

¹ Videogaming effects on mental health outcomes during three COVID-19 national lockdowns

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18

Abstract

19 Abstract goes here.

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23 **Introduction**

24 Intro here.

25 **Study 1**

26 **Methods**

27 **Participants.** Five hundred and seventy-one participants were recruited to take
28 part in this study online via Qualtrics. Of which 344 provided full informed consent. One
29 hundred and fifteen participants were excluded from this sample due to having completed
30 less than 90% of the questionnaire, providing invalid employment details (i.e. stating they
31 were both employed and unemployed) or for reporting having played no games before or
32 during lockdown. A further 9 participants were removed from the analysis due to having
33 more than 20% of trials with missing data and/or having reported hours played more than
34 98 hours per week (i.e. an average of 14 hours a day). From the remaining sample, only

35 `data_summary$01_study-01$missing_data_counts %>% group_by(is_missing) %>%
36 summarise(n = sum(n)) %>% pivot_wider(names_from = is_missing, values_from =
37 n) %>% mutate(percent =TRUE/FALSE) %>% pull(percent)%` of trials had missing
38 data, which was handled using multiple imputation with the mice R-package (van Buuren
39 & Groothuis-Oudshoorn, 2011).

40 After all exclusions we analysed data from 220 participants (age $M = 32.01$, $SD =$
41 8.96, Range = 19 - 72). On average participants took 25.77 minutes to complete the task
42 ($SD = 91.26$).

43 Figure 1 shows the number of participants in a given employment situation during
44 lockdown.

45 **Procedure and Materials.**

⁴⁶ ***Depression, Anxiety, Stress Scale – 21 items (DASS-21, Antony et al.,***
⁴⁷ ***1998; Lovibond & Lovibond, 1995).***

⁴⁸ The DASS-21 was used to measure mental health outcomes. This 21-item scale is
⁴⁹ comprised of three sub-scales: depression, anxiety, and stress. The analysis considered all
⁵⁰ three subscales individually. For each item, participants are required to indicate how often
⁵¹ the item applies to them via a 4-point Likert scale (1 = Did not apply to me at all, 4 =
⁵² Applied to me very much or most of the time).

⁵³ ***UCLA Three-item Loneliness Scale (Hughes et al., 2004).***

⁵⁴ The UCLA Three-item Loneliness Scale was used to measure of loneliness. The three
⁵⁵ items ask participants to indicate how often they felt that they lacked companionship, felt
⁵⁶ left out, and felt isolated from others, using a 3-point Likert scale (1 = Hardly ever, 3 =
⁵⁷ Often).

⁵⁸ ***Video gaming habits questionnaire (adapted from Waris et al., 2019).***

⁵⁹ To assess video gaming habits, we adapted the video gaming habits questionnaire as
⁶⁰ reported by Waris et al. (2019). Participants were asked to indicate whether they played
⁶¹ computer, console, or similar games, and to estimate how many hours they played on
⁶² average per week. They were then asked to estimate, as percentages, how much time per
⁶³ week they spent playing the following game genres: card, mobile, action, first-person
⁶⁴ shooter, exercise/music/party, adventure/puzzle/role-playing, simulation, strategy, and
⁶⁵ brain training/education. For each genre, participants were also asked to indicate whether
⁶⁶ they played alone or with others.

⁶⁷ ***Procedure.***

⁶⁸ After consenting, all participants completed a series of demographic questions (e.g.,
⁶⁹ age, sex/gender, education/employment status, living arrangement). They were also asked
⁷⁰ to provide information regarding the effect lockdown had on their employment (e.g.,
⁷¹ furloughed, worked from home, continued as normal). All participants were then presented

72 with the DASS-21, the Three-item Loneliness Scale, and the video gaming habits
73 questionnaires. All questionnaires were administered twice during one survey session. In
74 the first instance, participants were asked to complete the questionnaires with respect to
75 how they felt four weeks before lockdown (i.e., February 2020). This allowed for an
76 approximate baseline measure of each questionnaire. In the second instance, participants
77 were asked to report how they currently felt (i.e., during lockdown).

78 **Data Analysis and Model Fitting.** We used R [Version 4.0.3; R Core Team
79 (2020)] and the R-packages *BayesFactor* [Version 0.9.12.4.2; Morey and Rouder (2018)],
80 *bayestestR* [Version 0.9.0; Makowski, Ben-Shachar, and Lüdecke (2019)], *brms* [Version
81 2.14.4; Bürkner (2017); Bürkner (2018)], *here* [Version 1.0.1; Müller (2017)], *mice* [Version
82 3.13.0; van Buuren and Groothuis-Oudshoorn (2011)], *modelr* [Version 0.1.8; Wickham
83 (2020)], *papaja* [Version 0.1.0.9997; Aust and Barth (2020)], *tidybayes* [Version 2.3.1; Kay
84 (2020)], and *tidyverse* [Version 1.3.0; Wickham et al. (2019)] for all our analyses.

85 Prior to modelling the effect of lockdown and hours playing video games on mental
86 health outcomes, we assessed whether gaming hours increased from baseline during
87 lockdown. To do so, we used the *BayesFactor* R-package to perform a Bayesian
88 paired-samples *t*-test (with a default *Cauchy*(0, 0.707) prior) calculating the Bayes factor
89 in support of the alternative hypothesis (i.e. of a non-zero effect) in relation to the null
90 hypothesis (i.e. of a point-null effect) in regards to an increase in hours played after
91 lockdown. Estimates of the posterior mean and 95% credible intervals for the difference in
92 hours played was obtained using Markov Chain Monte Carlo (MCMC) sampling with 1000
93 posterior samples.

94 Primary analyses aimed to estimate the effect of hours played in games before and
95 after lockdown on mental health outcomes including depression, anxiety, and stress (as
96 measured by the DAS21) and loneliness (as measured by the three-item loneliness scale).
97 Given that all items are scored in each subscale of the DASS-21 and in the Three-item
98 Loneliness Scale by summing responses to each item from a 1-7 Likert scale, the summed

99 responses to these items are necessarily integers with a lower and upper bound and
100 represent ordinal responses. To accommodate this, we analysed the data using ordinal
101 models (Bürkner & Vuorre, 2019). These models are more appropriate than those that
102 assume the response variable is metric (e.g. typical linear regression assuming data are
103 drawn from a Gaussian distribution), which often result in poor effect size estimates
104 (e.g. predictions outside the possible range of values).

105 The models took the form of a cumulative linear model with a logit link function,
106 assuming that the response variable is generated from categorisation of an unobserved
107 continuous variable. These models were fitted using the `brm()` function from the `brms`
108 R-package (Bürkner, 2018). These models contained a fixed effect of total hours played,
109 lockdown period (i.e. before or during lockdown), and the interaction between them. The
110 categorical fixed effect of lockdown period was sum-coded (before = -1, after = 1) while the
111 continuous fixed effect of total hours played was z-transformed. Thus, the intercept
112 represents the grand mean and parameter estimates represent the impact of lockdown on
113 mental health outcomes across the average hours played (i.e. a main effect of lockdown
114 period), the impact of hours played across the average of both time points (i.e. a main
115 effect of hours played), and their interaction. All models contained random intercepts per
116 participant. Details of the priors for all models are outlined in the Appendix.

117 Parameter estimates and 95% credible intervals were again obtained using MCMC
118 sampling with 8000 posterior samples. We used the `hypothesis()` function from the `brms`
119 R-package to calculate Bayes factors using the Savage-Dickey density ratio to evaluate
120 evidence in support of the null hypothesis for each parameter estimate (i.e. for a point-null
121 effect of 0) in relation to the alternative hypothesis (i.e. of a non-zero effect). The
122 Supplemental Material contains prior-predictive and posterior-predictive checks along with
123 sensitivity checks evaluating how the prior scale affects parameter estimates and Bayes
124 factors.

Additional analyses were used to further delineate any effects of gaming habits on changes to mental health outcomes. Change scores for mental health outcomes were calculated subtracting scores during lockdown from before lockdown) and the effect of total hours played during lockdown was estimated on this outcome as a fixed effect. Here, simple Bayesian linear models were used to model change scores (i.e. assuming the data were drawn from a Gaussian distribution). 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 the Appendix and model checks are reported in the Supplemental Material.

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 model (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]). Having confirmed a general increase in hours spent gaming after lockdown we next established the role of total hours spent gaming on 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.

150 Table 1 shows the population-level parameter estimates, their standard error, and
151 95% credible intervals on the log scale, along with Bayes factors in support of the null
152 hypothesis relative to the alternative hypothesis for both main effects and their interaction
153 for each model.

154 Table 1 shows evidence in support of the alternative hypothesis for the effect of
155 lockdown period on depression, stress, and loneliness measures whereby parameter
156 estimates show a reliable increase in these measures during lockdown. While a similar
157 trend is shown for anxiety, the parameter estimate is small, with the credible intervals
158 spanning 0, and with an inconclusive Bayes factor. There is reliable evidence in support of
159 the null hypothesis that total hours played has no effect on loneliness or stress across both
160 lockdown periods. However, while there is evidence that as hours played increases
161 depression and anxiety also increase these effects span a range of negligible to rather large
162 effects and similarly have inconclusive Bayes factors. For all mental health outcomes the
163 lockdown period does not interact with any effect of total hours played.

164 Table 2 shows the population-level parameter estimates, their standard error, and
165 95% credible intervals for the effect of hours played during lockdown on changes to mental
166 health outcomes.

167 Table 2 shows evidence in support of the null hypothesis of no impact of hours played
168 during lockdown on changes to all mental health outcomes.

169 We next tested whether any effect of changes to hours played on mental health
170 outcomes during lockdown is moderated by loneliness during lockdown. Figure 4 shows
171 posterior predictions for mental health outcomes during lockdown as a function of
172 difference in hours played with lines fitted to the average loneliness scores during lockdown
173 $\pm 1 SD$ of the mean.

174 Table 3 shows the population-level parameter estimates, their standard error, and
175 95% credible intervals on the log scale, along with Bayes factors in support of the null

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). Effects are reported on the log scale.

Table 2

*Parameter estimates, 95% credible intervals,
and Bayes factors evaluating evidence in
support of the point null hypothesis that hours
played during lockdown has no impact on
changes to mental health outcomes.*

Model	Est.	SE	95% CI	BF_{01}
Depression	0.00	0.03	[-0.06, 0.05]	18.98
Anxiety	0.00	0.02	[-0.03, 0.03]	32.24
Stress	0.01	0.02	[-0.03, 0.06]	19.08
Loneliness	0.00	0.00	[-0.01, 0.01]	80.60

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.

¹⁷⁶ hypothesis relative to the alternative hypothesis for both main effects and their interaction
¹⁷⁷ for each model.

¹⁷⁸ Table 3 shows evidence in support of the null hypothesis for any effect of difference in
¹⁷⁹ hours played or any moderating effect of loneliness on hours played for all mental health
¹⁸⁰ outcomes. Here, all parameter estimates are very small, with credible intervals spanning
¹⁸¹ zero and with Bayes factors in support of the null hypothesis. relative to the alternative
¹⁸² hypothesis. However, there is substantial evidence in support of higher scores for loneliness
¹⁸³ during lockdown leading to poorer mental health outcomes during lockdown. Here, effects
¹⁸⁴ are positive and large, with Bayes factors in support of the alternative hypothesis relative

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 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). Effects are reported on the log scale.

185 to the null hypothesis.

186 **Interim Summary**

187 Study 1 showed that while on average participants played video games for more hours
188 during lockdown than before lockdown, the hours played or changes to hours played
189 gaming largely have no effect on mental health outcomes. However, mental health
190 outcomes were worse during lockdown when compared to before lockdown. There was no
191 effect of the difference in hours playing games on mental health outcomes, nor any
192 moderating effect of loneliness on the difference in hours playing games. Rather, we show
193 that as loneliness during lockdown increases, stress, anxiety, and depression also increase.

194 **Study 2**

195 The mediation analysis in Study 1 revealed that loneliness did not moderate the
196 relationship between video gaming and DASS-21 scores. However, the Three-Item
197 Loneliness Scale used in Study 1 was not necessarily the optimal measure for the required
198 analysis. Specifically, this measure is designed to provide binary classifications of “lonely”
199 and “not lonely,” as opposed to an average loneliness score (Steptoe et al., 2013).
200 Moreover, the scale measures loneliness as a unitary concept, rather than multidimensional
201 construct comprised of different forms of loneliness (Weiss, 1973). Therefore, to increase
202 the validity and sensitivity of the loneliness measurement, Study 2 included the De
203 Jong-Gierveld 11-Item Loneliness Scale (de Jong-Gierveld & Kamphuls, 1985). This scale
204 provides measurements of both emotional and social loneliness and may therefore be more
205 appropriate for assessing the specific forms of loneliness experienced during lockdown.

206 **Methods**

207 **Participants.** Two hundred and ten participants were recruited to take part in this
208 study online via Qualtrics. Of which 158 provided full informed consent. Sixty-two
209 participants were excluded from this sample due to having completed less than 90% of the
210 questionnaire, providing invalid employment details (i.e. stating they were both employed
211 and unemployed) or for reporting having played no games before or during lockdown. A
212 further 20 participants were removed from the analysis due to having more than 20% of
213 trials with missing data and/or having reported hours played more than 98 hours per week
214 (i.e. an average of 14 hours a day). From the remaining sample, only no trials had missing
215 data.

216 After all exclusions we analysed data from 76 participants (age $M = 29.96$, $SD =$
217 8.24, Range = 19 - 64). On average participants took 17.00 minutes to complete the task
218 ($SD = 15.36$).

219 Figure 5 shows the number of participants in a given employment situation during
220 lockdown.

221 **Procedure and Materials.** The DASS-21 and UCLA Three-Item Loneliness
222 scales were presented identically to Study 1. The assessment of video gaming habits was
223 presented using sliding scales as opposed to requiring participants to manually type in their
224 responses.

225 *The De Jong-Gierveld 11-Item Loneliness Scale (de Jong-Gierveld &
226 Kamphuls, 1985).*

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

Procedure.

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

Results

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

We found support of the null model (i.e. the point null hypothesis) compared to the alternative model (i.e. of a difference in means), $BF_{01} = 7.70 (\pm 0.00\%)$, 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 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 relative to the alternative hypothesis for both main effects and their interaction for each model.

Table 4 shows evidence in support of the null hypothesis relative to the alternative hypothesis for the effect of lockdown period on all mental health outcomes. However, there is evidence in support of the alternative hypothesis relative to the null hypothesis with regard to total hours played for depression, anxiety, and stress. Here, higher total hours played is associated with poorer mental health outcomes across both lockdown periods. For loneliness the effect of total hours played is small, with the credible interval spanning zero and with evidence in support of the null hypothesis relative to the alternative hypothesis.

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 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). Effects are reported on the log scale.

255 For all mental health outcomes the lockdown period does not interact with any effect of
 256 total hours played.

257 Table 5 shows the population-level parameter estimates, their standard error, and
 258 95% credible intervals for the effect of hours played during lockdown on changes to mental
 259 health outcomes.

Table 5

*Parameter estimates, 95% credible intervals,
 and Bayes factors evaluating evidence in
 support of the point null hypothesis that hours
 played during lockdown has no impact on
 changes to mental health outcomes.*

Model	Est.	SE	95% CI	BF_{01}
Depression	0.04	0.03	[-0.03, 0.10]	7.22
Anxiety	0.05	0.02	[0.00, 0.09]	3.41
Stress	0.07	0.03	[0.02, 0.13]	0.58
Loneliness	0.00	0.01	[-0.02, 0.02]	58.51

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.

260 Table 5 shows evidence in support of the null hypothesis of no impact of hours played
 261 during lockdown on changes to depression, anxiety, and loneliness. For changes to anxiety
 262 the parameter estimate is small, with the credible interval showing a range of values from
 263 nearly 0 to a small upper limit, and with an inconclusive Bayes factor.

We next tested whether any effect of changes to hours played on mental health outcomes during lockdown 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 $\pm 1 SD$ 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.

Table 6 shows 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.

Interim Summary

Unlike Study 1, Study 2 showed no average increase in hours spent gaming during lockdown when compared to before lockdown. In contrast to Study 1, there was no overall impact of lockdown period on mental health outcomes, but instead as hours spent gaming increased there were more negative outcomes for depression, anxiety, and stress, regardless of lockdown period. 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 depression, anxiety, and stress. Replicating effects for Study 1,

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	0.03	[-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.

289 we found that higher scores for loneliness during lockdown led to poorer mental health
290 outcomes during lockdown. Again, there was no effect of the the difference in hours playing
291 games on mental health outcomes, nor any moderating effect of loneliness on the difference
292 in hours playing games.

293 **Study 3**

294 [justification needed here – might be easier once we have the results plugged in
295 above?]

296 **Methods**

297 **Participants.** One hundred and five participants were recruited to take part in this
298 study online via Qualtrics. Of which 86 provided full informed consent. Twenty-six
299 participants were excluded from this sample due to having completed less than 90% of the
300 questionnaire, providing invalid employment details (i.e. stating they were both employed
301 and unemployed) or for reporting having played no games before or during lockdown. A
302 further 5 participants were removed from the analysis due to having more than 20% of
303 trials with missing data and/or having reported hours played more than 98 hours per week
304 (i.e. an average of 14 hours a day). From the remaining sample, no trials had missing data.

305 After all exclusions we analysed data from 55 participants (age $M = 30.49$, $SD =$
306 7.65, Range = 19 - 51). On average participants took 116.57 minutes to complete the task
307 ($SD = 737.51$).

308 Figure 9 shows the number of participants in a given employment situation during
309 lockdown.

310 **Procedure and Materials.** All questionnaire procedures were identical to Study
311 2, with wording updated to the lockdown under investigation (i.e., since the beginning of
312 January 2021).

313 **Results**

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

316 We show inconclusive evidence in support of the alternative model (i.e. of a difference
317 in means) relative to the null model (i.e. the point null hypothesis), $BF_{10} = 1.52 (\pm$
318 0.00%), with posterior summaries showing an average increase in total hours played of 5.17
319 ($SD = 2.37$, 95% CI = [0.60, 9.63]). Regardless, we applied the same models to the second
320 lockdown as in Study 1.

321 Figure 11 shows posterior estimates for mental health outcomes before and during
322 lockdown as a function of the total hours played before or during lockdown.

323 Table 7 shows the population-level parameter estimates, their standard error, and
324 95% credible intervals on the log scale, along with Bayes factors in support of the null
325 hypothesis relative to the alternative hypothesis for both main effects and their interaction
326 for each model.

327 Table 7 shows evidence in support of the null hypothesis relative to the alternative
328 hypothesis for all effects and for all mental health outcomes. In all cases however, given the
329 Bayes factors in this instance provide rather weak evidence (i.e. with Bayes factors between
330 1-3; Lee & Wagenmakers, 2013) and an insensitivity to conclusively provide evidence in
331 support of the null. This is likely due to a small sample size.

332 Most notably, as shown in Figure 11 depression, stress, and loneliness are all very
333 high before and during lockdown and regardless of the hours spent gaming. This likely
334 indicates that ceiling effects are present whereby if lockdown period or hours spent gaming
335 were to influence mental health outcomes in this instance it is difficult to detect due to
336 exceptionally high scores for these subscales.

337 Table 8 shows the population-level parameter estimates, their standard error, and

Table 7

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). Effects are reported on the log scale.

³³⁸ 95% credible intervals for the effect of hours played during lockdown on changes to mental
³³⁹ health outcomes.

Table 8

*Parameter estimates, 95% credible intervals,
and Bayes factors evaluating evidence in
support of the point null hypothesis that hours
played during lockdown has no impact on
changes to mental health outcomes.*

Model	Est.	SE	95% CI	BF_{01}
Depression	0.06	0.04	[-0.01, 0.14]	3.39
Anxiety	-0.02	0.02	[-0.07, 0.02]	12.21
Stress	0.05	0.03	[-0.01, 0.10]	5.22
Loneliness	0.01	0.01	[-0.01, 0.02]	48.72

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.

³⁴⁰ Table 8 shows evidence in support of the null hypothesis of no impact of hours played
³⁴¹ during lockdown on changes to all mental health outcomes.

³⁴² We next tested whether any effect of changes to hours played on mental health
³⁴³ outcomes during lockdown is moderated by loneliness during lockdown. Figure 12 shows
³⁴⁴ posterior predictions for mental health outcomes during lockdown as a function of
³⁴⁵ difference in hours played with lines fitted to the average loneliness scores during lockdown
³⁴⁶ $\pm 1 SD$ of the mean.

347 Table 9 shows the population-level parameter estimates, their standard error, and
348 95% credible intervals on the log scale, along with Bayes factors in support of the null
349 hypothesis relative to the alternative hypothesis for both main effects and their interaction
350 for each model.

351 Table 9 shows evidence in support of the null hypothesis for any effect of difference in
352 hours played or any moderating effect of loneliness on hours played for all mental health
353 outcomes. Here, all parameter estimates are very small, with credible intervals spanning
354 zero and with Bayes factors in support of the null hypothesis relative to the alternative
355 hypothesis. However, there is substantial evidence in support of higher scores for loneliness
356 during lockdown leading to poorer mental health outcomes during lockdown. Here, effects
357 are positive and large, with Bayes factors in support of the alternative hypothesis relative
358 to the null hypothesis.

359 **Interim Summary**

360 Study 3 showed inconclusive findings for any increase in hours playing games during
361 lockdown compared to before lockdown. Here, there was no impact of lockdown period,
362 hours playing games, or their interaction on mental health outcomes. However, given the
363 Bayes factors in this instance provide rather weak evidence (i.e. with Bayes factors between
364 1-3; Lee & Wagenmakers, 2013) this highlights potential insensitivity of the hypothesis test
365 to answering this question, largely due to a small sample size. Furhter, inspection of plots
366 shows potential ceiling effects – at least for depression, stress, and loneliness – whereby
367 scores were very high both before and during lockdown.

368 More strongly, there was convincing evidence for no impact of hours playing games
369 during lockdown on changes to mental health outcomes. Replicating effects for Studies 1
370 and 2, we found that higher scores for loneliness during lockdown led to poorer mental
371 health outcomes during lockdown. Again, there was no effect of the the difference in hours

Table 9

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.

³⁷² playing games on mental health outcomes, nor any moderating effect of loneliness on the
³⁷³ difference in hours playing games.

³⁷⁴

General Discussion

³⁷⁵ Potentially people with depression/subclinical depression may look on history with
³⁷⁶ increased negative appraisal.

377

Appendix

378 The main, cumulative models used a $Student - t(3, 0, 2.5)$ prior on the intercept, a
379 $Normal(0, 1)$ prior on the slope terms, and an $Exponential(1)$ prior on the standard
380 deviation term for the depression, anxiety, and stress outcomes. Given the outcome for the
381 loneliness model has a more limited range, the models based on loneliness as an outcome
382 had a $Student - t(3, 0, 1.5)$ prior on the intercept. The slope and standard deviation priors
383 remained unchanged.

384 The models assessing change to mental health outcomes during lockdown based on
385 changes to hours played before and during lockdown used a $Normal(0, 2)$ prior on the
386 intercept, a $Normal(0, 0.5)$ prior on the slope term, and an $Exponential(1)$ prior on the
387 standard deviation term for the depression, anxiety, and stress outcomes. Again, due to the
388 restricted range for the loneliness outcome the intercept prior was restricted to a
389 $Normal(0, 1)$ prior. The slope and standard deviation priors remained unchanged.

390 Finally, the models assessing whether loneliness moderates any effect of hours played
391 on mental health outcomes used a $Student - t(3, 0, 3)$ prior on the intercept and a
392 $Normal(0, 1)$ prior on the slope term.

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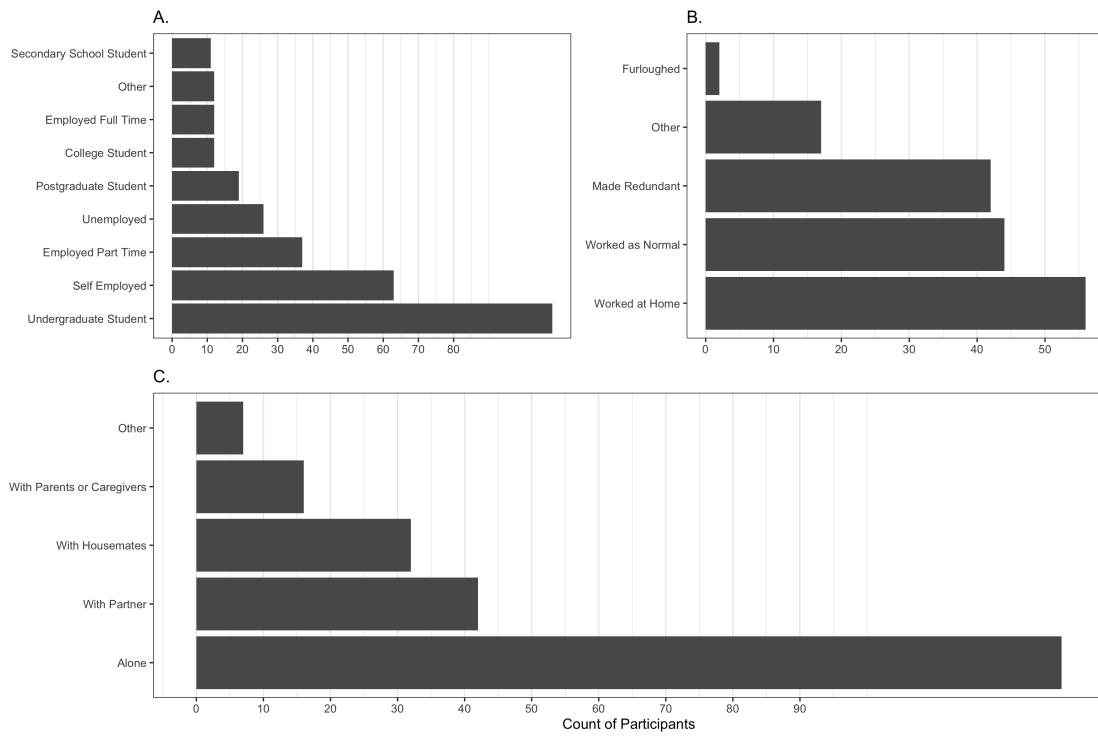


Figure 1. Count of participants by self-reported (a) employment status, (b) lockdown work situation, and (c) living situation.

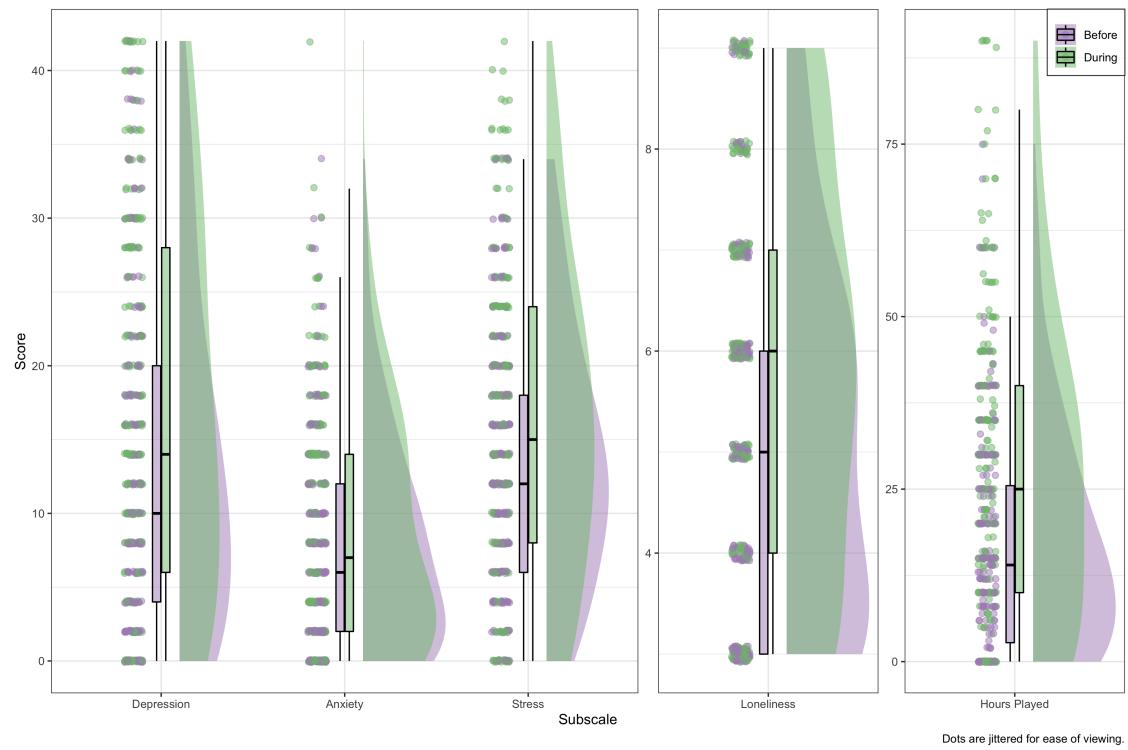


Figure 2. Mental health outcomes for the depression, anxiety, stress, and loneliness along with total hours played before and during lockdown. Dots represent individual participants' mean (jittered) scores.

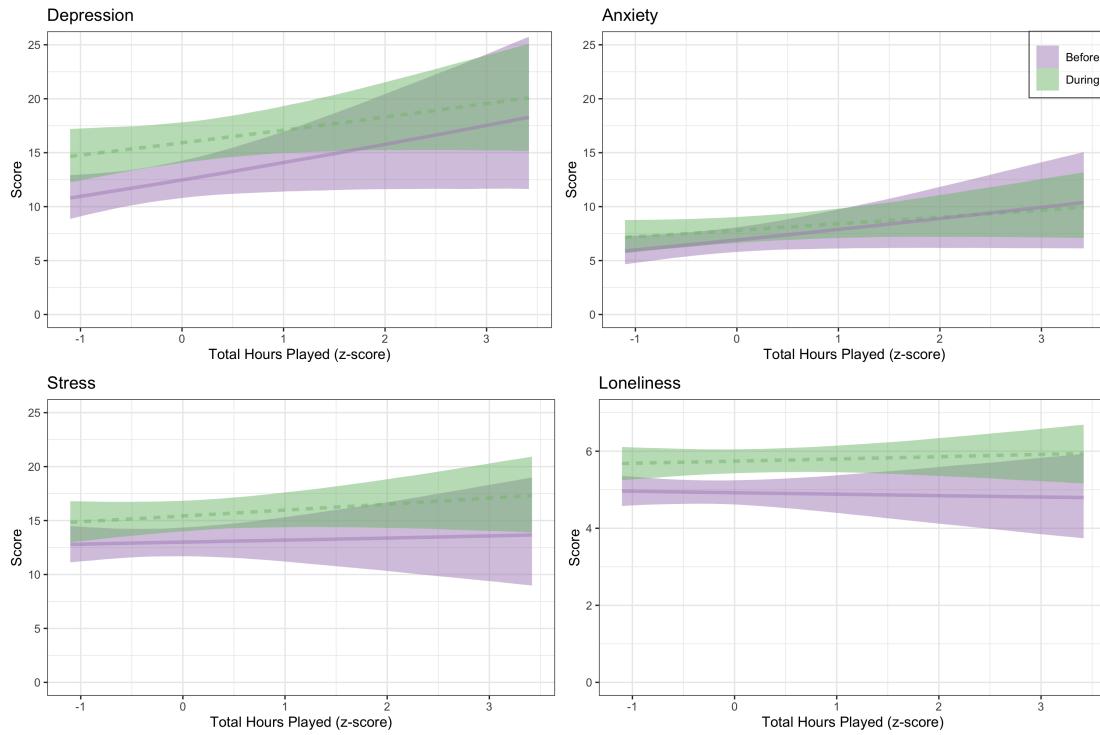


Figure 3. Mental health outcomes for the depression, anxiety, stress, and loneliness measures as a function of total hours played before and during lockdown. Lines and ribbons indicate the posterior median \pm 95% credible intervals.

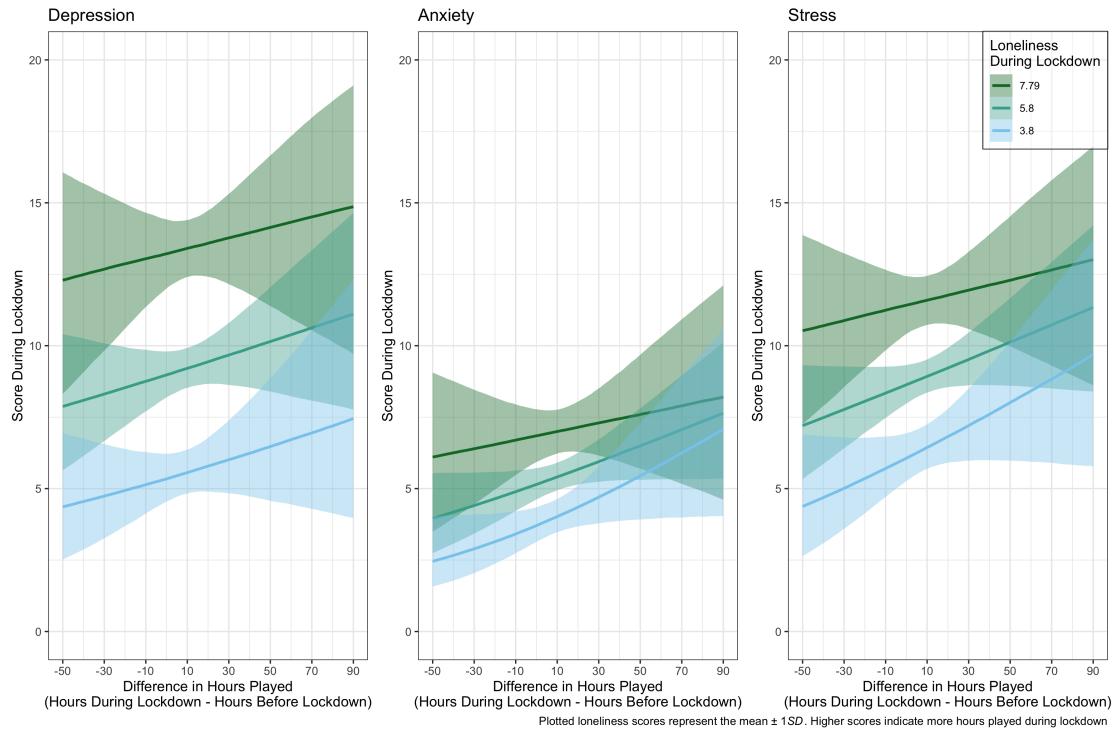


Figure 4. Mental health outcomes for the depression, anxiety, and stress measures as a function of the difference in hours played before and during lockdown and loneliness scores during lockdown. Lines and ribbons indicate the posterior mean $\pm 95\%$ credible intervals, with each line representing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

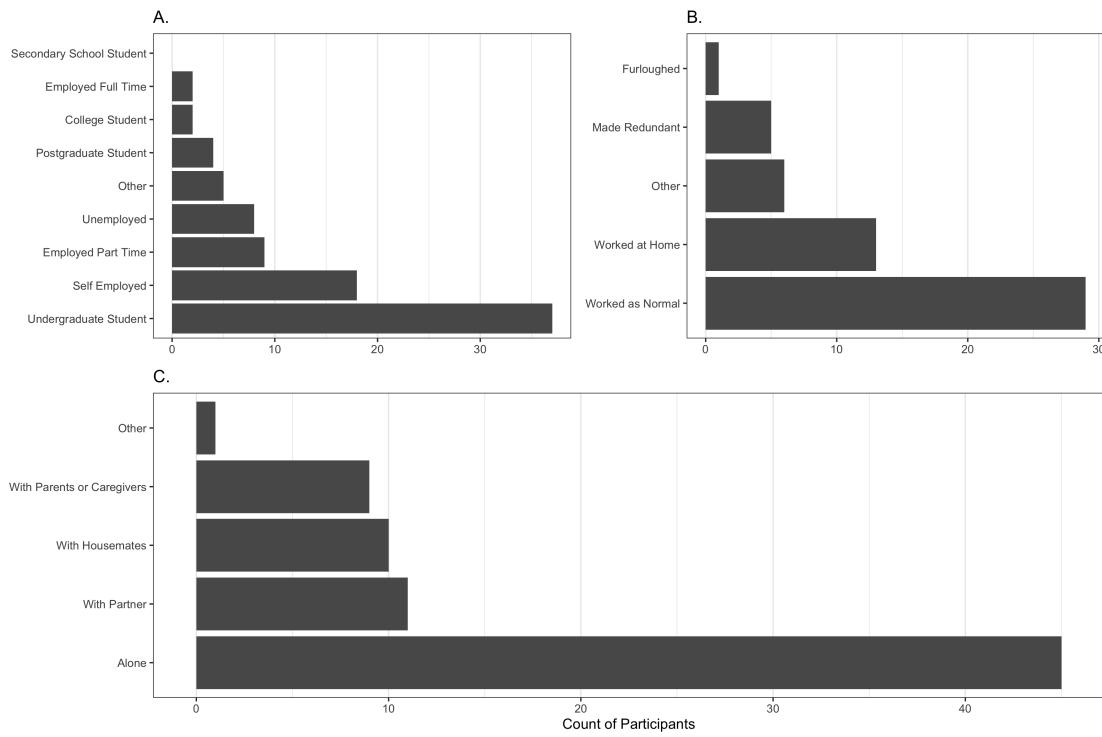


Figure 5. Count of participants by self-reported (a) employment status, (b) lockdown work situation, and (c) living situation.

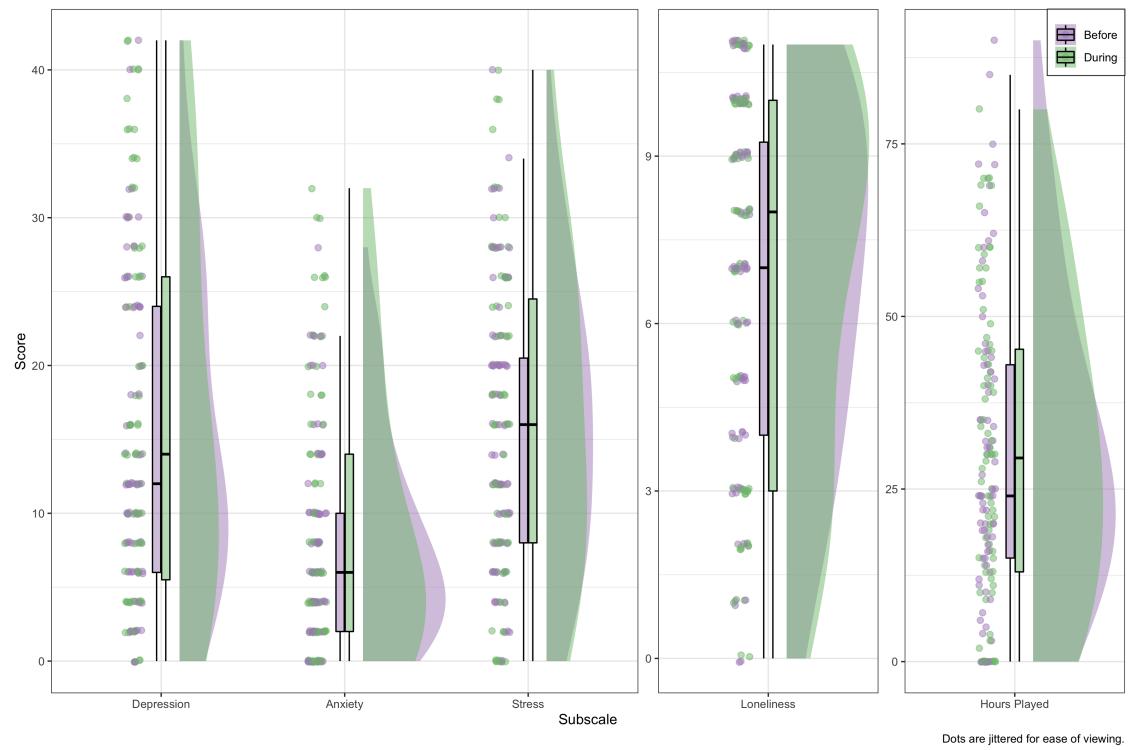


Figure 6. Mental health outcomes for the depression, anxiety, stress, and loneliness along with total hours played before and during lockdown. Dots represent individual participants' mean (jittered) scores.

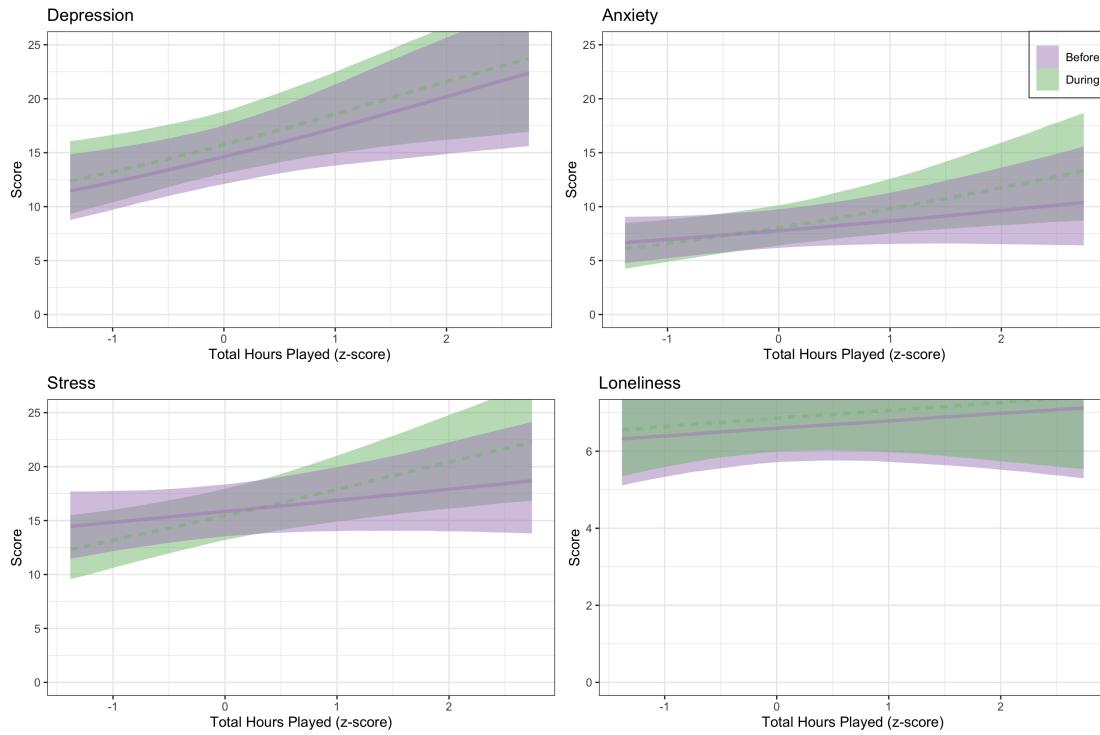


Figure 7. Mental health outcomes for the depression, anxiety, stress, and loneliness measures as a function of total hours played before and during lockdown. Lines and ribbons indicate the posterior median \pm 95% credible intervals.

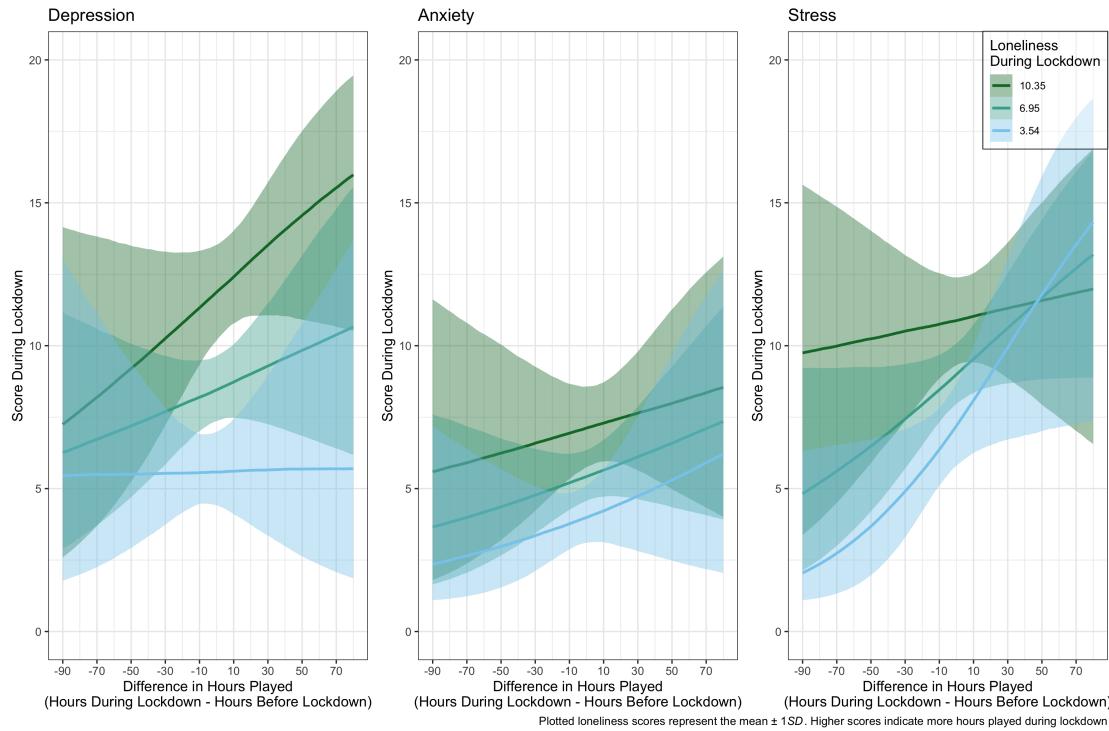


Figure 8. Mental health outcomes for the depression, anxiety, and stress measures as a function of the difference in hours played before and during lockdown and loneliness scores during lockdown. Lines and ribbons indicate the posterior mean $\pm 95\%$ credible intervals, with each line representing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

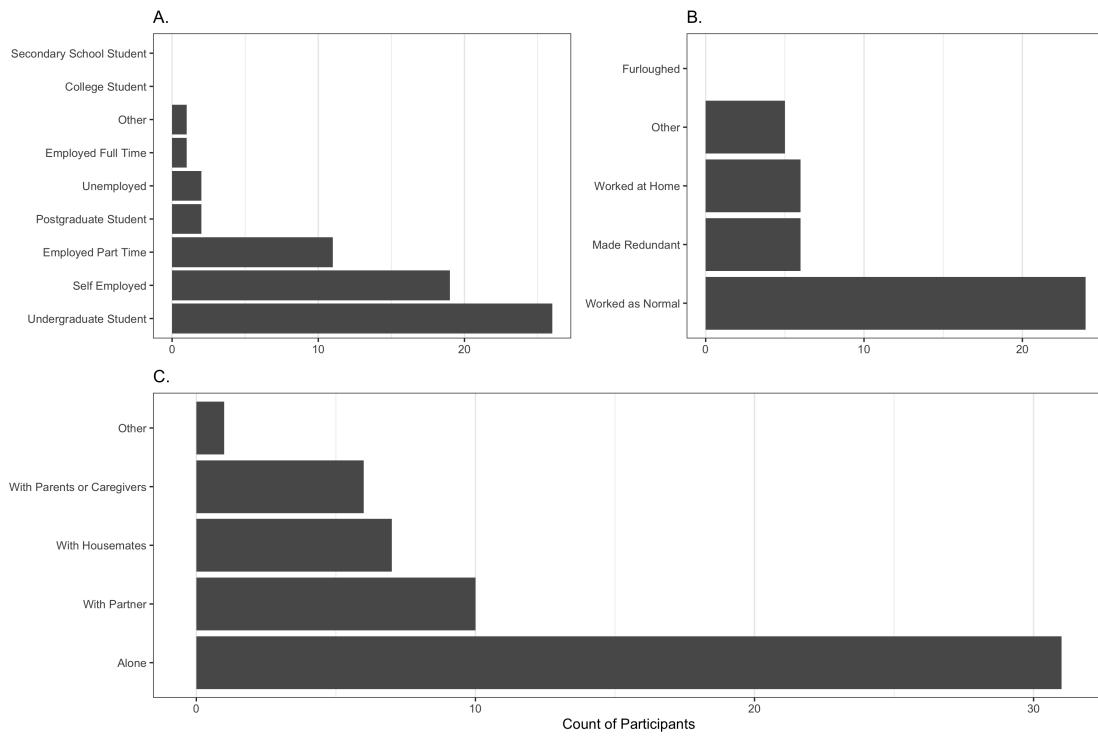


Figure 9. Count of participants by self-reported (a) employment status, (b) lockdown work situation, and (c) living situation.

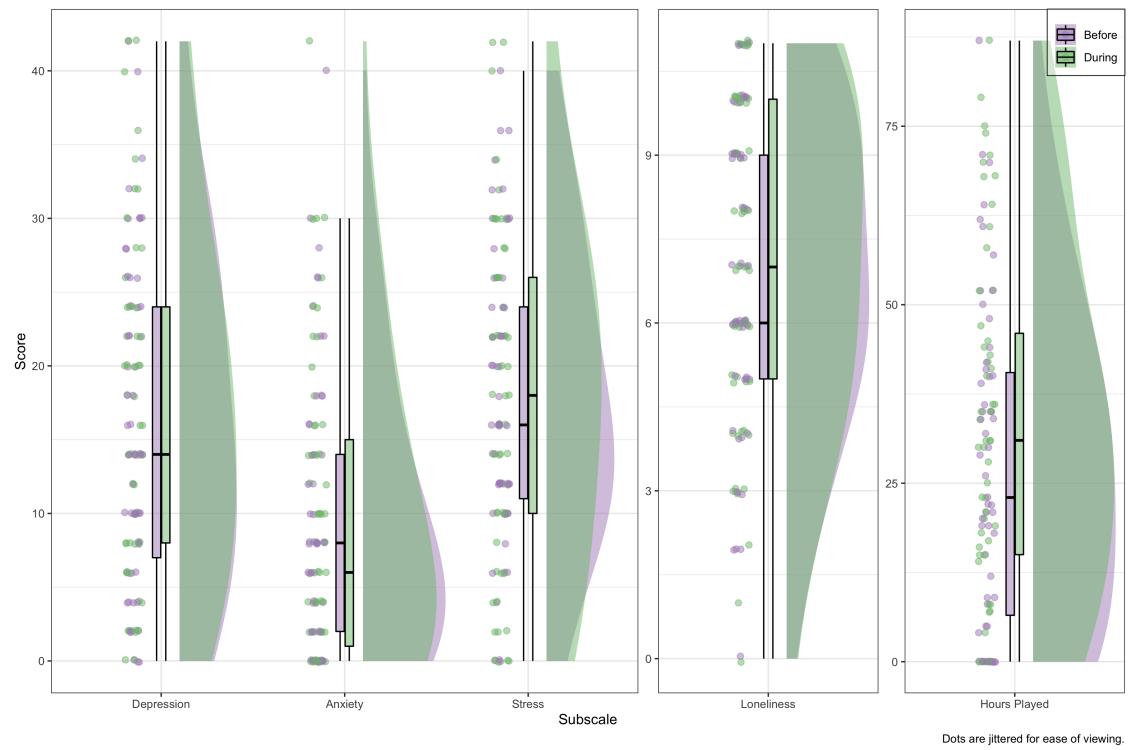


Figure 10. Mental health outcomes for the depression, anxiety, stress, and loneliness along with total hours played before and during lockdown. Dots represent individual participants' mean (jittered) scores.

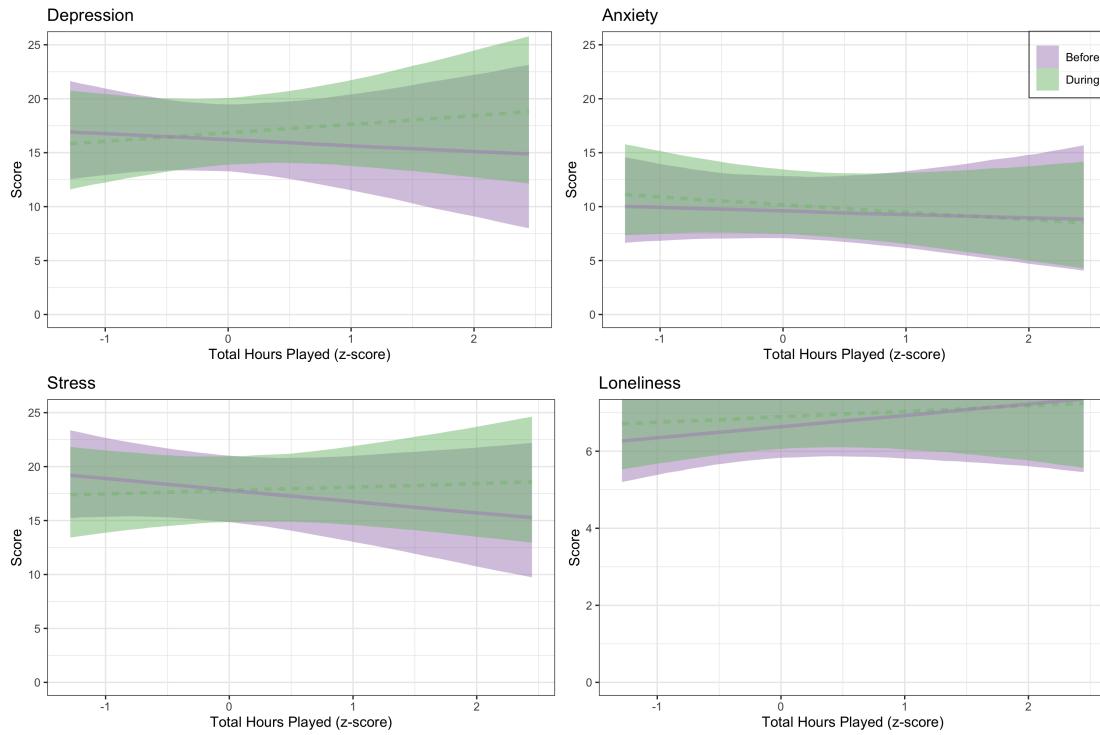


Figure 11. Mental health outcomes for the depression, anxiety, stress, and loneliness measures as a function of total hours played before and during lockdown. Lines and ribbons indicate the posterior median \pm 95% credible intervals.

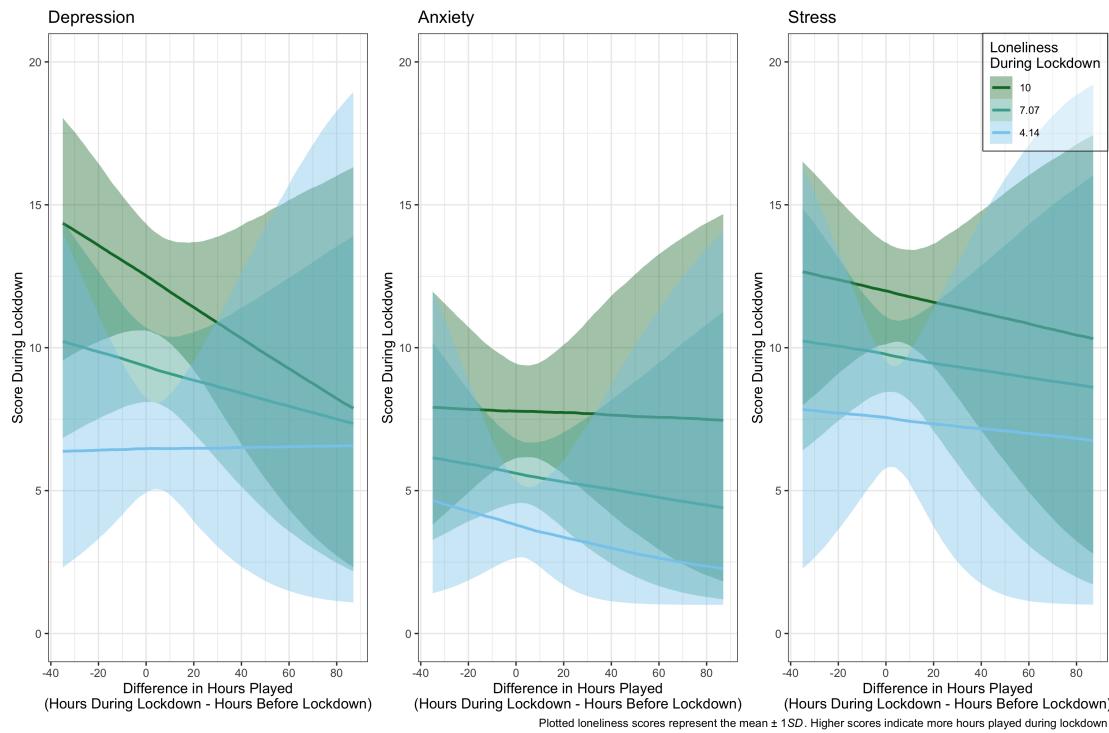


Figure 12. Mental health outcomes for the depression, anxiety, and stress measures as a function of the difference in hours played before and during lockdown and loneliness scores during lockdown. Lines and ribbons indicate the posterior mean $\pm 95\%$ credible intervals, with each line representing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