

# **Attitudes About COVID-19 and Health: A Mixed-Methods Smartphone-App and Online Survey Study**

Anna M. Hood, Hanne Stotesbury, Jennifer Murphy, Melanie Kölbel, April Slee, Charlie Springall, Matthew Paradis, Nadia Saraí Corral-Fría, Azalea Reyes-Aguilar, Alfredo B. Cuellar Barboza, Amy E. Noser, Stacey Gomes, Monica Mitchell, Sharon M. Watkins, Melinda Butsch Kovacic, Fenella J. Kirkham, Lori E. Crosby

Submitted to: JMIR Mental Health  
on: April 27, 2021

**Disclaimer:** © The authors. All rights reserved. This is a privileged document currently under peer-review/community review. Authors have provided JMIR Publications with an exclusive license to publish this preprint on its website for review purposes only. While the final peer-reviewed paper may be licensed under a CC BY license on publication, at this stage authors and publisher expressly prohibit redistribution of this draft paper other than for review purposes.

## Table of Contents

---

<b>Original Manuscript.....</b>	<b>5</b>
<b>Supplementary Files.....</b>	<b>38</b>
Figures .....	39
Figure 1.....	40
Figure 2.....	41
Figure 3.....	42
Figure 4.....	43
Multimedia Appendixes .....	44
Multimedia Appendix 1.....	45
Multimedia Appendix 2.....	45
Multimedia Appendix 3.....	45
Multimedia Appendix 4.....	45
Multimedia Appendix 5.....	45
Multimedia Appendix 6.....	45
Multimedia Appendix 7.....	45
Multimedia Appendix 8.....	45
Multimedia Appendix 9.....	45
Multimedia Appendix 10.....	45

# Attitudes About COVID-19 and Health: A Mixed-Methods Smartphone-App and Online Survey Study

Anna M. Hood<sup>1</sup> BA, MA, PhD; Hanne Stotesbury<sup>1</sup> MSc; Jennifer Murphy<sup>2</sup> PhD; Melanie Kölbel<sup>1</sup> MSc; April Slee<sup>3</sup> MS; Charlie Springall<sup>4</sup>; Matthew Paradis<sup>4</sup> PhD; Nadia Saraf Corral-Fría<sup>5</sup> PhD; Azalea Reyes-Aguilar<sup>6</sup> PhD; Alfredo B. Cuellar Barboza<sup>7</sup> MD; Amy E. Noser<sup>8</sup> PhD; Stacey Gomes<sup>8,9</sup> MS; Monica Mitchell<sup>8,10</sup> PhD; Sharon M. Watkins<sup>11</sup>; Melinda Butsch Kovacic<sup>10</sup> MPH, PhD; Fenella J. Kirkham<sup>1\*</sup> MD research; Lori E. Crosby<sup>8,12\*</sup> PsyD

<sup>1</sup>Developmental Neurosciences Unit and Biomedical Research Centre University College London Great Ormond Street Institute of Child Health London GB

<sup>2</sup>Department of Psychology Royal Holloway University of London London GB

<sup>3</sup>Axio Research, LLC Seattle US

<sup>4</sup>AirMyOpinion Ltd Weybridge GB

<sup>5</sup>Psychology Department Universidad de Sonora Hermosillo, Sonora MX

<sup>6</sup>Psychobiology & Neuroscience Department Facultad de Psicología Universidad Nacional Autónoma de México Ciudad de México MX

<sup>7</sup>Department of Psychiatry Universidad Autonoma de Nuevo Leon Monterrey MX

<sup>8</sup>Behavioral Medicine and Clinical Psychology Cincinnati Children's Hospital Medical Center Cincinnati US

<sup>9</sup>College of Criminal Justice Education and Human Services University of Cincinnati College of Medicine Cincinnati US

<sup>10</sup>Department of Pediatrics University of Cincinnati College of Medicine Cincinnati US

<sup>11</sup>Cincinnati-Hamilton County Community Action Agency Cincinnati US

<sup>12</sup>James M. Anderson Center for Health Systems Excellence Cincinnati Children's Hospital Medical Center Cincinnati US

\*these authors contributed equally

## Corresponding Author:

Anna M. Hood BA, MA, PhD

Developmental Neurosciences Unit and Biomedical Research Centre  
University College London Great Ormond Street Institute of Child Health  
30 Guilford Street  
London  
GB

## Abstract

**Background:** Behavioral mitigation strategies to slow the spread of COVID-19 have resulted in sweeping lifestyle changes, with short and long-term psychological, well-being, and quality of life implications. The Attitudes About COVID-19 and Health (ATTACH) study focuses on understanding attitudes and beliefs whilst considering the impact on mental and physical health and the influence of broader demographic and geographic factors on attitudes, beliefs, and mental health burden.

**Objective:** In this assessment of our first wave of data collection, we provide baseline cohort descriptives of ATTACH study participants in the United Kingdom (UK), United States of America (USA), and Mexico. Additionally, we assess responses to daily poll questions related to COVID-19 and conduct a cross-sectional analysis of baseline assessments collected in the UK between June 26 and October 31, 2020.

**Methods:** The ATTACH study uses smartphone-app technology and online survey data collection. Participants completed poll questions twice daily related to COVID-19 and a monthly survey assessing mental health, social isolation, physical health, and quality of life. Poll question responses were graphed using 95% Clopper-Pearson (exact) tests with 95% confidence intervals. Pearson correlations, hierarchical linear regression analyses, and generalized linear models assessed relationships, predictors of self-reported outcomes, and group differences, respectively.

**Results:** By October 31, 2020, 1405, 80, and 90 participants had consented to participate in the UK, USA, and Mexico, respectively. Descriptive data for the UK daily poll questions indicated that participants were generally following social distancing measures, but worry and negative impacts on families increased as the pandemic progressed. Although participants generally reported feeling that the reasons for current measures had been made clear, there was low trust that the government was doing everything in its power to meet public needs. In the UK, 1282 participants also completed a monthly survey (95% white,

72% female, 21% key or essential workers). Nineteen percent of UK participants reported a pre-existing mental health disorder, 31% reported a pre-existing chronic medical illness, and 35% were over 65. Fifty-seven percent of participants reported being more sedentary since the pandemic began, and 41% reported reduced access to medical care. Those with poorer mental health outcomes lived in more deprived neighborhoods, in larger households ( $p < .05$ ), had more pre-existing mental health disorders and medical conditions, and were younger than 65 years (all  $p < .001$ ).

**Conclusions:** Communities who have been exposed to additional harm during the COVID-19 pandemic were experiencing worse mental outcomes. Factors including having a medical condition, or living in a deprived neighborhood or larger household were associated with heightened risk. Future longitudinal studies should investigate the link between COVID-19 exposure, mental health, and sociodemographic and residential characteristics.

(JMIR Preprints 27/04/2021:29963)

DOI: <https://doi.org/10.2196/preprints.29963>

## Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**

Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.  
Only make the preprint title and abstract visible.

No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**

Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain visible to all users.

Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in a peer-reviewed journal, my preprint will be removed from the public version of the manuscript.

## Original Manuscript

# Attitudes About COVID-19 and Health: A Mixed-Methods Smartphone-App and Online Survey Study

Anna M. Hood PhD<sup>1</sup>, Hanne Stotesbury MSc<sup>1</sup>, Jennifer Murphy PhD<sup>2</sup>, Melanie Kölbel MSc<sup>1</sup>, April Slee MS<sup>3</sup>, Charlie Springall<sup>4</sup>, Matthew Paradis PhD<sup>4</sup>, Nadia Saraí Corral-Frías PhD<sup>5</sup>, Azalea Reyes-Aguilar PhD<sup>6</sup>, Alfredo B. Cuellar Barboza MD<sup>7</sup>, Amy E. Noser PhD<sup>8</sup>, Stacey Gomes MS<sup>8,9</sup>, Monica Mitchell PhD<sup>8,10</sup>, Sharon M. Watkins<sup>11</sup>, Melinda Butsch Kovacic MPH, PhD<sup>12</sup>, Fenella J. Kirkham MD research<sup>1</sup>, Lori E. Crosby PsyD<sup>8,10,13</sup>

<sup>1</sup> Developmental Neurosciences Unit and Biomedical Research Centre, UCL Great Ormond Street Institute of Child Health, London, United Kingdom

<sup>2</sup> Department of Psychology, Royal Holloway University of London, London, United Kingdom

<sup>3</sup> Axio Research, LLC, Seattle, Washington, United States of America

<sup>4</sup> AirMyOpinion Ltd, Weybridge, England

<sup>5</sup> Psychology Department, Universidad de Sonora, Hermosillo, Sonora 83000, México

<sup>6</sup> Psychobiology & Neuroscience Department, Facultad de Psicología, Universidad Nacional Autónoma de México, Ciudad de México, México

<sup>7</sup> Department of Psychiatry, Universidad Autonoma de Nuevo Leon, Monterrey, México

<sup>8</sup> Behavioral Medicine and Clinical Psychology, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio, United States of America

<sup>9</sup> College of Criminal Justice, Education and Human Services, University of Cincinnati College of Medicine, Cincinnati, Ohio, United States of America

<sup>10</sup> Department of Pediatrics, University of Cincinnati College of Medicine, Cincinnati, Ohio, United States of America

<sup>11</sup> Cincinnati-Hamilton County Community Action Agency, Cincinnati, Ohio, United States of America

<sup>12</sup> Department of Rehabilitative, Exercise and Nutrition Sciences, University of Cincinnati College of Allied Health Sciences

<sup>13</sup> James M. Anderson Center for Health Systems Excellence, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio, United States of America

All correspondence concerning this article should be addressed to Anna M. Hood, PhD,

Developmental Neurosciences, UCL Great Ormond Street Institute of Child Health, London, United Kingdom, 30 Guilford Street, London, WC1N 1EH. Telephone: 020.7905.2744, Email: [a.hood@ucl.ac.uk](mailto:a.hood@ucl.ac.uk).

## Abstract

**Background:** Behavioral mitigation strategies to slow the spread of COVID-19 have resulted in sweeping lifestyle changes, with short and long term psychological, well-being, and quality of life implications. The Attitudes About COVID-19 and Health (ATTACH) study focuses on understanding attitudes and beliefs whilst considering the impact on mental and physical health and the influence of

broader demographic and geographic factors on attitudes, beliefs, and mental health burden.

**Objective:** In this assessment of our first wave of data collection, we provide baseline cohort descriptives of ATTACH study participants in the United Kingdom (UK), United States of America (USA), and Mexico. Additionally, we assess responses to daily poll questions related to COVID-19 and conduct a cross-sectional analysis of baseline assessments collected in the UK between June 26 and October 31, 2020.

**Methods:** The ATTACH study uses smartphone-app technology and online survey data collection. Participants completed poll questions twice daily related to COVID-19 and a monthly survey assessing mental health, social isolation, physical health, and quality of life. Poll question responses were graphed using 95% Clopper-Pearson (exact) tests with 95% confidence intervals. Pearson correlations, hierarchical linear regression analyses, and generalized linear models assessed relationships, predictors of self-reported outcomes, and group differences, respectively.

**Results:** By October 31, 2020, 1405, 80, and 90 participants had consented to participate in the UK, USA, and Mexico, respectively. Descriptive data for the UK daily poll questions indicated that participants generally followed social distancing measures, but worry and negative impacts on families increased as the pandemic progressed. Although participants generally reported feeling that the reasons for current measures had been made clear, there was low trust that the government was doing everything in its power to meet public needs. In the UK, 1282 participants also completed a monthly survey (95% white, 72% female, 21% key or essential workers). Nineteen percent of UK participants reported a pre-existing mental health disorder, 31% reported a pre-existing chronic medical illness, and 35% were over 65. Fifty-seven percent of participants reported being more sedentary since the pandemic began, and 41% reported reduced access to medical care. Those with poorer mental health outcomes lived in more deprived neighborhoods, in larger households ( $ps < .05$ ), had more pre-existing mental health disorders and medical conditions, and were younger than 65 years (all  $ps < .001$ ).

**Conclusions.** Communities who have been exposed to additional harm during the COVID-19 pandemic were experiencing worse mental outcomes. Factors including having a medical condition, or living in a deprived neighborhood or larger household were associated with heightened risk. Future longitudinal studies should investigate the link between COVID-19 exposure, mental health,



and sociodemographic and residential characteristics.

## Keywords

COVID-19; mental health; international; mitigation strategies; deprivation

## Introduction

### Background

The coronavirus disease 2019 (COVID-19; SARS-CoV-2 virus) pandemic has placed an overwhelming burden on health systems and public health authorities to respond with effective interventions, policies, and messages [1]. Efforts to develop vaccines began quickly, with the first human clinical trial of a COVID-19 vaccine commencing on March 3rd, 2020, in the United States [2]. Authorization of the COVID-19 vaccine for clinical use in the United Kingdom (UK) on December 2nd, 2020 [3], with Mexico following soon afterwards on December 11th [4]. Even with these pharmacological measures, *behavioral* mitigation strategies (e.g., physical-distancing, handwashing, face-masks) [5] remain critical to slow the spread of COVID-19 [6]. However, the effectiveness of these behavioral strategies is dependent on adherence to policies and guidelines and

on a person's ability to perceive risks associated with the virus and adapt accordingly [7].

As the mitigation guidelines change over time and differ between countries and regions, there are many areas of uncertainty, including financial and health concerns, employment, and housing, along with fear about the future and social isolation. These sources of uncertainty may impact coping and increase the risk of developing mental health problems, with implications for quality of life in both the short and long term [8], [9]. Families have had to juggle home-schooling children with working remotely or being unable to work at all [10]. Evidence from previous viral disease outbreaks indicates that when the number of stressors is high, there can be a negative effect on mental health, particularly for high-risk persons (e.g., survivors and frontline healthcare workers) [11]–[15]. Currently, individuals are reporting widespread concerns about the effect of social distancing on well-being. There is evidence of increased anxiety, depression, and stress, along with reports of concern about the practical implications of the pandemic response, including for personal finances [9], [16].

Social and medical factors play a significant role in COVID-19 exposure and influence the impact on mental health. It has quickly become apparent that these social and medical consequences of COVID-19 do not affect all people equally. Older adults, people with medical conditions (e.g., asthma, sickle cell disease), as well as those facing longstanding societal inequities (i.e., Black, LatinX, Indigenous, Asian, and traveler communities), face a disproportionate burden [17]. A report from Public Health England indicates that socioeconomic disadvantage, population density, and household composition may increase the likelihood not only of COVID-19 illness and severe disease [18] but also of poorer mental health outcomes [19], [20]. Individuals' concerns about their mental health outcomes will likely result in additional pressure on referral systems. Known barriers to accessing mental health interventions may also increase during the pandemic, such as distance, work commitments, and caring responsibilities.

## Goal of This Study

The **Attitudes About COVID-19 and Health (ATTACH)** study aims to understand attitudes and beliefs about the COVID-19 pandemic whilst considering the impact on mental and physical health, along with the influence of demographic and geographic factors. We examine how the pandemic and behavioral mitigation strategies influence attitudes and beliefs, which in turn are predicted to affect mental and physical health (e.g., anxiety, social isolation) and therefore influence overall quality of

life (see Figure 1 for the theoretical model). Specifically, to assess the impact of COVID-19 related measures (e.g., isolation, physical distancing), our study:

- 1) tracks attitudes and behaviors daily as the pandemic evolves, and
- 2) longitudinally monitors mental and physical health symptoms using established measures that are reliable and sensitive to change.

The ATTACH study uses smartphone-app and online survey data collection. Our goals necessitate oversampling those communities who have been exposed to additional harm during the COVID-19 pandemic to guide the development of effective, and ideally, more person-centered interventions. Data encompasses a sample from the United Kingdom (UK; high-resource country). We also include data from two smaller-scale studies from the United States of America (USA; another high resource country) and Mexico (i.e., low resource country). We chose these countries for inclusion as, before the pandemic, the Global Health Security Index ranked the USA and the UK as the first and second most prepared to manage a pandemic, but by June 2020, they were first and second in excess deaths related to COVID-19 [21]. Mexico has Latin America's second-highest death toll and had 50% excess deaths when data collection began [22]. As Mexico is a primarily Spanish-speaking country with a similarly challenging COVID-19 response as the USA and UK, the comparison could help better understand attitudes, behaviors, and mental health during the COVID-19 pandemic. Although behavioral mitigation strategies changed regularly during the study period, all 3 countries used lockdowns (e.g., shelter in place), social distancing, and relied on individual compliance with the new rules. Additionally, some form of mask mandate had been introduced in all 3 countries, hospitality venues had been closed or required outdoor dining, and stores limited the number of individuals allowed inside [23]–[25]. However, COVID-19 vaccines had not been released in any of these countries at the time of data collection.

Data collection for ATTACH is on-going, and longitudinal aims and specific hypotheses have been preregistered [26]. This paper primarily focuses on a cross-sectional analysis of baseline assessments collected in the UK between June 26 and October 31, 2020. It also considers longitudinal changes in UK daily poll responses through the same period. Descriptive analyses for data from the USA and Mexico are also reported, but we did not conduct statistical analyses. During our first-wave, the sample sizes in those countries were less than 100 participants.

## Aims

1. To describe the baseline characteristics of participants in the ATTACH study in the UK, USA, and Mexico.
2. To describe changes in daily UK poll responses over time in relation to specific policy interventions (e.g., mask mandates) and the pandemic's trajectory (e.g., a 7-day rolling average of COVID-19 cases).

## Hypotheses

1. We hypothesize that residential population density, socioeconomic deprivation, and household composition will predict self-reported outcomes (i.e., anxiety and depressive symptoms, social isolation, physical health, quality of life) in our UK sample.
2. We hypothesize that determine there will be baseline differences in our UK sample in self-reported outcomes between 1) participants with and without mental health disorders, 2) participants with and without medical conditions, and 3) participants under and over 65 years of age.

## Methods

### Study Design

ATTACH is a prospective cohort study conducted nationwide during the COVID-19 pandemic with arms in the UK, the USA, and Mexico. Our research team developed the study between March and April 2020. Data collection began on June 26th, 2020, in the UK, on July 27th, 2020, in the USA, and on October 10th, 2020, in Mexico. In the UK, the ATTACH study partnered with Air My Opinion (AMO), a smartphone app that enables organizations to gather longitudinal poll data to interpret trends in attitudes and beliefs.

### Population

The ATTACH study purposely targets individuals with increased susceptibility to adverse health outcomes for recruitment, focusing on three priority groups: 1) those with a self-reported mental health disorder, 2) those with a self-reported chronic medical condition, and 3) those over 65 years of age. Participants were at least 16 years of age (18 years in the USA and Mexico), could read in English (UK; does not have to be their first language), Spanish (Mexico), or English or Spanish (USA). Participants had to reside in the country where the study was being completed and have access to a smartphone (UK) and the internet (UK, USA, Mexico). Participants provided informed

electronic consent before completing daily poll questions and monthly surveys. The ATTACH study received ethical approval from the University College London (UCL) Research Ethics Committee (18177/001), the Cincinnati Children's Hospital Medical Center Institutional Review Board (No. 2020-0465), and the Universidad de Sonora Ethics Committee (CEI-UNISON 010/2020). The study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology statement [27] and the Checklist for Reporting Results of Internet E-Surveys guidelines [28].

## Materials

### Air My Opinion App (UK data only)

The Air My Opinion (AMO) app was customized for the ATTACH study through an iterative design process between the research team and app developer. Before the study launched, the research team appraised a mock-up design, highlighted their satisfaction and dissatisfaction with the design and format, and provided feedback and suggestions for improvement. The AMO app uses the flutter framework, has embedded encryption and is general data protection regulation (GDPR) compliant. Participants could freely install the app on an internet-enabled smartphone (Google Play or Apple App Store) running Android or iOS operating systems. Responses to daily poll questions were collected via a short message service (SMS) service-centre voting platform. Some participants (N = 344) had difficulty sending their first SMS message (i.e., changed the wording, did not realize it had not sent), which included their registration data (i.e., postcode). As such, the app development team made changes so that registration data was incorporated within the app instead of being included in the first SMS message.

If a participant's phone plan is traditional pay-as-you-go, they pay per SMS message, and if they have a monthly plan or pay-as-you-go bundle, there is no additional cost. Each phone number is associated with a unique one-way encrypted participant key [e.g., 1::747d6f41-2f7a-47fd-a2a0-0cf41b8ca9f2::i2::1::484::], which feeds directly into a secure response firewall-protected database (see Figure 2). Per GDPR, age range, sex, postcode ethnic minority status (yes/no prefer not to say) and parent and chronic medical condition group status were stored in a separate secure firewall protected database. Data protection registration has been obtained for this study (UCL Data Protection Registration Number: Z6364106/2020/04/110). The data are minimized at the first opportunity, with new keys assigned and the original keys stored separately from the rest of the data on the UCL shared drive.

### **Poll Questions (UK data only)**

In March and April 2020, the research team conducted a literature review and held several virtual video conference meetings to develop daily poll questions using prior expertise, survey knowledge, group discussion, and reliable sources of COVID-19 information (e.g., World Health Organization [WHO]). Given the fast-moving nature of the COVID-19 pandemic, validation or pilot testing of questions externally was not possible. Poll questions track attitudes, beliefs, and behaviors related to the COVID-19 pandemic and fit into broad categories related to health and well-being, personal concerns, worry or hope, compliance or rationale, government trust, and habits. All questions have three Likert response options (e.g., yes, somewhat, not at all). There are currently 60 poll questions. New questions are added on a flexible schedule to capture changes during the pandemic whilst maintaining the original questions for longitudinal assessment [see Multimedia Appendix 1 for a complete list of poll questions]. Most questions are repeated every two weeks. In this study, 6 questions were focused on descriptive analyses (see below). These questions were chosen as they were asked continuously from the beginning of the study, represent a question from each category, and were chosen before any analyses were conducted.

- In the past week, have you followed social distancing measures?
- In the past week, have you felt that COVID-19 has had a negative impact on your family?
- In the past week, how worried have you been about the on-going COVID-19 pandemic?
- In the past week, have you felt that the reasons for the current pandemic measures have been made clear?
- In the past week, have you trusted the government to do everything in their power to ensure that the basic needs of the public are met?
- In the past week, have you spent more time than usual using social media (e.g., Facebook, WhatsApp, Instagram)?

### **Monthly survey**

Baseline sociodemographic characteristics include age, sex, relationship status, educational level, first language, household composition, and caregiver status. For race and ethnicity, participants could choose from categories (based on census data from each country) or self-identify using a free response. Mental health disorders and medical conditions were identified from free-response. Mental health disorders were classified based on the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition categories. To capture changes as the COVID-19 pandemic progresses, participants were

asked to provide their employment and keyworker status, effects on household income, sources of and trust in COVID-19-related information, political status on a 100-point scale (“0 = left” and “100 = right”) at baseline, and months 7 and 12.

Measures included in the study are validated, non-validated (developed rapidly during the COVID-19 pandemic), and measures designed by our research team. Internal consistency (i.e., Cronbach’s alpha) for this study and the assessment schedule are reported in Multimedia Appendices 2 and 3. When possible, short forms of measures were used to reduce participant burden. Measures included for analyses in this study were the Patient-Reported Outcomes Measurement Information System (PROMIS) Anxiety-Adult Short Form [29], Patient Health Questionnaire (PHQ-9) [30], UCLA Loneliness Scale [31], PROMIS Global Health [29], the PROMIS Meaning and Purpose – Short Form [29], and the Epidemic-Pandemic Impact Inventory (Physical Health questions) [32] [see Multimedia Appendix 4]. PROMIS measures were available in Spanish; for the other measures, a study team member (NSCF) completed the translation.

### **Residential Risk Factors (UK data only)**

Geographic region, socioeconomic disadvantage, and household composition may influence an individual’s ability to follow COVID-19 related guidelines and restrictions [18]. In our study, two measures captured these factors: deprivation and population density. Participants provided the first five characters of their UK postcode (i.e., postcode sector) on the AMO smartphone app. In 2016, there were 12,381 postcode sectors in the UK. Postcode sectors vary in terms of the number of dwellings but typically range between 200 & 5,000 [33].

### ***Socioeconomic Deprivation***

The index of multiple deprivation (IMD; 2017- 2020) is an official postcode based measure of relative deprivation in England [34], Wales [35], Scotland [36], and Northern Ireland [37] and is available as open-source government data. The IMD defines deprivation to encompass income, employment, education, health, crime, barriers to housing and services, and living environment. All neighborhoods are ranked on a relative rather than absolute scale according to their deprivation level relative to other areas. All zones are grouped into 5 bands (quintiles), each containing 20% of the zone, with “1 = most deprived, 5 = least deprived.” In this study, each participants’ postcode sector was assessed to determine the level of deprivation. IMD quintile scores are combined from all UK countries.

### ***Residential Population Density***

Population density estimates for England and Wales [38], Scotland [39], and Northern Ireland [40] are produced for each country using the cohort component method and cover the “usually resident population” from 2011 Census data. In this study, each participants’ postcode sector was assessed to determine the population density (i.e., number of usual residents per hectare), and population density was combined from all UK countries.

### ***Household Composition***

Participants responded to the question, “How many people (adults and children) live in your household?” The five response options were “1” through “5 or more”.

### **Procedures**

Recruitment strategies for all countries are described in Multimedia Appendix 5. Participants downloaded the smartphone app to complete consent in the UK and then provided their demographics (in case a participant chose not to complete monthly surveys) and their postcode. Participants received push notifications on their phones to complete daily 1-minute polls twice each day at 10 am and 2 pm. Participants could answer both questions at the same time, but each question was removed after 24 hours. Once the participant completed the daily poll questions, they could then click on an embedded link (with a unique access code) in the app to complete their monthly survey via Research Electronic Data Capture tools (REDCap) hosted at UCL (see Figure 3 for a schematic) [41], [42].

If responses to survey questions indicated that participants had severe depression or experienced high levels of stigma due to their medical condition, a pop-up message provided mental health resources along with the study email address, which was monitored regularly by a clinical psychologist (AMH) to provide additional resources or referrals. After the survey, participants were redirected to the study webpages (located on the UCL Child Health Institute website), which contain links to mental health (e.g., Mind), COVID-19 (e.g., government), and authoritative medical information (e.g., NHS). Participants could see the results of daily poll questions (i.e., pie charts) by clicking on a link in the app or via the study Twitter account.

In the USA, participants completed poll questions and monthly surveys using REDCap™, and in Mexico, participants completed monthly surveys using Qualtrics™ with open survey links. Participants in the UK and USA who completed the monthly survey were entered into a monthly



prize draw (UK £10/ US \$10 Amazon card). In Mexico, most participants did not receive any compensation. A subset of the sample (i.e., undergraduate students) had the opportunity to receive *culture credits* (obtained through research studies or going to concerts or workshops) for their participation.

## Statistical Analysis

Analyses were conducted using R version 4.0.3 [43] and SAS version 9.4 [44]. Descriptive statistics summarized demographic and clinical characteristics. The PROMIS [29] anxiety, physical health, and the meaning and purpose scales were scored using the online HealthMeasures scoring service [45] that utilizes information from each item to calculate a T-score (Mean = 50, SD = 10). For the PHQ-9 and the UCLA-10, raw scores were calculated in line with published norms. Mean imputation was used when a participant completed at least 80% of items [46], [47]. The frequency of somewhat and yes poll question responses from July 15th, 2020, to October 15th, 2020, were graphed based on the timing of response using 95% Clopper-Pearson (exact) tests with 95% confidence intervals (CI), alongside the 7-day average counts of daily COVID-19 cases (/100 persons) and deaths. Pearson correlations examined the relationship between household composition and self-reported outcomes. Hierarchical linear regression analyses assessed whether residential socioeconomic deprivation and population density independently predicted self-reported outcomes after controlling for age and sex.

Generalized linear models were used to produce adjusted least-square mean scores and differences to compare groups (participants with and without mental health and medical conditions, those under and over 65 years). Analyses controlled for demographic factors (i.e., age, sex, level of residential socioeconomic deprivation) and comorbidities (i.e., mental health and medical condition). All analyses were conducted using pairwise deletion as variables generally contained less than 1% of missing data. Adjusted p-values were based on the model t-statistics. Semi-partial eta squared ( $\eta^2$ ) was used as a measure of effect size to describe the proportion of total variation accounted for by the effect being tested. Statistical significance was determined at an alpha level of  $p < .05$  (two-tailed).

## Data Exclusion

The smartphone app and online survey data were examined for duplicates by matching unique app identifiers and participant numbers. Through this process, it was determined that 15 participants had downloaded the app more than once. Duplicate data were excluded before analyses.

## Power

The ATTACH study was powered to detect longitudinal effects and not baseline group differences [26], so power calculations were not performed for these largely descriptive first-wave baseline assessments. However, for our longitudinal analyses with 3 subgroups, 5 covariates, 5 or more repeated measures at .80 power, an error probability of .05, and an effect size of .3, the sample size required for between participants analyses is 153 and is 50 for the within-participants analyses.

## Results

### UK Preliminary Analyses

By October 31, 2020, 1405 individuals had downloaded the smartphone app and consented to participate in the UK ATTACH study. As of October 31, 2020, the study link that takes participants to the study recruitment page had been clicked on 5068 times, with Facebook and Twitter being the most common referrers. No participants reached out via email or social media to indicate that they had a mental health concern.

One hundred and twenty-three participants (8.8%) answered poll questions on at least one occasion but did not complete the monthly survey (see Table 1). Sensitivity analyses indicated that participants who did and did not go on to complete the survey were similar in age ( $p = .24$ ), sex ( $p = .62$ ), level of deprivation ( $p = .83$ ), and UK country of residence ( $p = .74$ ). However, those who did not complete a monthly survey were significantly more likely to identify as non-White ( $p < .001$ ) and were from a more populated geographic region ( $p = .02$ ) than those who did. Analyses assessed whether there were differences between participants who did and did not ( $N = 344$ ) send their first SMS message correctly. They did not differ in terms of identified race ( $p = .54$ ), but they were significantly older ( $p < .001$ ) and more likely to be female ( $p = .02$ ).

### UK Poll Questions

Sixty-two percent of participants answered each poll question separately at 10 am and 2 pm, with the fastest response at 8 seconds and the slowest response at 23 hours and 58 minutes. The average time to answer one question was 2 hours and 17 minutes, with 11.8% of participants answering within 10 minutes. Longitudinal data from 6 poll questions indicated that participants had generally followed social distancing measures, although there was variability across time (responses varied between 50 and 99%). Regarding whether the COVID-19 pandemic had a negative impact on the family and whether participants were worried about the pandemic, both increased over time. Over 80% of

participants responded “somewhat or yes” as the pandemic progressed and as the 7-day rolling average of cases and deaths increased. Although participants generally reported feeling that the reasons for current measures had been made clear (70-85% across the study period), there was much less trust that the government was doing everything in their power to meet public needs, with less variability in responses over time (25-50% across the study period). Increased social media use remained consistent, with 30-40% of participants reporting spending more time than usual (see Figure 4).

## UK Monthly survey

### *Descriptive data*

Participants at baseline had a mean age of 57 years, with the majority identifying as white (1326/1396, 95.3%), female (1014/1404, 72.2%), married (765/1282, 59.7%), speaking English as a first language (1231/1282, 96%), and educated to the college/university level or higher (996/1282, 77.7%). Five-hundred and forty participants (42.8%) were retired, and about a fifth (277/1377, 20.6%) were key or essential workers. Most lived in a two-person household (681/1282, 53.1%), and a minority were parents of children under 16 years (139/1282, 10.9%). Less than a quarter (300/1259, 23.8%) reported that their income had been affected by the COVID-19 pandemic, and when reporting where they see themselves on the political spectrum, scores ranged from 0-100 (Mean = 42.3, SD = 22.2).

A subgroup of participants reported pre-existing mental health disorders (242/1282, 18.9%), with depression and anxiety disorders the most commonly reported. Just over a third (402/1282, 31.4%) reported a pre-existing chronic medical illness, with asthma, Type 1 and 2 diabetes, and arthritis the most commonly reported [see Multimedia Appendix 6]. Some participants also had co-morbid (i.e., more than one) mental health disorders (94/1282, 7.3%) or chronic medical illnesses (71/1282, 5.5%). Additionally, some participants had at least one mental health disorder *and* at least one chronic medical condition (100/1282, 7.8%) [see Multimedia Appendix 7]. Scores on self-reported outcome measures indicated that just under a third (28.3%) were experiencing moderate-to-severe anxiety symptoms, while just under a fifth (19.2%) were experiencing moderate-to-severe depressive symptoms. Most of the sample (80%) reported feeling some loneliness or social isolation, 20.6% of participants reported poor-to-fair physical health, and 39.5% reported poor-to-fair quality of life [see Multimedia Appendix 8].

### ***Impact of the COVID-19 Pandemic***

Participants reported how the COVID-19 pandemic had changed their lives and impacted their household members. Generally, fewer participants reported physical health changes, though many had received less routine or preventative medical care. At least a third of the sample reported being less physically active and eating less healthy foods. In fact, 57.5% of participants reported being more sedentary since the pandemic began (see Table 3).

Table 3. COVID-19 pandemic related changes for participants and people in their home at baseline in the UK ATTACH study from June 26 to October 31, 2020

COVID-19 pandemic related changes	Participant	Person in home
Spent more time sitting down or being sedentary	57.5%	30.8%
Got less medical care than usual (e.g., routine or preventive care appointments)	41.7%	23.0%
Less physical activity or exercise	40.7%	23.7%
Overeating or eating more unhealthy foods (e.g., junk food)	31.9%	16.8%
Increase in health problems not related to this disease	21.1%	12.3%
Important medical procedure cancelled (e.g., surgery)	6.9%	5.4%
Elderly or disabled family member not in the home unable to get the help they need	5.5%	6.9%
Unable to access medical care for a serious condition (e.g., dialysis, chemotherapy)	2.3%	1.3%

### ***Residential Risk Factors***

Pearson correlations demonstrated that residential socioeconomic deprivation was significantly related to increased population density ( $r = -.24$ ,  $p < .001$ ) and household composition ( $r = .07$ ,  $p = .04$ ). Higher household composition (i.e., more people residing in the home) was however related to less residential population density ( $r = -.06$ ,  $p = .09$ ), although this result did not reach significance.

### ***Socioeconomic Deprivation***

Younger age, female sex, and living in a more deprived neighborhood (i.e., quintile 1 vs quintiles 2 through 5) were predictive of reporting more anxiety symptoms,  $F_{(8,880)} = 23.12$ ,  $r^2 = .13$ , 95% CI [.09, .17],  $p < .0001$ . For our second analysis, younger age, and living in a more deprived neighborhood (i.e., quintile 1 vs quintiles 2 through 5), but not sex, were predictive of reporting more depressive symptoms,  $F_{(6,862)} = 25.87$ ,  $r^2 = .15$ , 95% CI [.11, .19],  $p < .0001$ . For our third and fourth analyses, age and sex were not significant predictors, but living in a more deprived neighborhood (i.e., quintile 1) compared to living in a less deprived neighborhood (quintiles 2 through 5) was predictive of

reporting worse physical health,  $F_{(6,860)} = 2.88$ ,  $r^2 = .13$ , 95% CI [.00, .04],  $p < .001$  and more social isolation (only least deprived quintile),  $F_{(6,872)} = 11.60$ ,  $r^2 = .08$ , 95% CI [.04, .10],  $p < .0001$ . For our fifth analysis on quality of life, the overall model was significant,  $F_{(6,860)} = 6.19$ ,  $r^2 = .03$ , 95% CI [.01, .06],  $p < .001$ . However, only female sex was a significant predictor of worse quality of life. Overall, these analyses indicated that living in the most deprived neighborhoods (quintile = 1) predicted worse mental health, increased social isolation, and poorer physical health.

### ***Residential Population Density***

Hierarchical linear regression analyses assessed whether residential population density significantly predicted self-reported outcomes after controlling for the age and sex of participants. We found that age ( $ps < .01$ ) but not sex ( $ps > .05$ ) was a significant predictor in all 5 regression models, indicating that younger participants were more likely to live in neighborhoods with higher population density. With regard to self-reported outcomes, the severity of anxiety and depressive symptoms and reporting more social isolation and poorer physical health was not predictive of living in a more populated neighborhood ( $ps > .05$ ). In contrast, participants who reported poor quality of life were more likely to live in a more populated area than those who reported excellent quality of life,  $t_{(861)} = 2.21$ ,  $\beta = -.31$ , 95% CI[-0.58 – -0.03],  $p = .03$ .

### ***Household Composition***

Pearson correlations found small, but significant relationships between higher household composition and more anxiety ( $r = .07$ ,  $p = .01$ ) and depressive symptoms ( $r = .07$ ,  $p = .01$ ). Higher household composition was, however, related to *less* social isolation ( $r = -.06$ ,  $p = .07$ ), although this result did not reach significance. Household composition was not related to physical health or quality of life ( $ps > .05$ ).

### ***Differences between groups***

We found that participants with mental health disorders reported significantly more anxiety and depressive symptoms, more social isolation, worse physical health, and poorer quality of life than those without a mental health disorder (all  $ps < .001$ ) after controlling for age, sex, level of residential socioeconomic deprivation, and co-morbid medical conditions (see Table 4). Tables 3-5 focus on specific group contrasts; however, the covariates in each model are identical. Thus, the following model-level goodness of fit statistics apply to each model: Anxiety (PROMIS 7 T-score)  $R^2 = 0.224$ , Depression (PHQ-9 Total score)  $R^2 = 0.298$ , Social Isolation (UCLA 10-item total)  $R^2 =$

0.114, Social Isolation (UCLA 3 item total)  $R^2 = 0.111$ , Physical health (PROMIS T-score),  $R^2 = 0.204$ , quality of life (PROMIS T-score)  $R^2 = 0.091$ .

Table 4. Differences in self-reported outcomes for those with and without mental health disorders

Self-reported outcomes	N	No mental health disorder LSM (SE) <sup>a</sup>	N	Mental health disorder LSM (SE) <sup>b</sup>	LSM difference (CI) <sup>c</sup>	t	$\eta^2$	p
Anxiety: PROMIS 7a <sup>d</sup> T-score	987	52.2 (0.4)	227	60.6 (0.7)	-8.4 (-9.8 to -6.9)	-11.3	0.9	<.001
Depression: PHQ-9 <sup>e</sup> Total score	970	4.0 (0.2)	218	10.4 (0.4)	-6.4 (-7.2 to -5.6)	-15.5	0.6	<.001
Social Isolation: UCLA <sup>f</sup> 10 total	978	19.4 (0.3)	224	23.4 (0.5)	-4.1 (-5.1 to -3.1)	-8.1	0.9	<.001
Social Isolation: UCLA 3 total	978	6.3 (0.1)	224	7.6 (0.2)	-1.3 (-1.7 to -1.0)	-7.1	0.9	<.001
Physical health: PROMIS T-score	963	51.7 (0.4)	217	46.3 (0.7)	5.4 (4.0 to 6.8)	7.4	1.0	<.001
QoL <sup>g</sup> : PROMIS T-score	961	48.9 (0.5)	217	41.6 (0.9)	7.4 (5.6 to 9.2)	8.0	1.0	<.001

<sup>a</sup>LSM: Least Square Mean

<sup>b</sup>SE: Standard Error

<sup>c</sup>CI: Confidence interval

<sup>d</sup>PROMIS: Patient-Reported Outcomes Measurement Information System

<sup>e</sup>PHQ-9: Patient Health Questionnaire

<sup>f</sup>UCLA = UCLA Loneliness Scale

<sup>g</sup>Quality of life

After controlling for age, sex, level of residential socioeconomic deprivation, and co-morbid mental health disorders, we found that participants with medical conditions reported significantly more anxiety ( $p = .003$ ) and depressive symptoms ( $p = .002$ ), and worse physical health (all  $p < .001$ ) than those without a medical condition. Social isolation and quality of life were similar for both groups ( $ps > .05$ ) (see Table 5).

Table 5. Differences in self-reported outcomes for those with and without medical conditions

Self-reported outcomes	N	No Medical condition LSM (SE) <sup>a</sup>	N	Medical Condition LSM (SE) <sup>b</sup>	LSM difference (CI) <sup>c</sup>	t	$\eta^2$	p
Anxiety: PROMIS 7a <sup>d</sup> T-score	848	56.2 (2.0)	396	58.1 (2.1)	-1.9 (-3.1 to -0.6)	-2.9	1.0	.003

Depression: PHQ-9 <sup>e</sup> Total score	831	8.2 (1.1)	386	9.3 (1.1)	-1.1 (-1.8 to -0.4)	-3.1	0.5	.002
Social Isolation: UCLA <sup>f</sup> 10 total	842	21.1 (1.4)	390	21.6 (1.4)	-0.5 (-1.3 to 0.4)	-1.5	0.9	.25
Social Isolation: UCLA 3 total	842	6.7 (0.5)	390	6.9 (0.5)	-0.3 (-0.6 to 0.02)	-1.9	0.9	.06
Physical health: PROMIS T-score	823	45.8 (2.0)	385	52.6 (2.0)	6.9 (5.6 to 8.1)	11.1	1.0	<.001
QOL <sup>g</sup> : PROMIS T-score	821	43.2 (2.5)	385	42.6 (2.5)	0.7 (-0.9 to 2.2)	0.8	1.0	.40

<sup>a</sup>LSM: Least Square Mean

<sup>b</sup>SE: Standard Error

<sup>c</sup>CI: Confidence interval

<sup>d</sup>PROMIS: Patient-Reported Outcomes Measurement Information System

<sup>e</sup>PHQ-9: Patient Health Questionnaire

<sup>f</sup>UCLA = UCLA Loneliness Scale

<sup>g</sup>Quality of life

After controlling for sex, level of residential socioeconomic deprivation, and co-morbid mental health *and* medical conditions, we found that contrary to hypotheses, participants under 65 years of age reported significantly more anxiety and depressive symptoms and more social isolation than those over 65 years of age (all  $ps < .001$ ). They also reported slightly better quality of life ( $p = .05$ ), although both groups were in the average range according to the measure classifications. Participants over and under 65 years reported similar physical health ( $p = .88$ ) (see Table 6).

Table 6. Differences in self-reported outcomes for those with and without mental health disorders

Self-reported outcomes	N	Under 65 years LSM (SE) <sup>a</sup>	N	Over 65 years LSM (SE) <sup>b</sup>	LSM difference (CI) <sup>c</sup>	t	$\eta^2$	p
Anxiety: PROMIS 7a <sup>d</sup> T-score	800	58.6 (2.0)	444	55.7 (2.1)	3.0 (1.7 to 4.2)	4.7	1.0	<.001
Depression: PHQ-9 <sup>e</sup> Total score	827	9.8 (1.1)	454	7.8 (1.2)	2.0 (1.3 to 2.7)	5.7	0.5	<.001
Social Isolation: UCLA <sup>f</sup> 10 total	827	22.2 (1.4)	454	20.5 (1.4)	1.7 (0.8 to 2.5)	3.9	0.9	<.001
Social Isolation: UCLA 3 total	827	7.1 (0.5)	454	6.5 (0.5)	0.6 (0.3 to 1.0)	4.1	0.9	<.001
Physical health: PROMIS T-score	827	49.2 (2.0)	454	49.3 (1.9)	0.1 (-1.1 to 1.3)	0.2	1.0	.88
QOL <sup>g</sup> : PROMIS T-score	827	42.1 (2.5)	454	43.6 (2.5)	-1.5 (-3.0 to -0.1)	-1.98	1.0	.05

<sup>a</sup>LSM: Least Square Mean

<sup>b</sup>SE: Standard Error

<sup>c</sup>CI: Confidence interval

<sup>d</sup>PROMIS: Patient-Reported Outcomes Measurement Information System

<sup>e</sup>PHQ-9: Patient Health Questionnaire

<sup>f</sup>UCLA = UCLA Loneliness Scale

<sup>e</sup>Quality of life

## **USA**

At baseline, participants in the smaller scale USA ATTACH study ( $n = 90$ ) were younger than the UK sample ( $M = 47.1$ ,  $SD = 13.1$ ), more likely to identify as Black/African American (45/90, 50%), be employed (69/90, 75.6%), be key or essential workers (40/90, 44.4%), be parents of children under 16 years (34/90, 37.8%), and be educated at the college/university level or higher (85/90, 91.3%). Participants in the USA were less likely than those living in the UK to report that they were married (42/90, 46.7%), have a mental health disorder (12/90, 13.3%), and when reporting where they see themselves on the political spectrum, scores ranged from 0-100 (Mean = 34.0,  $SD = 21.6$ ). The two samples were similar in that the majority were female (68/90, 75.6%), English speakers (78/90, 86.7%), reported having a medical condition (26/90, 28.9%), most lived in a two-person household (33/90, 36.7%), and less than a quarter (22/90, 24.4%) reported that their income had been affected by the COVID-19 pandemic [see Multimedia Appendix 9].

## **Mexico**

During the first-wave of baseline assessments, the Mexico ATTACH study ( $n = 80$ ) had been collecting data for less than one month. Participants were more likely than the UK sample to be younger than 40 years (71/80, 88.7%), identify as mixed/multiple ethnic groups (40/80, 50%), be single (48/80, 60%), be unemployed or employed without income (i.e., furloughed) (42/80, 52.5%), to live in a 3-person household or larger (58/80, 72.4%), and be a caregiver to a child under 16 years (17/80, 21.1%). Similar to the UK sample, most participants were female (59/80, 73.8%), were educated to the college/university level or higher (48/80, 59.9%), had a mental health disorder (22/80, 27.5%), and when reporting where they see themselves on the political spectrum, scores ranged from 0-100 (Mean = 46.9,  $SD = 25.3$ ) [see Multimedia Appendix 10].

# **Discussion**

## **Principal Findings**

This paper offers a description of longitudinal trends in attitudes and behaviors related to the COVID-19 pandemic. Additionally, we report descriptive data from two smaller-scale mirror studies conducted in the USA and Mexico for comparison. Descriptive data for the UK daily poll questions indicated that participants generally followed social distancing measures, but worry and negative impact on families increased as the pandemic progressed. Our cross-sectional baseline assessment in



a UK adult population indicated that those with poorer mental health outcomes lived in more deprived neighborhoods, in larger households, had more pre-existing mental health disorders and medical conditions, and were younger than 65 years.

In terms of the UK pandemic trajectory, cases and deaths were relatively stable for most of this period, with more rapid increases observed only in the final month. UK longitudinal smartphone data from 6 of the poll questions indicated that as the pandemic progressed and the 7-day rolling average of cases and deaths began to increase rapidly, participants became more worried about the pandemic with a corresponding negative impact on their families. Although most people felt that information about the COVID-19 pandemic had been conveyed clearly, their trust in the government response was much lower. Nevertheless, participants reported generally following social distancing measures (responses varied between 50 and 99%), and 30-40% of participants also reported spending more time than usual using social media, even though the average age of our UK sample was nearly 60 years.

Cross-sectional data from our first-wave baseline assessments in the UK yielded several important findings. Participants with pre-existing mental health disorders reported worse outcomes across all mental health and psychosocial indicators. Unsurprisingly, those with pre-existing mental disorders reported more symptomatology. However, those with medical conditions and younger participants (less than 65 years) also had increased psychological symptomatology. Specifically, 25% and 17% of participants with chronic medical conditions reported currently experiencing moderate-to-severe anxiety and depressive symptoms, respectively. Similarly, 35% and 25% of younger participants reported currently experiencing moderate-to-severe anxiety and depressive symptoms, respectively.

These data parallel other UK cohort studies conducted during the COVID-19 pandemic as we found that depressive and anxiety symptomatology was higher in our UK sample relative to epidemiological data collected before the COVID-19 pandemic. [48]–[51]. We had hypothesized that older adults (> 65 years) in our sample would experience worse mental health outcomes than younger participants because older people are at higher risk for worse COVID-19 related outcomes. However, after controlling for demographic factors and co-morbid mental health and medical conditions, this was not the case. Instead, our data suggest chronic medical conditions are a greater risk factor than older age for poor mental health outcomes. The relationships identified between deprivation, population density, and household composition suggest that they may be surrogates for poorer housing,

overcrowding, or the need to use public transportation, which increase the risk of COVID exposure.

Consistent with other online surveys assessing mental health outcomes, women were over-represented in our study sample [50]. Although this overrepresentation limits some of our conclusions, women are experiencing a disproportionate economic and employment burden related to COVID-19, along with mothers having increased childcare responsibilities [52]. These factors could have long-term deleterious effects on mental health. As our study moves into longitudinal analysis, we can determine how mental health symptoms are related to attitudes and behaviors associated with COVID-19 and whether robust, rather than uncertain public health measures, ameliorate mental health difficulties [53]. Future interventions will need to be tailored to individual and community needs whilst tackling entrenched pre-existing mental health inequities.

Other notable findings from this study were the relationship between mental health, psychosocial outcomes, and potential risk factors, although they likely existed before the COVID-19 pandemic. Data revealed that those with poor quality of life were more likely than those with excellent quality of life to live in more populated neighborhoods. Further, higher household composition was related to more anxiety and depressive symptoms but appeared protective with regards to social isolation. Most prominently, living in the most socioeconomically deprived neighborhoods (quintile = 1) was predictive of worse outcomes for all indicators, except quality of life. These results are concerning because they indicate the potential for an exacerbation of pre-existing inequities, particularly if future interventions are not tailored with a consideration of these factors. Evidence shows that those who live in the most deprived neighborhoods are hospitalized more frequently for COVID-19 infections [54]. Our results indicate that the impact of neighborhood deprivation may not only encompass physical health but may be more wide-ranging and include mental health and quality of life.

Many participants reported physical health changes since the pandemic began. Strikingly, nearly 60% of participants reported being more sedentary, and over 40% reported engaging in less physical activity. These results are in conjunction with 40% of participants reporting receiving less preventative or routine medical care. Lockdown measures have reduced physical activity opportunities, and these restrictions to limit the spread of COVID-19 infection may result in a less healthy populace [50]. Given the importance of early detection for many diseases, the impact of reduced preventative care combined with poorer engagement in health-promoting behaviors may be profound. As the risk of infection may remain high for some time, medical providers, administrators,

and policymakers should continue to assess procedures to optimize care for all patients as well as identify safe avenues for increasing daily physical activity and reducing time spent sedentary [55].

### **Limitations**

There are limitations of the findings reported in this study. A potential limitation of our survey study is self-selection bias, as participants may have joined the study as they were particularly interested in the topic. Although we used various recruitment methods, targeted efforts to improve representation, and placed a strong emphasis on anonymity and confidentiality, our UK sample was more likely to be White and from higher educational backgrounds, which is not representative of the UK population and so limits the generalizability of our findings to non-White and lower-income communities. Efforts to engage and form partnerships have begun to increase the representativeness of our sample for future longitudinal analyses. Additionally, data from Mexico ATTACH currently includes over 1200 baseline assessments, so diverse between country analyses will be possible for future waves. However, for the current UK baseline assessment, cultural factors and behavioral strategies specific to the UK, such as strong public messaging to protect the National Health Service (NHS), may mean our results do not generalize outside the UK.

This study began recruiting after the first UK lockdown (March 2020), so we lack real-time data from before the COVID-19 pandemic and cannot know if symptomology has changed. Further, indicators of pre-existing mental health disorders and chronic medical conditions were based on self-report rather than clinical diagnoses. Given the unprecedented nature of the pandemic, we prioritized rapid deployment and data collection and so did not pilot test poll questions. However, many of the questions mirror those of other newly developed studies [56], [57]. The fast changes related to the pandemic meant that we could not consider all possible predictors before study initiation, so there are no measures related to quarantine status, fear of COVID-19, and duration of exposure to COVID-19-related information, and infection risk perception. Although 87% of the UK population has access to a smartphone, just 53% of those aged 65+ have internet access via smartphone ownership [58]. Access to digital devices and the internet are also limited among other marginalized communities. Therefore, those who are digitally excluded are likely to be underrepresented in our sample.

### **Strengths**

Strengths of our study include the mix of cross-sectional and longitudinal data collection methodology with the ability to assess daily attitudes and behaviors during the rapidly changing

COVID-19 pandemic. Through the use of smartphone technology and mHealth, we can capture real-time responses and bridge physical distance. Participants completed most measures with little missing data, indicating that items were not burdensome. Finally, although our UK sample needs to increase representation related to ethnic and racialized identities, our Mexican sample includes a cross-section of communities. Through targeted recruitment, the USA sample includes an overrepresentation of participants who identified as Black or African American.

## Implications

Smartphone apps are increasingly recognized as potentially powerful tools for mobile health studies and interventions [59], [60]. They have been utilized successfully in adult and pediatric chronic illness populations [61]–[64] and in ecological momentary assessment studies and interventions [65], [66]. Data from the UK ATTACH study demonstrates that people are also prepared to answer daily questions and provide mental health data in a longitudinal study using smartphone technology. Optimizing digital approaches and integrating them into the public health response is possible whilst considering logistical and technological barriers. However, currently, there is limited evidence that mHealth apps and interventions are cost-effective or cost-saving [67], [68]. This engagement increases the feasibility of undertaking potentially sensitive longitudinal research and reduces retrospective judgments that tend to be affected by recall bias [66]. Because of this engagement, moving forwards, the Mexico ATTACH study will use the Telegram messaging system to collect daily poll data, as it is widely accessible with an encrypted point-to-point connection. As we move forwards, it will be necessary to including participants input early in the research process to engender long and short term engagement [69].

## Conclusions

Our data indicate that those with mental health disorders and chronic medical conditions are experiencing increased anxiety and depressive symptoms. Socioeconomic deprivation also appears to be a considerable risk factor for poor mental health. Although these challenges are not new, they could become more deep-rooted and challenging to tackle in this new COVID-19 era and beyond. Along with a renewed focus on mental health, investment to increase access to preventative medical care and messaging to encourage health-promoting behaviors, including physical activity, will be critical.

## Acknowledgements

The authors want to thank all of the community stakeholders (i.e., Crescent Kids) and organizations (i.e., McPin Foundation), research recruitment sites (i.e., Join Dementia Research, Call for Participants, Psychology on the Net), charity organizations (i.e., Crohn's and Colitis UK, Pancreatic Cancer UK, Autistica, Sickle Cell Society, Parkinson's UK, Pancreatic Cancer UK), and the Avon & Wiltshire Mental Health Partnership NHS Trust.

## Author's Contributions

AH, HS, JM, MK, AS, CS, MP, NCF, AA, MM, SW, MK, FK, and LC contributed to the conception and design of the study. AH, HS, JM, MK, AS, CS, MP, NCF, AA, AB, AN, SG, MM, SW, MK, FK, and LC contributed to the organization of the conduct of the study. AH, CS, MP, NCF, AA, AB, AN, SG, and CW carried out the study (including data acquisition). AH and AS analyzed the data. AH drafted the initial output. All authors contributed to the interpretation of data. All authors have read and approved the final version of the manuscript.

## Conflicts of Interest

None declared

## Multimedia Appendix

Multimedia Appendix 1. Complete list of daily poll questions and the assessment schedule.

Multimedia Appendix 2. Validated measures and assessment schedule in the ATTACH Study.

Multimedia Appendix 3. Non-validated measures and assessment schedule in the ATTACH Study.

Multimedia Appendix 4. Measures used in the ATTACH study

Multimedia Appendix 5. Recruitment strategies and example Facebook advertisement used in the ATTACH study.

Multimedia Appendix 6. Mental health disorders and medical conditions reported in the ATTACH study.

Multimedia Appendix 7. Participant characteristics at baseline in the UK ATTACH Study from June 26 to October 31, 2020.

Multimedia Appendix 8. Participant clinical classifications and severity on self-reported outcomes at baseline in the UK ATTACH study from June 26 to October 31, 2020.

Multimedia Appendix 9. Participant characteristics at baseline in the USA ATTACH Study from June 26 to October 31, 2020.

Multimedia Appendix 10. Participant characteristics at baseline in the Mexico ATTACH Study from October 6 to October 31, 2020.

## Data Sharing

Data will be shared upon reasonable request and with permission according to the Attitudes About COVID-19 and Health Group data release policy.

## Abbreviations

AMO: Air My Opinion

ATTACH: Attitudes About COVID-19 and Health

BBC: British Broadcasting Corporation

CI: Confidence Interval

COVID-19: Coronavirus disease 2019

GDPR: General Data Protection Regulation

IMD: Index of Multiple Deprivation

NHS: National Health Service

PROMIS: Patient-Reported Outcomes Measurement Information System

PHQ-9: Patient Health Questionnaire

REDCap: Research Electronic Data Capture

SMS: Short Message Service

UCL: University College London

UK: United Kingdom

USA: United States of America

WHO: World Health Organization

## Figure Legends

Figure 1. Theoretical Model

Figure 2. Smartphone survey polling system. SMS: Short message service; AMO: Air My Opinion

Figure 3. Schematic of an Attitudes About COVID-19 and Health study notification and poll question on the Air My Opinion smartphone app.

Figure 4. Graphs represent United Kingdom longitudinal daily poll responses for 6 COVID-19-related questions in the categories of health, personal concerns, worry or hope, compliance or rationale, government trust, and habits from July 15th, 2020, to October 15th, 2020. Error bars represent 95% confidence intervals. Participant “somewhat” and “yes” are grouped together for analyses

## References

- [1] W. H. O. (WHO), "Coronavirus disease 2019 (COVID-19) Situation Report–36. Geneva: WHO; 2020." .
- [2] B. M. Prüß, "Current State of the First COVID-19 Vaccines," *Vaccines*, vol. 9, no. 1, p. 30, 2021.
- [3] E. Mahase, "Vaccinating the UK: how the covid vaccine was approved, and other questions answered." British Medical Journal Publishing Group, 2020.
- [4] "Cofepris aprueba uso en emergencias de vacuna Pfizer contra COVID-19," *Gobierno de México*. [Online]. Available: <https://www.gob.mx/salud/prensa/249-cofepris-aprueba-uso-en-emergencias-de-vacuna-pfizer-contra-covid-19>. Mexico was the first to approve in Latin America. [Accessed: 23-Mar-2021].
- [5] J. A. Lewnard and N. C. Lo, "Scientific and ethical basis for social-distancing interventions against COVID-19," *Lancet. Infect. Dis.*, 2020.
- [6] F. Jiang, L. Deng, L. Zhang, Y. Cai, C. W. Cheung, and Z. Xia, "Review of the clinical characteristics of coronavirus disease 2019 (COVID-19)," *J. Gen. Intern. Med.*, pp. 1–5, 2020.
- [7] J. A. C. Everett, C. Colombatto, V. Chituc, W. J. Brady, and M. Crockett, "The effectiveness of moral messages on public health behavioral intentions during the COVID-19 pandemic," 2020.
- [8] S. Galea, R. M. Merchant, and N. Lurie, "The Mental Health Consequences of COVID-19 and Physical Distancing: The Need for Prevention and Early Intervention," *JAMA Intern. Med.*, 2020.
- [9] J. Bueno-Notivol, P. Gracia-García, B. Olaya, I. Lasheras, R. López-Antón, and J. Santabárbara, "Prevalence of depression during the COVID-19 outbreak: a meta-analysis of community-based studies," *Int. J. Clin. Heal. Psychol.*, vol. 21, no. 1, p. 100196, 2021.



- [10] L. Cluver *et al.*, “Parenting in a time of COVID-19,” 2020.
- [11] G. A. Bonanno, C. R. Brewin, K. Kaniasty, and A. M. La Greca, “Weighing the costs of disaster: Consequences, risks, and resilience in individuals, families, and communities,” *Psychol. Sci. public Interes.*, vol. 11, no. 1, pp. 1–49, 2010.
- [12] V. E. Cobham, B. McDermott, D. Haslam, and M. R. Sanders, “The role of parents, parenting and the family environment in children’s post-disaster mental health,” *Curr. Psychiatry Rep.*, vol. 18, no. 6, p. 53, 2016.
- [13] A. S. Masten and F. Motti-Stefanidi, “Multisystem resilience for children and youth in disaster: reflections in the context of CoViD-19,” *Advers. Resil. Sci.*, vol. 1, no. 2, pp. 95–106, 2020.
- [14] J. M. Shultz, F. Baingana, and Y. Neria, “The 2014 Ebola outbreak and mental health: current status and recommended response,” *Jama*, vol. 313, no. 6, pp. 567–568, 2015.
- [15] I. W. C. Mak, C. M. Chu, P. C. Pan, M. G. C. Yiu, and V. L. Chan, “Long-term psychiatric morbidities among SARS survivors,” *Gen. Hosp. Psychiatry*, vol. 31, no. 4, pp. 318–326, 2009.
- [16] E. A. Holmes *et al.*, “Multidisciplinary research priorities for the COVID-19 pandemic: a call for action for mental health science,” *The Lancet Psychiatry*, 2020.
- [17] K. Qureshi, B. Kasstan, N. Meer, and S. Hill, “Submission of evidence on the disproportionate impact of COVID-19, and the UK government response, on ethnic minorities in the UK,” 2020.
- [18] “Beyond the data: Understanding the impact of COVID-19 on BAME groups,” 2020.
- [19] M. Lemstra, C. Neudorf, C. D’Arcy, A. Kunst, L. M. Warren, and N. R. Bennett, “A systematic review of depressed mood and anxiety by SES in youth aged 10–15 years,” *Can. J. Public Heal.*, vol. 99, no. 2, pp. 125–129, 2008.
- [20] V. Lorant, D. Delière, W. Eaton, A. Robert, P. Philippot, and M. Anseau, “Socioeconomic inequalities in depression: a meta-analysis,” *Am. J. Epidemiol.*, vol. 157, no. 2, pp. 98–112, 2003.
- [21] S. L. Dalglish, “COVID-19 gives the lie to global health expertise,” *Lancet*, vol. 395, no. 10231, p. 1189, 2020.
- [22] S. Dahal, J. M. Banda, A. I. Bento, K. Mizumoto, and G. Chowell, “Characterizing all-cause excess mortality patterns during COVID-19 pandemic in Mexico,” *BMC Infect. Dis.*, vol. 21, no. 1, pp. 1–10, 2021.
- [23] S. Michie, R. West, and R. Amlôt, “Behavioural strategies for reducing covid-19 transmission

- in the general population,” *BMJ Opin.*, vol. 3, 2020.
- [24] M. A. Acuña-Zegarra, M. Santana-Cibrian, and J. X. Velasco-Hernandez, “Modeling behavioral change and COVID-19 containment in Mexico: A trade-off between lockdown and compliance,” *Math. Biosci.*, vol. 325, p. 108370, 2020.
- [25] H. J. Hutchins *et al.*, “COVID-19 mitigation behaviors by age group—United States, April–June 2020,” *Morb. Mortal. Wkly. Rep.*, vol. 69, no. 43, p. 1584, 2020.
- [26] A. M. Hood *et al.*, “Attitudes About COVID-19 and Health (ATTACH) study,” 2021. [Online]. Available: [osf.io/dm4uv](https://osf.io/dm4uv).
- [27] E. Von Elm, D. G. Altman, M. Egger, S. J. Pocock, P. C. Gøtzsche, and J. P. Vandenbroucke, “The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies,” *Ann. Intern. Med.*, vol. 147, no. 8, pp. 573–577, 2007.
- [28] G. Eysenbach, “Improving the quality of Web surveys: the Checklist for Reporting Results of Internet E-Surveys (CHERRIES),” *J. Med. Internet Res.*, vol. 6, no. 3, p. e34, 2004.
- [29] D. Cella *et al.*, “The Patient-Reported Outcomes Measurement Information System (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005–2008,” *J. Clin. Epidemiol.*, vol. 63, no. 11, pp. 1179–1194, 2010.
- [30] A. Martin, W. Rief, A. Klaiberg, and E. Braehler, “Validity of the brief patient health questionnaire mood scale (PHQ-9) in the general population,” *Gen. Hosp. Psychiatry*, vol. 28, no. 1, pp. 71–77, 2006.
- [31] D. W. Russell, “UCLA Loneliness Scale (Version 3): Reliability, validity, and factor structure,” *J. Pers. Assess.*, vol. 66, no. 1, pp. 20–40, 1996.
- [32] D. J. Grasso, M. J. Briggs-Gowan, A. S. Carter, B. L. Goldstein, and J. D. Ford, “Profiling COVID-related experiences in the United States with the Epidemic-Pandemic Impacts Inventory: Linkages to psychosocial functioning,” *Brain Behav.*, p. e02197, 2021.
- [33] J. Crone, “Office for National Statistics Postcode Directory (ONSPD) Open February 2011 edition,” 2017.
- [34] C. & L. G. Ministry of Housing, “The English Indices of Deprivation 2019 (IoD2019),” 2019.
- [35] National Statistics, “Welsh Index of Multiple Deprivation,” 2019. [Online]. Available: <https://gov.wales/welsh-index-multiple-deprivation-full-index-update-ranks-2019>. [Accessed: 20-Feb-2021].
- [36] Scottish Government, “Scottish Index of Multiple Deprivation 2020,” 2019.
- [37] Northern Ireland Statistics and Research Agency, “Northern Ireland Multiple Deprivation

- Measure 2017,” 2019. [Online]. Available: <https://www.nisra.gov.uk/statistics/deprivation/northern-ireland-multiple-deprivation-measure-2017-nimdm2017>. [Accessed: 20-Feb-2021].
- [38] Office for National Statistics, “Key Statistics – Census 2011,” 2011. [Online]. Available: <https://www.ons.gov.uk>. [Accessed: 20-Feb-2021].
- [39] Scottish Census, “Standard Outputs: Population Density,” 2011. [Online]. Available: <https://www.scotlandscensus.gov.uk/ods-web/standard-outputs.html?year=2011&table=QS102SC&tableDescription=Population density>. [Accessed: 20-Feb-2021].
- [40] Northern Ireland Statistics and Research Agency, “Population Statistics,” 2011. [Online]. Available: <https://www.ninis2.nisra.gov.uk/public/Theme.aspx?themeNumber=74&themeName=Population>. [Accessed: 20-Feb-2021].
- [41] P. A. Harris, R. Taylor, R. Thielke, J. Payne, N. Gonzalez, and J. G. Conde, “Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support,” *J. Biomed. Inform.*, vol. 42, no. 2, pp. 377–381, 2009.
- [42] J. S. Obeid *et al.*, “Procurement of shared data instruments for research electronic data capture (REDCap),” *J. Biomed. Inform.*, vol. 46, no. 2, pp. 259–265, 2013.
- [43] R. D. C. T. 3.5.1., “A Language and Environment for Statistical Computing,” *R Found. Stat. Comput.*, vol. 2, p. <https://www.R-project.org>, 2018.
- [44] S. A. S. Institute, *Base SAS 9.4 procedures guide*. SAS Institute, 2015.
- [45] “HealthMeasures Scoring Service powered by Assessment Center.” [Online]. Available: [https://www.assessmentcenter.net/ac\\_scoringservice](https://www.assessmentcenter.net/ac_scoringservice). [Accessed: 27-Feb-2021].
- [46] K. Kroenke, R. L. Spitzer, J. B. W. Williams, and B. Löwe, “The patient health questionnaire somatic, anxiety, and depressive symptom scales: a systematic review,” *Gen. Hosp. Psychiatry*, vol. 32, no. 4, pp. 345–359, 2010.
- [47] M. J. Penning, G. Liu, and P. H. B. Chou, “Measuring loneliness among middle-aged and older adults: The UCLA and de Jong Gierveld loneliness scales,” *Soc. Indic. Res.*, vol. 118, no. 3, pp. 1147–1166, 2014.
- [48] R. Jia *et al.*, “Mental health in the UK during the COVID-19 pandemic: cross-sectional analyses from a community cohort study,” *BMJ Open*, vol. 10, no. 9, p. e040620, 2020.
- [49] M. Pierce *et al.*, “Mental health before and during the COVID-19 pandemic: a longitudinal probability sample survey of the UK population,” *The Lancet Psychiatry*, vol. 7, no. 10, pp. 883–892, 2020.

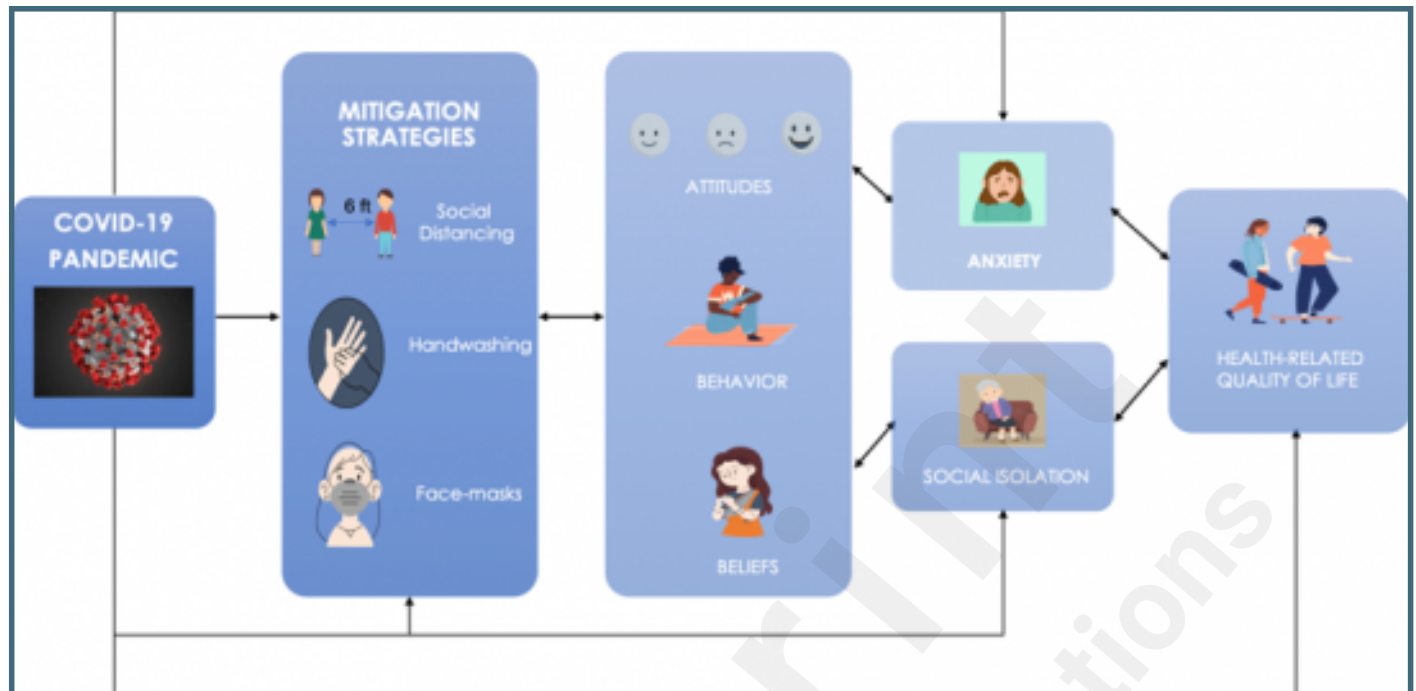
- [50] M. Daly, A. R. Sutin, and E. Robinson, "Longitudinal changes in mental health and the COVID-19 pandemic: Evidence from the UK Household Longitudinal Study," *Psychol. Med.*, pp. 1–10, 2020.
- [51] C. Pieh, S. Budimir, J. Delgadillo, M. Barkham, J. R. J. Fontaine, and T. Probst, "Mental health during COVID-19 lockdown in the United Kingdom," *Psychosom. Med.*, vol. 83, no. 4, pp. 328–337, 2021.
- [52] R. J. Petts, D. L. Carlson, and J. R. Pepin, "A gendered pandemic: Childcare, homeschooling, and parents' employment during COVID-19," *Gender, Work Organ.*, 2020.
- [53] S. Chakrabarti, L. C. Hamlet, J. Kaminsky, and S. V Subramanian, "Association of Human Mobility Restrictions and Race/Ethnicity–Based, Sex-Based, and Income-Based Factors With Inequities in Well-being During the COVID-19 Pandemic in the United States," *JAMA Netw. open*, vol. 4, no. 4, pp. e217373–e217373, 2021.
- [54] A. P. Khawaja *et al.*, "Associations with covid-19 hospitalisation amongst 406,793 adults: the UK Biobank prospective cohort study," *MedRxiv*, 2020.
- [55] A. Serlachius, S. M. Badawy, and H. Thabrew, "Psychosocial challenges and opportunities for youth with chronic health conditions during the COVID-19 pandemic," *JMIR Pediatr. Parent.*, vol. 3, no. 2, p. e23057, 2020.
- [56] M. S. Hagger, S. R. Smith, J. J. Keech, S. A. Moyers, and K. Hamilton, "Predicting social distancing intention and behavior during the COVID-19 pandemic: An integrated social cognition model," *Ann. Behav. Med.*, vol. 54, no. 10, pp. 713–727, 2020.
- [57] C. Armour, E. McGlinchey, S. Butter, K. McAloney-Kocaman, and K. E. McPherson, "The COVID-19 Psychological Wellbeing Study: Understanding the Longitudinal Psychosocial Impact of the COVID-19 Pandemic in the UK; a Methodological Overview Paper," *J. Psychopathol. Behav. Assess.*, pp. 1–17, 2020.
- [58] "Number of mobile phone users worldwide from 2015 to 2020 (in billions)," *Statista*, 2020. [Online]. Available: <https://www.statista.com/statistics/274774/forecast-of-mobile-phone-users-worldwide/>. [Accessed: 01-Apr-2020].
- [59] B. C. Zapata, J. L. Fernández-Alemán, A. Idri, and A. Toval, "Empirical studies on usability of mHealth apps: a systematic literature review," *J. Med. Syst.*, vol. 39, no. 2, pp. 1–19, 2015.
- [60] D. D. Luxton, R. A. McCann, N. E. Bush, M. C. Mishkind, and G. M. Reger, "mHealth for mental health: Integrating smartphone technology in behavioral healthcare.," *Prof. Psychol. Res. Pract.*, vol. 42, no. 6, p. 505, 2011.
- [61] M. Farzandipour, E. Nabovati, R. Sharif, M. H. Arani, and S. Anvari, "Patient self-

- management of asthma using mobile health applications: a systematic review of the functionalities and effects,” *Appl. Clin. Inform.*, vol. 8, no. 4, p. 1068, 2017.
- [62] S. M. Badawy *et al.*, “Patient-centered eHealth interventions for children, adolescents, and adults with sickle cell disease: systematic review,” *J. Med. Internet Res.*, vol. 20, no. 7, p. e10940, 2018.
- [63] A. M. Hood *et al.*, “Mobile Health Use Predicts Self-Efficacy and Self-Management in Adolescents with Sickle Cell Disease,” *Blood*, vol. 136, no. Supplement 1, pp. 57–58, Nov. 2020.
- [64] L. F. Garabedian, D. Ross-Degnan, and J. F. Wharam, “Mobile phone and smartphone technologies for diabetes care and self-management,” *Curr. Diab. Rep.*, vol. 15, no. 12, pp. 1–9, 2015.
- [65] J. D. Runyan, T. A. Steenbergh, C. Bainbridge, D. A. Daugherty, L. Oke, and B. N. Fry, “A smartphone ecological momentary assessment/intervention ‘app’ for collecting real-time data and promoting self-awareness,” *PLoS One*, vol. 8, no. 8, p. e71325, 2013.
- [66] J. D. Runyan and E. G. Steinke, “Virtues, ecological momentary assessment/intervention and smartphone technology,” *Front. Psychol.*, vol. 6, p. 481, 2015.
- [67] S. J. Iribarren, K. Cato, L. Falzon, and P. W. Stone, “What is the economic evidence for mHealth? A systematic review of economic evaluations of mHealth solutions,” *PLoS One*, vol. 12, no. 2, p. e0170581, 2017.
- [68] S. M. Badawy and L. M. Kuhns, “Economic evaluation of text-messaging and smartphone-based interventions to improve medication adherence in adolescents with chronic health conditions: a systematic review,” *JMIR mHealth uHealth*, vol. 4, no. 4, p. e121, 2016.
- [69] O. Perski, A. Blandford, R. West, and S. Michie, “Conceptualising engagement with digital behaviour change interventions: a systematic review using principles from critical interpretive synthesis,” *Transl. Behav. Med.*, vol. 7, no. 2, pp. 254–267, 2017.

## Supplementary Files

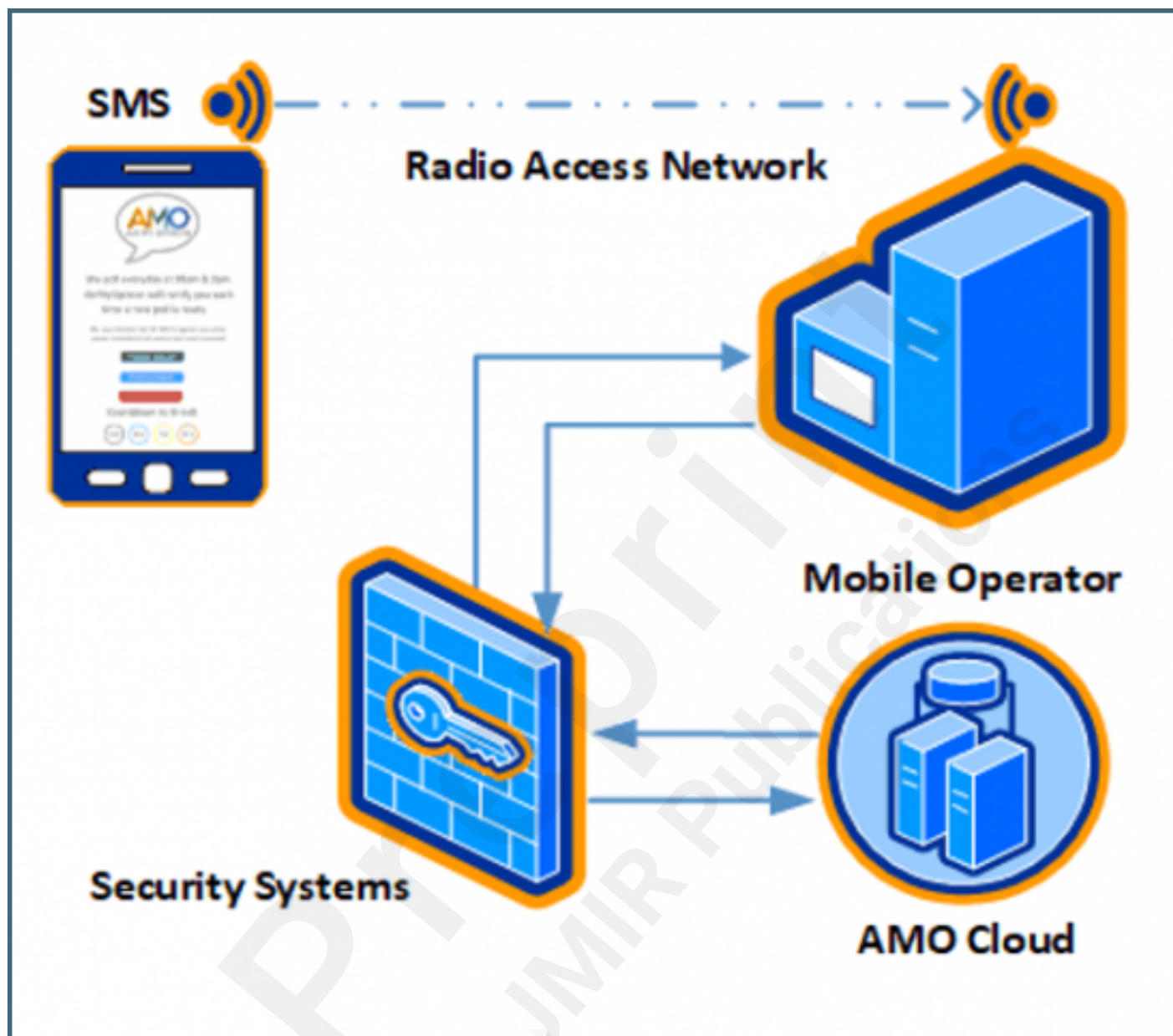
## Figures

## Theoretical Model.





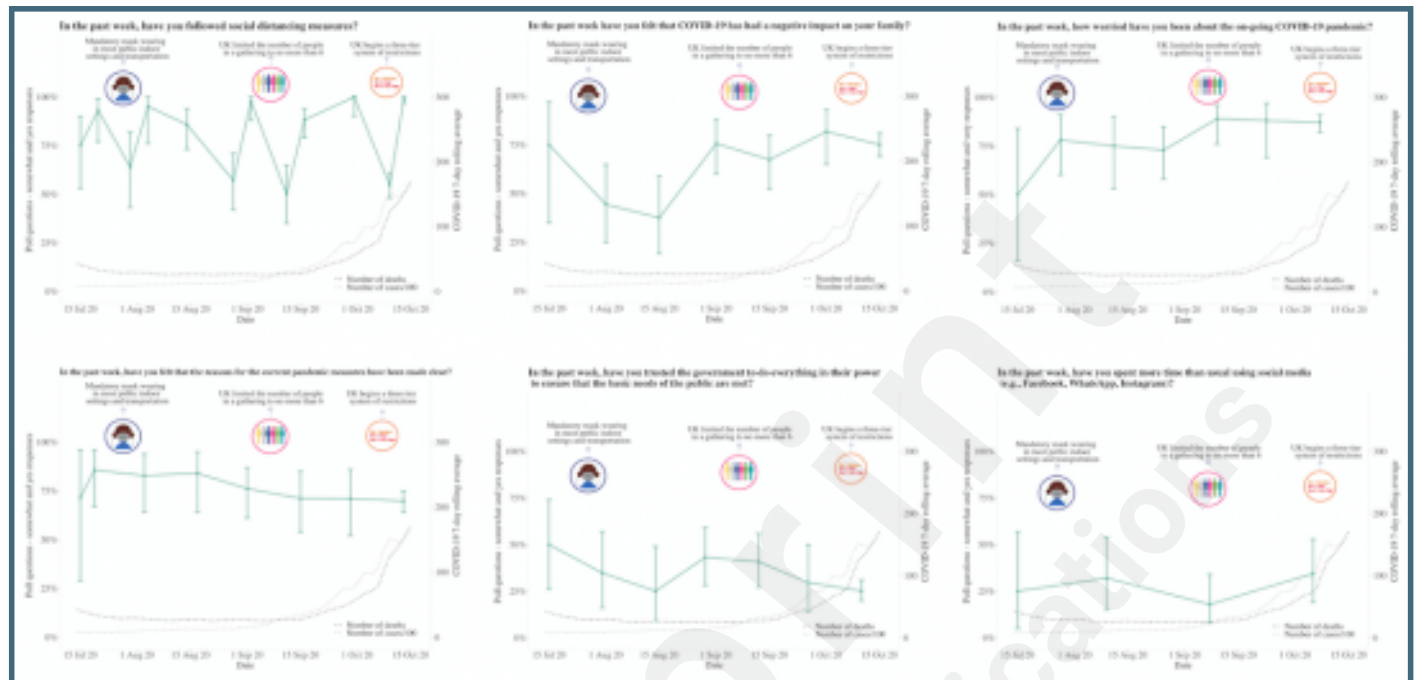
Smartphone survey polling system. SMS: Short message service; AMO: Air My Opinion.



Schematic of an Attitudes About COVID-19 and Health study notification and poll question on the Air My Opinion smartphone app.



Graphs represent United Kingdom longitudinal daily poll responses for 6 COVID-19-related questions in the categories of health, personal concerns, worry or hope, compliance or rationale, government trust, and habits from July 15th, 2020 to October 15th, 2020. Error bars represent 95% confidence intervals. Participant “somewhat” and “yes” are grouped together for analyses.



## **Multimedia Appendixes**

Complete list of daily poll questions and the assessment schedule.

URL: <http://asset.jmir.pub/assets/2ba176c6ac92c44317d274573fab7853.docx>

Validated measures and assessment schedule in the ATTACH Study.

URL: <http://asset.jmir.pub/assets/77649475faba33337ec5319364572bf3.docx>

Non-validated measures and assessment schedule in the ATTACH Study.

URL: <http://asset.jmir.pub/assets/da4443d7c5243499ae89e4e7650b0ebb.docx>

Measures used in the ATTACH study.

URL: <http://asset.jmir.pub/assets/8b483e6d3d42850dd764f37ca146b32e.docx>

Recruitment strategies and example Facebook advertisement used in the ATTACH study.

URL: <http://asset.jmir.pub/assets/cfc0d94d6acc3282196bcf6b49ecaa20.docx>

Mental health disorders and medical conditions reported in the ATTACH study.

URL: <http://asset.jmir.pub/assets/99fcd3f1bf974a0b4681959e80434099.docx>

Participant characteristics at baseline in the UK ATTACH Study from June 26 to October 31, 2020.

URL: <http://asset.jmir.pub/assets/342f679246e55f2f1ccebcbd83794268.docx>

Participant clinical classifications and severity on self-reported outcomes at baseline in the UK ATTACH study from June 26 to October 31, 2020.

URL: <http://asset.jmir.pub/assets/f219520cfb25bc6b77c6d2a9268fb7ed.docx>

Participant characteristics at baseline in the USA ATTACH Study from June 26 to October 31, 2020.

URL: <http://asset.jmir.pub/assets/065f12b355d6a4b1e797601b2f6bbc5b.docx>

Participant characteristics at baseline in the Mexico ATTACH Study from October 6 to October 31, 2020.

URL: <http://asset.jmir.pub/assets/342cbe4a4605a98f30b570ddb6df5c5c.docx>