Smartphone usage before and after Covid-19: a comparative study based on objective recording of usage data

Khansa Chemnad
Hamad Bin Khalifa University College of Science and Engineering
Sameha Alshakhsi
Hamad Bin Khalifa University College of Science and Engineering
Mohamed Basel Almourad
Zayed University College of Technological Innovation
Majid Altuwairiqi
Taif University
Raian Ali (raali2@hbku.edu.qa)
Hamad bin Khalifa University https://orcid.org/0000-0002-5285-7829

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Abstract

Most studies that claimed changes in smartphone usage during COVID-19 were based on self-reported usage data, e.g. collected through a questionnaire. These studies were also limited to reporting the overall smartphone usage, with no detailed investigation of distinct types of apps. The current study investigates smartphone usage before and after COVID-19. Our study uses a dataset from a smartphone app that objectively logs users' activities, including apps accessed and each app session's start and end time. These were collected during two periods: pre-COVID-19 (161 individuals with 77 females) and during COVID-19 (251 individuals with 159 females). We report on the top 15 apps used in both periods. Mann-Whitney U test was used for the inferential analysis. The results revealed that time spent on the smartphone has increased since COVID-19. Emerging adults were found to spend more time on the smartphone compared to adults during both periods. The time spent on social media apps has increased since COVID-19. Females were found to spend more time on social media than males. Females were also found to be more likely to launch social media apps than males. There has been an increase in the number of people who use gaming apps since the pandemic. Value: The use of objectively collected data is a methodological strength of our study. We draw parallels on the usage of smartphone with contexts similar to COVID-19 period, especially concerning limitation on social gathering, including working from home for extended periods.

1 Introduction

Many nations adopted lockdown measures in response to World Health Organization guidelines to reduce COVID-19 transmission [1]. In an attempt to stay socially connected during the pandemic, there was an increase in smartphone usage [2]. According to data from a global poll conducted in March 2020 [3], it was revealed that 70 per cent of respondents used their smartphones more as a direct result of COVID-19. Ofcom's research on online behaviour during the pandemic showed an increase in adults' average time on phones in the U.K. [4]. Daytime data usage increased by 70–80% on Australia's National Broadband Network (NBN) compared to February data before lockdown [5]. Given the possible mental and physical health consequences of passive smartphone usage, tracking and evaluating patterns in screen time during COVID-19 is critical to understanding the pandemic's overall health repercussions [6], [7].

A growing corpus of work investigating screen time and its many health implications, with results from Spain, Ecuador, Italy, Portugal, India, China, Canada, and Zimbabwe, report that individuals increased their screen time during the pandemic [8]–[12]. A survey found that 71.4% of the 3254 participants reported increased online media usage after COVID-19 [13]. They assessed online media usage through a series of questions on time spent on different apps to estimate the change in usage. However, when the replies on certain online activities were compared before and after the lockdown, most individuals reported no changes in their online activity.

Recent research by Lemenager et al. showed that COVID-19 has led to an increase in the usage of social networks [13]. A study on the influence of lockdown found that teens have expanded their usage of social

networking sites [10]. There is evidence in literature that suggests that social media use decreases as age increases [14]. A study by Ryu et al. on the usage of social media after the pandemic found that participants who reported significant anxiety symptoms after the enforced lockdown were more active in social networking apps and less active in communication apps overall, indicating a distinct pattern of digital social activity for coping with the crisis [15]. Furthermore, Ryu et al. made use of the Google Play store labels to categorise social media apps into two categories: communication and social networking. Messaging, chat/I.M., dialer, and browser apps such as WhatsApp, Telegram, Facebook Messenger, and Gmail were examples of communication apps; social networking apps primarily featured those for sites such as Instagram, Twitter, and TikTok.

Literature from before the pandemic has revealed various demographic factors to be associated with increased smartphone usage and screen time. However, findings regarding gender appear to be mixed. There is evidence that smartphone addiction is more prevalent in females than males [16], [17]. There is also evidence that females spent more time per session than males [18]. Lin et al. found that men are more prone to excessive phone usage and internet addiction [19]. Research by van Deursen et al. found that men experienced less social stress than women and used their smartphones less for social purposes [20]. Consequently, women have a higher chance of developing habitual or addictive smartphone behaviour. Conversely, other studies have found no gender differences in smartphone addiction prevalence [21], [22]. There were some differences in terms of specific app use, with smartphone addiction in males being more associated with game app use, and in women, it was more associated with social networking and multimedia apps.

Research from before the pandemic shows that age is negatively associated with smartphone usage and addiction [21]. Age also negatively affects the addiction process, social usage, and social stress, with older people showing more self-regulation and, therefore, less likely to develop habitual or addictive smartphone behaviours [20]. In terms of usage, Chen et al. found that younger individuals use their smartphones more often but with a shorter duration than older people [22]. At the same time, And one et al. reported that younger individuals use their phones for longer, with usage directed more towards entertainment and social interactions, while older people use their phones less often and use them for phone function and getting information [23].

Using self-reported data to assess smartphone usage is a crucial shortcoming in previous studies. Self-reporting might contribute to reporting bias as the users might not accurately estimate their actual usage. Furthermore, Ohme et al. demonstrated that users tend to underestimate their smartphone usage data such as average screen time and average launches [24]. Research by McAlaney et al. showed that most users overestimate the amount of time they spend on their smartphones per day but underestimate the number of times they check their smartphones [25]. Previous research on the use of social media is limited as they do not consider all of the social media platforms used by the participants and are primarily based on self-reported usage of 4 to 5 platforms. Most of the comparative studies are based on adolescents' smartphone usage, limiting generalizability to other age groups. Regarding our research, we shall re-examine the demographic factors associated with the time spent on the smartphone in the

context of COVID-19 to identify whether the relationships still endure during the pandemic. This shall also inform the revision of strategies designed to combat problematic usage of technology [26] when living under conditions similar to COVID-19, e.g. working from home.

This paper aims to compare smartphone usage before and after the COVID-19 pandemic using objectively recorded data. The study will look at the top apps used among all users, and separately by age group, and gender during each period – before and during COVID-19. The study will investigate if there is a difference in the time users spend on the smartphone daily and the total number of app launches in a day. The study will also look at the difference in the daily time spent on social media apps, communication apps, and gaming apps as well as the daily number of social media app launches, communication app launches, and gaming app launches between both the periods. In addition to the time and number of launches, the study further looks at whether there has been a change in the number of people who use communication apps, social media apps, and gaming apps between both periods.

2 Methodology

2.1 Dataset

The dataset for this study was obtained via a third-party app on Google Play which helps users track their smartphone usage. The data collected from the app includes the name of the app, the start time and end time of each app session. Demographic data of age, gender and country were also collected from the app. The app privacy policy which all users have to agree to while signing up on the app, states that collected data can be shared with academic partners for research purposes. Although there are thousands of users on the app, data for this study were taken from the users who provided explicit approval for this research.

The data collection process was carried out during two distinct periods: pre-COVID-19 (2019) and during COVID-19 (2020-21). The pre-COVID-19 (2019) data collection period lasted from June to September 2019. The data collected during COVID data was between October 2020 to April 2021. The paper refers to pre-COVID-19 as 2019 and during COVID-19 as 2020-21. For our study, only users who installed the app during our data collection period were included. Only those users who had signed up on the app during our data collection period and had seven days of usage were considered in our study. The seven days of usage was chosen to take into account weekdays and weekend usage. The study was reviewed and approved by the Institutional Review Board (IRB) of the first author.

2.2 Data preparation

Python 3.0 was used to pre-process the data, and JASP 0.14.1 was used to perform the statistical analysis for the whole study [27], [28]. The data pre-processing steps included removing duplication in data records, eliminating users with missing answers for their demographics, calculating screen time, checking for apparent anomalies and discarding users or days when found, merging broken sessions of the same apps into one, e.g., two sessions when the start of the second matches the end of the first. We

also unified the dates format and language as users came from different countries. Since the app is available only on Google Play, all participants of the study were Android users. The app tracks all of the apps that a user uses and each session's start and end timestamps. However, it does not categorise these apps, such as whether an app is in social media, communications, or gaming categories. As a result, to obtain this information, all of the apps discovered in the user's daily usage were extracted and classified using Google app classification. Still, we manually cross-checked the results obtained from Google Play API of the top 500 used apps in the dataset and all the gaming, social media, and communication apps for misclassification as the classification on Google Play is based on developers' choices. We recategorised the misclassified apps into communication, communication tools, lifestyle apps, and other categories manually.

A total of 251 users participated in the 2020-21 study, while 2019 had 161 users. The participants in the 2020-21 dataset were different to the ones in the 2019 dataset. Most of the participants in both groups came from the following ten countries: Australia, Brazil, Canada, Germany, France, India, Netherlands, Sweden, United Kingdom, and the United States. In the data collected, age was categorised into five groups: 15–24, 25–34, 35–44, 45–54 and 55–64. Participants were grouped into emerging adults (Below 25 years old) and adults (25 and above) as per the UNICEF [29] and U.N. [30] age categorisation. This categorisation helped balance the dataset since fewer respondents were above the 15–24 age bracket.

2.3 Measures

We compared smartphone usage between 2019 and 2020-21 through the following metrics:

- **Average daily screentime**: From the seven days of usage collected for each user, the time spent on all the apps is calculated in minutes based on the start and end time of the sessions on each of the apps. The average time spent on apps over seven days was computed to get the average daily screen time.
- **Daily total app launches**: Each session on an app was counted as a launch of that app. To get the daily total app launches, the total daily count of all apps' sessions over seven days was taken, and the average over seven days was computed.
- **Average daily time spent on communication apps, social media apps, gaming apps**: Based on the classification of apps, all the app sessions in each class – communication apps, social media apps, and gaming apps were extracted for all users from their seven days usage. The total time spent in minutes on each of them were computed, and then their average over seven days was calculated.
- **Daily communication app launches, social media app launches, gaming app launches**: Based on the app classification, the app sessions were grouped into whether they belonged to social media apps, communication apps, gaming apps or other types of apps. The aggregate of the app session launches was computed for each of them separately and its average was taken over seven days to get each of the daily launches.

2.4 Data Analysis

Descriptive statistical analyses were conducted. For continuous data, measures of central tendency (i.e., medians) and dispersion (i.e., Interquartile Range (IQR), minimum, maximum) were computed. For categorical data, frequency distributions were calculated. Shapiro-Wilk test was computed to check the normality of the data. We also studied each period against the demographics separately. As the data was not normally distributed, the Mann-Whitney U test was used for the analysis. The Chi-Square test was used to compare groups on nominal variables. The significance level was set at 0.05.

The analysis looked at whether there was a difference in the time spent in minutes on the smartphone between 2019 and 2020-21. The differences between 2019 and 2020-21 were also studied for the time spent on communication apps, social media apps, and gaming apps. We further analysed the differences between 2019 and 2020-21 in the average number of daily app launches, social media app launches, communication app launches, and gaming app launches.

3 Results

3.1 Descriptive Statistics

Two different sets of users were studied to assess differences in smartphone usage. Our sample consisted of 251 users (159 females) in 2020-21 and 161 users (77 females) in 2019. Approximately 42.86% of the participants in 2019 were emerging adults and 48% were females; As for the 2020-21 dataset, 42.63% were emerging adults and 63% were females. Of the 161 users in 2019, communication apps were used by everyone. Social media apps were used by 133 (83%) users, and gaming apps by 94 (58%) users. Among the 251 users in 2020-21, communication apps were used by everyone, social media apps were used by 218 (87%), and gaming apps by 198 (79%) users. As far as communication apps are concerned, they were used by everyone in both periods, which is normal. The differences expected are in the time of usage of communication apps and not in the number of users and non-users.

Table 1 summarises the distribution of the overall daily screen time, daily time spent on communication apps, social media apps and gaming apps. Table 2 summarises the distribution of daily total app launches and daily app launch distribution across communication, social media, and gaming apps. The numbers in the communication app usage, social media usage, and gaming app usage are based on the users who have used the apps in each category and do not include those who have no usage recorded during this period.

Table 1
A summary of the time spent on smartphone in 2019 and 2020-21

	Average daily screen time (min)		Average daily time spent on communication apps (min)		Average daily time spent on social media apps (min)		Average daily time spent on gaming apps (min)	
	2019	2020-21	2019	2020-21	2019	2020-21	2019	2020-21
Valid	161	251	161	251	133	218	69	166
Median	233.21	279.64	33.30	34.78	51.27	60.51	22.47	18.53
IQR	156.70	209.89	40.26	43.88	75.32	85.34	49.80	46.37
Minimum	29.64	57.78	0.42	0.60	0.05	0.02	0.02	0.02
Maximum	687.12	970.08	288.66	272.90	414.46	386.86	144.40	304.90

Table 2
A summary of the daily average number of app launches in 2019 and 2020-21

	Daily total app launches		Daily communication app launches		Daily social media app launches		Daily gaming app launches	
	2019	2020-21	2019	2020-21	2019	2020-21	2019	2020-21
Valid	161	251	161	251	133	218	69	166
Median	182	170	42.29	38.71	23.86	24.21	5.67	4.52
IQR	117	107	48.86	41.07	38.14	35.21	6	5.82
Minimum	19	34	4	2	1	1	1	1
Maximum	716	613	262.57	213.14	191.43	179.29	28.29	45.86

The list of top used apps was extracted by the percentage of users in the sample who were using each of the apps. The average daily time spent on each app was also calculated. Table 3 summarises the top 15 apps of all users in 2019 and 2020-21. The 2019 sample had 161 users, and the 2020-21 sample had 251 users. Table 4 summarises the top 15 apps of male users in 2019 and 2020-21. 84 male users were present in the 2019 sample and 92 male users were present in the 2020-21 sample. Table 5 summarises the top 15 apps of female users in 2019 and 2020-21. 77 female users were present in the 2019 sample and 159 female users were present in the 2020-21 sample. Table 6 summarises the top 15 apps of adult users in 2019 and 2020-21. 92 adult users were present in the 2019 sample and 144 adult users were present in the 2020-21 sample. Table 7 summarises the top 15 apps based on screen time of emerging adult users in 2019 and 2020-21. 69 emerging adult users were present in the 2019 sample and 107 emerging adult users were present in the 2020-21 sample.

Among the top used apps were

- Audio call apps: Call
- Communication Tool App: Phone
- Internet browser apps: Chrome, Samsung Internet
- Mailing app: Gmail
- Messaging apps: WhatsApp, Telegram, Messenger (by Facebook), Messages, Discord
- Music player app: Spotify
- Navigation app: Maps
- Video streaming apps: YouTube, Netflix, Prime Video
- Search app: Google
- Social media apps: Instagram, Facebook, Snapchat, TikTok, Twitter, Reddit

We have noted that some users used the app Phone but not Call. Phone seems to be used to save and edit contacts who are then contacted through Messages or through communication apps that are linked to the contact book, e.g. WhatsApp.

Table 3
Top 15 Apps based on Time Spent in minutes in 2019 and 2020-21

	2019				2020-21		
App name	**Avg. Time**	**Std. Deviation**	**% (n = 161)**	**App name**	**Avg Time**	**Std deviation**	**% (n = 251)**
Chrome	31.2	46.83	90.68	Chrome	34.12	43.28	92.03
YouTube	39.27	47.77	88.82	YouTube	45.79	57.25	90.04
Phone	5.63	9.14	88.82	Google	4.13	5.79	88.84
Maps	10.8	16.72	85.71	WhatsApp	35.55	41.52	67.33
Google	3.73	4.17	81.99	Instagram	45.96	45.68	66.93
Messages	6.4	8.12	70.19	Messages	8.91	13.71	66.53
WhatsApp	32.68	40.82	65.22	Spotify	8.73	12.12	64.54
Instagram	35.84	43.6	59.01	Facebook	36.29	47.69	52.19
Facebook	36.18	39.05	55.90	Messenger	9.35	13.97	46.61
Messenger	7.74	10.78	54.04	Snapchat	18.79	31.30	37.05
Snapchat	14.49	25.9	34.78	Netflix	28.41	43.75	29.48
Call	9.93	14.6	31.68	Twitter	17.60	24.20	29.08
Netflix	53.28	65.74	21.74	Samsung Internet	19.88	32.42	19.52
Twitter	15.28	21.16	21.74	TikTok	49.53	55.18	19.12
Reddit	22.82	24.74	14.29	Reddit	21.67	26.82	18.33

Table 4
Top 15 Apps by male users based on Time Spent in minutes in 2019 and 2020-21

	2019				2020-21		
App name	Avg. Time	Std. Deviation	% (n = 84)	App name	Avg Time	Std. Deviation	% (n = 92)
Chrome	32.44	58.93	90.48	Chrome	37.17	54.99	93.48
Phone	6.39	10.90	90.48	Google	4.17	7.11	93.48
YouTube	50.81	53.86	86.90	YouTube	50.39	59.52	92.39
Maps	9.19	13.98	78.57	Gmail	5.81	10.43	83.70
WhatsApp	36.08	44.30	69.05	Phone	5.11	8.07	77.17
Messages	5.07	6.62	65.48	WhatsApp	36.24	46.21	70.65
Instagram	27.96	28.50	50.00	Messages	5.58	7.09	67.39
Messenger	7.83	12.16	48.81	Instagram	33.00	38.19	59.78
Facebook	29.73	34.56	46.43	Spotify	8.99	11.29	58.70
Snapchat	10.55	13.22	30.95	Facebook	17.20	17.55	36.96
Call	11.81	17.81	28.57	Snapchat	14.05	24.68	34.78
Netflix	51.78	60.41	25.00	Twitter	16.36	22.60	31.52
Twitter	18.67	25.56	25.00	Reddit	17.19	22.86	22.83
Reddit	25.64	25.35	19.05	Discord	21.58	45.84	18.48
Telegram	17.78	26.19	14.29	TikTok	51.90	50.87	14.13

Table 5
Top 15 Apps by female users based on Time Spent in minutes in 2019 and 2020-21

	2019				2020-21		
App name	Avg. Time	Std. Deviation	% (n = 77)	App name	Avg Time	Std. Deviation	% (n = 159)
Maps	12.27	18.87	93.51	Chrome	32.31	34.62	91.19
Chrome	29.85	28.81	90.91	YouTube	43.01	55.87	88.68
YouTube	27.24	37.17	90.91	Google	4.10	4.81	86.16
Phone	4.77	6.59	87.01	Instagram	52.27	47.80	71.07
Google	4.33	4.79	85.71	Spotify	8.60	12.56	67.92
Messages	7.66	9.21	75.32	Messages	10.88	16.13	66.04
Instagram	42.09	52.02	68.83	WhatsApp	35.13	38.54	65.41
Facebook	41.11	41.82	66.23	Facebook	42.98	52.91	61.01
WhatsApp	28.49	36.1	61.04	Messenger	9.84	14.12	55.97
Spotify	6.44	6.65	61.04	Snapchat	21.27	34.19	38.36
Messenger	7.66	9.53	59.74	Netflix	35.85	49.09	30.82
Snapchat	17.92	33.1	38.96	Twitter	18.43	25.42	27.67
Call	8.26	11.1	35.06	Samsung Internet	20.72	34.70	23.90
Netflix	55.53	75.36	18.18	TikTok	48.65	57.38	22.01
Prime Video	41.56	37.75	9.09	Reddit	25.44	29.69	15.72

Table 6
Top 15 Apps by adult users based on Time Spent in minutes in 2019 and 2020-21

	2019				2020-21		
App name	Avg. Time	Std. deviation	% (n = 92)	App name	Avg Time	Std. deviation	% (n = 144)
Maps	11.31	10.26	90.22	Chrome	34.71	43.05	95.14
Phone	6.12	10.26	88.04	YouTube	27.49	42.1	86.81
Chrome	36.11	59.20	85.87	Maps	8.25	12.5	84.03
Google	3.57	4.13	84.78	Gmail	5.55	7.72	77.78
YouTube	25.09	34.05	83.70	Phone	5.92	11.06	72.92
Gmail	3.78	3.58	82.61	Messages	10.6	16.57	71.53
Messages	8.04	8.77	69.57	Instagram	39.85	45.89	70.14
Facebook	43.41	42.22	59.78	WhatsApp	31.43	40.15	65.28
Instagram	24.70	26.53	59.78	Facebook	39.65	46.15	63.19
Messenger	7.44	9.94	59.78	Spotify	9.01	12.29	61.11
WhatsApp	35.45	35.21	56.52	Messenger	9.96	15.11	59.03
Call	11.47	16.79	34.78	Call	11.79	11.38	37.50
Twitter	14.07	24.49	19.57	Snapchat	13.78	25.5	27.08
Samsung Internet	14.84	21.46	18.48	Netflix	25.39	38.17	26.39
Netflix	41.70	58.66	17.39	TikTok	37.02	53.48	15.28

Table 7
Top 15 Apps by emerging adult users based on Time Spent in minutes in 2019 and 2020-21

	2019				2020-21		
App name	Avg. Time	Std. deviation	% (n = 69)	App name	Avg Time	Std. deviation	% (n = 107)
Chrome	25.40	24.75	97.10	YouTube	68.44	65.11	94.39
YouTube	55.82	55.8	95.65	Google	4.23	5.50	90.65
Phone	4.99	7.48	89.86	Chrome	33.27	43.83	87.85
Maps	10.03	15.36	79.71	WhatsApp	40.72	42.90	70.09
Google	3.96	4.26	78.26	Spotify	8.39	11.97	69.16
WhatsApp	29.97	45.85	76.81	Instagram	55.18	44.10	62.62
Messages	4.25	6.67	71.01	Messages	6.20	6.25	59.81
Spotify	6.89	6.16	65.22	Snapchat	22.41	34.68	50.47
Instagram	51.16	56.49	57.97	Facebook	28.64	50.78	37.38
Facebook	24.82	30.69	50.72	Netflix	31.59	49.31	33.64
Snapchat	18.66	31.33	50.72	Twitter	25.39	27.58	28.97
Messenger	8.26	12.24	46.38	TikTok	60.11	55.39	24.30
Netflix	63.03	71.25	27.54	Discord	23.21	39.97	23.36
Twitter	16.55	17.62	24.64	Samsung Internet	29.06	40.49	21.50
Reddit	27.31	24.92	17.39	Reddit	26.05	30.94	18.69

3.2 Analysis

3.2.1 Difference in smartphone usage

We examined the difference in the average daily smartphone usage time, and the average daily app launches between 2019 and 2020-21. A Mann-Whitney U test showed that time spent on smartphone in 2020-21 significantly increased (Mdn = 279.64, n = 251) compared to 2019 (Mdn = 233.21, n = 161), U = 17014.00, p = 0.0068, |r|= 0.16. However, no significant difference was found in the daily average app launches between the two periods.

3.2.2 Difference in social media apps usage

The difference between time spent on social media apps in 2019 and 2020-21 was tested using the Mann-Whitney U test under two different scenarios. Additionally, chi-square was employed to investigate

the difference in the number of people who used and did not use social media between both periods.

In the first scenario, users who did not use social media apps were excluded during the analysis. A Mann-Whitney U test showed that time spent on social media apps in 2020-21 significantly increased (Mdn = 60.51, n = 218) compared to the time spent on social media apps in 2019 (Mdn = 51.27, n = 133), U = 12323.00, p = 0.02, |r|= 0.15. No significant difference was found in the number of social media app launches between the two periods.

In the second scenario, those who did not use any social media apps during the seven days were considered to have zero usage. The Mann-Whitney U test showed that time spent on social media apps during 2020-21 significantly increased (Mdn = 47.95, n = 251) compared to the time spent on social media apps in 2019 (Mdn = 31.94, n = 161), U = 17174, p = 0.01, |r|= 0.15 in this scenario as well. No significant difference was found between the social media app launches between the two periods.

We performed a chi-square test to investigate the difference in the number of people who used social media apps between the two periods. No significant difference was found.

3.2.3 Difference in gaming apps usage

The difference in the time spent on gaming apps in 2019 and 2020-21 was tested using the Mann-Whitney U Test under two different scenarios. Additionally, chi-square was used to study whether there was a difference in the number of people who used gaming apps in 2019 and 2020-21.

In the first case, users who did not use gaming apps in the seven days were filtered out during the analysis. A Mann-Whitney U test showed no significant differences between the time spent on gaming apps or gaming app launches between 2019 and 2020-21.

In the second scenario, those who did not use gaming apps were considered to have zero usage. Mann-Whitney U test showed that time spent on gaming apps during 2020-21 significantly increased (Mdn = 3.02, n = 251) compared to the time spent on gaming apps in 2019 (Mdn = 0, n = 161), U = 15866.50, $p < 0.001$, |r|= 0.21. The Mann Whitney U test also showed a difference in the number of gaming app launches with an increase in 2020-21 (Mdn = 2.17, n = 251) from 2019 (Mdn = 0, n = 161), U = 16058.00, $p < 0.001$, |r|=0.21.

We performed a chi-square test to investigate the difference in the number of people who used and did not use gaming apps in 2019 and 2020-21. The result of the chi-square test on the number of people who used gaming apps and the years showed a significant relationship $\chi 2(1, N = 412) = 21.69$, $p < 0.001$. People were more likely to use gaming apps in 2020-21 than in 2019.

3.2.4 Difference in communication app usage

The difference between the time spent on communication apps in 2019 and 2020-21 was also tested using the Mann-Whitney U test. The tests on the time spent on communication apps revealed no significant difference in the average time spent in 2019 and 2020-21. Mann-Whitney U test was also used

to analyse the difference in number of communication app launches between 2019 and 2020-21. The test revealed no significant difference in the number of communication app launches between 2019 and 2020-21.

3.2.5 Effect of age and gender on daily smartphone usage in 2019 and 2020-21 separately

On studying the daily time spent on the smartphone separately for age in 2019 using the Mann-Whitney U test, it was found that the average daily time spent on the phone was significantly higher for emerging adults (Mdn = 269.03, n = 69) compared to the adults (Mdn = 215.98, n = 92), U = 3836.0, p = 0.02, |r|= 0.21. In 2020-21, similarly the daily time spent on the phone was significantly higher for emerging adults (Mdn = 324.33, n = 107) compared to the adults (Mdn = 241.21, n = 144), U = 9462.0, p = 0.002, |r|= 0.23. Emerging adults were found to spend more time on the phone daily than adults during both periods.

No significant difference was found between age and the average daily app launches in either of the years.

No significant difference was found between gender and average daily time spent on the phone in either of the periods. No significant difference was found between gender and average daily app launches in either of the years.

3.2.6 Effect of age and gender on the usage of social media apps in 2019 and 2020-21 separately

Although the relationship between gender and the number of people who used social media apps was not significant in 2019, the relationship between gender and the number of people who used social media apps during 2020-21 $\chi 2(1, N = 251) = 5.24$, $p = 0.02$ was found to be significant. In 2020-21, females were more likely to use social media apps compared to males.

Effect of gender when people who did not use social media apps was filtered out. On studying the difference in daily time spent on social media apps separately for gender in 2019 and 2020-21 using Mann-Whitney U test, it was found that in 2019 females (Mdn = 68.24, n = 67) spent more time on social media apps than males (Mdn = 32.75, n = 66), U = 1644.0, p = 0.01, |r| = 0.26. Similarly in 2020-21, it was found that females (Mdn = 76.18, n = 144) spent more time on social media apps than males (Mdn = 43.05, n = 74), U = 3504.0, p < 0.001, |r| = 0.34. In 2020-21, Females (Mdn = 28.14, n = 144) were also found to launch social media apps more often than males (Mdn = 19.86, n = 74), U = 4226.5, p = 0.01, |r| = 0.21.

Effect of gender when people who did not use social media apps were considered to have zero social media apps usage. On studying the daily time spent on social media apps separately for gender in 2019 and 2020-21 using Mann-Whitney U test, it was found that in 2019 females (Mdn = 54.24, n = 77) spent more time on social media apps than males (Mdn = 18.82, n = 84), U = 2394.00, p = 0.004, |r| = 0.26. In 2019, Females (Mdn = 25.71, n = 77) were also found to launch social media apps more often than males (Mdn = 7.93, n = 84), U = 2565.50, p = 0.02, |r| = 0.21. Similarly in 2020-21, it was found that females (Mdn = 67.59, n = 159) spent more time on social media apps than males (Mdn = 37.8 = 57, n = 92), U = 4749.0,

$p < 0.001$, $|r| = 0.35$. Females (Mdn = 24.14, n = 159) were also found to launch social media apps more often than males (Mdn = 14.07, n = 92), $U = 5471.50$, $p < 0.001$, $|r| = 0.25$.

Effect of age when people who did not use social media apps was filtered out. No significant differences were found in the social media app usage between adults and emerging adults in 2019 or 2020-21

Effect of age when people who did not use social media apps was considered to have zero social media apps usage. No significant differences were found in the social media app usage between adults and emerging adults in 2019 or 2020-21

3.2.7 Effect of age and gender on the usage of communication apps in 2019 and 2020-21 separately

On performing the Mann-Whitney U test, it was found that in 2020-21 adults (Mdn = 43.86, n = 144) launched communication apps more than emerging adults (Mdn = 34.71, n = 107), $U = 6447.50$, $p = 0.03$, $|r| = 0.16$. However, in 2019 no significant difference was found with regards to age and communication app launches.

No significant differences were found for time spent on communication apps in 2019 or 2020-21 with regards to age or gender. No significant difference was found for gender with regards to the number of times communication apps were launched daily in 2019 or 2020-21 separately.

3.2.8 Effect of age and gender on the usage of gaming apps in 2019 and 2020-21 separately

Effect of age when people who did not use gaming apps was filtered out. No significant difference was found with regards to age and gaming app launches in 2019 or 2020-21. No significant difference was found for age with regards to the time spent on gaming apps in 2019 or 2020-21.

Effect of age when people who did not use gaming apps was considered to have zero gaming apps usage. In 2019, on performing the Mann-Whitney U test, it was found that emerging adults (Mdn = 0.10, n = 69) spent more time on gaming apps than adults (Mdn = 0, n = 92) $U = 3791$, $p = 0.02$, $|r| = 0.19$. In 2019, it was also found that emerging adults (Mdn = 1.0, n = 69) launched gaming apps in a day more than adults (Mdn = 0, n = 92) $U = 3761$, $p = 0.03$, $|r| = 0.18$. No significant difference was found with regards to age on the daily time spent on gaming apps in 2020-21. No significant difference was found regarding age and daily gaming app launches in 2020-21.

Effect of gender when people who did not use gaming apps was filtered out. No significant differences were found regarding gender and time spent on gaming apps in 2019 or 2020-21. No significant difference was found with regards to gender and daily gaming app launches in 2019 or 2020-21.

Effect of gender people who did not use gaming apps was considered to have zero gaming apps usage. No significant differences were found with regards to gender and time spent on gaming apps in 2019 or 2020-21. No significant difference was found with regards to gender and daily gaming app launches in 2019 or 2020-21.

4 Discussion

Overall, our study shows there has been a change in smartphone usage due to COVID-19. When people have to adapt to a lifestyle with restrictions on social gatherings and limited face-to-face interactions, there is a change in how much time they spend on their smartphones. The findings of this study can be highly credible since objectively collected data was utilized to measure smartphone usage. We, however, note that people who installed the app are those who wanted mainly to be conscious of the amount of their usage.

Among the top apps used in 2019 and 2020-21 (Table 4, 5, 6, 7), YouTube, Chrome, Instagram, WhatsApp, and Facebook were the most-used apps by all users during both periods. Although Maps was one of the top used apps in 2019, similar usage was not found in 2020-21. A possible explanation for this could be due to the restrictions on social gatherings and working from home during COVID-19. Although apps such as Phone and Call appeared in the top used apps prior to COVID-19, similar usage of these apps was not found in 2020-21. The decrease in Phone and Call apps could be due to the increase in web-conferencing and video-call apps [31] and ease of access to devices such as laptops and PCs for communication. It can also be due to the limited need to use these apps when people are close to their partners and family under restrictions on social gathering. Although TikTok was not present in the top apps used in 2019, it became one of the most used apps in 2020-21with people spending an average of 40 minutes or more on the app. These results are likely to be related to TikTok being a source of entertainment during a period where leisure options were limited. Similar popularity was not seen in the use of Facebook, a social media app where people can connect with their contacts. This may imply that during periods of social isolation where people had little to share, people preferred platforms with interesting content created by others to those where they could connect with their contacts. Besides the increase in time spent on entertainment apps such as TikTok, it was interesting to note the appearance of utilitarian apps such as Gmail among the top apps during COVID-19 meaning that people also relied on smartphone more, e.g. for working and communicating in flexible manner. The average time spent on each of the top 15 apps by adults (Table 6) and males (Table 4) remained almost the same between 2019 and 2020-21. However, the average time on most of the apps was seen to have increased for females (Table 5) and emerging adults (Table 7). Emerging adults spent on average 25–30 minutes on social media apps before COVID-19 and spent at least an hour on the social media apps in 2020-21.

The results from our analysis showed that there has been an increase in the daily time spent on smartphones. The results from our study are in line with reports from U.K based regulator Ofcom which stated that screen usage increased by 47 minutes per day as compared to before the pandemic [4]. Our study extends the findings of previous studies showing an increase in screen time since the pandemic [32]–[34]. Research by Meyer et al. reported a 40% increase in overall screen time among adults over 18 during COVID-19 compared to before the pandemic [35]. However, these studies use self-reported data and recent research found that self-reported screen time can be quite different from actual phone usage time [36]. The inclusion of objectively collected data is a methodological strength of our study.

One unanticipated result was that there was no significant increase in the use of communication apps even in the situation of a pandemic, in which face-to-face interaction has been almost entirely substituted by online communication. This result may be explained by the fact that due to ease of access to laptops and tablets, alternate communication means such as web-conferencing systems (e.g. Zoom, Microsoft Teams [37], [38]) may have been utilized. This is further supported by a report from Consumer Technology Association, USA which stated that between 27 March and May 31, 2020, Web Conferencing Systems use almost doubled reaching 24% of US homes [31]. Further, there is evidence to suggest that engaging in digital media with a lower social presence (e.g., email) has a detrimental impact on one's feeling of social connection, while the opposite is true for digital communication techniques with a greater social presence (e.g. video calls) [39].

Our study indicates that there has been a significant increase in time spent on social media during the pandemic. Our findings reflect those of Fumagalli et al. who also found a significant increase in the use of social media apps but no significant difference in the use of communication apps during the pandemic [40]. There is preliminary evidence to show that increased social media use rates imply that for some, social media may be a coping technique for dealing with feelings of loneliness caused by long-term social distance [41], [42]. People who are socially connected can better control their emotions, cope with stress, and remain resilient through difficult circumstances. Online connections can promote a sense of belonging. Increase in social media usage in literature [43] has been mostly confined to reporting time spent on selected platforms, whereas in our study, all the social media apps used by the participants were considered while recording the actual time spent on social media objectively. Another possible explanation for the increase in time spent on social media in 2020-21 could have been to access information related to the pandemic. This is further supported by evidence from Liu who reported that COVID-19 information searching through Social Networking and Live Streaming applications (e.g. Tiktok) was an important variable that motivated individuals to help them with preventive behaviors during the pandemic [44].

Remote working has proven to be an important aspect of ensuring business continuity during COVID-19, whereas prior to the pandemic, it was associated with reduced commuting time, and an opportunity for better work-life balance [45]. According to our study, communication apps were launched more often by adults than emerging adults. The increase in communication app launches could be attributed to the fact that adults were most likely to be employed and had to switch to remote working during the lockdown periods and rely on communication apps on the smartphone. Though the number of individuals working remotely part-time or full-time has progressively increased over the years [46], the pandemic has accelerated employer adoption of remote working modalities. Remote working has also not been the norm for a significant section of the working population. For example, around 4.7 million Canadians who do not normally work remotely did so from March 22, 2020 to March 28, 2020 due to the impact of COVID-19 [47]. While working from home, people are likely to check their phones more often. Notifications and usage of smartphones may also contribute to procrastination [48], [49], impairing the quality and pace of work. Individuals are more aware of security concerns and countermeasures than in the past, yet some fundamental security principles continue to be breached, demonstrating that training and guidance

are constantly required to enforce current security status and awareness level [50]. The sudden shift to remote work and increasing smartphone use for work-related communication raises the need to implement more training and cyber security measures [51]–[53].

Previous research does not consider smartphone gaming alone when studying online gaming and also takes into account time spent on other devices for online gaming e.g., P.C., console. Contrary to the research findings that suggest online mobile gaming engagement and traffic increased during the pandemic [54], our results suggest no significant difference in the time people spent on gaming apps. However, more people have started using gaming apps after the pandemic according to our analysis. Furthermore, the increase in the number of people using gaming apps may suggest that individuals may increase their participation in activities such as online gaming to alleviate boredom and monotony caused by lack of engaging real-life events during COVID-19 [55]. Although there is evidence in the literature [13] that found males to spend more time on gaming apps, our results showed no significant difference in the use of gaming apps by males or females. This difference could be due to the fact that in our study we used the time spent on smartphone gaming apps and objectively recorded data as compared to other comparative studies which made use of self-report and did not restrict online gaming to smartphone alone but also included other gaming devices as well.

On studying the impact of age and gender separately on time spent on the phone, it was found that emerging adults spent more time on the phone than adults in 2019 and 2020-21. Females were found to spend more time on social media during both periods. Although females were using social media more than males in 2019, the usage increased even more for females since 2020-21. This could be due to the fact that women are more socially oriented and hence more prone to developing addictions to activities that entail components of social interaction [20]. Our results further confirm the research by Lemenager et al. where social media usage increased for female users during the pandemic by using objectively collected data [13]. Our results show that although males had an increase in time spent on social media after the pandemic, the increase was not statistically significant as it was the case for females. This may suggest that even when males lack options of face-to-face interactions, they do not feel the need to significantly increase the time spent on social media compared to females.

Our study has a few limitations. One limitation is that majority of the participants in our sample were from Western countries except for India. Another limitation was the lack of data from users of the iOS operating system. Also, we had to group our users into two age groups as some of the age groups did not have enough users to consider them separately. We have dealt with communication apps, social media apps and gaming apps each as a coherent category while more refined categorization can lead to more accurate results. Another limitation is that the study is not longitudinal in nature, as COVID-19 was not a predicted phenomenon. However, we still make comparison between people who resided in the same countries during two different periods – one before COVID-19 when there were no restrictions on social gathering in place, and the other a period during COVID-19 where there existed some restrictions in social gatherings in place. This study has some notable strengths. First, the app usage statistics are realistic and impartial (unlike many comparable studies that exclusively utilise survey data). Furthermore,

participants are drawn from a broad sample of smartphone users. This allows us to better understand how age/gender groups from different countries have modified their smartphone usage during the pandemic. Additionally, the findings from our study can be used to assess time spent on smartphones in a social isolation setting since measures to curb COVID-19 has resulted in prolonged periods of social isolation.

5 Conclusion

COVID-19 has impacted many parts of people's lives, including how they spend time on screens. Our study on mobile phone usage is one of the very few studies with objectively collected data. In line with Montag et al., objective data is likely to yield more credible results [56]. Through our research, we have been able to find an increase in the time spent online and time spent on social media after COVID-19. An increasing number of current studies have revealed a rising trend of screen time in various groups, with potential health consequences. Practical recommendations for companies include taking steps to facilitate efficient team collaborations to reduce burnout, including scheduling time for work that needs to be done alone and time for personal or recreational activities [57]. If more people choose hybrid or remote working options, employers and institutions will need to make particular efforts to implement programs that train people how to work from home, regulate their smartphone usage, and help people maintain their digital well-being. Future work in this area may focus on using a more refined taxonomy to classify the categories of apps further to get more accurate results. Another direction of study could look at the impact of employment status and psychometrics in smartphone usage. Given the mental health consequences of various forms of screen time [58], [59], more research is needed to separate the possible benefits and harms of screen time and social media use.

Declarations

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References

1. ‘Timeline (2021) : WHO’s COVID-19 response’. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline
2. Chin J, Rajermani T(2021) ‘The Usage of Mobile Phone User during Covid-19 Pandemic’, *INTI J.*, vol. no. 04, Art. no. 04, 2021, Accessed: Nov. 10, 2021. [Online]. Available: https://intijournal.intimal.edu.my/intijournal.htm
3. ‘Coronavirus impact: global device usage increase by country 2020’, *Statista*. https://www.statista.com/statistics/1106607/device-usage-coronavirus-worldwide-by-country/

4. ‘Online Nation’, *Ofcom*, Jul. 02, https://www.ofcom.org.uk/research-and-data/internet-and-on-demand-research/online-nation (accessed Nov. 10, 2021)
5. ‘Australian Broadband Data Demand (2021) : new peak in data demand | nbn’. https://www.nbnco.com.au/corporate-information/media-centre/media-statements/data-demand-new-peak-in-data-demand (accessed Nov. 21,
6. Moreno-Llamas A, García-Mayor J (Nov. 2020) De la Cruz-Sánchez, ‘The impact of digital technology development on sitting time across Europe’. Technol Soc 63:101406. doi: 10.1016/j.techsoc.2020.101406
7. Twenge JM, Joiner TE, Rogers ML, Martin GN (Jan. 2018) ‘Increases in Depressive Symptoms, Suicide-Related Outcomes, and Suicide Rates Among U.S. Adolescents After 2010 and Links to Increased New Media Screen Time’. Clin Psychol Sci 6(1):3–17. doi: 10.1177/2167702617723376
8. Tejedor S, Cervi L, Pérez-Escoda A, Tusa F(2020) ‘Smartphone usage among students during COVID-19 pandemic in Spain, Italy and Ecuador’, in *Eighth International Conference on Technological Ecosystems for Enhancing Multiculturality*, New York, NY, USA, Oct. pp. 571–576. doi: 10.1145/3434780.3436587
9. Francisco R et al (2020) ‘Psychological Symptoms and Behavioral Changes in Children and Adolescents During the Early Phase of COVID-19 Quarantine in Three European Countries’. Front Psychiatry 11:570164. doi: 10.3389/fpsyt.2020.570164
10. Fernandes B, Biswas UN, Tan-Mansukhani R, Vallejo A, Essau CA (2020) ‘The impact of COVID-19 lockdown on internet use and escapism in adolescents’. Rev Psicol Clínica Con Niños Adolesc 7(3):59–65
11. Hu Z, Lin X, Kaminga AC, Xu H(2020) ‘Impact of the COVID-19 Epidemic on Lifestyle Behaviors and Their Association With Subjective Well-Being Among the General Population in Mainland China: Cross-Sectional Study’, *J. Med. Internet Res.*, vol. 22, no. 8, p. e21176, Aug. doi: 10.2196/21176
12. Matsungo TM, Chopera P (Dec. 2020) ‘Effect of the COVID-19-induced lockdown on nutrition, health and lifestyle patterns among adults in Zimbabwe’. BMJ Nutr Prev Health 3(2). doi: 10.1136/bmjnph-2020-000124
13. Lemenager T et al(2020) ‘COVID-19 Lockdown Restrictions and Online Media Consumption in Germany’, *Int. J. Environ. Res. Public. Health*, vol. 18, no. 1, p. E14, doi: 10.3390/ijerph18010014
14. Hruska J, Maresova P(2020) ‘Use of Social Media Platforms among Adults in the United States—Behavior on Social Media’, *Societies*, vol. 10, no. 1, Art. no. 1, Mar. doi: 10.3390/soc10010027
15. Ryu J et al (Sep. 2021) ‘Shift in Social Media App Usage During COVID-19 Lockdown and Clinical Anxiety Symptoms: Machine Learning–Based Ecological Momentary Assessment Study’. JMIR Ment Health 8(9):e30833. doi: 10.2196/30833
16. Park J, Jeong J-E, Rho MJ(2021) ‘Predictors of Habitual and Addictive Smartphone Behavior in Problematic Smartphone Use’, *Psychiatry Investig.*, vol. 18, no. 2, pp. 118–125, Feb. doi: 10.30773/pi.2020.0288

17. Yang S-Y, Lin C-Y, Huang Y-C, Chang J-H(2018) ‘Gender differences in the association of smartphone use with the vitality and mental health of adolescent students’, *J. Am. Coll. Health*, vol. 66, no. 7, pp. 693–701, Oct. doi: 10.1080/07448481.2018.1454930
18. Beierle F et al(2020) ‘Frequency and Duration of Daily Smartphone Usage in Relation to Personality Traits’, *Digit. Psychol.*, vol. 1, no. 1, Art. no. 1, doi: 10.24989/dp.v1i1.1821
19. Lin C-Y et al (Aug. 2019) ‘Smartphone Application-Based Addiction Among Iranian Adolescents: A Psychometric Study’. Int J Ment Health Addict 17(4):765–780. doi: 10.1007/s11469-018-0026-2
20. van Deursen AJAM, Bolle CL, Hegner SM, Kommers PAM(2015) ‘Modeling habitual and addictive smartphone behavior: The role of smartphone usage types, emotional intelligence, social stress, self-regulation, age, and gender’, *Comput. Hum. Behav.*, vol. 45, pp. 411–420, Apr. doi: 10.1016/j.chb.2014.12.039
21. Mitchell L, Hussain Z, ‘Predictors of Problematic Smartphone Use (2018) An Examination of the Integrative Pathways Model and the Role of Age, Gender, Impulsiveness, Excessive Reassurance Seeking, Extraversion, and Depression’. Behav Sci 8 8, Art. no. 8, Aug. doi: 10.3390/bs8080074
22. Chen B, Liu F, Ding S, Ying X, Wang L, Wen Y (Oct. 2017) ‘Gender differences in factors associated with smartphone addiction: a cross-sectional study among medical college students’. BMC Psychiatry 17(1):341. doi: 10.1186/s12888-017-1503-z
23. Andone I, Błaszkiewicz K, Eibes M, Trendafilov B, Montag C, Markowetz A(2016) ‘How age and gender affect smartphone usage’, in *Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct*, New York, NY, USA, Sep. 2016, pp. 9–12. doi: 10.1145/2968219.2971451
24. Ohme J, Araujo T, de Vreese CH, Piotrowski JT (May 2021) ‘Mobile data donations: Assessing self-report accuracy and sample biases with the iOS Screen Time function’. Mob Media Commun 9(2):293–313. doi: 10.1177/2050157920959106
25. McAlaney J, Almourad MB, Powell G, Ali R(2020) ‘Perceptions and Misperceptions of Smartphone Use: Applying the Social Norms Approach’, *Information*, vol. 11, no. 11, Art. no. 11, Nov. doi: 10.3390/info11110513
26. Cemiloglu D, Almourad MB, McAlaney J, Ali R (Feb. 2022) ‘Combatting digital addiction: Current approaches and future directions’. Technol Soc 68:101832. doi: 10.1016/j.techsoc.2021.101832
27. ‘JASP - A Fresh Way to Do Statistics’ (2021) *JASP - Free and User-Friendly Statistical Software*. https://jasp-stats.org/(accessed Nov.29,
28. ‘Welcome to Python.org’, *Python.org*. https://www.python.org/ (accessed Nov. 29, 2021)
29. ‘UNICEF Programme guidance for the second decade (2021) : Programming with and for adolescents - World’, *ReliefWeb*. https://reliefweb.int/report/world/unicef-programme-guidance-second-decade-programming-and-adolescents
30. Nations U, ‘Youth’(2021) *United Nations*. https://www.un.org/en/global-issues/youth
31. ‘COVID-19 impact on tech services U.S (2020) ’ *Statista*. https://www.statista.com/statistics/1112040/covid-19-impact-on-tech-services-usage-in-the-us/

(accessed Jan. 27, 2022)

32. Dong H, Yang F, Lu X, Hao W (2020) 'Internet Addiction and Related Psychological Factors Among Children and Adolescents in China During the Coronavirus Disease 2019 (COVID-19) Epidemic'. Front Psychiatry 11:751. doi: 10.3389/fpsyt.2020.00751
33. Wagner BE, Folk AL, Hahn SL, Barr-Anderson DJ, Larson N, Neumark-Sztainer D (2021) 'Recreational Screen Time Behaviors during the COVID-19 Pandemic in the U.S. Int J Environ Res Public Health 18 no. 9, Art. no. 9, Jan. doi: 10.3390/ijerph18094613A Mixed-Methods Study among a Diverse Population-Based Sample of Emerging Adults'
34. Raphaely S, Goldberg SB, Moreno M, Stowe Z(2021) 'Rates of Assessment of Social Media Use in Psychiatric Interviews Prior to and During COVID-19: Needs Assessment Survey', *JMIR Med. Educ.*, vol. 7, no. 3, p. e28495, Sep. doi: 10.2196/28495
35. Meyer J et al (Jan. 2020) 'Changes in Physical Activity and Sedentary Behavior in Response to COVID-19 and Their Associations with Mental Health in 3052 US Adults'. Int J Environ Res Public Health 17 no. 18, Art. no. 18. doi: 10.3390/ijerph17186469
36. Hodes LN, Thomas KGF (Feb. 2021) 'Smartphone Screen Time: Inaccuracy of self-reports and influence of psychological and contextual factors'. Comput Hum Behav 115:106616. doi: 10.1016/j.chb.2020.106616
37. 'Video Conferencing C, Phone(2022) Webinars, Chat, Virtual Events | Zoom', *Zoom Video Communications*. https://zoom.us/
38. 'Video, Conferencing(2022) Meetings, Calling | Microsoft Teams'. https://www.microsoft.com/en-us/microsoft-teams/group-chat-software (accessed Jan.27,
39. Nguyen MH, Gruber J, Marler W, Hunsaker A, Fuchs J, Hargittai E (Feb. 2021) 'Staying connected while physically apart: Digital communication when face-to-face interactions are limited'. New Media Soc 1461444820985442. doi: 10.1177/1461444820985442
40. Fumagalli E, Dolmatzian MB, Shrum LJ (Feb. 2021) 'Centennials, FOMO, and Loneliness: An Investigation of the Impact of Social Networking and Messaging/VoIP Apps Usage During the Initial Stage of the Coronavirus Pandemic'. Front Psychol 12:620739. doi: 10.3389/fpsyg.2021.620739
41. Shah SGS, Nogueras D, van Woerden HC, Kiparoglou V(2020) 'The COVID-19 Pandemic: A Pandemic of Lockdown Loneliness and the Role of Digital Technology', *J. Med. Internet Res.*, vol. 22, no. 11, p. e22287, Nov. doi: 10.2196/22287
42. Stevic A, Koban K, Binder A, Matthes J (Nov. 2021) 'You are not alone: Smartphone use, friendship satisfaction, and anxiety during the COVID-19 crisis'. Mob Media Commun 20501579211051820. doi: 10.1177/20501579211051820
43. Valdez D, ten Thij M, Bathina K, Rutter LA, Bollen J(2020) 'Social Media Insights Into US Mental Health During the COVID-19 Pandemic: Longitudinal Analysis of Twitter Data', *J. Med. Internet Res.*, vol. 22, no. 12, p. e21418, Dec. doi: 10.2196/21418
44. Liu PL(2020) : The Mediation Role of Worry', *Cyberpsychology Behav. Soc. Netw.*, vol. 23, no. 10, pp. 677–682, doi: 10.1089/cyber.2020.0250

45. International Labour Office (2020) ‘Teleworking during the COVID-19 pandemic and beyond’, https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---travail/documents/instructionalmaterial/wcms_751232.pdf (accessed Nov. 29, 2021)
46. ‘Working from home in the EU’ (2021) https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20180620-1 (accessed Nov. 29,
47. S. C. Government of Canada, ‘The Daily — Canadian Perspectives Survey Series 1: COVID-19 and working from home, 2020’, Apr. 17, 2020. https://www150.statcan.gc.ca/n1/daily-quotidien/200417/dq200417a-eng.htm (accessed Nov. 29,
48. Aalbers G, vanden Abeele MMP, Hendrickson AT, de Marez L, Keijsers L(2022) ‘Caught in the moment: Are there person-specific associations between momentary procrastination and passively measured smartphone use?’, *Mob. Media Commun.*, vol. 10, no. 1, pp. 115–135, Jan. doi: 10.1177/2050157921993896
49. Alblwi A, McAlaney J, Al Thani DAS, Phalp K, Ali R (Feb. 2021) ‘Procrastination on social media: predictors of types, triggers and acceptance of countermeasures’. Soc Netw Anal Min 11(1):19. doi: 10.1007/s13278-021-00727-1
50. Georgiadou A, Mouzakitis S, Askounis D (Feb. 2021) ‘Working from home during COVID-19 crisis: a cyber security culture assessment survey’. Secur J. doi: 10.1057/s41284-021-00286-2
51. Almaiah MA, Al-Zahrani A, Almomani O, Alhwaitat AK (2021) ‘Classification of Cyber Security Threats on Mobile Devices and Applications’. In: Maleh Y, Baddi Y, Alazab M, Tawalbeh L, Romdhani I (eds) Artificial Intelligence and Blockchain for Future Cybersecurity Applications. Springer International Publishing, Cham, pp 107–123. doi: 10.1007/978-3-030-74575-2_6.
52. Furnell S, Shah JN(2020) ‘Home working and cyber security – an outbreak of unpreparedness?’, *Comput. Fraud Secur.*, vol. no. 8, pp. 6–12, Aug. 2020, doi: 10.1016/S1361-3723(20)30084-1
53. Prodanova J, Kocarev L (Aug. 2021) ‘Is job performance conditioned by work-from-home demands and resources?’. Technol Soc 66:101672. doi: 10.1016/j.techsoc.2021.101672
54. Amin KP, Griffiths MD, Dsouza DD (Jul. 2020) ‘Online Gaming During the COVID-19 Pandemic in India: Strategies for Work-Life Balance’. Int J Ment Health Addict. doi: 10.1007/s11469-020-00358-1
55. Maison D, Jaworska D, Adamczyk D, Affeltowicz D(2021) ‘The challenges arising from the COVID-19 pandemic and the way people deal with them. A qualitative longitudinal study’, *PLOS ONE*, vol. 16, no. 10, p. e0258133, Oct. doi: 10.1371/journal.pone.0258133
56. Montag C et al(2015) ‘Recorded Behavior as a Valuable Resource for Diagnostics in Mobile Phone Addiction: Evidence from Psychoinformatics’, *Behav. Sci.*, vol. 5, no. 4, Art. no. 4, doi: 10.3390/bs5040434
57. Cross R, Rebele R, Grant A(2016) ‘Too much teamwork exhausts employees and saps productivity. Here’s how to avoid it.’, p. 7,
58. Abi-Jaoude E, Naylor KT, Pignatiello A(2020) ‘Smartphones, social media use and youth mental health’, *CMAJ*, vol. 192, no. 6, pp. E136–E141, Feb. doi: 10.1503/cmaj.190434

59. Kim H, Cho M-K, Ko H, Yoo JE, Song Y-M(2020) ‘Association between Smartphone Usage and Mental Health in South Korean Adolescents: The 2017 Korea Youth Risk Behavior Web-Based Survey’, *Korean J. Fam. Med.*, vol. 41, no. 2, pp. 98–104, Mar. doi: 10.4082/kjfm.18.0108