**Adverse effects of loneliness but no effect of gaming on mental health in gamers during
three UK COVID-19 lockdowns.**

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Author note:

All supplemental material (including data and analysis code) can be found via the OSF: <https://osf.io/d5byr/>. This study was not preregistered. Correspondence concerning this article should be address to Sophie Hodgetts, School of Psychology, Murray Library, University of Sunderland, Sunderland, U.K. SR1 3SD. E-mail address: sophie.hodgetts@sunderland.ac.uk.

Acknowledgements:

The authors wish to thank Jon Rees for his valuable assistance and support during the preparation of the analyses.

Abstract

Current consensus is that poor mental health outcomes are a likely outcome of the multiple stay-at-home mandates (i.e., ‘lockdowns’) during the COVID-19 pandemic. Such lockdowns are characterised by loneliness, which is known to adversely impact mental health. Other factors, such as video gaming, have previously been associated with positive mental health outcomes. Indeed, evidence suggests that lockdowns led to a substantial increase in the number of people engaging with gaming. Therefore, in the present paper, we investigated the relationship between video gaming, loneliness, and mental health outcomes using online survey measures during three national lockdowns. We found that depression, anxiety, and stress increased from baseline during the first lockdown only, while loneliness increased relative to baseline in all three lockdowns. Time spent gaming had no direct relationship with mental health outcomes, nor was this relationship moderated by loneliness. While lockdown alone did not impact mental health, loneliness during lockdown was consistently associated with poor mental health outcomes. Our results add to the existing body of literature and emphasise the need for targeted public mental health interventions to improve public mental health following the COVID-19 pandemic. Data and analysis code associated with this project is accessible at <https://osf.io/d5byr/>.

Keywords: depression, loneliness, video games, COVID-19 pandemic

Word count (excluding title, references, author affiliations, acknowledgments, figures and figure legends, but including the abstract): 7837

1. Introduction

Following the declaration of a global COVID-19 pandemic by the World Health Organisation (WHO), the U.K. Government has issued three nationwide stay-at-home mandates (i.e., ‘lockdowns’) to date: March – June 2020, November – December 2020, and January – March 2021. Each lockdown required the public to stay at home (with limited exception), non-essential businesses (e.g. libraries, gyms, entertainment facilities) to close, and mass gatherings (i.e., meeting of more than two people) to be cancelled (UK Government, 2020). Studies have shown that COVID-19 lockdowns are characterised by high levels of loneliness (Bu et al., 2020; Groarke et al., 2020; Jerome et al., 2020) and clinically significant levels of mental distress (Dawson & Golijani-Moghaddam, 2020; Jerome et al., 2020; Shah et al., 2021). In contrast, video gaming is associated with good mental health, wellbeing, and resilience (for a review, see Jones et al., 2014). As such, the COVID-19 lockdowns present a unique opportunity as a model in which to test the effects of video gaming on loneliness and mental health in a large sample of gamers. During the first lockdown, the video game industry experienced significant growth, with several reports documenting increased numbers of people engaging in online video gaming (Dring, 2020; Perez, 2020) and related activities (e.g., watching video game streams, Narassiguin & Garnès, 2020). It is likely that this was driven by an increased availability of time to engage in leisure activities and hobbies (Williams, Rollins, et al., 2021) and the ability of gaming to facilitate social connectivity from home (Arbeau et al., 2020). Therefore, in the present study, we aimed to investigate the potential relationship between video gaming, loneliness, and mental health outcomes, using the three COVID-19 lockdowns in England as a model of stress.

Current consensus is that poor mental health outcomes at population level are a likely outcome of COVID-19 lockdowns (Brooks et al., 2020; Rettie & Daniels, 2020; Xiang et al., 2020). Indeed, lockdowns during previous outbreaks of severe acute respiratory syndrome and Middle

East respiratory syndrome were characterized by increased stress (Bai et al., 2004; DiGiovanni et al., 2004), depression (Lee et al., 2005; Liu et al., 2012), anxiety (Bai et al., 2004; Jeong et al., 2016) and clinically significant symptoms of post-traumatic stress disorder (Reynolds et al., 2008; Wu et al., 2009). Studies of the psychological effects of COVID-19 lockdowns also reveal increased levels of stress (Jiao et al., 2020; Shah et al., 2021), anxiety (Chen et al., 2020; Dawson & Golijani-Moghaddam, 2020; Gray et al., 2020; Jia et al., 2020; Jiao et al., 2020; J. Lee, 2020; Shah et al., 2021; White & Van Der Boor, 2020), and depression (Chen et al., 2020; Dawson & Golijani-Moghaddam, 2020; Gray et al., 2020; Jia et al., 2020; Shah et al., 2021; White & Van Der Boor, 2020). It has been argued such effects are likely to be long-term at a global level (for a review, see Serafini et al., 2020).

Loneliness is likely to exacerbate the negative effects of COVID-19 lockdowns on mental health (Shah et al., 2020). Loneliness is defined as the unpleasant subjective experience of a discrepancy between the desired and present social relationships of an individual (Shah et al., 2020; Vanderweele et al., 2012). It is typically characterised by subjective feelings sadness and emptiness during objective social isolation (Weiss, 1973). During the first national lockdown, one U.K. based population study reported that 30.9% (approx. 7.4 million) of people felt that their wellbeing had been negatively affected by loneliness (Office for National Statistics, 2020). A further large study (N = 38, 217) showed that loneliness levels were consistently high for the entirety of the lockdown (Bu et al., 2020). Moreover, a large body of research prior to the COVID-19 pandemic has shown that loneliness is associated with poor mental health, with several studies indicating that loneliness precedes the onset of depressive symptoms in particular (Beutel et al., 2017; Cacioppo et al., 2006; Erzen & Çikrikci, 2018; Holvast et al., 2015; Lee et al., 2021). Additional studies have suggested that the relationship between depression and loneliness is reciprocal (McHugh Power et al., 2020; Tian et al., 2021). Given that loneliness and poor mental health outcomes are a likely result of multiple COVID-19

lockdowns, it is important to identify factors that may reduce impact of loneliness during lockdown and in turn, protect mental health.

One such factor is video gaming, 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). COVID-19 lockdowns have seen increased engagement with video games and related content. For example, in March 2020 the digital video game distribution service Steam reported over 20 million concurrent online users, with over 6.2 million people concurrently gaming, the most recorded by the service since its launch (Perez, 2020). 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. Moreover, the WHO expressed support for the video gaming industry's social media campaign, #PlayApartTogether, which was designed to encourage adherence to social distancing and other COVID-19 safety measures. Additionally, the WHO highlighted video games as a potential relaxation tool in published guidance concerning mental health during COVID-19 lockdowns (World Health Organization, 2020).

Research into the relationship between video-gaming and mental health is complicated. 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 & Higuchi, 2017; Stockdale & Coyne, 2018; Wang et al., 2018; Wittek et al., 2016; Yau et al., 2013). However, these studies typically examine participants who exhibit pathological gaming behaviour such as Internet gaming disorder; defined as excessive engagement with video games despite negative social and/or emotional consequences (Desai et al., 2010; Lemmens et

al., 2011). 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 & Leung, 2004; Ko et al., 2005; Lemmens et al., 2011; Van Rooij et al., 2011). On the other hand, several studies have shown potential benefits of video gaming on mental health and psychological wellbeing (Colwell, 2007; Desai et al., 2010; Granic et al., 2014; Jones et al., 2014; Pallavicini et al., 2018; Snodgrass, Lacy, Dengah, et al., 2011; Snodgrass, Lacy, Francois Dengah, et al., 2011). For example, multiple studies using quantitative and qualitative methodologies have shown that moderate video game engagement can elicit positive emotions (Comello et al., 2019; Durkin & Barber, 2002; Hoffman & Nadelson, 2010; Pallavicini & Pepe, 2020; Przybylski et al., 2012; Russoniello et al., 2009; Shin et al., 2012; Snodgrass, Lacy, Dengah, et al., 2011; Wang et al., 2008), reduce negative emotions (e.g., stress and/or anxiety; (Caro & Popovac, 2020; Horovitz et al., 2016; Pallavicini & Pepe, 2020; Russoniello et al., 2009; Snodgrass et al., 2019; Soyooof & 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 & Barber, 2002). For example, in a recent large study (N = 3227) Johannes et al. (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 (however, this effect was correlational and did not replicate in longitudinal data; see Vuorre et al. 2021).

Still further research suggests that video gaming provides psychological benefits to non-clinical groups in domains that are particularly affected by COVID-19 lockdowns, including stress, loneliness, and mood (Arbeau et al., 2020a; Caro & Popovac, 2020; Hemenover & Bowman, 2018; Hoffman & Nadelson, 2010). 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. Moreover, 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 & Popovac, 2020; Iacovides & Mekler, 2019; van Ingen et al., 2016). Caro et al. (2020) 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 COVID-19 lockdowns.

The current paper presents three studies in which we used 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 all studies, participants provided baseline measures in a retrospective manner (i.e., recalling from prior to the lockdown in question) and current measures (i.e., during the lockdown in question). Based on results from previous studies (e.g., Caro & Popovac, 2020; Iacovides & Mekler, 2019; van Ingen et al., 2016), we tested three hypotheses in each study. Firstly, we hypothesised that loneliness would increase, and all mental health outcomes (i.e., depression, stress, and anxiety) would worsen during each lockdown, relative to baseline. Secondly, we hypothesised that hours spent gaming would increase during each lockdown, relative to baseline. 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

All studies were approved by the Research Ethics Committee of the University of Sunderland, and all participants provided informed consent before each study. These studies were not preregistered. 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. 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 hours 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).

Figure 1 shows the number of participants in each employment situation during lockdown.

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

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 & 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 DASS-21, 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 Rouder (2018)], bayestestR [Version 0.9.0; Makowski, Ben-Shachar, and Lüdtke (2019)], brms [Version 2.14.4; Bürkner (2017); Bürkner (2018)], here [Version 1.0.1; Müller (2017)], mice [Version 3.13.0; van Buuren and Groothuis-Oudshoorn (2011)], modelr [Version 0.1.8; Wickham (2020)], papaja [Version 0.1.0.9997; Aust and Barth (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 increased from baseline during lockdown. 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) in relation to the null hypothesis (i.e. of a point-null effect) 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 Markov Chain Monte Carlo (MCMC) sampling with 1000 posterior samples.

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). Given that all items are scored in each subscale of the DASS-21 and the Three-item Loneliness Scale by summing responses to each item, the summed responses to these items are necessarily integers with a lower and upper bound and represent ordinal responses. To accommodate this, we analysed the data using ordinal models (Bürkner & Vuorre, 2019). These models are more appropriate than those that assume the response variable is metric (e.g., typical linear regression

assuming data are drawn from a Gaussian distribution), which often result in poor effect size estimates (e.g., predictions outside the possible range of values).

The models took the form of a cumulative linear model with a logit link function, assuming that the response variable is generated from categorisation of an unobserved continuous variable. 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, the intercept represents the grand mean and parameter estimates represent the impact of lockdown on mental health outcomes across the average hours played (i.e., a main effect of lockdown period), the impact of hours played across the average of both time points (i.e. a main effect of hours played), and their interaction. All models contained random intercepts per participant. Details of the priors for all models are outlined in Appendix A. Parameter estimates and 95% credible intervals were again obtained using MCMC sampling with 8000 posterior samples. We used the `hypothesis()` function from the `brms` R-package to calculate Bayes factors using the Savage-Dickey density ratio to evaluate evidence in support of the null hypothesis for each parameter estimate (i.e. for a point-null effect of 0) in relation to the alternative hypothesis (i.e. of a non-zero effect).¹ The Supplemental Material (see <https://osf.io/d5byr/>) 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 insensitive to changes to the prior scales.

¹ Bayes factors are used here to evaluate the relative evidence in support of the alternative hypothesis against the null hypothesis. That is, considering the priors in the model, is 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.

Additional analyses were used to further delineate any effects of gaming habits on changes to mental health outcomes. 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. 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 B 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, $BF_{10} > 1,000,000$ ($\pm 0.00\%$), with posterior summaries showing an average increase in total hours played of 9.84 ($SD = 1.20$, 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.

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.

Dots are jittered for ease of viewing.

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.

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 $\pm$ 95% credible intervals.

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.

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	<i>Est.</i>	<i>SE</i>	95% CI	<i>BF</i> 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). Effects are reported on the log scale.

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 $\pm 1-3$). 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.

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 $\pm 95\%$ credible intervals, with each line representing the mean loneliness score ± 1 SD.

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.

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	<i>Est.</i>	<i>SE</i>	95% CI	<i>BF</i> 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). Effects are reported on the log scale.

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 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 (Stephoe et al., 2013). Therefore Study 2 included the De Jong-Gierveld 11-Item Loneliness Scale (de Jong-Gierveld & 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 responded to an online study advert specifically targeted to gamers. Exclusion criteria were the same as in Study 1 (see section 2.1.1.).

After all exclusions, the sample included 76 participants (age $M = 29.96$, $SD = 8.24$, Range = 19 - 64). On average participants took 17.00 minutes ($SD = 15.36$) to complete the task. Figure 5 shows the number of participants in each employment situation during lockdown.

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

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 baseline 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 & 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

The average mental health outcomes and total hours played before and during lockdown are depicted in Figure 6.

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, $BF_{01} = 7.70 (\pm 0\%)$, 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.

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 $\pm$ 95% credible intervals.

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.

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	<i>Est.</i>	<i>SE</i>	95% CI	<i>BF</i> 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). Effects are reported on the log scale.

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 in 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 $\pm 1SD$ of the mean.

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 $\pm$ 95% credible intervals, with each line representing the mean loneliness score $\pm$ 1 SD.

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.

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	<i>Est.</i>	<i>SE</i>	95% CI	<i>BF</i> 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				
Difference in Hours Played	0.02	0.03	[-0.03, 0.07]	32.25
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). Effects are reported on the log scale.

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.

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 hours 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.

4. Study 3

Study 2 yielded several different results from Study 1. Unlike Study 1, Study 2 suggested that a) gaming hours did not increase from baseline during lockdown, b) there was no effect of lockdown on mental health outcomes, 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.

4.1. Methods

4.1.1. Participants

One hundred and five participants responded to an online study advert specifically targeted to gamers. 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 minutes ($SD = 737.51$) to complete the task. Figure 9 shows the number of participants in each employment situation during lockdown.

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

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).

4.2. Results

The average mental health outcomes and total hours played before and during lockdown are depicted in Figure 10.

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.

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), $BF_{10} = 1.52 (\pm 0\%)$, 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 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 $\pm$ 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	<i>Est.</i>	<i>SE</i>	95% CI	<i>BF₀₁</i>
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). Effects are reported on the log scale.

Table 6 shows evidence in support of the null hypothesis relative to the alternative hypothesis for all effects and for all mental health outcomes. In all cases however, given the Bayes factors in this instance provide rather weak evidence (i.e. with Bayes factors between 1–3; Lee & 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 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.

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 $\pm$ 95% credible intervals, with each line representing the mean loneliness score $\pm$ 1 SD.

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.

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	<i>Est.</i>	<i>SE</i>	95% CI	<i>BF</i> 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.

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 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 aim of the present study was to test the relationship between video gaming, loneliness, and mental health outcomes, using the three national COVID-19 lockdowns as a model of stress. We hypothesised that each lockdown would be characterised by i) increased depression, stress, anxiety, and loneliness, ii) increased time spent playing video games, and central to our thesis, that iii) there would be a beneficial effect of gaming on mental health outcomes, but that loneliness would moderate this relationship. Taken together, the present studies highlight several interesting issues regarding the effects of lockdowns and loneliness on mental health. In line with the first hypothesis, Study 1 revealed that depression, stress, and anxiety all

worsened during the first lockdown relative to baseline. However, this was not replicated during the second and third lockdowns. Moreover, all three lockdowns were characterised by increased loneliness, relative to baseline. Evidence regarding the second hypothesis was inconsistent; while the first lockdown was associated with an increase in time spent gaming, this was not replicated in subsequent lockdowns. Contrary to our third hypothesis, gaming did not have a beneficial effect on mental health, nor was this effect 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.

The present studies yield several interesting findings concerning the influence of lockdown on mental health. In line with similar studies (Pieh et al., 2021; Rossi et al., 2020; Valdez et al., 2020), only the first lockdown was yielded a main effect of lockdown on stress, depression, and anxiety, with an increase in scores relative to baseline. 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 et al., 2020). Following this explanation, the lack of a main effect of the second and third lockdowns on mental health may reflect 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 et al., 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).

We observed partial support for the second hypothesis, as the amount of time spent gaming increased during the first lockdown, relative to baseline. However, no such increase was evident during the second and third lockdown contrary to previous research (e.g., Balhara, Kattula, Sing & Chukkali, 2020; Barr & Copeland-Stewart, 2021). A possible explanation for this pattern is that participants' gaming hours may be subject to a ceiling effect following the first lockdown. That is, during the first lockdown participants' gaming hours increased relative to baseline and remained at the increased level prior to and during 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). Further qualitative data revealed participants' intentions to maintain these positive changes post-lockdown (Williams, MacDonald, et al., 2021). Whether such positive effects are long-term positive changes is yet to be directly investigated.

The third hypothesis which is central to this present work was two-fold: Firstly, we predicted that time spent gaming would reduce depression, stress, and anxiety scores. Secondly, we predicted that 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 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 (Durkin and Barber 2002; Allahverdi-pour et al. 2010; Desai et al. 2010; Johannes et al. 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 “causal” games that yield a beneficial effect (Croissant & Frister, 2021; Fish et al., 2014; Pearce et al., 2021; Russoniello et al., 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 be noted that several studies have reported small effects of gaming on mental health (e.g. Johannes et al. 2021), leading some researchers to question whether a direct relationship between gaming time and mental health truly exists (Ferguson, 2009), or if it is likely to be of clinical and/or subjective importance (Norman et al., 2003).

A number of studies have also reported a negative effect of time spent gaming on mental health, though most of these studies focus on “excessive” or “pathological” gaming (Lemmens et al., 2011; Peng & Liu, 2010; H. R. Wang et al., 2018) (for a review see Männikkö et al. 2020). In the present paper, only Study 2 provided strong evidence that more time gaming 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 et al., 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 (Ryan et al. 2006; Lafrenière et al. 2009; Carras et al. 2017; Halbrook et al. 2019). As such, the present findings support the concept of an ‘optimal gaming profile’ described by Halbrook et al. (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, all three lockdowns were characterised by greater loneliness relative to baseline. 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 & Vella 2021). Secondly, while lockdown alone did not affect mental health, all three studies provided evidence that loneliness during lockdown resulted in poorer mental health relative to baseline. This is in line with several cross-sectional (González-Sanguino et al. 2020; Li & Wang 2020; Okruszek et al. 2020; Tso & Park 2020; Losada-Baltar et al. 2021) 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 lockdown 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 et al., 2020) and there is evidence suggesting that the COVID-19 pandemic has increased already high levels of loneliness (Heidinger & Richter, 2020; C. M. Lee et al., 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.

The present studies are not without limitation. Firstly, the use of self-reported measures of gaming hours throughout may have impacted the results. Previous research comparing telemetry data to self-report has shown that participants typically over-estimate their gaming time (Johannes et al., 2021). Therefore, it is possible the relationship between gaming hours and mental health in the present study was underestimated (Jones-Jang et al., 2020). Secondly, although each present study included baseline measures it is important to note that they were taken retrospectively, due to the unpredictable nature and timing of COVID-19 lockdowns. As such, it is possible that the baseline measures were subject to cognitive and emotional biases. 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, see Vanderlind et al., 2020), resulting in an underestimation of the effect lockdown had on mental health. Finally, 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).

Conclusions

In conclusion, the evidence presented across three studies has shown that the effect of COVID-19 lockdowns on mental health is largely driven by the presence of loneliness. In all three lockdowns, loneliness increased from baseline and was associated with increased levels of depression, stress, and anxiety. Moreover, contrary to our predictions, gaming did not have a beneficial effect on mental health, nor was this relationship moderated by loneliness. These findings provide an enhanced understanding of the effect that lockdown 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). In addition, the present studies provide evidence for the theoretical concept of an optimal gaming profile, as a linear relationship between gaming and mental health outcomes was not evident. Most important, 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 & Vella, 2021) investigating mental health during the pandemic, emphasise the need for targeted public mental health interventions to alleviate potentially widespread mental distress.

6. Context of the Research

This project developed from the research teams' general interest in both gaming effects on cognition, and the psychosocial factors that can influence mental health outcomes. Inspired by public discourse and media narratives concerning both the effect of lockdown on public mental health and the effect of video gaming on mental health during lockdown, we sought to provide

empirical data to answer the applied question of whether video games could help alleviate some of the frequently reported difficulties (i.e., depression, anxiety, stress, and loneliness) associated with being in lockdown. To our knowledge, this is the only study that has collected data on mental health, loneliness, and gaming habits during all three lockdowns. Our use of modelling to examine the relationships under investigation is an additional strength to the present studies, as such statistical techniques are currently underutilised in most clinically relevant research. Our finding that loneliness during lockdown presents a significant risk to mental health, and videogaming is not sufficient to prevent this effect, should be of interest to researchers and clinicians working to develop suitable interventions that aim to reduce the effect of lockdown-related loneliness on mental health.

Appendices

Appendix A

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 B

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.

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