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Smartphone Usage before and during COVID-19: A Comparative Study Based on Objective Recording of Usage Data

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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., that 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 investigated smartphone usage before and during COVID-19. Our study used a dataset from a smartphone app that objectively logged users' activities, including apps accessed and each app session 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. The Mann–Whitney U test was used for the inferential analysis. The results revealed that the time spent on smartphones has increased since COVID-19. During both periods, emerging adults were found to spend more time on smartphones compared to adults. The time spent on social media apps has also 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 also been an increase in the number of people who use gaming apps since the pandemic. The use of objectively collected data is a methodological strength of our study. Additionally, we draw parallels with the usage of smartphones in contexts similar to the COVID-19 period, especially concerning the limitations on social gatherings, including working from home for extended periods. Our dataset is made available to other researchers for benchmarking and future comparisons.

Keywords: smartphone usage; COVID-19; digital consumption

Citation: Chemnad, K.; Alshakhsi, S.; Almourad, M.B.; Altuwairiqi, M.; Phalp, K.; Ali, R. Smartphone Usage before and during COVID-19: A Comparative Study Based on Objective Recording of Usage Data. *Informatics* **2022**, *9*, 98. https://doi.org/10.3390/informatics9040098

Academic Editor: Jiang Bian

Received: 7 November 2022
Accepted: 5 December 2022
Published: 7 December 2022

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% of respondents used their smartphones more as a direct result of COVID-19. Ofcom's research on online behavior 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 from before the 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 [8], Italy [9], Portugal [9], India [10], China [11],

Canada, and Zimbabwe [12], reports that individuals increased their screen time during the pandemic. A survey by [13] found that 71.4% of 3254 participants reported increased online media usage during COVID-19. The authors assessed online media usage through a series of questions on time spent on different apps to estimate the change in usage. However, when certain online activities were compared before and after the lockdown, most individuals reported no changes in their online activity.

Recent research by [13] showed that COVID-19 has led to an increase in the usage of social networks. A study on the influence of the lockdown found that teens have expanded their usage of social networking sites [10]. There is evidence in the literature to suggest that social media use decreases as age increases [14]. A study by [15] on the usage of social media after the pandemic found that participants who reported significant anxiety symptoms after the enforced lockdown were more active on social networking apps and less active on communication apps overall, indicating a distinct pattern of digital social activity for coping with the crisis. Furthermore, ref. [15] made use of the Google Play store labels to categorize 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 that various demographic factors are 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 spend more time per session than males [18]. Ref. [19] found that men are more prone to excessive phone usage and internet addiction. Research by [20] found that men experienced less social stress than women and use their smartphones less for social purposes. Consequently, women have a higher chance of developing habitual or addictive smartphone behavior. Conversely, other studies have found no gender differences in smartphone addiction prevalence [21,22]. There are some differences in terms of specific app use, with smartphone addiction in males being more associated with game app use, and in women, it is 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 likelihood of developing habitual or addictive smartphone behaviors [20]. In terms of usage, ref. [22] found that younger individuals use their smartphones more often but for a shorter duration than older people. At the same time, ref. [23] 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 for phone function and getting information.

Using self-reported data to assess smartphone usage is a crucial shortcoming of previous studies. Self-reporting might contribute to reporting bias as the users might not accurately estimate their actual usage. Furthermore, ref. [24] demonstrated that users tend to underestimate their smartphone usage data such as average screen time and average launches. Research by [25] 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. Previous research on the use of social media is limited as it does not consider all of the social media platforms used by participants and has primarily been based on self-reported usage of four to five platforms. Furthermore, 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 smartphones in the context of COVID-19 to identify whether the relationships still endured 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.

According to Compensatory Internet Use Theory (CIUT) [27], individuals tend to overuse technology to avoid real-life issues or alleviate depressive symptoms; this coping method may be harmful. Ref. [28] revealed a positive association between daily smartphone usage and COVID-19 infection anxiety. In times of crisis such as COVID-19, where face-to-face interactions are limited, people are more likely to be stressed, and we hypothesized that there might be a change in smartphone usage and usage of communication apps as people rely on their phones as an escape or to connect with their families. Based on Social Compensation Theory, there may be an increase in the use of communication and social media apps to compensate for the lack of socializing and face-to-face interaction, and we wanted to further investigate whether this held under COVID-19 restrictions [29]. On the other hand, such change may also be based on Social Enhancement Theory, where individuals who have a large offline network utilize communication and social media apps as a means of maintaining and improving their relationships online [30], e.g., by receiving and providing social support. CUIT further mentions that if there is a shortage of social stimulation in real life, the person is motivated to go online to socialize, which is aided by applications that allow for socialization, such as online gaming or social networking sites [27]. The use of games as a form of escapism and as avoidance coping mechanisms has been studied extensively in the literature [31]. From the above, we assume that there may have been a change in people's social media and gaming app usage during COVID-19. Although the differences in smartphone usage relating to age and gender have been studied in the literature [23], these have not been studied in the context of a period when there were restrictions on social gatherings and face-to-face interactions. Although there may have been situations where people may have had restricted social gatherings, e.g., when in boot camps, these settings did not apply to everyone. COVID-19 presented a natural condition where people could not engage in social activities freely, and these restrictions were applied in many countries to everyone in a uniform manner.

This paper aimed to compare smartphone usage before and after the COVID-19 pandemic using objectively recorded data by answering the following research questions:

RQ1: What were the top apps used among all users, and separately by age group and gender during each period—before and during COVID-19?

RQ2: Comparing pre-COVID-19 and during COVID-19, was there a difference in the time spent on smartphones daily and the total number of app launches daily among all users, and separately by age group and gender?

RQ3: Comparing pre-COVID-19 and during COVID-19, was there a difference in the daily time spent on social media apps, and in the daily number of social media app launches between both periods among all users, and separately by age group and gender? Was there a change in the number of people who used social media apps between both periods?

RQ4: Comparing pre-COVID-19 and during COVID-19, was there a difference in daily time spent on gaming apps, and in the daily number of gaming app launches between both periods among all users, and separately by age group and gender? Was there a change in the number of people who used gaming apps between both periods?

RQ5: Comparing pre-COVID-19 and during COVID-19, was there a difference in daily time spent on communication apps, and in the daily number of communication app launches between both periods among all users, and separately by age group and gender? Was there a change in the number of people who used communication apps between both periods?

2. Materials & Methods

In this section, we first introduce the dataset that was used in the study. We then present information on how the data was pre-processed and the measures that were used. Finally, we introduce the statistical methods used.

2.1. Dataset

The dataset for this study was obtained via a third-party app on Google Play that helps users track their smartphone usage. The data collected from the app included the name of the app and the start time and end time of each app session. Users of the app must enter their age, gender, and country demographic details while registering on the app. The app privacy policy, to which all users agreed, states that collected data can be shared anonymously for research purposes. Still, data for this study were collected from users who provided explicit consent through a designated interface of the app. Participation was voluntary, and a premium version of the app was offered in return.

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 COVID-19 data collection was from October 2020 to April 2021. This 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 took into account weekdays and weekend usage. The study was reviewed and approved by the Institutional Review Board of Hamad Bin Khalifa University (Ethical Application Ref: QBRI-IRB 2021-08-102).

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 [32,33]. The data pre-processing steps included removing duplication in data records, eliminating users with missing answers for their demographics, calculating screen time, checking and discarding users and days when apparent anomalies were found, and merging broken sessions of the same apps into one, e.g., two sessions when the start of the second matched the end of the first. We also unified the date format and language as users came from different countries. Since the app is only available on Google Play, all the study participants were Android users. The app tracks all of the apps a user uses and the session start and end timestamps. However, it does not categorize 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. As the classification on Google Play is based on developers' choices, we manually cross-checked the results obtained from Google Play API for the top 500 used apps in the dataset and all the gaming, social media, and communication apps for misclassification. We manually recategorized the misclassified apps into communication, communication tools, lifestyle apps, and other categories. Three authors individually classified 10% of each of the app categories and then met to discuss and agree on a strategy. The first author completed the work and consulted with the others when in doubt. For example, apps such as Instagram have messaging and call features in them, but they were still considered to be social media as their primary goal is not communication. Another example, gaming apps that were catered towards education and fitness, were recategorized from the gaming apps category to education and health, respectively. Finally, a senior author made random checks on the classifications to assure their quality.

A total of 251 users participated in the 2020-21 study, while the 2019 study had 161 users. The participants in the 2020-21 dataset were different from those in the 2019 dataset. Most of the participants in both groups came from the following 10 countries: Australia, Brazil, Canada, Germany, France, India, Netherlands, Sweden, the United Kingdom, and the United States. In the data collected, age was categorized 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 [34] and U.N. [35] age categorization. This categorization helped balance the dataset since fewer respondents were above the 15–24 age bracket.

2.3. Measures

The measures used in our study were objective and derived from the metadata of the data, e.g., timestamps for opening and closing an app, and duration to complete the survey. To start, the app classification was based on Android Google Play classifications of apps and then scrutinized further by the authors to assure accuracy. We compared smartphone usage between 2019 and 2020-21 through the following metrics:

Average daily screen time: From the seven days of usage collected for each user, the time spent on all the apps was 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 achieve the average daily screen time.

Daily total app launches: Each session on an app was counted as a launch of that app. To achieve the daily total app launches, the total daily count of all app 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-day usage. The total time spent in minutes on each was computed, and then the 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 one separately and its average was taken over seven days to achieve 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. The Shapiro–Wilk test was computed to check the normality of the data. We also studied each period against the demographics separately. As the data were not normally distributed, the Mann–Whitney U test was used for the analysis. The Chi-Square test was used to compare groups of nominal variables. Phi-coefficients were used to determine the effect size. The significance level was set at 0.05.

The analysis looked at whether there was a difference in the time spent in minutes on smartphones 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 analyzed the differences between 2019 and 2020-21 for 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 2019 participants 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 2019 users, communication apps were used by everyone. Social media apps were used by 133 (83%) users, and gaming apps by 94 (58%) users. Of the 251 2020-21 users, communication apps were used by everyone, social media apps were used by 218 (87%), and gaming apps by 198 (79%). As far as communication apps were concerned, they were used by everyone in both periods, which is normal. The differences expected were 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 the 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 numbers of users who 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 daily time spent on smartphones 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

From Table 1, it can be noted that individuals spent on average from 29.64 to 687.12 min on screen in 2019 and from 57.78 to 970.08 min in 2020-21.

From Table 2, it can be noted that individuals launched apps from 19 to 716 times in a day in 2019 and from 34 to 613 times in a day in 2020-21.

RQ1: Top apps among all users during both periods

The list of top-used apps was extracted using the percentage of users in the sample who used each of the apps. The average daily time spent on each app was also calculated. Table 3 summarises the top 15 apps used by all users in 2019 and 2020-21. The 2019 sample had 161 users, and the 2020-21 sample had 251 users.

Table 3. Top 15 apps based on time spent in minutes in 2019 and 2020-21.

2019				2020-21			
App Name	**Avg. Time (min)**	**Std. Deviation**	**% (n = 161)**	**App Name**	**Avg. Time (min)**	**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

From Table 3 it can be noted that the top apps used in 2019 were internet browsing, social media, communication, video streaming, messaging, and navigation apps. The top

apps used in 2020-21 included internet browsing, social media, communication, music player, messaging, and video streaming apps.

Table 4 summarises the top 15 apps used by 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 4. Top 15 apps used by male users based on time spent in minutes in 2019 and 2020-21.

2019				2020-21			
App Name	**Avg. Time (min)**	**Std. Deviation**	**% (n = 84)**	**App Name**	**Avg. Time (min)**	**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

From Table 4, it can be noted that the top apps used by males in 2019 were internet browsing, communication, messaging, social media, navigation, and video streaming apps. The top apps used by males in 2020-21 included internet browsing, search, communication, mailing, messaging, and music player apps.

Table 5 summarises the top 15 apps used by 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 5. Top 15 apps used by female users based on time spent in minutes in 2019 and 2020-21.

2019				2020-21			
App Name	**Avg. Time (min)**	**Std. Deviation**	**% (n = 77)**	**App Name**	**Avg. Time (min)**	**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

From Table 5, it can be noted that the top apps being used by females in 2019 were internet browsing, communication, social media, navigation, messaging, music player,

and video streaming apps. In 2020-21, the top apps being used by females were internet browsing, search, communication, video streaming, social media, messaging, and music player apps.

Table 6 summarises the top 15 apps used by 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 6. Top 15 apps used by adult users based on time spent in minutes in 2019 and 2020-21.

2019				2020-21			
App Name	**Avg. Time (min)**	**Std. Deviation**	**% (n = 92)**	**App Name**	**Avg. Time (min)**	**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

The top apps used by adults in 2019 included navigation, communication, messaging, mailing, search, video streaming, social media, and internet browsing apps. In 2020-21, the top apps used by adults included internet browsing, navigation, messaging, mailing, communication, social media, music player, and video streaming apps.

Table 7 summarises the top 15 apps based on the 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.

Table 7. Top 15 apps used by emerging adult users based on time spent in minutes in 2019 and 2020-21.

2019				2020-21			
App Name	**Avg. Time (min)**	**Std. Deviation**	**% (n = 69)**	**App Name**	**Avg. Time (min)**	**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

From Table 7 it can be noted that the top apps used by emerging adults based on spent time in 2019 included internet browsing, video streaming, social media, messaging, communication, and navigation apps. In 2020-21, the top apps used by emerging adults were video streaming, search, social media, music player, and messaging apps.

Among the top-used apps were:

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

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

3.2. Analysis

RQ2: Difference in smartphone usage

We examined the differences 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 the time spent on smartphones in 2020-21 significantly increased (Mdn = 279.64, n = 251) compared to 2019 (Mdn = 233.21, n = 161), U = 17,014.00, $p = 0.0068$, $|r| = 0.16$. However, no significant difference was found in the daily average app launches between the two periods.

Effect of age and gender on daily smartphone usage in 2019 and 2020-21 separately. On studying the daily time spent on smartphones separately for age in 2019 using the Mann–Whitney U test, it was found that this was significantly higher for emerging adults (Mdn = 269.03, n = 69) compared to 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 adults (Mdn = 241.21, n = 144), U = 9462.0, $p = 0.002$, $|r| = 0.23$. Emerging adults were found to spend more time on their phones 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 the 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.

RQ3: 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, a Chi-Square test 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 = 12,323.00, $p = 0.02$, $|r| = 0.15$. 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, in this scenario, time spent on social media apps during 2020-21 also significantly increased (Mdn = 47.95, n = 251) compared to the time spent on social media apps in 2019 (Mdn = 31.94,

n = 161), U = 17,174, $p = 0.01$, $|r| = 0.15$. 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.

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, $p = 0.02$, w = 0.14 was 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 were filtered out. On studying the difference in daily time spent on social media apps separately for gender in 2019 and 2020-21 using the 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, $p = 3.55 \times 10^{-5}$, $|r| = 0.34$. 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 the 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, $p = 3.62 \times 10^{-6}$, $|r| = 0.35$. 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, $p = 8.77 \times 10^{-4}$, $|r| = 0.25$.

Effect of age when people who did not use social media apps were filtered out. No significant differences were found in 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 were 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.

RQ4: 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, a Chi-Square test was used to examine 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. The 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. The 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 = 15,866.50, $p = 1.26 \times 10^{-4}$, $|r| = 0.21$. 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 = 16,058.00, $p = 2.47 \times 10^{-4}$, $|r| = 0.21$.

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 results showed a significant

relationship, χ^2 (1, N = 412) =21.69, $p = 3.20 \times 10^{-6}$, w = 0.23. People were more likely to use gaming apps in 2020-21 than in 2019.

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 were filtered out. No significant difference was found regarding age and gaming app launches in 2019 or 2020-21. No significant difference was found for age regarding the time spent on gaming apps in 2019 or 2020-21.

Effect of age when people who did not use gaming apps were considered to have zero gaming app 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 more gaming apps in a day than did adults (Mdn = 0, n = 92) U = 3761, $p = 0.03$, $|r| = 0.18$. No significant difference was found regarding age in 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 were 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 regarding gender and daily gaming app launches in 2019 or 2020-21.

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

RQ5: 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 average time between 2019 and 2020-21. A Mann–Whitney U test was also used to analyze the difference in the number of communication app launches between 2019 and 2020-21. The test revealed no significant difference.

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 regarding age and communication app launches.

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

4. Discussion

Overall, our study showed that there was a change in smartphone usage due to COVID-19. When people had to adapt to a lifestyle with restrictions on social gatherings and limited face-to-face interactions, there was a change in how much time they spent on their smartphones. The findings of this study are highly credible since objectively collected data were utilized to measure smartphone usage. However, we note that people who installed the app were mainly those who wanted to be conscious of the amount of their usage. We also contributed to the research in this area by using a unique objectively monitored and collected dataset on smartphone usage that includes the usage of smartphones prior to and during COVID-19. This allows future studies to perform benchmarking and analyze study changes and trends in using smartphones.

Among the top apps used in 2019 and 2020-21 (Tables 4–7), 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 the restrictions on social gatherings and working from home during COVID-19; there was no need for the Maps app. 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 have been due to the increase in web-conferencing and video-call apps [36], and ease of access to devices such as laptops and PCs for communication, especially as it became practically mandatory for people to have sophisticated technology devices and internet connectivity during COVID-19 periods of restrictions on social gatherings. It could also be due to the limited need to use these apps when people were close to their partners and family under social gathering restrictions. Although TikTok was not present in the top apps used in 2019, it became one of the most used apps in 2020-21, with people spending an average of 40 min or more on the app. These results are likely to be related to TikTok being a source of entertainment and time-passing 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, people had little to share. 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, which suggests that people also relied on smartphones more for tasks typically done through PCs and laptops. 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 increased for females (Table 5) and emerging adults (Table 7). Emerging adults spent on average 25–30 min on social media apps pre-COVID-19 and at least an hour on social media apps in 2020-21.

The results from our analysis showed that there was an increase in the daily time spent on smartphones. These results are in line with reports from the U.K.-based regulator Ofcom, which state that screen usage increased by 47 min per day compared to before the pandemic [4]. Our study extends the findings of previous studies showing an increase in screen time since the pandemic [37–39]. Research by [40] reported a 40% increase in overall screen time among adults over age 18 during COVID-19 compared to before the pandemic. However, these studies used self-reported data and recent research has found that self-reported screen time can be quite different from actual phone usage time [41]. 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 during the pandemic, when face-to-face interaction was almost entirely substituted by online communication. This result may be explained by the fact that due to the ease of access to laptops and tablets, alternate communication means such as web-conferencing systems (e.g., Zoom [42], Microsoft Teams [43]) may have been utilized. This is further supported by a report from the Consumer Technology Association, USA, which states that between 27 March and May 31, 2020, the use of web conferencing systems almost doubled, reaching 24% of U.S. homes [36]. Furthermore, 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 that have a greater social presence (e.g., video calls) [44].

Our study indicates that there was a significant increase in time spent on social media during the pandemic. Our findings reflect those of [45], 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. 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 distancing [46,47]. 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. Increases in social media usage in literature [48] have been mostly confined to analysis of the reporting time spent on selected platforms, whereas in our study, all the social media apps used by the participants were considered while the actual time spent on social media was objectively recorded. Another possible explanation for the increase in time spent on social media in 2020-21 could be to access information related to the pandemic.

This is further supported by evidence from [49], who reported that COVID-19 information searching through social networking and live streaming applications (e.g., TikTok) was an important variable that motivated an important variable that motivated individuals to help them with preventive behaviors during the pandemic.

Remote working proved 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 achieving a better work-life balance [50]. 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, relying on communication apps on their smartphones. Although the number of individuals working remotely part-time or full-time has progressively increased over the years [51], the pandemic accelerated employer adoption of remote working modalities. Remote working was also not the norm for a significant section of the working population. For example, around 4.7 million Canadians who did not normally work remotely did so from March 22 to March 28, 2020, due to the impact of COVID-19 [52]. While working from home, people are likely to check their phones more often. Notifications and smartphone usage may also contribute to procrastination [53,54], impairing the quality and pace of work. Individuals are also 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 levels [55]. 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 [56–58].

Previous research has not considered smartphone gaming alone when studying online gaming and has also taken into account time spent on other devices for online gaming e.g., PCs and consoles. Contrary to research findings that suggest online mobile gaming engagement and traffic increased during the pandemic [59], our results showed no significant difference in the time people spent on gaming apps. However, more people have begun to use gaming apps since 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 the boredom and monotony caused by the lack of engaging real-life events during COVID-19 [60]. Although there is evidence in the literature [13] that males spend more time on gaming apps, our results showed no significant gender differences in the use of gaming apps. This difference could be because we used the time spent on smartphone gaming apps and objectively recorded data, compared to other comparative studies, which made use of self-report data and did not restrict online gaming to smartphone use alone but also included other gaming devices.

On studying the impact of age and gender separately on time spent on the phone, it was found that, in 2019 and 2020-21, emerging adults spent more time on the phone than adults. Females were found to spend more time on social media during both periods. Although females used social media more than males in 2019, their usage increased even more in 2020-21. This could be because 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 research by [13], which used objectively collected data to show that social media usage increased for female users during the pandemic. Our results show that although males increased their time spent on social media after the pandemic, the increase was not statistically significant, as was the case for females. This may suggest that even when males lack the option of face-to-face interactions, they do not feel the need to significantly increase the time spent on social media compared to females.

5. Conclusions

COVID-19 impacted many parts of people's lives, including how they spend time on their screens. Our study of mobile phone usage is one of the very few studies that utilizes objectively collected data, i.e., smartphone data collected through a designated app. In line with [61], objective data collection methods are likely to yield more credible results. Most of the literature has relied on the self-reporting of digital usage by users, which has been shown in several works to differ from the actual usage due to individual biases, such as recall bias and denial [25]. In addition, we have contributed to the research in this field by relying on a unique, objectively monitored and gathered dataset on smartphone use, which includes smartphone usage both before COVID-19 and during COVID-19. We have also made the dataset available as Supplementary Material for this paper. This will enable future researchers to perform benchmarking and analyze smartphone use changes and trends. Furthermore, our research differs from the literature because of the scrutiny we provided and our measurements of the time and frequency of launching the main types of smartphone apps (social, communication, and gaming), while other works only measured the overall smartphone screen time. Our study was also carried out during COVID-19, which is an example of a time when people were working from home with limited physical mobility and face-to-face social interaction. The stay-at-home and outdoor activity restrictions applied equally to everyone. Through our research, we have been able to find an increase in the time spent online and time spent on social media during COVID-19. The implications of this study can be extended to those who work in remote locations, people who have long commute hours, people who are undergoing medical treatments and are advised to be on rest, and people who may be economically poor and have access to no alternative entertainment options and so spend a lot of time on their smartphones in the absence of other entertainment options. The lack of leisure and entertainment alternatives is correlated with excessive screen time [62,63]. Experts in technology design may need to develop designs that help reduce excessive smartphone usage. For example, smartphone interfaces may have to be designed with people's digital well-being in mind, taking into account that the design should not be so attractive and immersive and provide features that allow people to maintain control over their behavior and empower them to avoid succumbing to peer pressure [64]. People's susceptibility to peer pressure and impulse control disorder have been shown to be associated with excessive screen time [65]. Interface designs for digital well-being could be used to help people use their smartphones to communicate more effectively through non-intrusive features and a simplified user interface design, which would support autonomy [66]. The concept of positive computing is an example of a beneficial model for creating new concepts and metrics that may help define the parameters of digital well-being [67]. Positive computing employs a paradigm that highlights the importance of multidisciplinary viewpoints in the continued development of well-being-enhancing digital technologies. Health practitioners and psychologists may have to go beyond creating awareness and educating people on how to spend time on their screens more positively. According to [68], the increase in screentime during COVID-19 has led to a decrease in physical activity, which in turn has negatively impacted both physical and mental health.

Since the increase in time spent online is inevitable, more attention should be paid to humanizing the web [69], and designing platforms that will allow users to take control of their online behavior and enhance their digital well-being. Some forms of technology can be addictive and lead to people spending excessive time on them without keeping in mind their posture and health [70]. Incorrect ergonomics, especially while working from home, may have major long-term health consequences [71]. People who are unaware of ergonomics, with the increase in smartphone and technology usage, may need access to occupational therapists who guide people towards taking precautionary and corrective measures, such as taking adequate breaks between sessions, engaging in physical activity, and paying attention to body posture [71]. Psychologists and companies will need to work together to train employees who work from home to help them find a good work-life

balance. Practical recommendations for companies include taking steps to facilitate efficient team collaborations to reduce burnout, and scheduling time for personal or recreational activities and work that needs to be done alone [72]. If more people choose hybrid or remote working options, employers and institutions will need to make a particular effort to implement programs that train people on how to work from home, regulate their smartphone usage, and help them maintain their digital well-being.

Our study has a few limitations. One limitation is that majority of the participants in our sample were from Western countries, except for some participants from India. Another limitation was the lack of data from users of the iOS operating system. Furthermore, 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 also dealt with communication apps, social media apps, and gaming apps as coherent categories, while more refined categorization could have led to more accurate results. For example, apps like Twitter and Instagram can differ in terms of the intention and purpose of typical use, but they are still considered under the general term of social media. Another limitation is that our study was not longitudinal, as COVID-19 was not a predicted phenomenon and we could not have the same participants in both periods. However, we still made a comparison between people who resided in the same countries during two different periods—one pre-COVID-19, when there were no restrictions on social gatherings in place, and the other during COVID-19, when there existed many restrictions on social gatherings. The current research was not designed to capture the intended use of the apps. A further study could assess smartphone usage along with intended use as there is preliminary evidence to suggest that intention may matter when studying an increase in screen time and the usage of different apps. This was demonstrated [73] in their study of gaming apps, where those with high escapism motives were more likely to be prone to gaming addiction.

This study has some notable strengths. First, the app usage statistics were realistic and impartial (unlike many comparable studies that exclusively utilized survey data). Furthermore, participants were drawn from a broad sample of smartphone users. This allowed us to better understand how age/gender groups from different countries 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 resulted in prolonged periods of social isolation. 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 on smartphone usage. Given the mental health consequences of various forms of screen time [74,75], more research is needed to separate the possible benefits and harms of screen time and social media use.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/informatics9040098/s1.

Author Contributions: Conceptualization, K.C. and R.A.; Data curation, M.B.A., M.A., K.P. and R.A.; Formal analysis, K.C. and S.A.; Funding acquisition, M.B.A. and M.A.; Investigation, K.C.; Methodology, K.C., M.B.A. and R.A.; Project administration, M.A.; Software, K.C. and S.A.; Supervision, R.A.; Validation, S.A.; Writing—original draft, K.C.; Writing—review & editing, S.A., M.B.A., K.P. and R.A. All authors have read and agreed to the published version of the manuscript.

Funding: This work received support from Zayed University, UAE, under grant number R18053 and the Scientific Research Department at Taif University, grant number 1-441-79.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of QATAR BIOMEDICAL RESEARCH INSTITUTE (protocol code QBRI-IRB 2021-08-102 and 12 August 2021).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The dataset used for this study is uploaded as Supplementary Material.

Conflicts of Interest: The authors declare no conflict of interest.

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