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Time spent playing video games during periods of isolation has no effect on loneliness or mental health

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ABSTRACT

Video games are a ubiquitous form of entertainment that also have the potential to fulfil the socialisation needs of players. In recent years, policy makers and healthcare providers have voiced growing concerns regarding the potential for video gaming to negatively impact mental health and foster social isolation. However, empirical data regarding the potential relationship between time spent gaming, loneliness, and mental health outcomes is lacking. Therefore, the present study aimed to examine this potential relationship using three nationwide COVID-19 lockdowns as models of increased risk of loneliness and poor mental health, across three individual studies. Time spent gaming had no direct relationship with either mental health or loneliness measures taken during lockdown, and this relationship was not moderated by loneliness. While lockdown alone did not impact mental health, loneliness was consistently associated with poor mental health outcomes during lockdown. Our results add to the existing body of literature on the relationship between video gaming and mental health and emphasise the need for targeted public mental health interventions to improve public mental health during periods of isolation. Data and analysis code associated with this project is accessible at: https://osf.io/d5byr/?view_only=6b1b0cd0be9b4e34b6e0a07881d2ef50.

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KEYWORDS
Depression; stress; anxiety loneliness; video games

1. Introduction

Video gaming is defined as playing electronic games via consoles (e.g. Sony PlayStation, Microsoft Xbox, Nintendo Wii), tablets (e.g. iPads), mobile devices (e.g. smart phones), or personal computers (PCs). Globally, it is estimated that in 2022 approximately 3.2 billion people play video games, and forecasts suggest this number is likely to increase (Newzoo 2022). Consequently, several stakeholders, including national governments and healthcare providers, have publicised their concerns regarding potential negative effects that time spent playing video games could have on players' mental health (e.g. defined in this context as increased depression/low mood, anxiety/worry, risk of substance misuse, for a review see Männikkö et al. 2020). Such concerns have led to substantial policy changes in some regions, in attempts to restrict the amount of time available for online gaming (Colder Carras et al. 2021).

However, empirical research into the relationship between video gaming and mental health is complicated. For example, several studies have reported that video gaming is associated with symptoms of mental illness and poor psychosocial functioning (Caplan 2007; Faulkner et al. 2015; Mathers et al. 2009; Mihara and Higuchi 2017; Stockdale and Coyne 2018; Wang, Cho, and Kim 2018; Wittek et al. 2016; Yau, Potenza, and White 2013). Critically, it should be noted that these studies typically examine participants who exhibit pathological gaming behaviour (e.g. gaming addiction). Further studies have shown that indices of poor mental health (e.g. low self-esteem, increased loneliness, poor social function) are precursors to pathological video gaming rather than consequences (Chak and Leung 2004; Ko et al. 2005; Lemmens, Valkenburg, and Peter 2011; Van Rooij et al. 2011). In contrast, other studies have demonstrated potential benefits of video gaming on mental health and psychological wellbeing (Colwell 2007; Desai et al. 2010; Granic, Lobel, and Engels 2014; Jones et al. 2014; Pallavicini, Ferrari, and Mantovani 2018; Snodgrass et al. 2011). For example, multiple studies using quantitative and qualitative methodologies

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have shown that moderate video game engagement can elicit positive emotions, (e.g. happiness, excitement, and surprise Comello et al. 2021; Durkin and Barber 2002; Hoffman and Nadelson 2010; Pallavicini and Pepe 2020; Przybylski et al. 2012; Russoniello, O'Brien, and Parks 2009; Shin et al. 2012; Snodgrass et al. 2011), reduce negative emotions (e.g. stress and/or anxiety; Caro and Popovac 2021; Horovitz et al. 2016; Pallavicini and Pepe 2020; Russoniello, O'Brien, and Parks 2009; Snodgrass et al. 2019; Soyoof and Mclay 2018) and improve players' emotional stability/emotion regulation (Przybylski et al. 2012; Villani et al. 2018).

Interestingly, the positive effects of video gaming may be dependent on the amount of time spent playing (Durkin and Barber 2002). For example, in a recent large study ($N = 3227$) Johannes, Vuorre, and Przybylski (2021) used both self-report and telemetry data to demonstrate a small dose-dependent effect of gaming on mental health outcomes, with more time spent playing producing the greatest benefits. In addition to mental health outcomes, it has been suggested that time spent video gaming may provide social benefits for players. In a qualitative study, Arbeau et al. (2020) reported that all participants described online gaming as a socially rewarding experience, with several participants highlighting social interaction while playing as integral to their enjoyment of the game. Similarly, several participants reported that online gaming helped them to maintain existing friendships when in-person socialising was not possible. On the other hand, a large-scale study ($N = 38{,}935$) reported that time spent playing video games was unlikely to yield any significant, causal effect on mental health (Vuorre et al. 2022). Unlike most previous studies, Vuorre et al. (2022) used a longitudinal design to establish a causal relationship between time spent gaming and wellbeing. Moreover, this study was not subject to the limitations often imposed by self-report measures, instead collecting game-play data (e.g. duration of each play session) directly by collaborating with game publishers. As such, the authors argued that a variety of methodological limitations may be responsible for inconsistent results throughout the gaming and mental health literature.

In addition to the methodological inconsistencies discussed by Vuorre et al. (2022), it is possible that the relationship between gaming and mental health outcomes are dependent on the presence of external, contextual factors. Indeed, a small number of studies have shown that video gaming is used by individuals as a coping mechanism specifically during stressful or negative life events (Caro and Popovac 2021; Iacovides and Mekler 2019; van Ingen, Utz, and Toepoel 2016). Caro and Popovac (2021) demonstrated that gaming during stress is underpinned by direct (connection with others, in-game character connection) and indirect factors (distraction, sense of achievement), and that poor emotion regulation and poor self-efficacy predicted the use of gaming during life stress. Consequently, it seems likely that individuals may use video gaming to socialise, reduce loneliness, improve mood, and feel a sense of achievement during particularly stressful situations.

The current paper attempts to investigate this potential relationship using the three COVID-19 lockdowns across the U.K. as a model of stress to investigate the relationship between video gaming, loneliness, and mental health outcomes. In the present studies, loneliness is defined as the affective component of social isolation, i.e. a distressing emotional state that occurs when an individuals' social needs are unmet. COVID-19 lockdowns provided a unique opportunity to examine this potential relationship for three reasons. Firstly, the lockdowns were associated with increased levels of stress (Jiao et al. 2020; Shah et al. 2021), anxiety (Chen et al. 2020; Dawson and Golijani-Moghaddam 2020; Gray et al. 2020; Jia et al. 2020), high levels of loneliness (Bu, Steptoe, and Fancourt 2020; Groarke et al. 2020; Jerome et al. 2020) and clinically significant levels of mental distress (Dawson and Golijani-Moghaddam 2020; Jerome et al. 2020; Shah et al. 2021). Secondly, COVID-19 lockdowns were associated with increased engagement with video games and related content. For example, in the week prior to the first U.K. lockdown, week-on-week increases in sales were reported for consoles (250%), physical games (218.2%), and digital downloads (67.4%, Dring 2020). These findings indicate an increase in individuals engaging with video games and suggest that many individuals became new console owners immediately prior to lockdown. Thirdly, a small number of studies have shown that video gaming is used by individuals as a coping mechanism specifically during stressful or negative life events (Caro and Popovac 2021; Iacovides and Mekler 2019; van Ingen, Utz, and Toepoel 2016). Consequently, it seems likely that individuals may use video gaming to socialise, reduce loneliness, improve mood, and feel a sense of achievement during COVID-19 lockdowns.

Each study followed the same cross-sectional, correlational design with the aim of investigating the relationship between gaming and mental health outcomes during highly stressful situations. In all studies, participants provided retrospective measures in place of a 'true' baseline measure (i.e. recalling from prior to the lockdown in question) and current measures (i.e. during the lockdown in question). Although retrospective measures are subject to potential emotional/

cognitive biases (Ross 1989), the unpredictable nature of the beginning of each lockdown did not allow for longitudinal data collection. Based on results from previous studies (e.g. Caro and Popovac 2021; Iacovides and Mekler 2019; van Ingen, Utz, and Toepoel 2016), we tested three hypotheses in each study. Firstly, we hypothesised that loneliness, depression, stress, and anxiety would worsen during each lockdown, in contrast to the weeks prior. Secondly, we hypothesised that hours spent gaming would be higher during each lockdown, compared to the weeks prior. Finally, we hypothesised that there would be a beneficial effect of gaming on mental health outcomes, but that loneliness would moderate this relationship. Specifically, we predicted that any beneficial effect of gaming hours on mental health outcomes would be dependent on the presence of loneliness, with greater levels of loneliness reducing any beneficial effect of gaming on depression, stress, and anxiety.

2. Study 1

Data for this study was collected during the first national lockdown in England (March–June 2020).

2.1. Methods

2.1.1. Participants

Five hundred and seventy-one participants responded to an online study advert specifically targeted to gamers. Adverts were placed on various forms of social media (e.g. Facebook, Twitter, Reddit) by members of the research team; all adverts contained a direct link to the study itself along with the participant information sheet. No incentive was offered for completing the study. Participants were excluded from the analysis if they met one or more of the following criteria: did not provide full consent, completed less than 90% of the survey, provided invalid employment details (i.e. stating they were both employed and unemployed at the time of participation), reporting having played no games before and during lockdown, more than 20% of responses missing data (e.g. skipped questions). We also excluded participants who reported more than 14 h per day playing video games to ensure that data was unlikely to include participants with a possible addiction to gaming.

After all exclusions, the sample included 220 participants (age $M = 32.01$, SD = 8.96, Range = 19–72). On average participants took 25.77 min (SD = 91.26) to complete the questionnaire. Figure 1 shows the number of participants in each employment situation during lockdown.

2.1.2. Procedure and materials

Participants were asked to complete the questionnaires below with respect to how they felt four weeks before lockdown (i.e. February 2020), and again with respect to how they felt at present (i.e. during the lockdown). This allowed for an approximate, albeit retrospective, baseline measure of each questionnaire.

2.1.3. Depression, anxiety, stress scale – 21 items (DASS-21, Antony et al. 1998; Lovibond and Lovibond 1995)

The DASS-21 was used to measure mental health outcomes. This 21-item scale is comprised of three subscales: depression, anxiety, and stress. The analysis considered each subscale individually. For each item, participants are required to indicate how often the item applies to them via a 4-point Likert scale (1 = Did not apply to me at all, 4 = Applied to me very much or most of the time).

2.1.4. UCLA Three-item Loneliness Scale (Hughes et al. 2004)

The UCLA Three-item Loneliness Scale was used to measure of loneliness. The three items ask participants to indicate how often they felt that they lacked companionship, felt left out, and felt isolated from others, using a 3-point Likert scale (1 = Hardly ever, 3 = Often).

2.1.5. Video gaming habits questionnaire (adapted from Waris et al. 2019)

We adapted the video gaming habits questionnaire reported by Waris et al. (2019) to measure whether participants played via a computer or console and to estimate how many hours they played on average per week.

2.1.6. Procedure

After consenting, all participants completed a series of demographic questions (e.g. age, sex/gender, education/employment status, living arrangement). They were also asked to provide information regarding the effect lockdown had on their employment (e.g. furloughed, worked from home, continued as normal). All participants were then presented with the DASS21, the Three-item Loneliness Scale, and the video gaming habits questionnaires. All questionnaires were administered twice during one survey session. After completing each questionnaire twice participants were fully debriefed and provided with contact information of relevant mental health support agencies.

2.2. Data analysis and model fitting

We used R [Version 4.0.3; R Core Team (2020)] and the R-packages BayesFactor [Version 0.9.12.4.2; Morey and

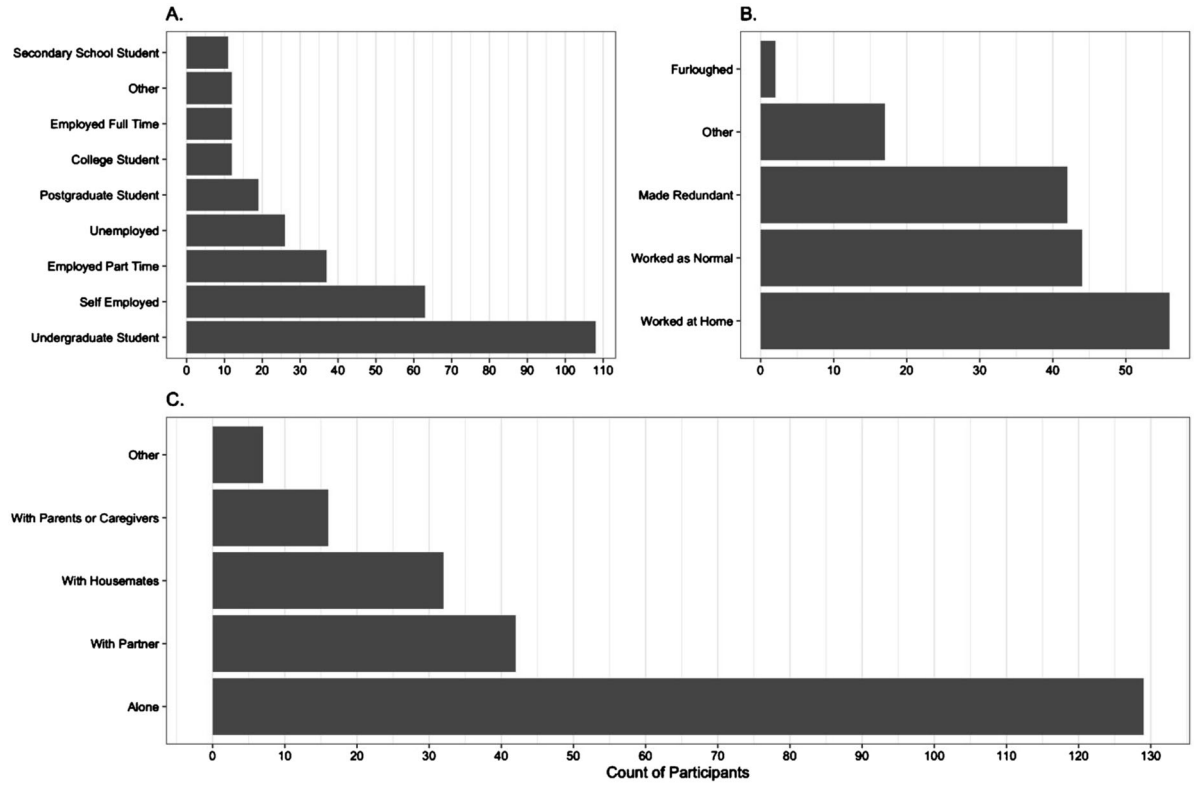

Figure 1. Count of participants by self-reported (a) employment status, (b) lockdown work situation, and (c) living situation.

Rouder (2018)], bayestestR [Version 0.9.0; Makowski, Ben-Shachar, and Lüdecke (2019)], brms [Version 2.14.4; Bürkner (2017); Bürkner (2018)], here [Version 1.0.1; Müller (2020)], mice [Version 3.13.0; van Buuren and Groothuis-Oudshoorn (2011)], modelr [Version 0.1.8; Wickham (2020)], tidybayes [Version 2.3.1; Kay (2020)], and tidyverse [Version 1.3.0; Wickham et al. (2019)] for all our analyses.

Prior to modelling the effect of lockdown and hours playing video games on mental health outcomes, we assessed whether gaming hours were higher during lockdown compared to prior. To do so, we used the BayesFactor R-package to perform a Bayesian paired samples t-test (with a default *Cauchy*$(0, \frac{\sqrt{2}}{2})$ prior) calculating the Bayes factor in support of the alternative hypothesis (i.e. of a non-zero effect) relative to the point-null hypothesis for an increase in hours played after lockdown. Estimates of the posterior mean and 95% credible intervals for the difference in hours played was obtained using MCMC sampling with 1000 posterior draws.

Primary analyses aimed to estimate the effect of hours played in games before and after lockdown on mental health outcomes including depression, anxiety, and stress (as measured by the DASS-21) and loneliness (as measured by the three-item loneliness scale). For all outcomes missing data was imputed using predictive mean matching. This affected .0029%, .0013%, .0013%, and .0023% of trials in the depression, anxiety, stress, and loneliness scales respectively. As the DASS-21 subscales and the Three-item Loneliness Scale are scored by summing ordinal responses, we analysed the data using ordinal models (Bürkner and Vuorre 2019). These models are more appropriate than typical methods (e.g. linear regression) for these data, even when based on sum scores, which can result in poor effect size estimates leading to incorrect inferences (Liddell and Kruschke 2018). A comparison of posterior predictive checks for candidate models showed the ordinal models to best capture the data generation process (see the Supplemental Materials at https://osf.io/d5byr/?view_only=6b1b0cd0be9b4e34b6e0a07 881d2ef50 for details).

The models took the form of a cumulative linear model with a logit link function. These models were fitted using the brm() function from the brms R-package (Bürkner 2018). Models contained a fixed effect of total hours played, lockdown period (i.e. before or during lockdown), and the interaction between them. The categorical fixed effect of lockdown period was sum-coded (before = −1, after = 1) while the continuous fixed effect of total hours played was z-transformed. Thus, individual parameter estimates for lockdown period and hours played represent main effects. All models contained random intercepts per participant.

Details of the priors for all models are outlined in Appendix 1. Parameter estimates and 95% credible intervals were obtained using MCMC sampling with 8000 posterior samples. We used the hypothesis() function from the brms R-package to calculate Bayes factors to evaluate evidence in support of the point-null hypothesis for each parameter estimate in relation to the alternative hypothesis (i.e. of a non-zero effect).[1] The Supplemental Material (see https://osf.io/d5byr/?view_only=6b1b0cd0be9b4e34b6e0a07881d2ef50) contains prior-predictive and posterior-predictive checks along with sensitivity checks evaluating how the prior scale affects parameter estimates and Bayes factors. All reported models show parameter estimates and Bayes factors to be relatively robust to different prior scales.

Finally, models were fitted evaluating whether depression, anxiety, or stress during lockdown are affected by any difference in hours played before and during lockdown, and further whether this effect is moderated by loneliness during lockdown. These models contained fixed effects of difference scores for hours played before and during lockdown, loneliness during lockdown, and their interaction using the same contrasts as in the main models. Again, these models took the form of a cumulative linear model with a logit link function, with continuous fixed effects of the difference in hours played and loneliness during lockdown.

Parameter estimates and hypothesis tests were carried out for these models using the same methods outlined above. Similarly, priors for these models are outlined in Appendix 2 and model checks are reported in the Supplemental Material.

2.3. Results

The average mental health outcomes and total hours played before and during lockdown are depicted in Figure 2. We found evidence in support of the alternative hypothesis (i.e. of a difference in means) when compared to the point null hypothesis, $BF_{10} > 1{,}000{,}000$ (± 0.00%), with posterior summaries showing an average increase in total hours played of 9.84 per week (SD = 1.20, 95% CI = [7.44, 12.25]). Here, the alternative hypothesis is over 1 million times more likely to have produced the data than the null hypothesis.

Having confirmed a general increase in hours spent gaming during lockdown we next established the role of total hours spent gaming in mental health outcomes. Figure 3 shows posterior estimates for mental health outcomes before and during lockdown as a function of the total hours played before or during lockdown.

Table 1 shows the population-level parameter estimates, their standard error, and 95% credible intervals on the log scale, along with Bayes factors in support of the null hypothesis relative to the alternative hypothesis for both main effects and their interaction for each model.

The results provide evidence in support of the alternative hypothesis for the effect of lockdown period on depression, stress, and loneliness measures whereby parameter estimates show a reliable increase in these measures during lockdown (Table 1). While a similar trend is shown for anxiety, the parameter estimate is small, with the credible intervals spanning 0, and with an inconclusive Bayes factor (i.e. between ± 1 and 3; Lee and Wagenmakers 2013). There is reliable evidence in support of the null hypothesis that total hours played has no effect on loneliness or stress across both lockdown periods. While there is evidence that as hours played increases depression and anxiety also increase, these effects span a range of negligible to rather large effects and similarly have inconclusive Bayes factors. For all mental health outcomes, the lockdown period does not interact with total hours played.

We next tested whether any effect of changes to hours played on mental health outcomes is moderated by loneliness during lockdown. Figure 4 shows posterior predictions for mental health outcomes during lockdown as a function of difference in hours played with lines fitted to the average loneliness scores during lockdown ± 1 SD of the mean.

Table 2 shows the population-level parameter estimates, their standard error, and 95% credible intervals on the log scale, along with Bayes factors in support of the null hypothesis relative to the alternative hypothesis for both main effects and their interaction for each model.

The results provide evidence in support of the null hypothesis for any effect of difference in hours played or any moderating effect of loneliness on hours played for all mental health outcomes. Here, all parameter estimates are very small, with credible intervals spanning zero and with Bayes factors in support of the null hypothesis. However, there is substantial evidence in support of higher scores for loneliness during lockdown leading to poorer mental health outcomes during lockdown. Here, effects are positive and large, with Bayes factors in support of the alternative hypothesis relative to the null hypothesis.

2.4. Interim summary

Study 1 revealed all mental health outcomes were worsened during lockdown. Data also revealed that participants played video games for more hours during lockdown than before lockdown. Evidence regarding the effect of gaming on mental health outcomes was inconclusive but suggested that higher depression and anxiety

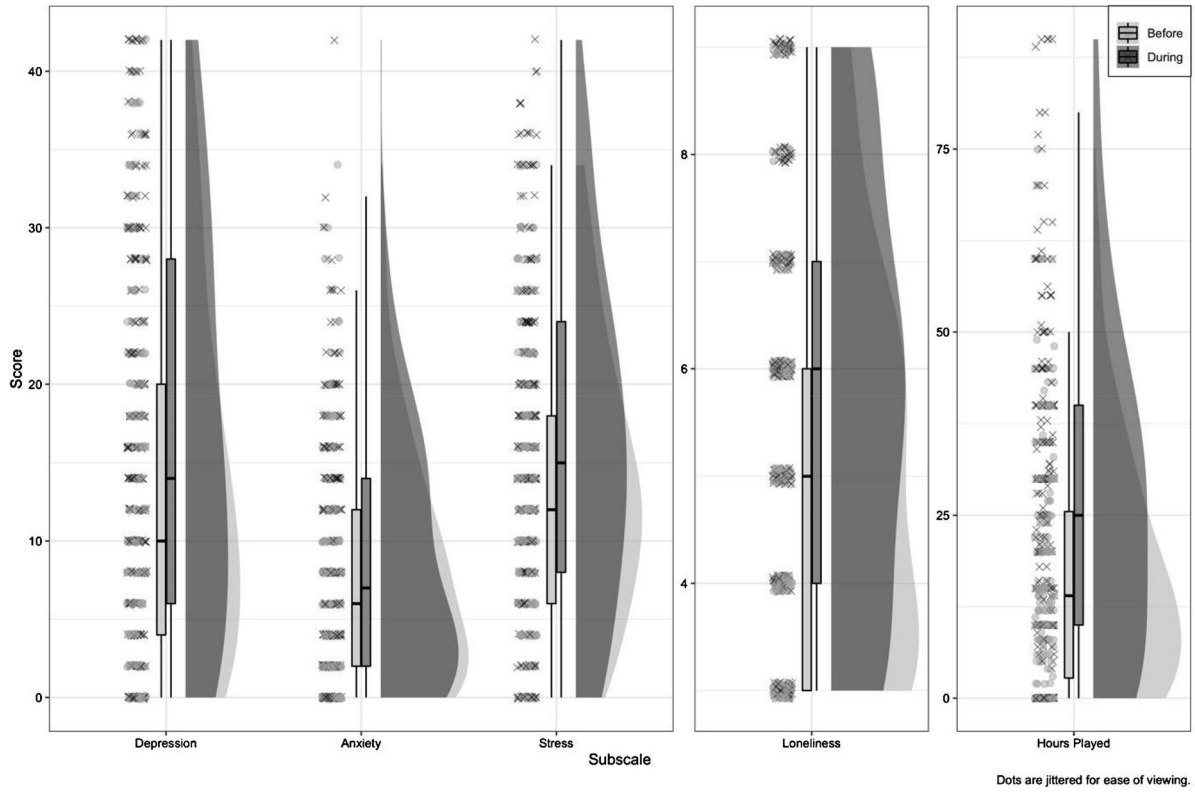

Figure 2. Mental health outcomes for the depression, anxiety, stress, and loneliness along with total hours played before and during lockdown. Dots represent individual participants' mean (jittered) scores.

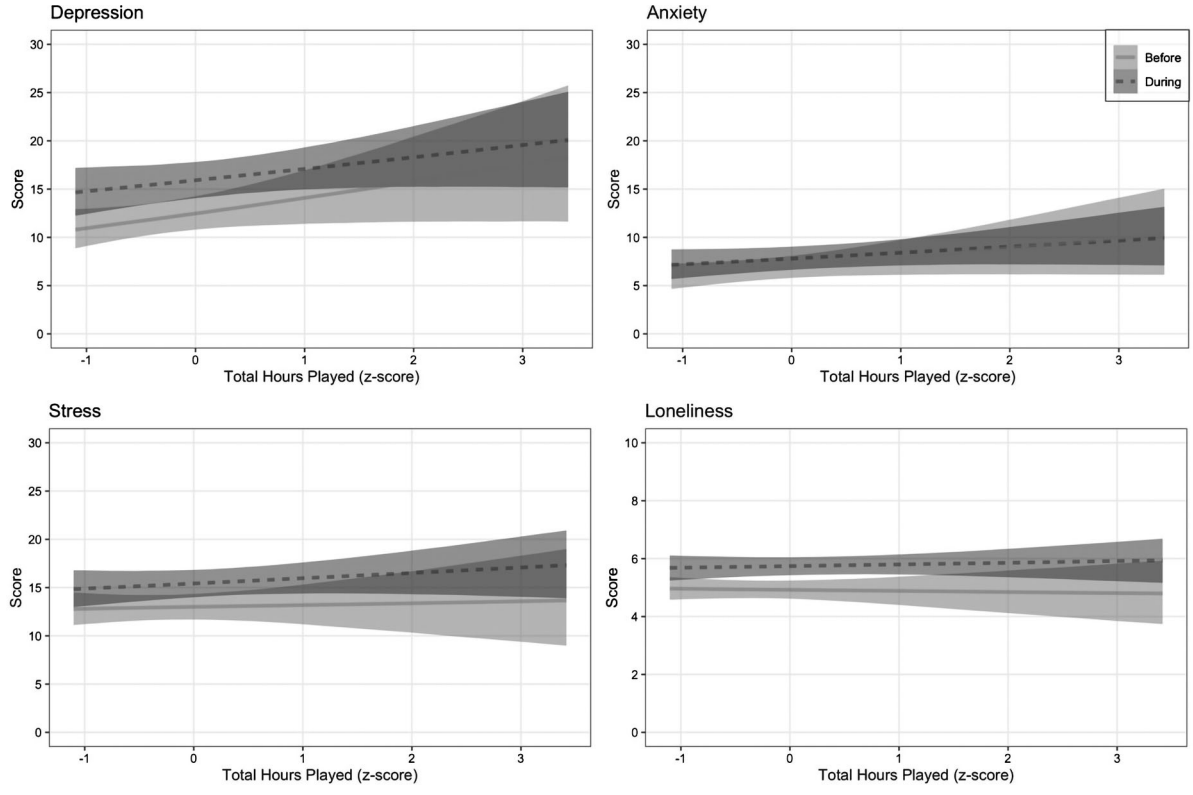

Figure 3. Mental health outcomes for the depression, anxiety, stress, and loneliness measures as a function of total hours played before and during lockdown. Lines and ribbons indicate the posterior median ± 95% credible intervals.

Table 1. Parameter estimates, 95% credible intervals, and Bayes factors evaluating evidence in support of the point null hypothesis that each parameter estimate is equal to zero for the effect of lockdown period, total hours played, and their interaction on mental health outcomes.

Parameter	*Est.*	*SE*	95% CI	BF_{01}
Depression				
Lockdown Period	0.45	0.10	[0.26, 0.64]	< .001
Total Hours	0.36	0.17	[0.02, 0.70]	0.71
Lockdown Period by Hours	−0.07	0.11	[−0.28, 0.14]	7.48
Anxiety				
Lockdown Period	0.19	0.10	[−0.00, 0.39]	1.59
Total Hours	0.33	0.17	[0.00, 0.68]	0.94
Lockdown Period by Hours	−0.08	0.11	[−0.29, 0.13]	6.92
Stress				
Lockdown Period	0.39	0.10	[0.20, 0.58]	< .001
Total Hours	0.12	0.16	[−0.19, 0.42]	5.02
Lockdown Period by Hours	0.05	0.10	[−0.15, 0.26]	9.15
Loneliness				
Lockdown Period	0.62	0.11	[0.41, 0.83]	< .001
Total Hours	0.01	0.17	[−0.33, 0.34]	5.86
Lockdown Period by Hours	0.07	0.11	[−0.15, 0.30]	7.35

Note: Higher Bayes factor values indicate support for the null hypothesis while lower numbers indicate support for the alternative hypothesis (i.e. of a non-null effect). Parameter estimates are reported on the log scale.

scores are associated with more hours spent gaming. Loneliness did not moderate the effect of the change in hours played on mental health outcomes. Finally, the results show that as loneliness increases during lockdown, depression, stress, and anxiety also increase.

3. Study 2

Contrary to our hypothesis, Study 1 revealed that loneliness did not moderate the relationship between video gaming and DASS-21 scores. However, the Three-Item Loneliness Scale used in Study 1 was not the optimal measure for the required analysis. Specifically, this measure is designed to provide binary classifications of 'lonely' and 'not lonely' as a unidimensional construct, as opposed to an average loneliness score indicative of the degree to which a person feels lonely (Steptoe et al. 2013). Therefore Study 2 included the De Jong-Gierveld 11-Item Loneliness Scale (De Jong-Gierveld and Kamphuls 1985) instead. This scale provides an average loneliness score and includes measurements of both emotional and social loneliness and may therefore be more appropriate for assessing the specific forms of loneliness experienced during lockdown.

3.1. Methods

3.1.1. Participants

Two-hundred and ten participants were recruited using the same method described in Study 1. Exclusion criteria were the same as in Study 1 (see section 2.1.1.).

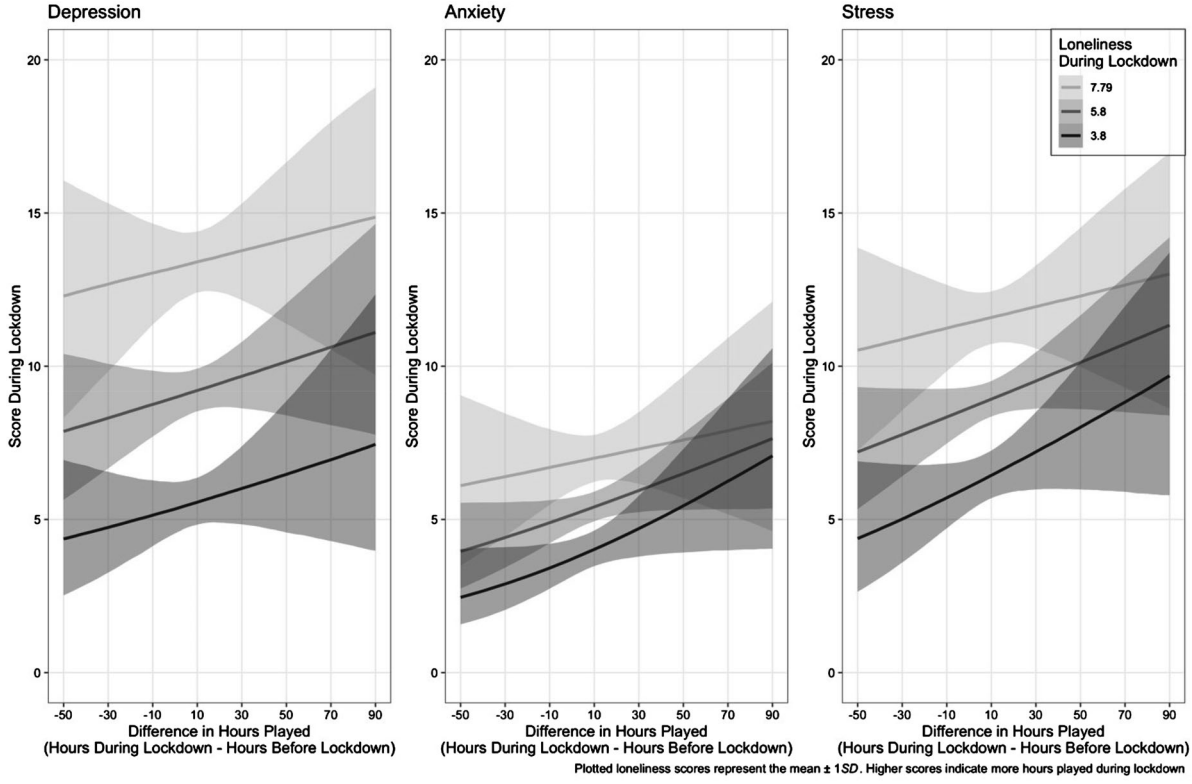

Figure 4. Mental health outcomes for the depression, anxiety, and stress measures as a function of the difference in hours played before and during lockdown and loneliness scores during lockdown. Lines and ribbons indicate the posterior mean ± 95% credible intervals, with each line representing the mean loneliness score ± 1 SD.

Table 2. Parameter estimates, 95% credible intervals, and Bayes factors evaluating evidence in support of the point null hypothesis that each parameter estimate is equal to zero for the effect of difference in hours played, loneliness during lockdown, and their interaction on mental health outcomes.

Parameter	*Est.*	*SE*	95% CI	BF_{01}
Depression				
Difference in Hours Played	0.01	0.02	[−0.03, 0.06]	39.41
Loneliness During Lockdown	0.70	0.08	[0.55, 0.85]	< .001
Hours by Loneliness	0.00	0.00	[−0.01, 0.01]	256.99
Anxiety				
Difference in Hours Played	0.03	0.02	[−0.01, 0.07]	19.10
Loneliness During Lockdown	0.40	0.08	[0.25, 0.55]	< .001
Hours by Loneliness	0.00	0.00	[−0.01, 0.00]	197.66
Stress				
Difference in Hours Played	0.03	0.02	[−0.02, 0.07]	22.60
Loneliness During Lockdown	0.53	0.08	[0.38, 0.68]	<.001
Hours by Loneliness	0.00	0.00	[−0.01, 0.00]	224.12

Note: Higher Bayes factor values indicate support for the null hypothesis while lower numbers indicate support for the alternative hypothesis (i.e. of a non-null effect). Parameter estimates are reported on the log scale.

After all exclusions, the sample included 76 participants (age $M = 29.96$, SD = 8.24, Range = 19–64). On average participants took 115.56 min (SD = 737.52) to complete the questionnaire. Figure 5 shows the number of participants in each employment situation during lockdown.

3.1.2. Procedure and materials

The DASS-21 was presented as in Study 1. The assessment of video gaming habits was presented using sliding scales as opposed to requiring participants to manually type in their responses. As in Study 1, participants completed each questionnaire twice to provide a retrospective measure and a current measure. All wording was updated to reflect the most present lockdown dates.

3.1.3. The De Jong-Gierveld 11-Item Loneliness Scale (De Jong-Gierveld and Kamphuls 1985)

This scale was used instead of the UCLA scale to measure loneliness. The 11 items ask participants to respond 'yes', 'no', or 'more or less' to a series of statements regarding either emotional (e.g. 'I experience a general sense of emptiness.') or social (e.g. 'There are enough people I feel close to.') loneliness.

3.1.4. Procedure

All questionnaire procedures were identical to Study 1, with wording updated to reflect the relevant lockdown (i.e. before/during November 2020).

3.2. Results

After carrying out the same data processing procedure as in Study 1, there was no missing data such that imputation was not necessary. The average mental health outcomes and total hours played before and during lockdown are depicted in Figure 6.

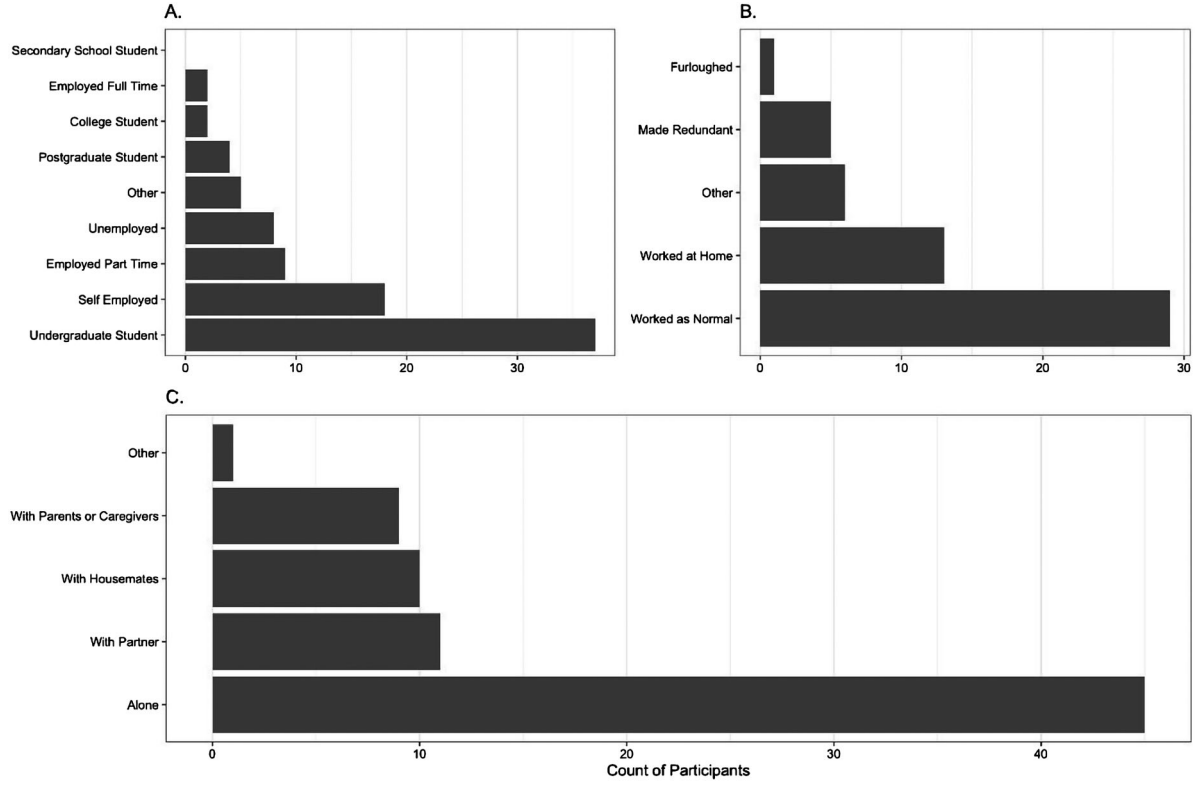

Figure 5. Count of participants by self-reported (a) employment status, (b) lockdown work situation, and (c) living situation.

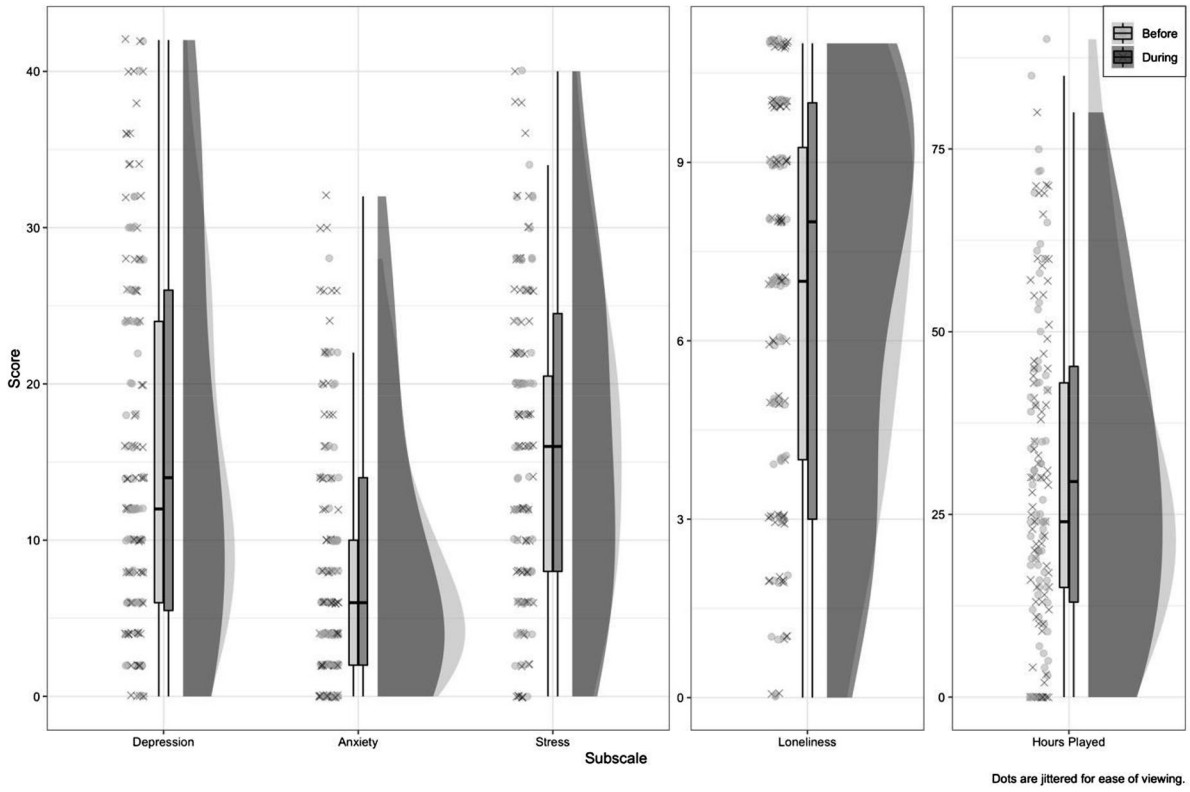

Figure 6. Mental health outcomes for the depression, anxiety, stress, and loneliness along with total hours played before and during lockdown. Dots represent individual participants' mean (jittered) scores.

We found support of the null model compared to the alternative model, $BF_{01} = 7.70$ (± 0%), with posterior summaries showing an average increase in total hours played of 0.66 (SD = 2.62, 95% CI = [−4.65, 5.68]). Despite showing no change in hours spent gaming, we applied the same models to the second lockdown as in Study 1. Figure 7 shows posterior estimates for mental health outcomes before and during lockdown as a function of the total hours played before or during lockdown.

Table 3 shows the population-level parameter estimates, their standard error, and 95% credible intervals on the log scale, along with Bayes factors in support of the null hypothesis relative to the alternative hypothesis for both main effects and their interaction for each model.

The results provide evidence in support of the null hypothesis relative to the alternative hypothesis for the effect of lockdown on all mental health outcomes. However, there is evidence in support of the alternative hypothesis regarding total hours played for depression, anxiety, and stress. Here, more total hours played is associated with poorer mental health outcomes both before and during lockdown. The effect of total hours played is smaller for loneliness, with the credible interval spanning zero and with evidence is support of the null hypothesis, rather than the alternative hypothesis. There was no evidence of an interaction between lockdown period and total hours played.

We next tested whether any effect of changes to hours played on mental health outcomes is moderated by loneliness during lockdown. Figure 8 shows posterior predictions for mental health outcomes during lockdown as a function of difference in hours played with lines fitted to the average loneliness scores during lockdown ±1SD of the mean.

Table 4 shows the population-level parameter estimates, their standard error, and 95% credible intervals on the log scale, along with Bayes factors in support of the null hypothesis for both main effects and their interaction for each model.

The results provide evidence in support of the null hypothesis for any effect of changes in hours played during lockdown or any moderating effect of loneliness on the relationship between hours played and mental health outcomes. Here, all parameter estimates are very small, with credible intervals spanning zero and with Bayes factors in support of the null hypothesis relative to the alternative hypothesis. However, there is substantial evidence in support of higher scores for loneliness during lockdown leading to poorer mental health outcomes during lockdown. Here, effects are positive and large, with Bayes factors in support of the alternative hypothesis as opposed to the null.

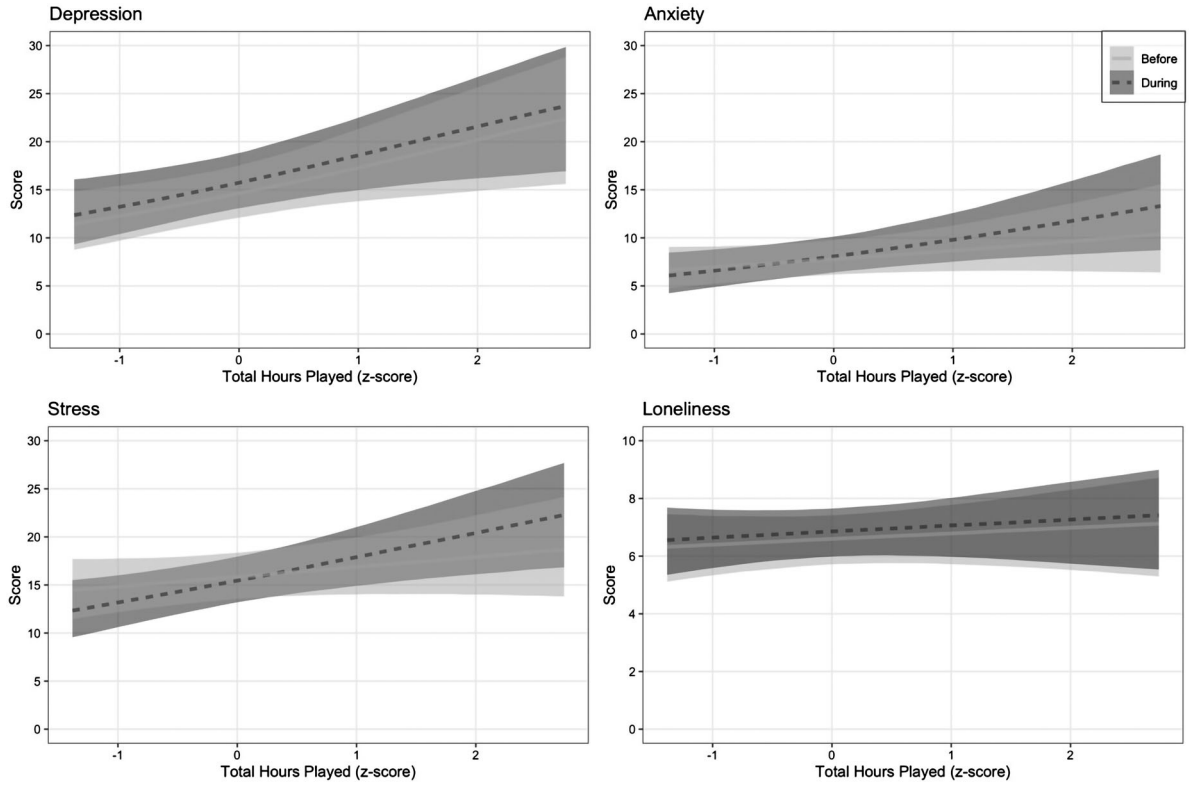

Figure 7. Mental health outcomes for the depression, anxiety, stress, and loneliness measures as a function of total hours played before and during lockdown. Lines and ribbons indicate the posterior median ± 95% credible intervals.

3.3. Interim summary

In contrast to Study 1, Study 2 showed no average increase in hours spent gaming during lockdown relative to before lockdown and no evidence of an effect of the second lockdown on mental health outcomes. In Study 2, as hours spent gaming increased so did depression, anxiety, and stress scores both before and during lockdown. Additionally, while more hours spent gaming during lockdown was associated with a greater increase in anxiety, as in Study 1 time spent gaming during lockdown had no effect on overall depression, anxiety, and stress scores. Like Study 1, Study 2 showed that higher scores for loneliness during lockdown led to poorer mental health outcomes during lockdown. Finally, there was no moderating effect of loneliness on the difference in hours playing games in Study 2.

Table 3. Parameter estimates, 95% credible intervals, and Bayes factors evaluating evidence in support of the point null hypothesis that each parameter estimate is equal to zero for the effect of lockdown period, total hours played, and their interaction on mental health outcomes.

Parameter	*Est.*	*SE*	95% CI	BF_{01}
Depression				
Lockdown Period	0.18	0.15	[−0.11, 0.46]	3.42
Total Hours	0.80	0.27	[0.29, 1.33]	0.02
Lockdown Period by Hours	0.00	0.17	[−0.32, 0.33]	5.92
Anxiety				
Lockdown Period	0.07	0.15	[−0.22, 0.37]	6.01
Total Hours	0.60	0.26	[0.10, 1.10]	0.25
Lockdown Period by Hours	0.18	0.16	[−0.15, 0.50]	3.70
Stress				
Lockdown Period	−0.07	0.14	[−0.34, 0.21]	6.13
Total Hours	0.63	0.26	[0.12, 1.15]	0.20
Lockdown Period by Hours	0.25	0.17	[−0.07, 0.58]	1.87
Loneliness				
Lockdown Period	0.14	0.15	[−0.16, 0.44]	4.26
Total Hours	0.21	0.26	[−0.30, 0.72]	2.77
Lockdown Period by Hours	0.01	0.17	[−0.33, 0.34]	5.89

Note: Higher Bayes factor values indicate support for the null hypothesis while lower numbers indicate support for the alternative hypothesis (i.e. of a non-null effect). Parameter estimates are reported on the log scale.

4. Study 3

Study 2 yielded several different results from Study 1. Unlike Study 1, Study 2 suggested that (a) gaming hours did not differ between the two timepoints (b) there was no difference in mental health outcomes between timepoints, (c) a larger number of gaming hours was associated with poorer mental health outcomes, both before and during lockdown. In Study 3, we aimed to determine which effects could be replicated during the third national lockdown.

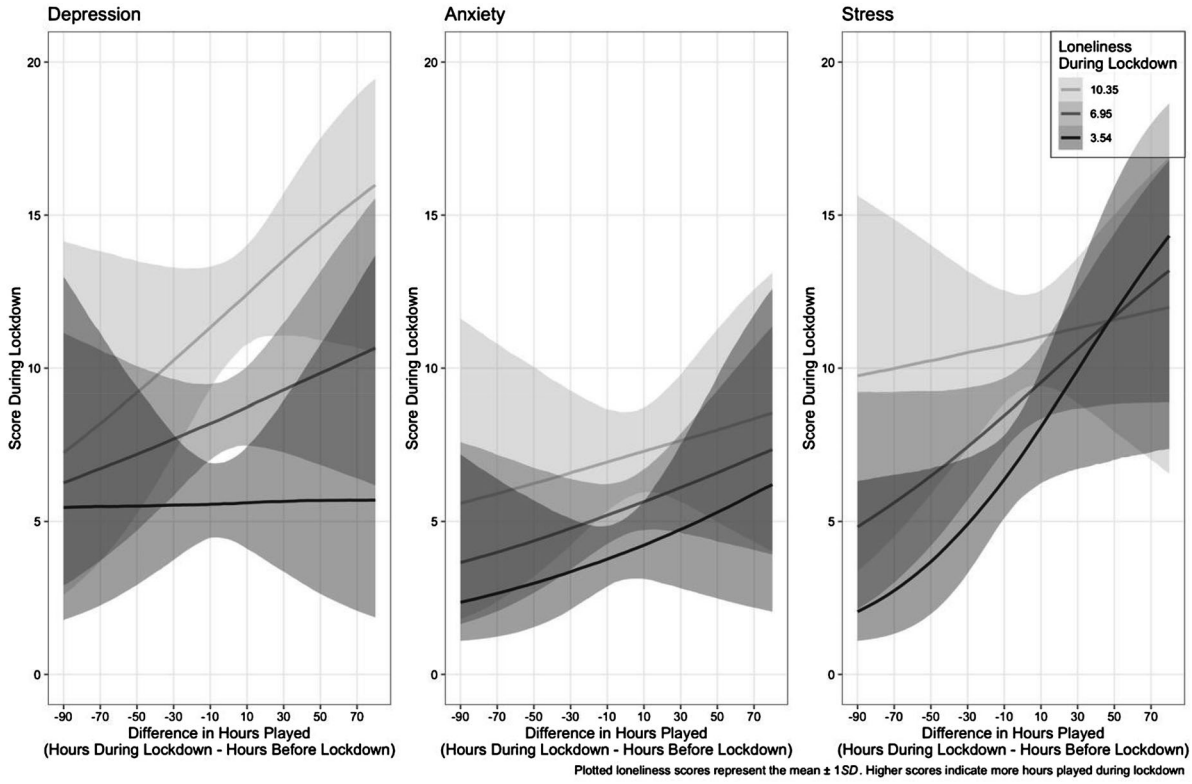

Figure 8. Mental health outcomes for the depression, anxiety, and stress measures as a function of the difference in hours played before and during lockdown and loneliness scores during lockdown. Lines and ribbons indicate the posterior mean ± 95% credible intervals, with each line representing the mean loneliness score ± 1 SD.

4.1. Methods

4.1.1. Participants

One hundred and five participants were recruited using the same method described in Study 1 and 2. Exclusion criteria were the same as in Study 1 (see section 2.1.1.). After all exclusions, the sample included 55 participants (age $M = 30.49$, SD = 7.65, Range = 19–51). On average participants took 116.57 min (SD = 737.51) to complete the task. Figure 9 shows the number of participants in each employment situation during lockdown.

4.1.2. Procedure and materials

All questionnaire procedures were identical to Study 2, with wording updated to the relevant lockdown (i.e. since the beginning of January 2021).

Table 4. Parameter estimates, 95% credible intervals, and Bayes factors evaluating evidence in support of the point null hypothesis that each parameter estimate is equal to zero for the effect of difference in hours played, loneliness during lockdown, and their interaction on mental health outcomes.

Parameter	*Est.*	*SE*	95% CI	BF_{01}
Depression				
Difference in Hours Played	−0.01	0.03	[−0.06, 0.04]	35.55
Loneliness During Lockdown	0.35	0.07	[0.22, 0.49]	< .001
Hours by Loneliness	0.00	0.00	[−0.00, 0.01]	233.20
Anxiety	0.02	0.03	[−0.03, 0.07]	32.25
Difference in Hours Played				
Loneliness During Lockdown	0.22	0.06	[0.10, 0.35]	0.05
Hours by Loneliness	0.00	0.00	[−0.01, 0.01]	303.03
Stress				
Difference in Hours Played	0.05	0.03	[0.00, 0.10]	6.11
Loneliness During Lockdown	0.21	0.07	[0.08, 0.34]	0.08
Hours by Loneliness	0.00	0.00	[−0.01, 0.00]	129.74

Note: Higher Bayes factor values indicate support for the null hypothesis while lower numbers indicate support for the alternative hypothesis (i.e. of a non-null effect). Parameter estimates are reported on the log scale.

4.2. Results

After carrying out the same data processing procedure as in Studies 1 and 2, there was no missing data such that imputation was not necessary. The average mental health outcomes and total hours played before and during lockdown are depicted in Figure 10.

We show inconclusive evidence in support of the alternative model (i.e. of a difference in means) relative to the null model (i.e. the point null hypothesis), $BF_{10} = 1.52$ (± 0%), with posterior summaries showing an average increase in total hours played of 5.17 ($SD = 2.37$, 95% CI = [0.60, 9.63]). Regardless, we applied the same models to the second lockdown as in Study 1. Figure 11 shows posterior estimates for mental health outcomes before and during lockdown as a function of the total hours played before or during lockdown.

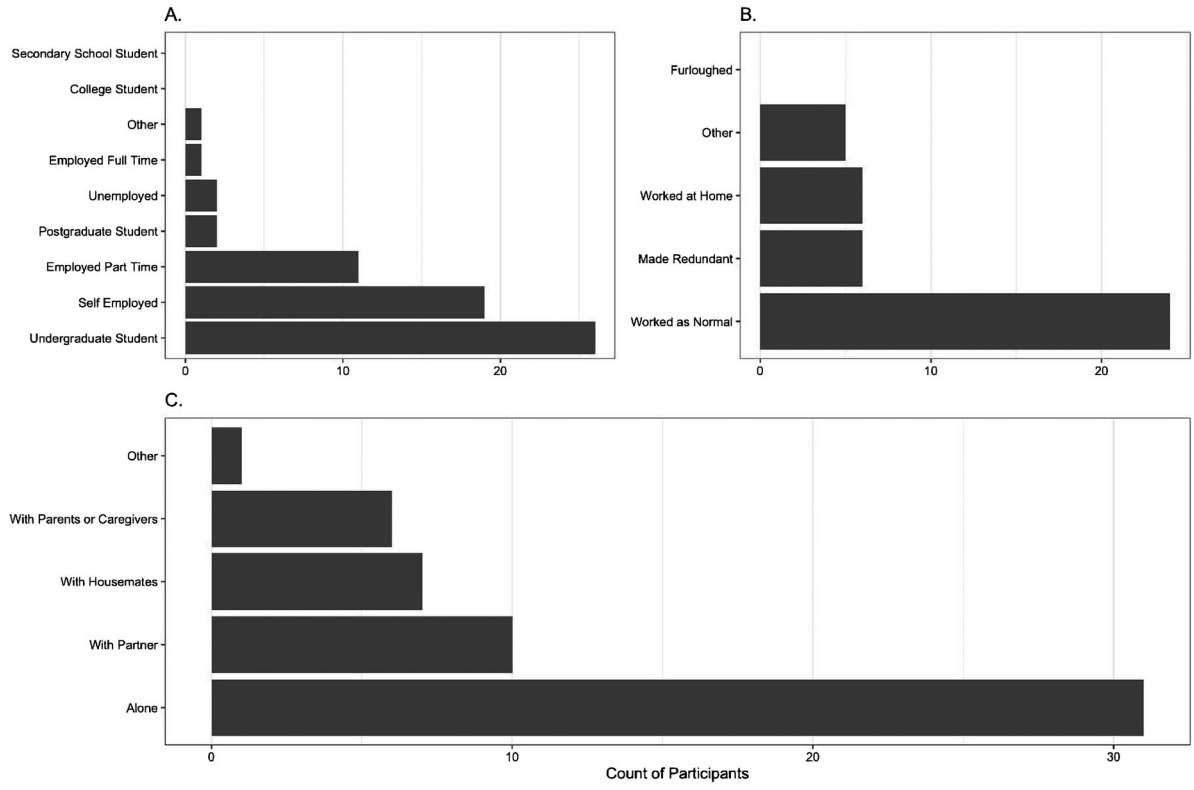

Figure 9. Count of participants by self-reported (a) employment status, (b) lockdown work situation, and (c) living situation.

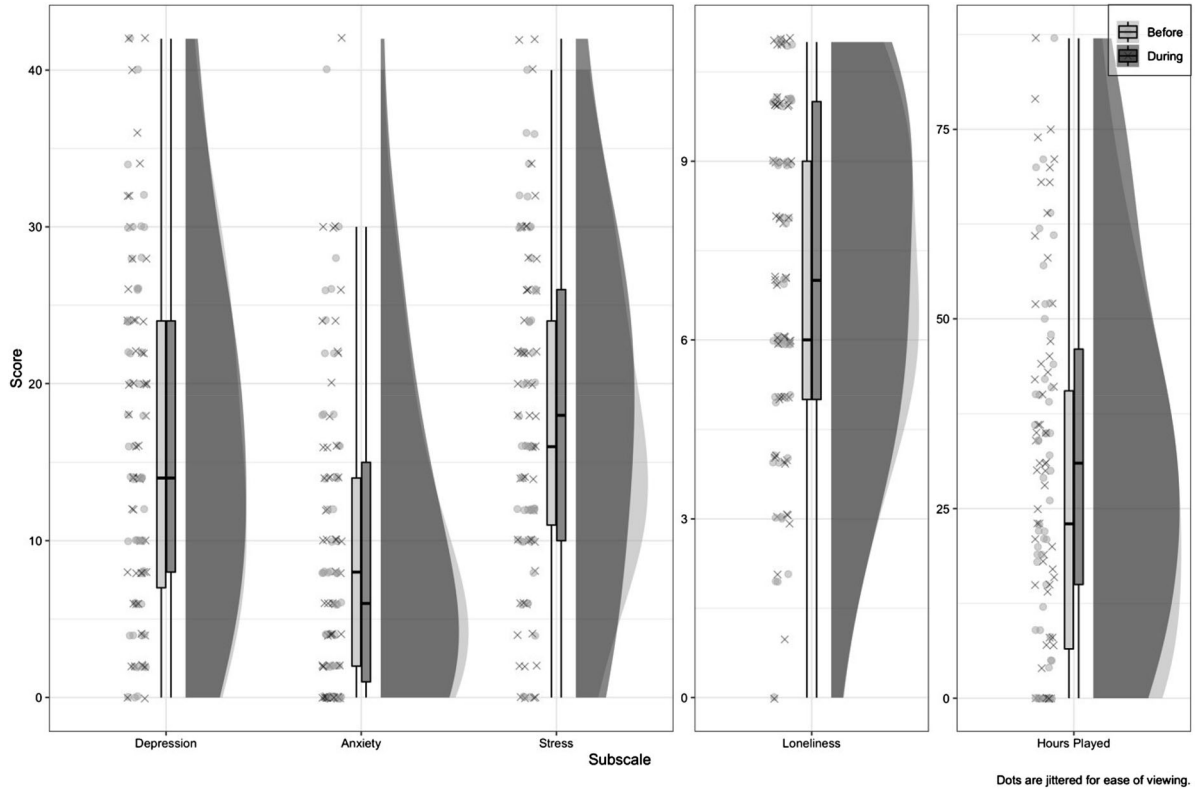

Figure 10. Mental health outcomes for the depression, anxiety, stress, and loneliness along with total hours played before and during lockdown. Dots represent individual participants' mean (jittered) scores.

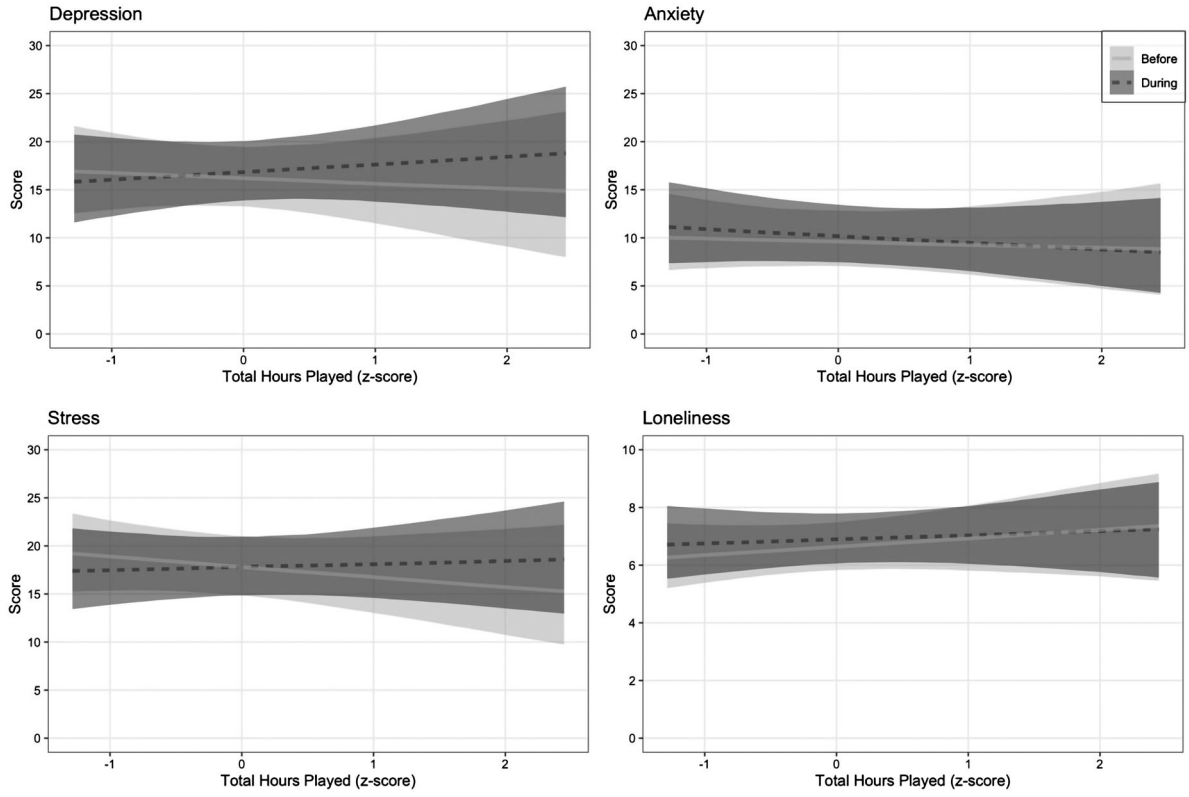

Figure 11. Mental health outcomes for the depression, anxiety, stress, and loneliness measures as a function of total hours played before and during lockdown. Lines and ribbons indicate the posterior median ± 95% credible intervals.

Table 5 shows the population-level parameter estimates, their standard error, and 95% credible intervals on the log scale, along with Bayes factors in support of the null hypothesis relative to the alternative hypothesis for both main effects and their interaction for each model.

Table 5. Parameter estimates, 95% credible intervals, and Bayes factors evaluating evidence in support of the point null hypothesis that each parameter estimate is equal to zero for the effect of lockdown period, total hours played, and their interaction on mental health outcomes.

Parameter	*Est.*	*SE*	95% CI	BF_{01}
Depression				
Lockdown Period	0.09	0.17	[−0.24, 0.43]	5.10
Total Hours	0.03	0.36	[−0.69, 0.75]	2.66
Lockdown Period by Hours	0.20	0.19	[−0.18, 0.57]	3.09
Anxiety				
Lockdown Period	0.12	0.18	[−0.24, 0.47]	4.39
Total Hours	−0.22	0.39	[−0.99, 0.52]	2.29
Lockdown Period by Hours	−0.08	0.20	[−0.48, 0.32]	4.75
Stress				
Lockdown Period	0.00	0.18	[−0.35, 0.35]	6.16
Total Hours	−0.13	0.35	[−0.82, 0.57]	2.79
Lockdown Period by Hours	0.24	0.19	[−0.14, 0.61]	2.55
Loneliness				
Lockdown Period	0.15	0.18	[−0.20, 0.51]	3.99
Total Hours	0.25	0.34	[−0.40, 0.95]	2.23
Lockdown Period by Hours	−0.09	0.18	[−0.46, 0.27]	4.76

Note: Higher Bayes factor values indicate support for the null hypothesis while lower numbers indicate support for the alternative hypothesis (i.e. of a non-null effect). Parameter estimates are reported on the log scale.

Table 6 shows evidence in support of the null hypothesis for all effects and for all outcomes. In all cases however, given the Bayes factors in this instance provide rather weak evidence (i.e. with Bayes factors between 1 and 3; Lee and Wagenmakers 2013) and an insensitivity to conclusively provide evidence in support of the null. This is likely due to a small sample size. Most notably, as shown in Figure 11 depression, stress, and

Table 6. Parameter estimates, 95% credible intervals, and Bayes factors evaluating evidence in support of the point null hypothesis that each parameter estimate is equal to zero for the effect of difference in hours played, loneliness during lockdown, and their interaction on mental health outcomes.

Parameter	*Est.*	*SE*	95% CI	BF_{01}
Depression				
Difference in Hours Played	0.01	0.06	[−0.12, 0.14]	15.75
Loneliness During Lockdown	0.41	0.10	[0.21, 0.61]	<.001
Hours by Loneliness	0.00	0.01	[−0.02, 0.01]	122.33
Anxiety				
Difference in Hours Played	−0.02	0.07	[−0.17, 0.11]	13.50
Loneliness During Lockdown	0.31	0.10	[0.13, 0.50]	0.03
Hours by Loneliness	0.00	0.01	[−0.01, 0.02]	115.09
Stress				
Difference in Hours Played	0.00	0.08	[−0.16, 0.14]	13.35
Loneliness During Lockdown	0.28	0.09	[0.10, 0.47]	0.10
Hours by Loneliness	0.00	0.01	[−0.02, 0.02]	117.58

Note: Higher Bayes factor values indicate support for the null hypothesis while lower numbers indicate support for the alternative hypothesis (i.e. of a non-null effect). Effects are reported on the log scale.

loneliness are all very high before and during lockdown and regardless of the hours spent gaming. This likely indicates that ceiling effects are present whereby if lockdown period or hours spent gaming were to influence mental health outcomes in this instance it is difficult to detect due to exceptionally high scores for these subscales.

We next tested whether any effect of changes to hours played on mental health outcomes during lockdown is moderated by loneliness during lockdown. Figure 12 shows posterior predictions for mental health outcomes during lockdown as a function of difference in hours played with lines fitted to the average loneliness scores during lockdown ± 1 SD of the mean.

Table 6 shows the population-level parameter estimates, their standard error, and 95% credible intervals on the log scale, along with Bayes factors in support of the null hypothesis relative to the alternative hypothesis for both main effects and their interaction for each model.

The results show evidence in support of the null hypothesis for any effect of difference in hours played or any moderating effect of loneliness on hours played for all mental health outcomes.

Here, all parameter estimates are very small, with credible intervals spanning zero and with Bayes factors in support of the null hypothesis relative to the alternative hypothesis. However, there is substantial evidence in support of higher scores for loneliness during lockdown leading to poorer mental health outcomes during lockdown. Here, effects are positive and large, with Bayes factors in support of the alternative hypothesis relative to the null hypothesis.

4.3. Interim summary

Study 3 showed inconclusive findings for any increase in hours playing games during lockdown compared to before lockdown. There was no impact of lockdown period, hours spent playing games, or their interaction on mental health outcomes. However, the Bayes factors in this instance provide rather weak evidence. This highlights potential insensitivity of the hypothesis test to answer this question, presumably due to a small sample size. Further, inspection of plots shows potential ceiling effects – at least for depression, stress, and loneliness – whereby scores were very high both before and during lockdown. More strongly, there was convincing evidence for no impact of hours spent playing games during lockdown on mental health outcomes. Replicating effects for Studies 1 and 2, we found that higher scores for loneliness during lockdown led to poorer mental health outcomes during

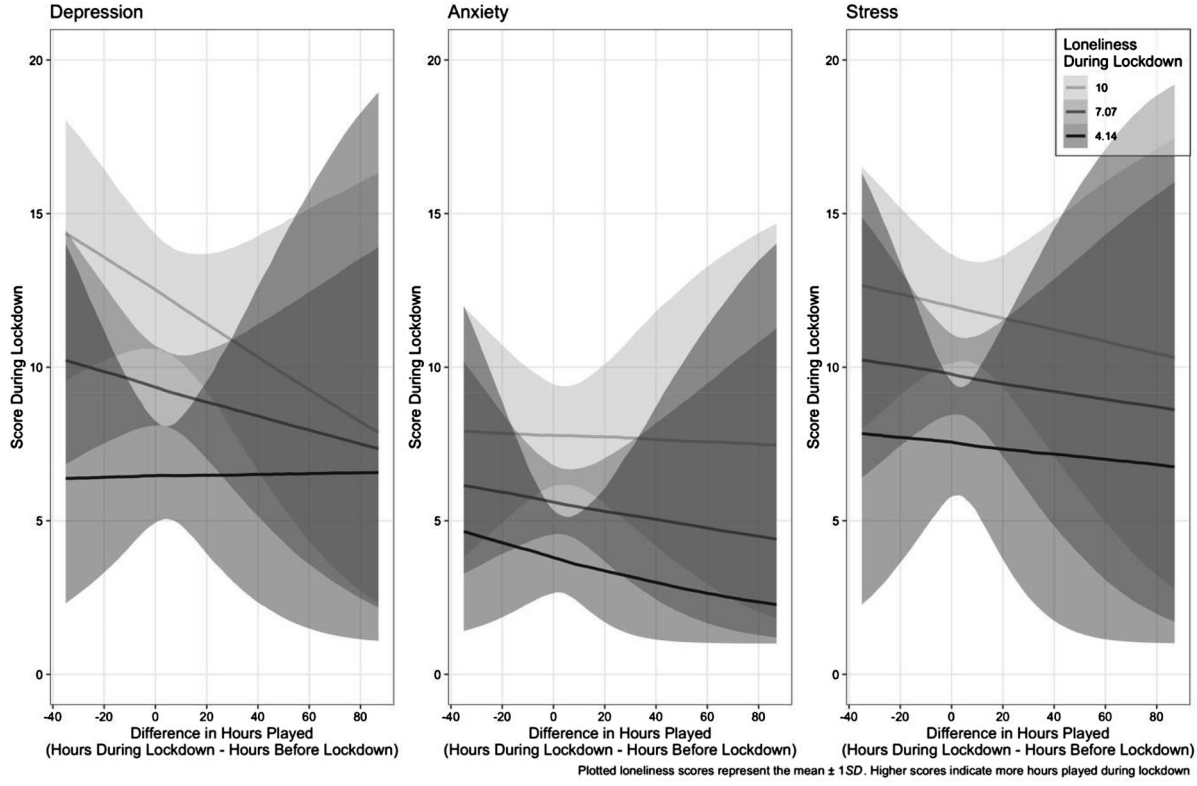

Figure 12. Mental health outcomes for the depression, anxiety, and stress measures as a function of the difference in hours played before and during lockdown and loneliness scores during lockdown. Lines and ribbons indicate the posterior mean ± 95% credible intervals, with each line representing the mean loneliness score ± 1 SD.

lockdown. Again, there was no effect of the change in hours spent playing games on mental health outcomes, nor any moderating effect of loneliness on the difference in hours playing games.

5. General discussion

The present study aimed to investigate the relationship between time spent playing video games, loneliness, and mental health outcomes during stressful and isolating situations. We used three national COVID-19 lockdowns as a model of stress and isolation and tested three hypotheses in each study: (i) depression, stress, and anxiety would worsen during each lockdown, relative to before lockdown, (ii) hours spent gaming would increase during lockdown, relative to before lockdown, and (iii) time spent gaming would have a beneficial effect on mental health outcomes, but this relationship would be moderated by loneliness. Study 1 revealed higher scores for depression, stress, and anxiety during the first lockdown compared to the weeks prior. However, this was not replicated during the second and third lockdowns. Similarly, while the first lockdown was associated with an increase in time spent gaming, this was not replicated in subsequent lockdowns. Moreover, all three lockdowns were characterised by greater loneliness scores compared to before lockdown. There was no evidence of a relationship between loneliness and time spent gaming. In addition, time spent gaming was not related to mental health outcomes, nor was this relationship moderated by loneliness. The results of Study 1 suggested (inconclusively) that more time spent gaming was associated with increased depression and anxiety scores, while Study 2 yielded conclusive evidence that more time gaming was associated with poor mental health. Study 3 found no such effects, however, there was evidence that mental health scores were at ceiling both before and during the third lockdown. Finally, during all three lockdowns, loneliness was associated with poorer mental health.

Our findings concerning the influence of lockdown on mental health suggested that only the first lockdown was yielded a main effect of lockdown on stress, depression, and anxiety, with higher scores for each measure during lockdown compared to the weeks prior. A possible explanation for this is 'pandemic fatigue', defined as the natural tendency for a population to tire of the rules in place to prevent the spread of COVID-19, resulting in reduced adherence (Michie, West, and Harvey 2020). That is, mental health may not have been affected by the second and third lockdowns due to a lack of compliance with rules that were likely to cause poor mental health. Indeed, the third lockdown in England was characterised by a decline in population adherence to the rules, following news of government officials' non-adherence (Fancourt, Steptoe, and Wright 2020). However, this explanation is speculative, as lockdown fatigue and adherence were not assessed in the present studies. An alternative explanation is that this pattern may reflect an adjustment to the restrictions, i.e. habituation, resulting in an attenuated effect of lockdown on mental health outcomes; however, whether habituation to such lockdowns is possible is an open question (Meda et al. 2021). Another potential explanation is that specifically the first lockdown was characterised by a marked shift in the publics' sociocultural values and expectations of behaviour, as well as several political events, all of which persisted into the later lockdowns. Thus, the consistently poorer mental health outcomes in the later two lockdowns relative to the first may be reflective of this, rather than the lockdown restrictions per se. Critically, it is important to note that all the measures of before lockdown behaviour were taken retrospectively due to the unpredictable nature and often short-notice of COVID-19 lockdowns beginning in the UK. As such, it is possible that the baseline measures were subject to cognitive and emotional biases (Ross 1989); for example, participants with low mood during lockdown may have inaccurately recalled their pre-lockdown mood as low (i.e. down-regulation of positive emotions, Vanderlind et al. 2020), resulting in an underestimation of the effect lockdown had on mental health. As such, caution is needed when interpreting the present findings concerning lockdown effects on mental health, as there may be substantial biases present that could not be accounted for.

The amount of time spent gaming was higher during (compared to before) the first lockdown only, contrary to previous research (e.g. Balhara et al. 2020; Barr and Copeland-Stewart 2022). A possible explanation for this pattern is that participants' gaming hours may be subject to a ceiling effect following the first lockdown. That is, participants reported that their gaming hours were higher during the first lockdown relative to the weeks prior and remained at that level prior to and during the subsequent lockdowns. It should be noted that the gaming hours were not measured longitudinally in the present studies and therefore, we cannot infer participants' gaming habits between each lockdown. Moreover, the cross-sectional design used in the present studies means that intra-individual comparisons of gaming hours across each lockdown are not possible. There is limited evidence from studies that have investigated behavioural change during the COVID-19 pandemic which provide some support for this explanation. For example, a large study ($N = 3342$) of Scottish adults

provided evidence of unintended positive lifestyle changes as a result of lockdown (e.g. 'more time doing enjoyable activities', 'developed new hobbies', Williams et al. 2021). However, it is important to note that the use of self-reported measures of gaming hours in our studies may have impacted the results. Previous research comparing telemetry data to self-report has shown that participants typically overestimate their gaming time (Johannes, Vuorre, and Przybylski 2021). Therefore, it is possible our measures did not accurately capture any changes (either increases or decreases) in time spent gaming because of lockdown.

We predicted that during lockdown, time spent gaming would reduce depression, stress, and anxiety scores, and this would be moderated by loneliness. Evidence regarding the effect of time spent gaming on mental health was inconsistent, with Study 1 and 2 suggesting (to varying degrees) that more time spent gaming was associated with poorer mental health. In contrast, Study 3 suggested no relationship between gaming time and mental health. As such, none of the present studies provide support for the claim that more time spent gaming will have a beneficial effect on mental health. This is contrary to previous studies that have reported mental health benefits from gaming as a function of time spent playing (Allahverdipour et al. 2010; Desai et al. 2010; Durkin and Barber 2002; Johannes, Vuorre, and Przybylski 2021; for a review see Jones et al. 2014). One explanation for this inconsistency is that the effect of gaming on mental health may depend on additional factors. Indeed, some studies suggest it is specifically 'casual' games that yield a beneficial effect (Croissant and Frister 2021; Fish, Russoniello, and O'Brien 2014; Pearce et al. 2022; Russoniello, Fish, and O'Brien 2013; 2019; for a review see Pine et al. 2020). As different game types were not assessed in the present analyses, it is possible that any beneficial effects that were present in participants playing such games were washed out or masked by data from participants playing other game types. It should also be noted that in all three studies, time spent gaming did not influence loneliness. This is contrary to previous studies, which have shown gaming is often used in a compensatory manner, as a substitute for social interaction during times of stress (for a recent review, see Koban et al. 2022). Information on participants' socialisation during gaming was not captured by the quantitative measures used in this study, and therefore it is possible that there was significant variability in the nature and quality of any social interactions that were had during gaming. For example, it is possible that participants could routinely play online with others in non-verbal manner (e.g. with their own microphone/text-based chat turned off, while continuing to listen to/watch others engage in chat), while others are content using text-based chat only, still others may play with others and use visual cues only (e.g. communicating using character emotes or movements, sprays, location pings). Moreover, the content of such communication likely varies considerably (e.g. ranging from casual conversations amongst friends to casual conversation with strangers, to hostile interactions with strangers, to strategic discussions focused on the game at hand), and it is also likely that individual differences exist with respect to what is gained from such interactions (e.g. some players may gain enjoyment from seemingly negative/hostile communications). As such, future research investigating the possible effect of gaming on loneliness should take a mixed-methods approach, collecting both quantitative (e.g. hours spent) and qualitative information on participants' social experiences during gaming.

In contrast, Study 2 provided strong evidence that more time gaming during lockdown was associated with poorer mental health, while Study 1 and 3 respectively yielded inconclusive evidence or no evidence of a relationship. Thus, the findings from the present studies are reflective of the larger body of literature i.e. inconsistent. Critically, and despite this inconsistency, there is a strong narrative pushed by the media that video gaming leads to poor mental health (Bean et al. 2017; Bowman 2016). Instead, the evidence to date suggests that the relationship between gaming and mental health is neither direct nor linear. For example, in the present studies it was hypothesised that loneliness would moderate the influence of gaming on mental health, but this was not supported. However, it is possible that the relationship is reciprocal, such that good mental health underpins gaming habits and vice versa (Johannes, Vuorre, and Przybylski 2021). Indeed, several studies show that motivation is a key factor in determining the effect gaming has on mental health with playing for enjoyment purposes being most likely to support good mental health as opposed to escapism, avoidance, or achievement motivations (Colder Carras et al. 2017; Halbrook, O'Donnell, and Msetfi 2019; Lafrenière et al. 2009; Ryan, Rigby, and Przybylski 2006). As such, the present findings support the concept of an 'optimal gaming profile' described by Halbrook, O'Donnell, and Msetfi (2019) as it is possible that participants' motivations in the present studies were not related to enjoyment and as a result, the potential mental health benefits of gaming were negated.

The most consistent findings from the present studies are concerned with loneliness. Firstly, during all three lockdowns participants reported more loneliness relative to pre-lockdown weeks. This is in line

with the larger body of literature suggesting the COVID-19 pandemic has significantly increased loneliness on a global scale (for a review see Pai and Vella 2021). Secondly, while lockdown alone did not affect mental health, all three studies provided evidence that loneliness during lockdown was associated with poor mental health. This is in line with several cross-sectional (González-sanguino et al. 2020; Li and Wang 2020; Losada-Baltar et al. 2021; Okruszek et al. 2020; Tso and Park 2020) and longitudinal (Okruszek et al. 2020) studies that have reported a significant association between loneliness and poor mental health during the COVID-19 pandemic. Together, these findings have several implications regarding the future state of public mental health. For example, it is likely that the effect of loneliness on mental health during periods of isolation does not diminish with multiple lockdowns as the same relationship was found in all three samples in the present paper. However, we cannot conclude that habituation to lockdown-related loneliness did not occur, as the present studies used cross-sectional designs and intra-individual comparisons across the lockdowns is not possible. Additionally, the present findings indicate that loneliness-induced mental illness is likely to become a major public mental health concern in the wake of the COVID-19 pandemic. This is an important implication, as concerns regarding the impact of loneliness on mental health were present prior to the COVID-19 pandemic (e.g. Jeste, Lee, and Cacioppo 2020) and there is evidence suggesting that the COVID-19 pandemic has increased already high levels of loneliness (Heidinger and Richter 2020; Lee, Cadigan, and Rhew 2020). Thus, in line with Pai and Vella (2021), the present study provides support for the need to address loneliness generally and due to COVID-19 restrictions, via public mental health interventions.

In addition to the limitations regarding the use of retrospective self-report measures, there are two further limitations that should be considered when interpreting the present finding. Firstly, the inconsistency in results across all three studies may be due to the difference in sample sizes. Studies 2 and 3 had relatively small sample sizes compared to Study 1. Indeed, in Study 3 some of the Bayes factors provided only weak support for the hypotheses in question, suggesting that the smaller sample size resulted in a potential insensitivity of the hypothesis test. Alternatively, the inconsistency in results may be driven by factors that were not accounted for in the present studies. For example, while speculative, it is possible that the adjustment of workplaces to remote working during later lockdowns meant that the additional time for gaming people found during the first lockdown was no longer available, leading to some of the inconsistencies reported here. Secondly, as the present studies were conducted online and used self-selection recruitment measures, the generalisability of the findings are limited. For example, as most of the participants recruited were already gamers, it is possible that a ceiling effect was present in terms of the mental health benefits they could experience from gaming. Similarly, self-selection may have resulted in the recruitment of participants who were particularly struggling during lockdown relative to the wider population. This may explain the ceiling effect evident for mental health outcomes in Study 3. Taken together, self-selection may limit the generalisability of the current results to other populations (e.g. non-gamers).

In conclusion, the evidence presented across the three studies suggest that the amount of time spent playing video games does not affect players' mental health or loneliness. Instead, our findings demonstrate that loneliness during periods of isolation has a significant negative on mental health. Using three COVID-19 lockdowns in England as a model of a highly stressful period of isolation, it was found that participants consistently experienced an increase in loneliness during the lockdown periods, which in turn was associated with increased levels of depression, stress, and anxiety. Moreover, contrary to our predictions, time spent gaming did not have a beneficial effect on mental health, nor was this relationship moderated by loneliness. These findings raise several questions for future research concerning the relationship between gaming and mental health, particularly with regards to the specific aspects of gaming that might yield beneficial effect on loneliness and/or mental health outcomes to be seen. Specifically, we suggest that future studies should acknowledge potential individual differences in players' motivations for gaming, and adopt a mixed-methods approach, such that qualitative data on the social experiences of gamers during play can be collected, as it is possible that these factors play a determining role in the effect of gaming on mental health outcomes and loneliness. These findings provide an enhanced understanding of the effect that periods of isolation can have on mental health, by demonstrating that there are specific conditions under which lockdowns can produce poor mental health (i.e. high levels of loneliness). Most importantly, the present findings support the notion that loneliness-induced mental illness will be a major public mental health issue following the COVID-19 pandemic. Our results, in conjunction with the wider body of literature (Pai and Vella 2021) investigating mental health during the pandemic, emphasise the

need for targeted public mental health interventions to alleviate potentially widespread mental distress.

Note

1. Bayes factors were estimated using the Savage-Dickey density ratio. Bayes factors are used here to evaluate the relative evidence in support of the null hypothesis relative to the alternative hypothesis. That is, are the data more consistent with a point-null or non-null effect? Note that this is a measure of relative evidence between these two competing hypotheses given the model and priors, and not an absolute measure of evidence.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Author contributions

S.H and J.B conceived, planned and executed the study. S.H and J.B. collected the data. G.P.W performed the formal analysis. G. P. W. conducted the data curation and validation. G.P.W drafted and wrote the results section. G.P.W. designed all figures. S.H. and J.B drafted the main manuscript plan. S.H wrote the main manuscript text with assistance from J.B. All authors provided critical feedback.

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Appendices

Appendix 1

The main, cumulative models used a *Student*−*t*(3, 0, 2.5) prior on the intercept, a *Normal*(0, 1) prior on the slope terms, and an *Exponential*(1) prior on the standard deviation term for the depression, anxiety, and stress outcomes. Given the outcome for the loneliness model has a more limited range, the models based on loneliness as an outcome had a *Student*−*t*(3, 0, 1.5) prior on the intercept. The slope and standard deviation priors remained unchanged.

Appendix 2

The models assessing whether loneliness moderates any effect of hours played on mental health outcomes used a *Student*−*t* (3, 0, 3) prior on the intercept and a *Normal*(0, 1) prior on the slope terms.