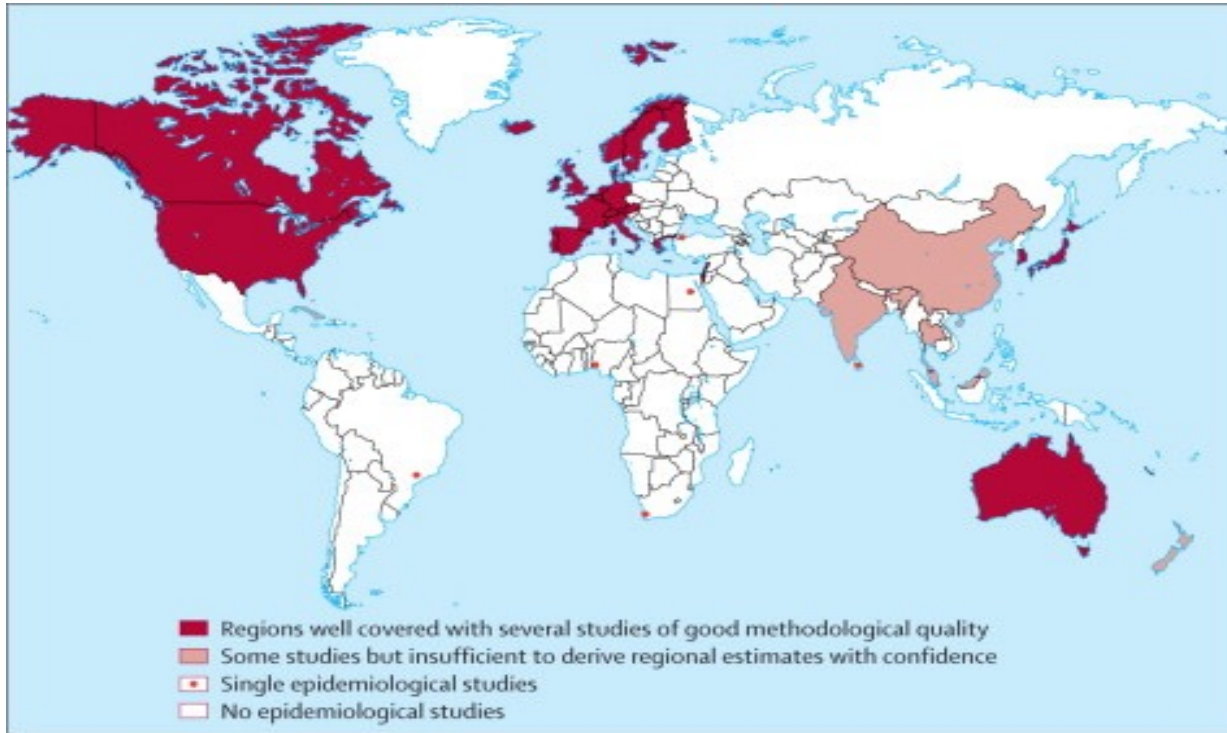
Ferri CP, Prince M, Brayne C, Brodaty H, Fratiglioni L, Ganguli M, Hall K, Hasegawa K, Hendrie H, Huang Y, Jorm A, Mathers C, Menezes PR, Rimmer E, Scazufca M; Alzheimer's Disease International. Global prevalence of dementia: a Delphi consensus study. Lancet. 2005 Dec 17;366(9503):2112-7. doi: 10.1016/S0140-6736(05)67889-0. PMID: 16360788; PMCID: PMC2850264.

This is the Bias…
90% of GWAS Studies on 10% of World Population
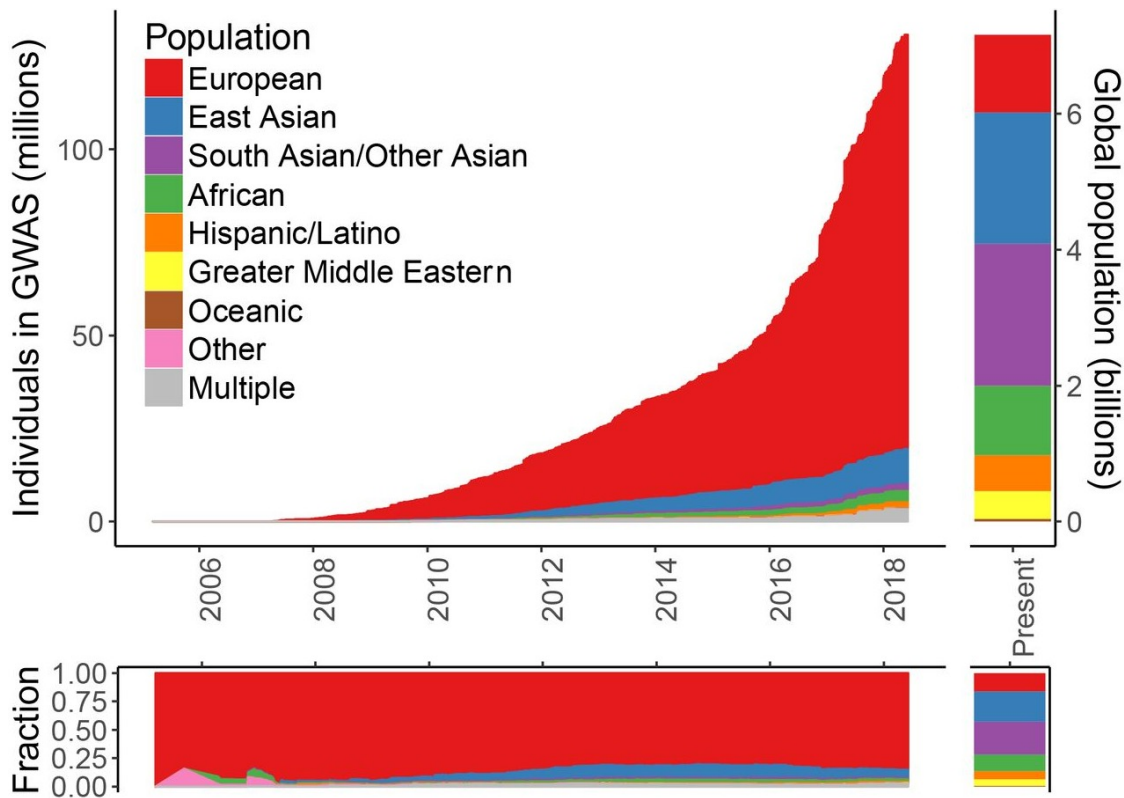
From: Hidden 'risk' in polygenic scores: clinical use today could exacerbate health disparities
Alicia R. Martin, Masahiro Kanai, Yoichiro Kamatani, Yukinori Okada, Benjamin M. Neale, Mark J. Daly
bioRxiv 441261; doi: https://doi.org/10.1101/441261

Even in the U.S.

Characteristic	Race/ethnicity, No. (%)				
	Hispanic (N = 261)	Black (N = 323)	White (N = 5107)	Asian (N = 112)	Other (N = 142)
Age, mean (SD), y	71.8 (4.8)	71.3 (4.9)	71.7 (4.9)	72.5 (5.3)	71.5 (5.0)
Education, mean (SD), y	15.5 (3.2)	15.4 (3.1)	16.7 (2.8)	16.9 (3.4)	16.6 (3.3)

	Hispanic	Black	White	Asian	Other
	4.3%	**5.4%**	**85.9%**	**1.9%**	**2.4%**
2021	**18.9%**	**12.6%**	**59.3%**	**5.9%**	**3.3%**

Raman R, Quiroz YT, Langford O, et al. Disparities by Race and Ethnicity Among Adults Recruited for a Preclinical Alzheimer Disease Trial. *JAMA Netw Open.* 2021;4(7):e2114364. doi:10.1001/jamanetworkopen.2021.14364

Digital Promise: Encouraging Start

Digital is the New Blood
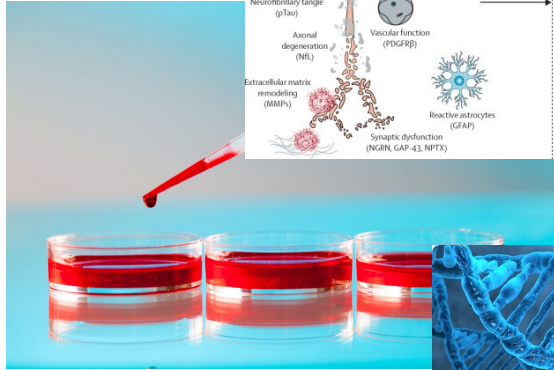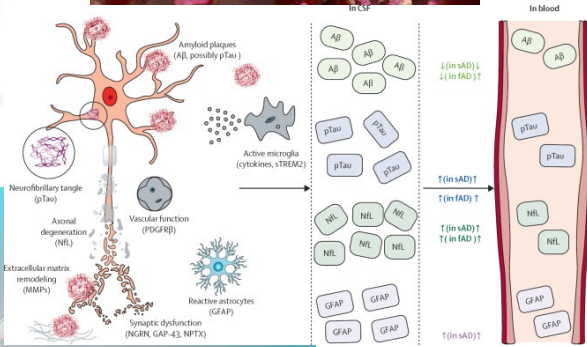
Digital Voice (2005-2022)

Participants	2+	3+	Female	Ave. Age
5,477	3,205	1,264	55%	63.8+4.6

- Amini S, Hao B, Zhang L, Song M, Gupta A, Karjadi C, Kolachalama VB, Au R, Paschalidis IC. Automated detection of mild cognitive impairment and dementia from voice recordings: A natural language processing approach. Alzheimers Dement. 2022 Jul 7. doi: 10.1002/alz.12721. Epub ahead of print. PMID: 35796399.

- Xue C, Karjadi C, Paschalidis IC, Au R, Kolachalama VB. Detection of dementia on voice recordings using deep learning: a Framingham Heart Study. Alzheimers Res Ther. 2021 Aug 31;13(1):146. doi: 10.1186/s13195-021-00888-3. PMID: 34465384; PMCID: PMC8409004.

- Tavabi N, Stück D, Signorini A, Karjadi C, Al Hanai T, Sandoval M, Lemke C, Glass J, Hardy S, Lavallee M,Wasserman B, Ang TFA, Nowak CM, R. Kainkaryam2, L. Foschini L, Au R. Cognitive Digital Biomarkers from Automated Transcription of Spoken Language. J Prev Alz Dis 2022; Published online July 13, 2022, http://dx.doi.org/10.14283/jpad.2022.66

- Thomas JA, Burkhardt HA, Chaudhry S, Ngo AD, Sharma S, Zhang L, Au R, Hosseini Ghomi R. Assessing the Utility of Language and Voice Biomarkers to Predict Cognitive Impairment in the Framingham Heart Study Cognitive Aging Cohort Data. J Alzheimers Dis. 2020;76(3):905-922. doi: 10.3233/JAD-190783. PMID: 32568190.

- Lin H, Karjadi C, Ang TFA, Prajakta J, McManus C, Alhanai TW, Glass J, Au R. Identification of digital voice biomarkers for cognitive health. Explor Med. 2020;1:406-417. doi: 10.37349/emed.2020.00028. Epub 2020 Dec 31. PMID: 33665648; PMCID: PMC7929495.

Digital Clock Drawing (2011-2022)

Participants	2+	3+	Female	Ave. Age
3,717	1,217	101	55%	64.4±13.5

- Souillard-Mandar W, Davis R, Rudin C, Au R, Libon DJ, Swenson R, Price CC, Lamar M, Penney DL. Learning Classification Models of Cognitive Conditions from Subtle Behaviors in the Digital Clock Drawing Test. Mach Learn. 2016 Mar;102(3):393-441. doi: 10.1007/s10994-015-5529-5. Epub 2015 Oct 20. PMID: 27057085; PMCID: PMC4821477.

- Yuan J, Libon DJ, Karjadi C, Ang AFA, Devine S, Auerbach SH, Au R, Lin H. Association Between the Digital Clock Drawing Test and Neuropsychological Test Performance: Large Community-Based Prospective Cohort (Framingham Heart Study). J Med Internet Res. 2021 Jun 8;23(6):e27407. doi: 10.2196/27407. PMID: 34100766; PMCID: PMC8241432.

- Piers RJ, Devlin KN, Ning B, Liu Y, Wasserman B, Massaro JM, Lamar M, Price CC, Swenson R, Davis R, Penney DL, Au R, Libon DJ. Age and Graphomotor Decision Making Assessed with the Digital Clock Drawing Test: The Framingham Heart Study. J Alzheimers Dis. 2017;60(4):1611-1620. doi: 10.3233/JAD-170444. PMID: 29036819; PMCID: PMC7286350.

- Yuan J, Au R, Karjadi C, Ang TF, Devine S, Auerbach S, DeCarli C, Libon DJ, Mez J, Lin H. Associations Between the Digital Clock Drawing Test and Brain Volume: Large Community-Based Prospective Cohort (Framingham Heart Study). J Med Internet Res. 2022 Apr 15;24(4):e34513. doi: 10.2196/34513. PMID: 35436225; PMCID: PMC9055470.

- Davoudi A, Dion C, Formanski E, Frank BE, Amini S, Matusz EF, Wasserman V, Penney D, Davis R, Rashidi P, Tighe PJ, Heilman KM, Au R, Libon DJ, Price CC. Normative References for Graphomotor and Latency Digital Clock Drawing Metrics for Adults Age 55 and Older: Operationalizing the Production of a Normal Appearing Clock. J Alzheimers Dis. 2021;82(1):59-70. doi: 10.3233/JAD-201249. Erratum in: J Alzheimers Dis. 2021;83(2):937. PMID: 34219739; PMCID: PMC8379638.

- Souillard-Mandar W, Penney D, Schaible B, Pascual-Leone A, Au R, Davis R. DCTclock: Clinically-Interpretable and Automated Artificial Intelligence Analysis of Drawing Behavior for Capturing Cognition. Front Digit Health. 2021 Oct 15;3:750661. doi: 10.3389/fdgth.2021.750661. PMID: 34723243; PMCID: PMC8553980.
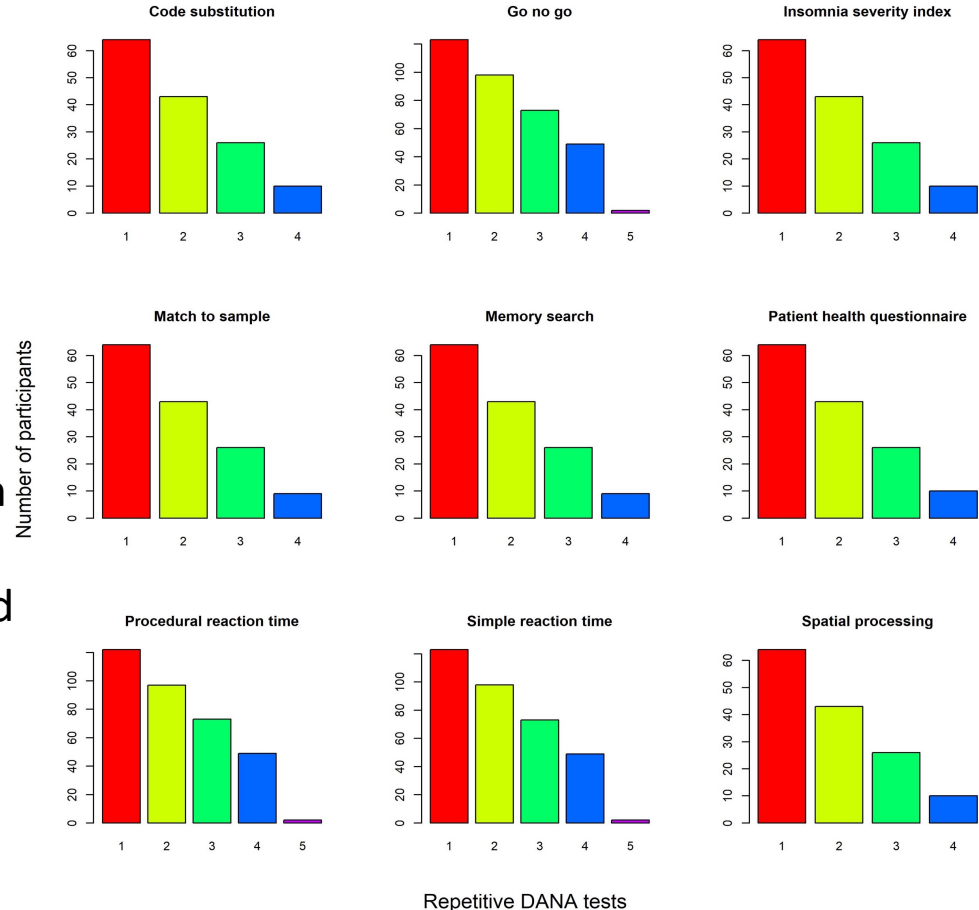
1st Smartphone Pilot Study

NO CLOUD USE

Clinical characteristics	
Variable	All (N=121)
Age (years), mean (SD)	71 ± 8
Female, n (%)	78 (64.5)
APOE4 positive	24 (19.8)
Education, n (%)	
No high school	13 (10.7)
High school	15 (12.4)
Some college	33 (27.3)
College and higher	60 (49.6)

Participants completed an average of 2.9 repeated tests during a median of seven month follow-up period

Figure 2. Number of participants for repeated DANA tests

Au R, Devine S, Young K, McManus C, Lin HH, Correlation of a mobile based cognitive test app with traditional neuropsychological tests in a community-based cohort . Presented at AAIC 2020

Correlates with Neuropsychological Tests

- Procedural Reaction Time was the most significant DANA test that was associated with multiple NP tests administered face-to-face

  - The correlation remained relatively consistent during follow-up DANA tests (correlation coefficient of 0.46, 0.45, 0.35, and 0.42 for the 1st, 2nd, 3rd and 4th DANA exams, respectively).
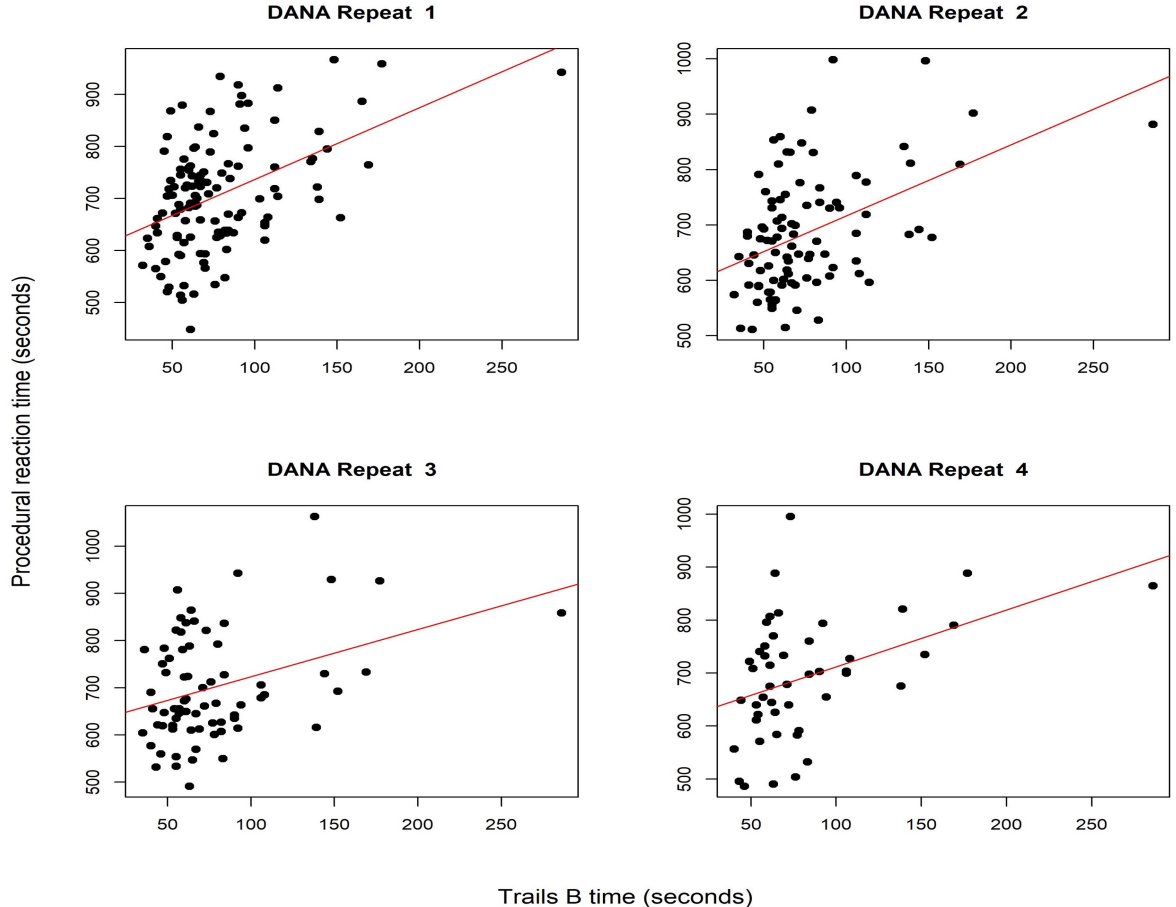
Smartphone Studies

2 months and counting!

Cohort	N	Female	Ave. Age	Used App
Gen 2	17	60%	73.6+3.5	9
OmniGen 1	3	0%	66.3+2.1	3

Cohort	N	Female	Ave. Age	Used App
Gen 3	78	62%	60.8+8.3	50
OmniGen 2	7	71%	67.4+8.7	5
NOS*	3	33%	75.0+3.0	3

*New Offspring Spouses

Participant-Driven Design and Technology Use

Reaction Time
Processing Speed
Task Adherence
Gait and Balance
Speech

Reaction Time
Processing Speed
Task Adherence
Motor Control
Speech

Reaction Time
Processing Speed
Task Adherence

Sleep EEG
Sleep Movement and Breathing

Pulse Oxygen
Heart Rate Variability
Pleth

Physical Activity
Heart Rate
Sleep

To Be Added:
Medication Use and Refills
Medication Adherence

To Be Added:
Typing Behavior
Embedded Phone Sensors
(Movement, GPS, Social Engagement)

Typing Behavior
Phone Usage

To Be Added:
Sleep
Breathing
Movement
Home Behaviors

Physical Activity
Sleep
Gait

Typing Behavior
Computer Usage

Demographics: Race, Sex, & Age (N=50)

White: 84.0%

Black/African American: 12.0%

Unknown: 4.0%

42

6

2

22

28

Female: 56.0%

Male: 44.0%
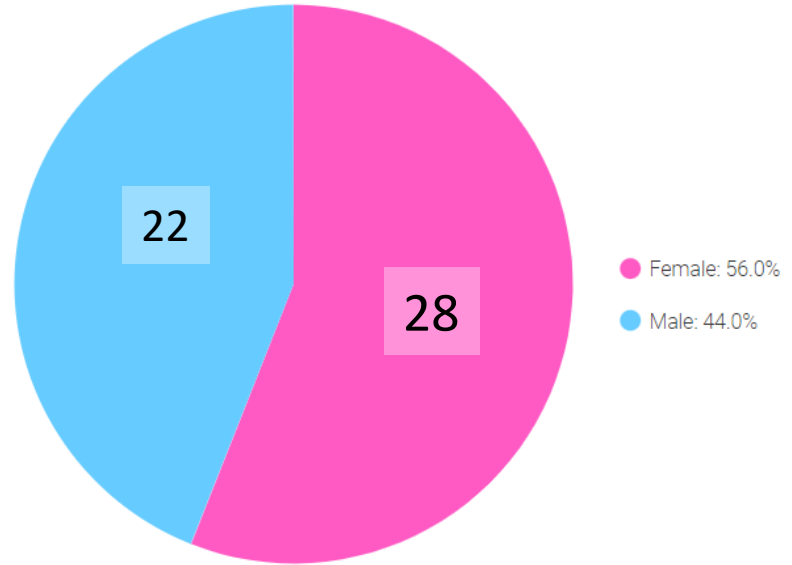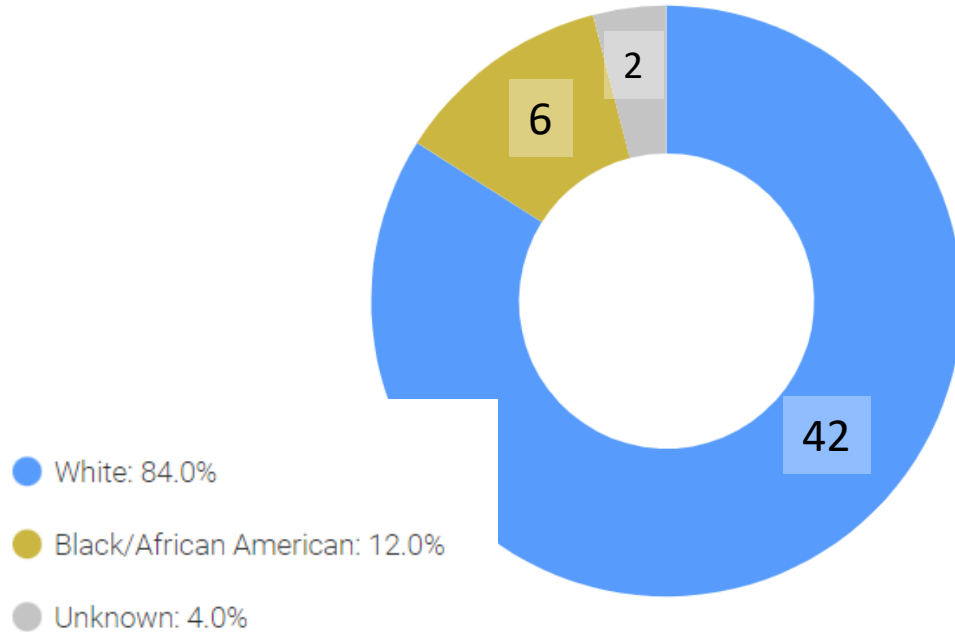
Average Age: 73.3 ± 8.57

Boston University Alzheimer's Disease Research Center
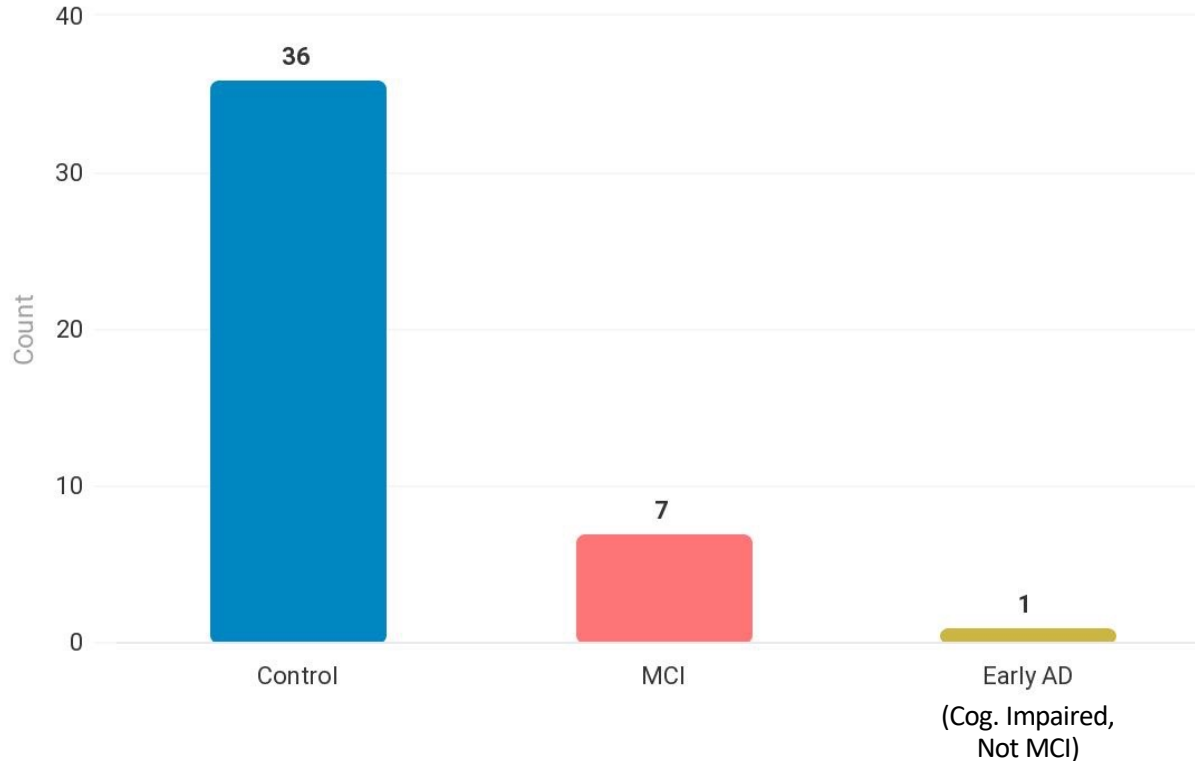
Diagnosis

*Excludes 6 participants with Pending diagnosis

Linus Health Application: Adherence

Application Components
- DANA (Defense Automated Neurobehavioral Assessment) tasks
- Gait and Balance Assessment
- Voice Data Collection
- Questionnaire Responses

24/30 (80%) of Linus users have completed multiple longitudinal DANA assessments.

*6 of 50 total BU ADRC participants opted out of Linus.
*14 of 50 total BU ADRC participants were enrolled in the past 3 months

Other Applications
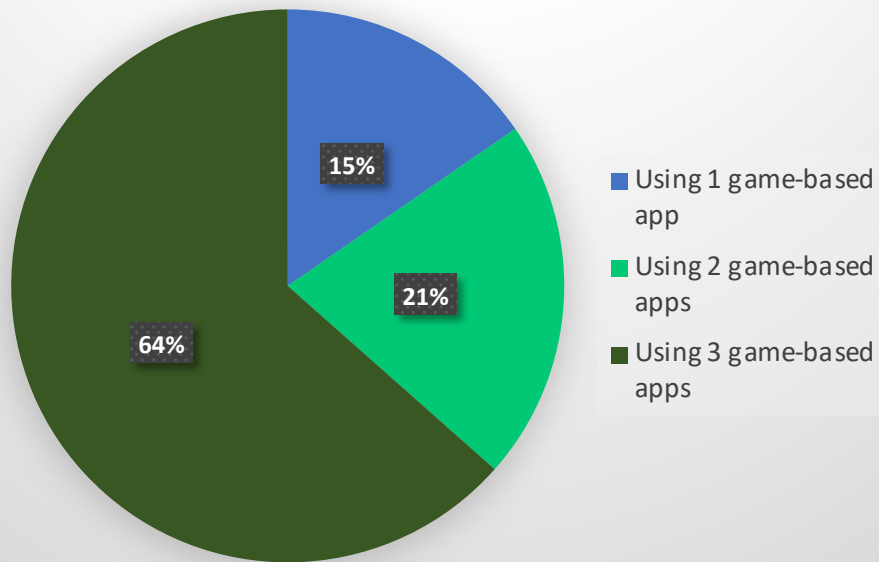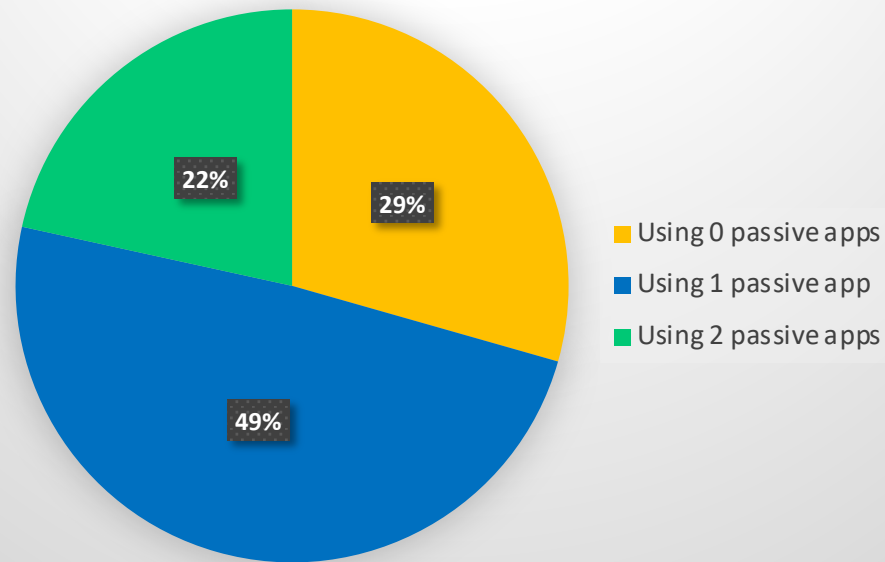
Wearables

Activity Wearable Uptake

- 26% — Using multiple wearables
- 64% — Using one wearable
- 10% — Using no wearables

Sleep Wearable Uptake

- 52% — Using multiple wearables
- 36% — Using one wearable
- 12% — Using no wearables
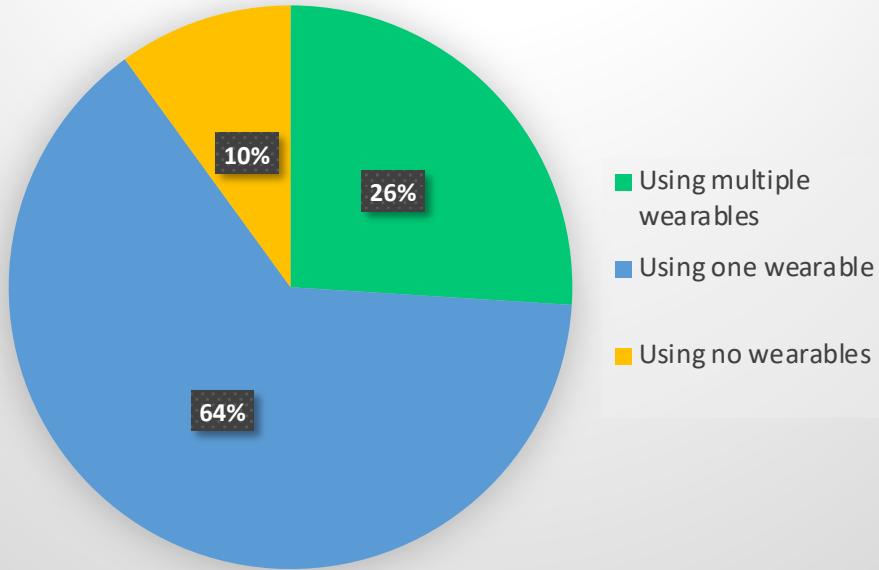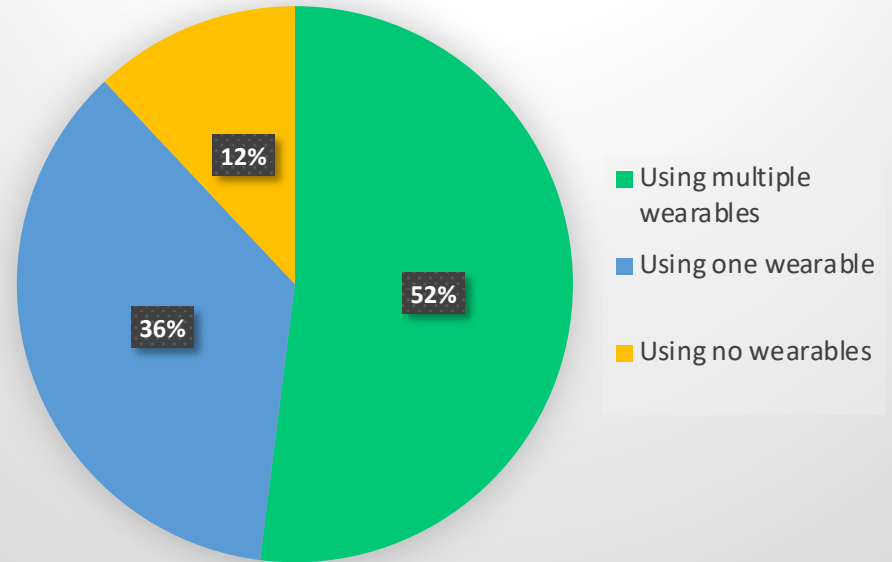
You Too Are Already Using Digital

Enhancing Traditional Tests with Digital Tools

Already Using 52%
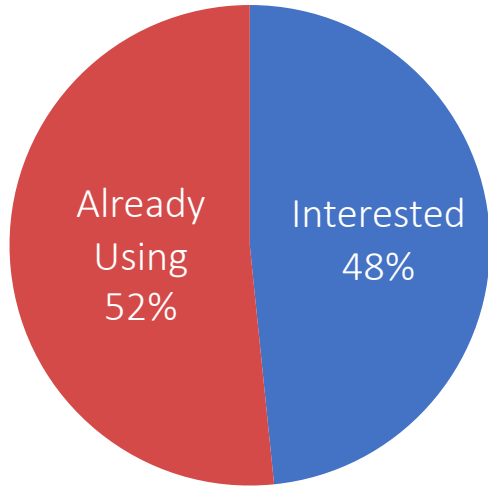
Interested 48%

Use of Digital Technology to Monitor Behavior and Health

3%

36%

61%

Already Using   Interested

Interest in Working with a Digital Technology Team

No 13%

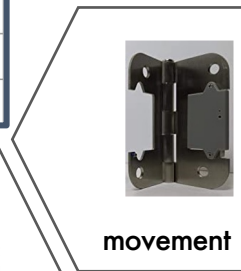Yes 87%

*Results are from 2021 survey of 31 ADRC's

Here is What You are Using

DIGITAL TECHNOLOGY	n (using)
Actigraphy	4
Sleep	3
Driving	3
General	3
Total Responses	**11**

DIGITAL TECHNOLOGY	n (using)
Computerized Cognitive Assessment	10
Surveys	6
Vital Measurements	2
Phone	7
Video	4
General	5
Total Responses	**15**

cognition

movement

sleep

actigraphy

driving

gait

body metrics

medication adherence

physical activity

digital voice

EDoN Early Detection of Neurodegenerative diseases

LINUS HEALTH
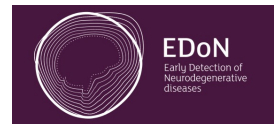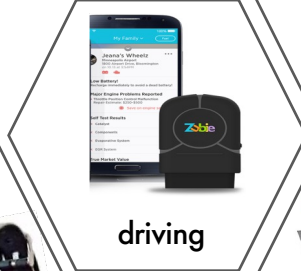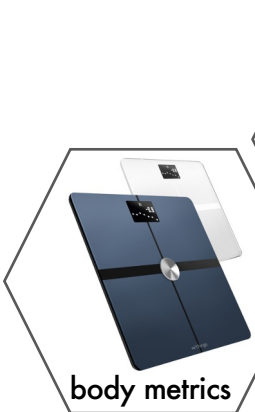
First Day Pilot Results (10/7/22):
31 participants registered/downloaded app
24 completed all 5 tasks
3 completed 1 task, will complete at home
4 had issues accessing cognitive tests after registering

Opting Out Reasons:
1. Phone storage limitations
2. Redundant with other cognitive tests (MoCA, VCAT)
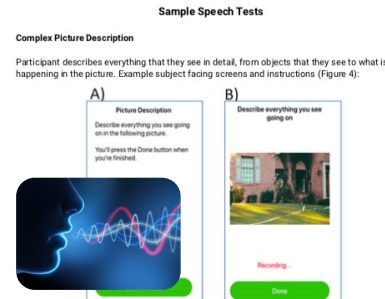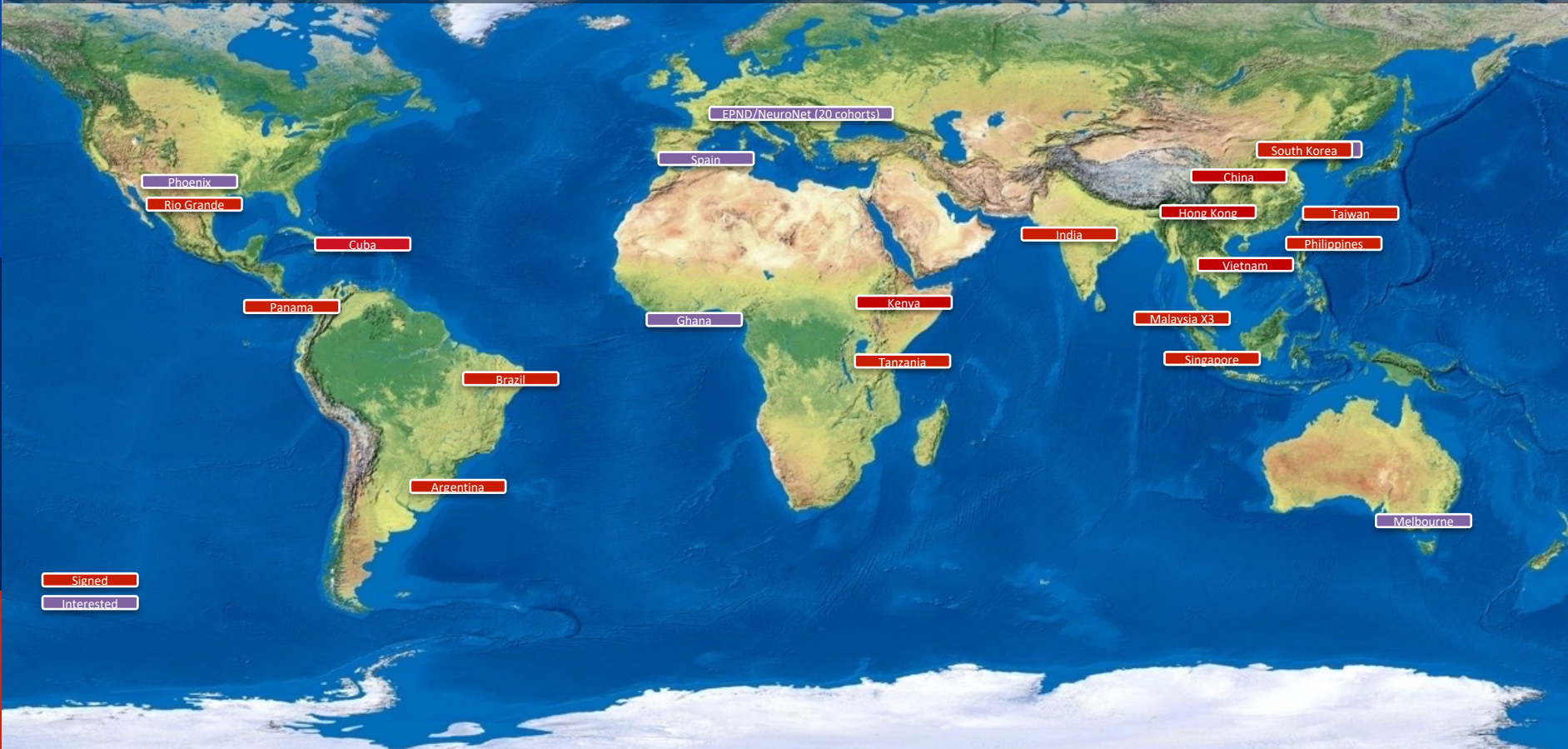3. Wanted something else in return

Smartphone
Cognitive Assessment

LINUS HEALTH

DANA

Start naming...

Vegetables

Recording...

BLAST

Sample Speech Tests

Complex Picture Description

Participant describes everything that they see in detail, from objects that they see to what is happening in the picture. Example subject facing screens and instructions (Figure 4):

A)
Picture Description
Describe everything you see going on in the following picture.
You'll press the Done button when you're finished.

B)
Describe everything you see going on

Recording...
Done

Figure 4: Complex picture description instructions and example task.

Current DAC Cohorts

Growth Rate in LMIC > HIC

Smartphones Market - Growth Rate by Region (2022 - 2027)

High
Medium
Low

Source: Mordor Intelligence

Thank you