The Moderating and Mediating Role of Social Interactions within the Relationship Between Extraversion and Loneliness during the COVID-19 Pandemic

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Github link: https://github.com/FloorDP/CAEDproject

Introduction

The COVID-19 pandemic had a clear impact on the mental health of human beings (Lee et al., 2020). Loneliness was one of the most frequently reported mental health problems during this period and could be described as “the painful feeling that results from a discrepancy between the quantity and/or the quality of the desired social connection on the one hand, and actual social connection on the other hand” (Ernst et al., 2022; Lee et al., 2020). Whereas quantity refers to the number of social contacts, quality refers to the subjective experience of characteristics such as intimacy of conflict.

It is important to note that loneliness could be separated from social isolation. Whereas loneliness focuses on experiencing a discrepancy between the desired social contacts and actual social contacts, social isolation could be defined as “the objective state of having few or infrequent social interactions” (Ernst et al., 2022). The differences between loneliness and social isolation could in turn explain the fact that not all people who have few contacts, feel lonely. Individual characteristics such as personality traits and environmental factors could explain why the pandemic does not affect everyone in the same psychological manner (Ernst et al., 2022). Research showed that personality traits shape the need or desire for social contact and the quantity and quality of social relationships (Ernst et al., 2022). Concretely, extraversion is an interesting personality trait as it is related to fewer experiences of loneliness (Buecker et al., 2020). People scoring higher on extraversion have an innate higher need for social contact and have more social interactions compared to introverts (Entringer & Gosling, 2022). Consequently, multiple studies indicated that during the COVID-19 pandemic, extraversion is related to increased loneliness and lower well-being (Alt et al., 2021; Bellingtier et al., 2021; Entringer & Gosling, 2022; Gubler et al., 2021; Zager Kocjan et al., 2021). Concretely, the restriction of social contacts during the lockdown results in a higher deviation in social behavior for more extraverted people. In turn,

individuals scoring high on extraversion are more negatively affected by social distancing policies which makes them more susceptible to experiencing loneliness or depressive symptoms (Entringer & Gosling, 2022; Gubler et al, 2021).

However, whereas restrictions were imposed regarding the quantity of social contacts in person, individuals were able to maintain relationships with friends and family through online communication. (Saltzman et al., 2020). Individuals differ in the amount of online social interactions during the COVID-19 pandemic. Regarding extraversion, studies showed that extraverted people have an increased activity on social media during the corona pandemic compared to introverted people (Meier et al., 2021; Zdonek & Król, 2021). Extraverted people use social media in order to enhance their social connections (Blackwell et al., 2017). Taken together, there is consistent evidence regarding the higher impact of social restrictions on loneliness for extraverts, and regarding the higher social media use among extraverts during the pandemic. However, there is contradictory evidence on whether (online) interactions can suppress the negative impact of extraversion on loneliness during the COVID-19 pandemic.

Concretely, the friendship protection hypothesis states that (online) contact with friends may help to buffer against loneliness during the lockdown (Espinoza & Hernandez, 2022). Research showed that online time spent with friends may help to decrease feelings of loneliness and stress during the pandemic (Espinoza & Hernandez, 2022). Additionally, Boursier and colleges (2023) showed that relational closeness to online friends buffered the effect of loneliness on depression among adolescents. On the other hand, several studies found that social media use during the lockdown increased negative feelings such as loneliness (Bonsaksen et al., 2021; Boursier et al., 2020; Geirdal et al., 2021). For example, studies showed that excessive social media use increases the anxiety level. Even though online social interactions can temporarily allow people to keep in touch with one another,

online interactions cannot reduce loneliness in the long term (Boursier et al., 2020). As such, using online social media can reinforce loneliness. Moreover, high-frequency use of social media is related to poorer mental health, well-being and increased loneliness (Geirdal et al., 2021). These effects could be related to the overload of COVID-19-related information on social media (Geirdal et al., 2021).

Because of the contradictory evidence for the effect of social online interactions on loneliness during the corona pandemic, this study focuses on examining how extraversion and social interactions influence loneliness during the COVID-19 pandemic. Additionally, we extend existing research by comparing the effects of in person/direct interactions and interactions via chat or phone (indirect interactions). Concretely, the moderating and mediating effects of in person and online interactions in the association between extraversion and loneliness during the corona pandemic were examined.

Based on existing literature, we expected that people scoring higher on extraversion report more loneliness during the COVID-19 pandemic (H1). Further, we hypothesized that direct (in person) and indirect (chat/phone) interactions *moderate* this relationship in the sense that both types of interactions decrease the negative impact of extraversion on loneliness (H2 + H3). In addition, the effect of direct and indirect interactions is tested with *mediation* analysis. Partially in line with the friendship protection hypothesis (Espinoza & Hernandez, 2022), we hypothesized that extravert people seek more contact, either in direct or indirect ways, which in turn decreases loneliness (H4 + H5).

Method

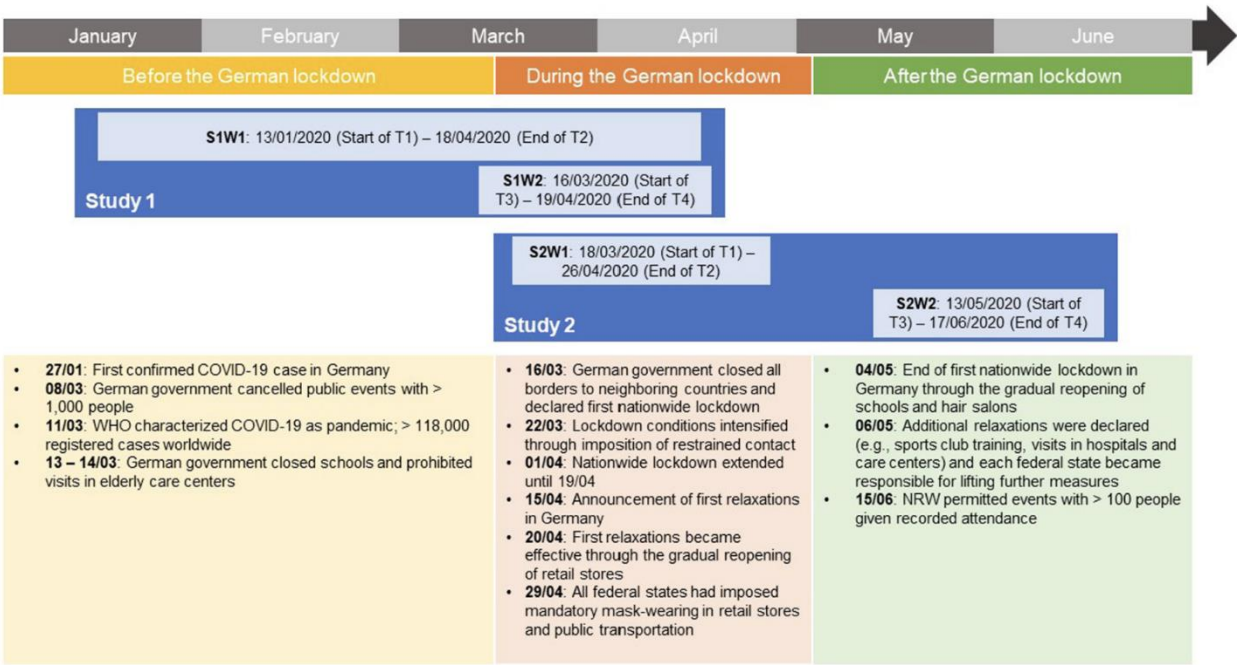
Dataset

We used data from the EMOTIONS project (Ryvkina et al., 2023) to answer our research questions. The data can be found on the OSF webpage (https://osf.io/6kzx3/). The

project examines psychological measures before, during and after the COVID-19 pandemic, in addition to interindividual differences. Instead of using retrospective assessments for the psychological responses, the experience sampling methodology (ESM; Brandstätter, 1983) was employed. The data collection consisted of two studies, one with students from the University of Münster and one with a more general population of people living in Münsterland. Each study included two waves of data collection (see Figure 1). As we were interested in effects *during* the pandemic, we only used the data from wave one of the second study, which was collected between March 18 and April 26, 2020. This subset of the data contains information from 1645 participants (75.9% females) with M_{age} = 33.2 (range 16 – 99).

Figure 1

EMOTIONS Project Timeline Including Central COVID-19 events



Note. S1W1 = Study 1 Wave 1, all other waves are abbreviated analogously. NRW = North Rhine Westphalia. Date format: DD/MM/YYYY. From 'Understanding Psychological Responses to the COVID-19 Pandemic Through ESM Data: The EMOTIONS Project' by E. Ryvkina, L. Kroencke, K. Geukes, J. Scharbert, M. D. Back, 2023, *Journal of Open Psychology Data,11*(6), p. 3. (https://doi.org/10.5334/jopd.83)

Procedure

A German convenience sample was recruited via (social) media advertisements in the Münsterland region. As compensation, participants received personalized feedback regarding their emotional well-being in their social lives, as assessed by the study. The feedback was provided at the end of the data collection.

The procedure had a duration of 16 days and was divided into three phases. On day one (phase one), participants completed questionnaires concerning socio-demographic variables, personality traits, well-being, political attitudes, and COVID-19-related cognition, emotions, and behavior. In the subsequent 14 days (phase two), state measures were collected employing the experience sampling methodology (ESM). Participants received up to six emails per day with a minimum delay of 40 minutes between each email. Each email contained a personalized link to the state questionnaires, which assessed the situational context of participants' most recent interaction or non-social activity lasting at least five minutes, as well as their current cognitive, emotional, and behavioral states. On day 16 (phase three), a similar trait questionnaire as in phase one was administered.

Measures

Since we were interested in the effect of COVID-19, we analyzed the measures taken at the last day of data collection to answer our research questions. We implemented two of the trait measures, namely measures of personality and loneliness. Personality (extraversion) was assessed by the Big Five Inventory-2-Short Form (BFI-2-S; Soto & John, 2017; German adaptation by Rammstedt et al., 2018). This questionnaire contains 30 items, with six items for each personality dimension. The items are scored on a 5-point Likert scale (1: Strongly Disagree – 5: Strongly Agree). In the current study, we only incorporated extraversion-related items. This resulted in an extraversion score ranging from 6 to 30.

Loneliness was measured using the UCLA Loneliness Scale (ULS; Russell et al., 1980; German adaptation by Luhmann et al., 2016). This scale consists of 9 items, originally scored on a 4-point Likert scale (1: Never – 4: Always). For the EMOTIONS project, an extra response option 'Often' was added to provide an equally spaced rating scale.

Concerning the ESM reports, we implemented 'mode of communication' as a variable in our analyses. This variable is categorical, with '1' representing 'direct interactions in person', and '2' representing 'interactions via chat or phone'. If participants had no interactions, this is indicated by '0'. Since participants were asked to report their interactions multiple times a day for two weeks, we have a repeated measures design.

Data Analysis

Data analysis was entirely done in R (version 4.2.3, R Core Team, 2020). The dataset containing measures of extraversion and loneliness was merged with the dataset containing reports of communication, based on the subject number. Participants who did not fill out the BFI-2-S and/or the UCLA were excluded from further analysis. Furthermore, to ensure data quality, we made the arbitrary choice to only include participants who completed the state survey at least once a day for a minimum of seven out of 14 days. This led to a final sample of 323 participants. Datasets did not include demographic information, which made it impossible to report demographics of the final sample. We assigned extraversion and loneliness scores to each participant. These scores were derived by reverse coding the relevant items of the BFI-2-S and UCLA and then summing all items per scale. These scores were standardized for further analysis.

The aim of this study was to determine whether, during the COVID-19 pandemic, extraversion affected people's loneliness, and whether this was *moderated* or *mediated* by the amount and type of interactions people had.

Moderation

We started with the moderation analysis, using a linear model approach. The linear models were fitted using the lm() function of the *stats* R package (version 4.2.3; R Core Team, 2020). Contrasts were set sum-to-zero, which was the case for all of the following models. P-values were obtained by using a Type III Anova of the *car* package (version 3.1.0; Fox & Weisberg, 2019). The two fitted models (the main effect model and the moderating effect model) looked as follows:

(1) Loneliness ~ Extraversion + Communication

*(2) Loneliness ~ Extraversion * Communication*

Then we examined whether the amount of variance explained by model 2 was higher than the amount of variance explained by model 1 by looking at the R^2. Additionally, we conducted a model comparison test with the anova() function of the *stats* R package (R Core Team, 2020). Post hoc tests for significant interactions were conducted using the emtrends() function of the *emmeans* R package (version 1.8.5; Lenth, 2023)

Since multiple measures were taken for communication, data points of one person may not be truly independent. Therefore, we fitted linear mixed-effects models besides our first approach with regular linear models. The linear mixed models were fitted with the lmer() function of the *lme4* R package (version 1.1.30; Bates et al., 2015), and looked similar to the models mentioned above but allowed for varying intercepts per participant. The standard optimizer was 'bobyqa', but due to convergence warnings, we used the optimizer 'nmkwb'. P-values were obtained using Type 3 F-tests with Kenward-Roger approximation for degrees of freedom, using the Anova() function of the *car* package (Fox & Weisberg, 2019).

Mediation

The fact that our categorical variable (communication) contained three levels posed a challenge for the mediation analysis. Therefore, we opted to split the dataset, and look at the

mediating effect of ‘in person communication’ and ‘online communication’, separately. Thereby, we were able to binarize the variable and apply a binary logistic regression (see further).

For the mediation analysis, we used multiple approaches. We started with the Baron and Kenny method (Baron & Kenny, 1986), using (generalized) linear models. These models were also fitted, using the (g)lm() function of the *stats* R package (R Core Team, 2020). The Baron and Kenny method contains the following four steps:

1. Test whether the independent variable (extraversion) predicts the dependent variable (loneliness);
2. Test whether the independent variable (extraversion) predicts the mediator (communication);
3. Test whether the mediator (communication) predicts the dependent variable (loneliness), controlling for the independent variable (extraversion);
4. To test for *complete* mediation, the effect of the independent variable (extraversion) on the dependent variable (loneliness) should be zero when controlling for the mediator (communication). If all steps above are met, with the exception of step 4, there is *partial* mediation.

Steps 3 and 4 can be tested within the same model. This led to the following models:

(3) Loneliness ~ Extraversion

(4) Communication ~ Extraversion

(5) Loneliness ~ Communication + Extraversion

P-values were derived using a Type III Anova of the car package (Fox & Weisberg, 2019).

Next, we used the mediate() function of the *mediation* R package (version 4.5.0; Tingley et al., 2014). This function tested the mediating effect of communication, based on models 4 and 5.

Furthermore, we applied the sem() function of the *lavaan* R package (Rosseel, 2012). This function uses Structural Equation Modelling to estimate statistical models, including the classical mediation model we needed. The input model looked as follows:

Direct effect: *Loneliness ~ c * Extraversion*

Mediator: *Communication ~ a * Extraversion*

*Loneliness ~ b * Communication*

Indirect effect: *a * b*

Total effect: *a * b + c*

Next, we took the subject level into account using linear mixed models in the Baron and Kenny method. A 2-1-2 mixed mediation model was used, where level 2 stands for the between-subjects variables extraversion and loneliness and level 1 for the within-subjects variable communication. The models looked similar to the models above:

(6) Loneliness ~ Extraversion + (1 | Subject)

(7) Communication ~ Extraversion + (1 | Subject)

(8) Loneliness ~ Communication + Extraversion + (1 | Subject)

Models 6 and 8 were fitted using the lmer() function of the *lme4* package (Bates et al., 2015). P-values were obtained using Type 3 F-tests with Kenward-Roger approximation for degrees of freedom, using the Anova() function of the *car* R package (Fox & Weisberg, 2019). Model 7 was fitted using the mixed() function from the *afex* R package (version 1.2-1; Singmann et al., 2016), and P-values were obtained using Type 3 Likelihood Ratio Tests of this function. The standard optimizer was 'bobyqa'. In case of convergence warnings, the optimizer 'nmkbw' was used.

Lastly, we used the mediate() function of the *mediation* R package (Tingley et al., 2014), including linear mixed models instead of the linear models we used earlier. This function tested the mediating effect of communication, based on models 7 and 8.

We applied the same types of analysis of mediation for both ‘in person communication’ and ‘online communication’.

Results

Descriptive statistics of loneliness and extraversion can be found in **Table 1**. Score distributions of the scores on the extraversion and loneliness scales can be found in **Figure 2**.

Table 1

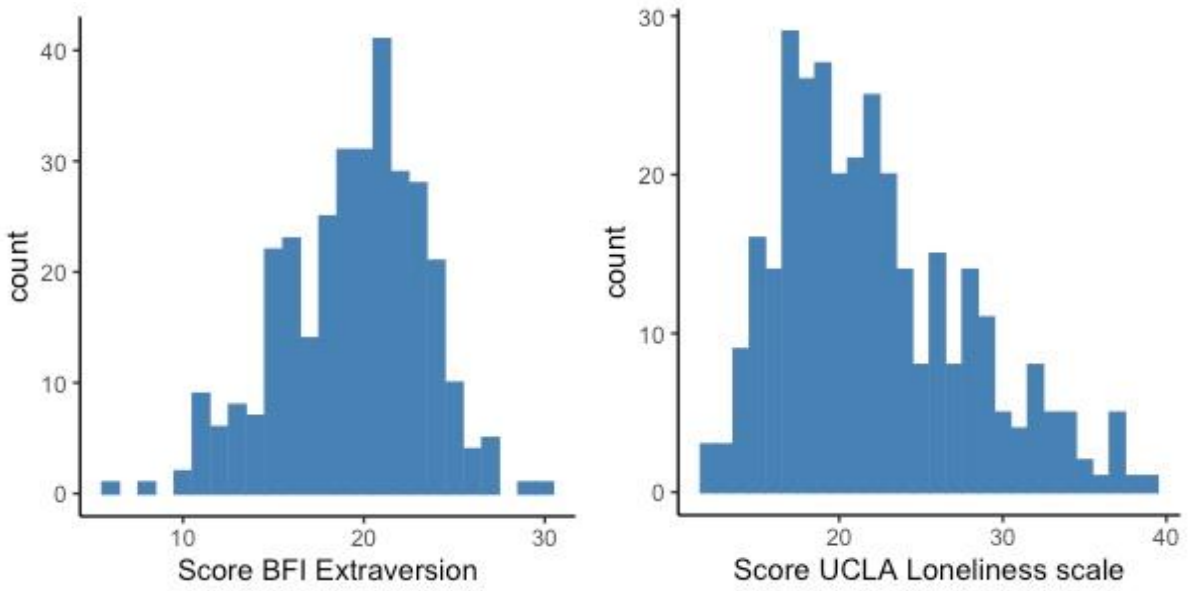
Descriptive statistics of extraversion and loneliness scores on the BFI and UCLA

	Mean	Sd	Range	Reference
Extraversion	19.61	3.89	6 – 30	0 – 30
Loneliness	21.78	5.81	12 – 39	9 – 45

Note. This table represents the descriptive statistics of the scores on the BFI and UCLA, including the mean, standard deviation, range (minimum and maximum score in our sample) and the reference (minimum and maximum scores possible on the scales).

Figure 2

Histogram representing the score distributions of the BFI and UCLA



Note. This figure represents the score distribution of the BFI Extraversion (**A**) and the UCLA Loneliness scale (**B**)

Moderation

Analysis of the moderating role of communication within the association between extraversion and loneliness, using linear models, revealed that extraversion negatively predicts loneliness (B = -0.52 , SE = 0.01; $F(1) = 5016.45$, $p < .0001$). Additionally, we observed a main effect of communication on loneliness (B_{NoCom} *= 0.01, SE* = 0.01, $B_{InPerson}$ = *- 0.06, SE* = 0.01*; F*(2) = 25.7, $p < .001$). Overall, people reporting more in person interactions reported being less lonely than people having more online interactions. The difference between no interactions and online interactions was not significant.

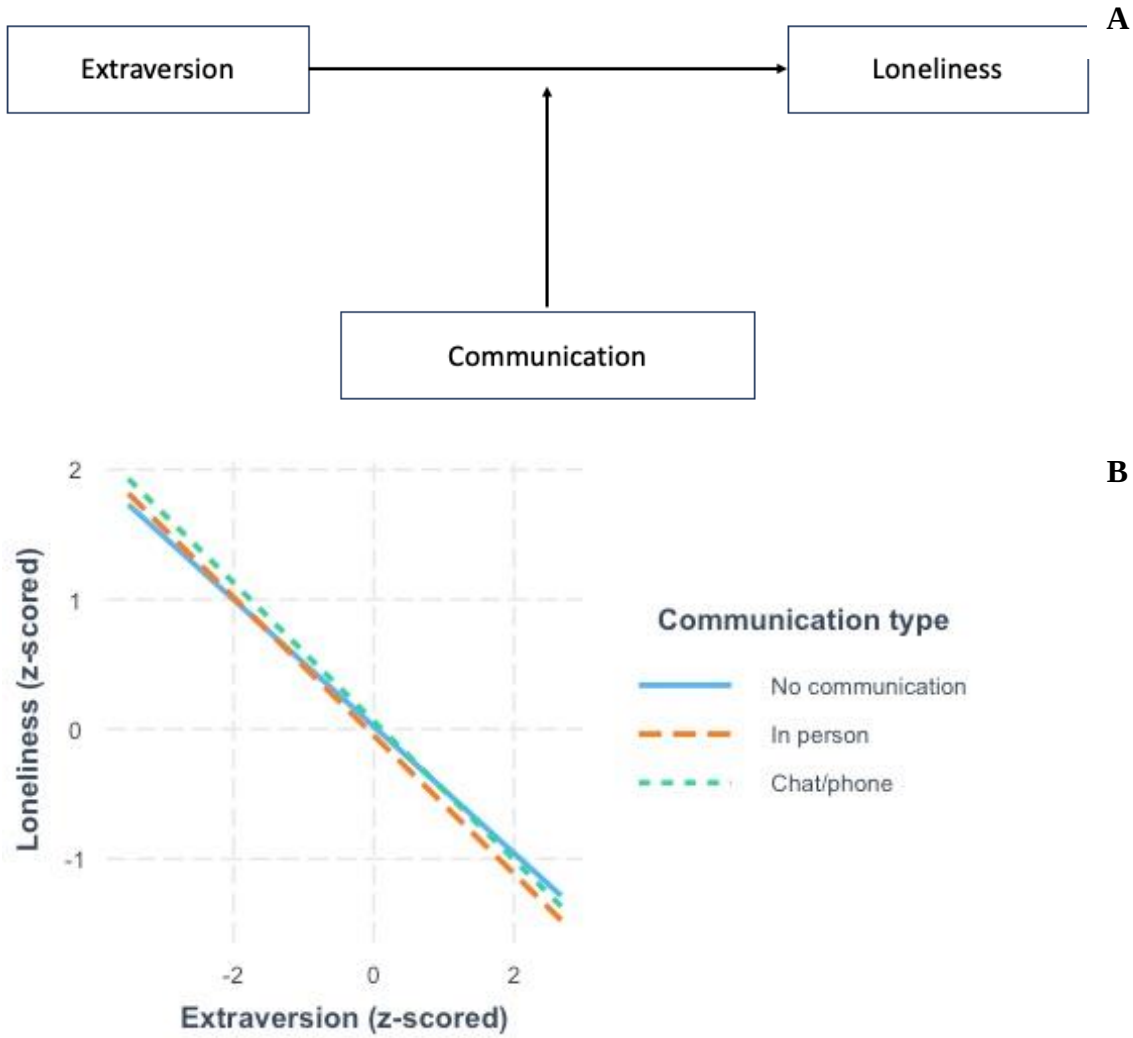
Furthermore, the interaction effect of communication and extraversion was found to be significant ($B_{Extr:NoCom}$ *= 0.03, SE* = 0.01, $B_{Extr:InPerson}$ = *- 0.01, SE* = 0.01*; F*(2) = 4.46, p = .012). Including the interaction term in the model did not lead to an increase of Adjusted R^2, but an anova test for model comparison showed that the model including the interaction term significantly fitted the data better ($F(2, 13853) = 4.46$, $p = .012$). These results suggest that communication serves as a moderator of the relationship between extraversion and loneliness. Post hoc pairwise comparison revealed that this was mainly driven by the difference between no interaction and in person interaction ($B_{\text{NoCom – InPerson}} = 0.04$, $SE = 0.02$; $t_{(13853)} = 2.72$, p = .018). This suggests that, overall, people who are more extraverted are less lonely, but when they have no interactions, they feel lonelier than when having in person interactions, compared to people who are less extraverted. Visualization of the moderating effect of communication can be found in **Figure 3**.

After implementation of each subject as a random effect in the models, we still observed a significant effect of extraversion on loneliness (B = -0.51, SE = 0.01; $F(1, 318) = 5186.30$, $p < .001$), however, no interaction effect of extraversion and communication was observed ($B_{Extr:NoCom}$ = 0.00, SE = 0.00, $B_{Extr:InPerson}$= 0.00 , SE = 0.00; $F(2, 13535) = 0.00$, p

= .999). This undermines the previous conclusion that communication serves as a moderator of the relationship between extraversion and loneliness.

Figure 3

Model and graph representing the moderation effect



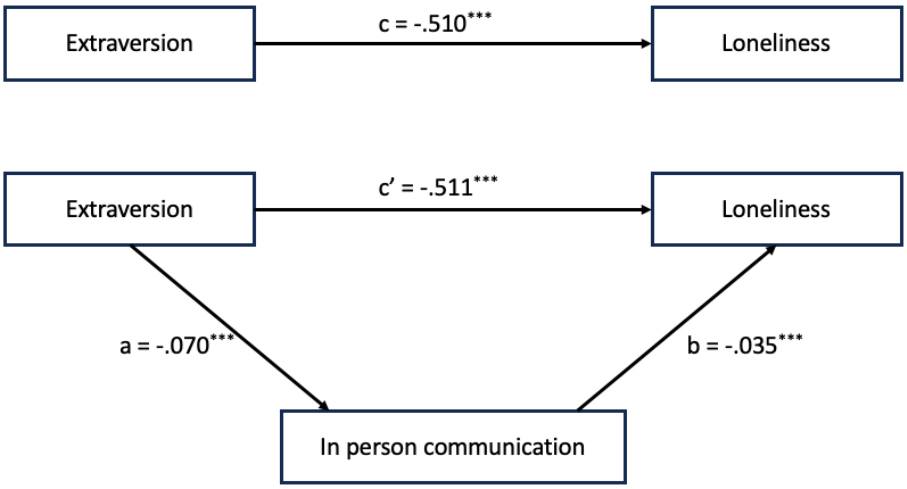
Note. Figure **3A** represents the general idea of how moderation works, applied to our variables. Communication affects the relationship between extraversion and loneliness. Figure **3B** represents how the effect of extraversion on loneliness is affected by the type of communication.

Mediation by In Person Communication

Results of the analyses following the Baron and Kenny method with linear models showed that extraversion negatively predicts loneliness (B = -0.51, SE = 0.008; F(1) = 3948.25, $p < .001$). Analyzing the indirect effects, results revealed that in person communication significantly mediates the relationship between extraversion and loneliness; extraversion negatively predicts communication (B = -0.07, SE = 0.02; $Chisq(1)$ = 13.53, p = .0002) and no communication, in turn, positively affects loneliness, compared to having in person interactions **(**B_{NoCom} **=** 0.04, SE = 0.008; $F(1)$ = 18.88, $p < .001$). This means that people scoring higher on extraversion reported less interactions, which was surprising; and people more frequently reporting having no interactions scored higher on loneliness compared to people having more in person interactions. Nonetheless, results suggest that after accounting for the mediating role of in person communication, extraversion still affects loneliness in a negative manner (B = -0.51, SE = 0.008; $F(1)$ = 3968.67, $p < .001$). Since the direct effect of extraversion on loneliness is still present, there is only partial mediation. Similar conclusions were drawn from the analysis using the mediation package. The Average Causal Mediation Effect was found to be significant (B = 0.001, 95%CI [0.0005, 0.00], $p <$ .001), implying in person communication has mediating role in the effect of extraversion on loneliness. The Structural Equation Modeling approach, using the Lavaan package, also confirmed the mediating role of in person communication (B = 0.002, SE = 0.001, p = .005). A visualization of the mediating effect of in person communication, tested with linear models, can be found in **Figure 4**.

Figure 4

Mediation model for in person communication with linear models

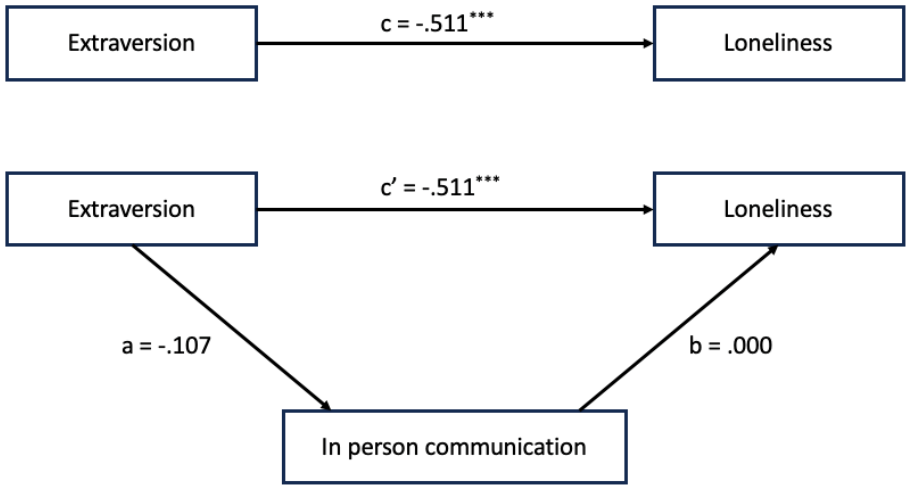


Note. This model represents the mediating effect of in person communication on the relationship between extraversion and loneliness. tested with linear models. The mediating effect was found to be significant.

However, after implementing each subject as a random effect in the models, we observed different results. The negatively predicting effect of extraversion on loneliness was confirmed (B = -0.51, SE = 0.008; F(1, 318) = 4233.26, p < .001), but extraversion did not affect in person communication (B = -0.12, SE = 0.07; $Chisq$(1) = 2.28, p = .131), and in person communication did not affect loneliness (B = 0.00, SE = 0.00; F(1, 10990) = 0, p = .996). This indicates that in person communication does not serve as a mediator between extraversion and loneliness. The same conclusion was drawn from the analysis using the mediation package, which revealed that the Average Causal Mediation Effect was not statistically significant (B = -0.00, 95%CI [-0.00, 0.00], p = .99). A visualization of the (non-significant) mediating effect of in person communication, tested with linear mixed models,can be found in **Figure 5**.

Figure 5

Mediation model for in person communication with linear mixed models



Note. This model represents the mediating effect of in person communication on the relationship between extraversion and loneliness, tested with linear mixed models. The mediating effect was found to be non-significant.

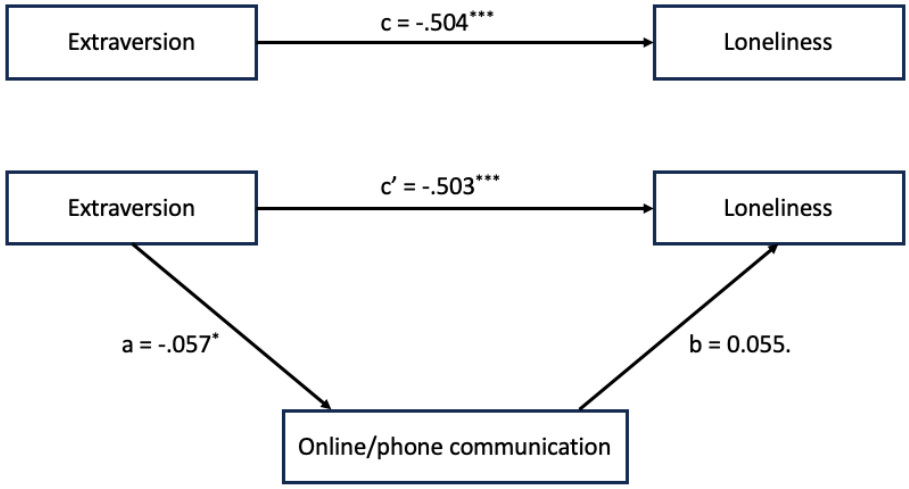
Mediation by Online Communication

Analysis of the mediating role of online communication in the relationship between extraversion and loneliness revealed no statistically significant effects. Starting with the Baron and Kenny method with linear models, we observed that extraversion negatively predicts loneliness (B = -0.50, SE = 0.009; $F(1)$ = 2813.86, p < .001). Analysis of the indirect effects revealed that extraversion negatively predicts in online communication (B = -0.06, SE = 0.02; $Chisq(1)$ = 5.77, p = .016), but online communication does not affect loneliness (B_{NoCom} = -0.02, SE = 0.01; F(1) = 3.69, p = .054), although the effect is marginally significant. This suggests that online communication does not mediate the relationship between extraversion and loneliness. The Average Causal Mediation Effect, found by the mediation package, confirmed this (B = -0.0005, CI [-0.001, 0] , p = 0.071), but again, this effect was marginally significant. The Structural Equation Modeling approach suggested no indirect effect (B = -0.001, SE = 0.001, p = .136), and thus no mediating effect of

communication on the relationship between extraversion and loneliness. A visualization of the (non-significant) mediating effect of online communication, tested with linear models,can be found in **Figure 6**.

Figure 6

Mediation model for online communication with linear models

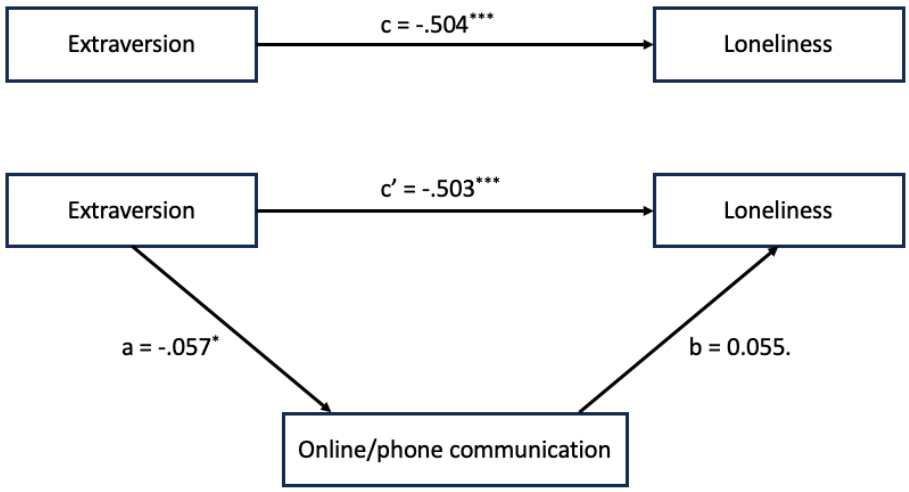


Note. This model represents the mediating effect of online communication on the relationship between extraversion and loneliness, tested with linear models. The mediating effect was found to be non-significant.

An analogous analysis with each subject implemented as a random effect in the models revealed comparable results. The direct effect of extraversion on loneliness was confirmed (B = -0.51, SE = 0.009; $F(1,314) = 3031$, $p < .001$), but there was no evidence of an indirect effect. Extraversion did not affect online communication (B = -0.04, SE = 0.07; $Chisq(1) = 0.51$, $p = .473$), and online communication did not affect loneliness (B_{NoCom} = 0.00, SE = 0.00; $F(1,314) = 3031.02$, $p = .996$). These results confirm that online communication does not serve as a mediator between extraversion and loneliness, which was also found in the analysis using the mediation package (B = -0.00, 95%CI [-0.00, 0.00] , p = .99). A visualization of the (non-significant) mediating effect of online communication, tested with linear mixed models, can be found in **Figure 7**.

Figure 7

Mediation model for online communication with linear mixed models



Note. This model represents the mediating effect of online communication on the relationship between extraversion and loneliness, tested with linear mixed models. The mediating effect was found to be non-significant.

Assumptions

Given that the independence assumption of linear models was already violated because of the repeated measures design, we implemented linear mixed models, which would allow for more accurate conclusions. Therefore, we focused on the assumption checks for the (generalized) linear mixed models.

Model diagnostics were performed on the model residuals. For linear mixed models we checked for outliers, normality, homoscedasticity, linearity, and multicollinearity. QQ-plots, density plots and plots including residuals vs. fitted values can be found in **Appendix A.** Regarding the outliers, we allowed 0% of your cases to be more extreme than 3.5 standard deviations away from the mean, 1% to be more extreme than 2.5 standard deviations away from the mean, and 5% to be more extreme than 2 standard deviations away from the mean. This condition was not violated when fitting the original data. Checking for normality, linearity, and homoscedasticity, we observed violations of all three assumptions. However,

based on the plots, they appeared to be minimal. Three participants were excluded from further analysis due to outlier results regarding normality. Furthermore, log-transforming the data did not lead to improvement of the visualizations, so this was not applied for further analysis. No multicollinearity occurred, as indicated by the Variance Inflation Factor (VIF).

Checking assumptions for generalized linear mixed models was challenging, as there did not seem to be a clear consensus about which assumptions are required to be fulfilled. We used the DHARMa package (Hartig, 2022), which checked for dispersion, normality, outliers, heteroscedasticity, and linearity based on simulations of model fitting. Plots can be found in **Appendix B**. For one model, normality was violated according to the Kolmogorov–Smirnov test. However, based on the QQ-plot, we did not consider this assumption to be violated. Other assumptions were not violated. Furthermore, we also constructed a ROC-curve (**Appendix C**) to check for the sensitivity and specificity of the models. The area under the curves were 77.14% and 76.66% for the two generalized linear mixed models.

Discussion

One of the most common mental health problems during the COVID-19 pandemic was loneliness. However, the risk of developing loneliness depends on individual characteristics such as personality traits like extraversion. Since extraverts have an innate higher need for social interactions and do have more social interactions, they experience more loneliness during the COVID-19 lockdown. However, existing research focusing on the interactions between extraversion, in person interactions, online interactions and loneliness is limited. Moreover, findings about the effects of social interactions on loneliness are contradictory. As such, the aim of this study was to examine the moderating and mediating role of social interactions, both in a direct and indirect way, within the association between extraversion and loneliness during the corona pandemic.

Linear Regression Models

Main Effects and Moderation

Regarding the linear regression models for the main effects, we found a significant negative main effect of extraversion on loneliness. Individuals scoring higher on extraversion experienced less loneliness during the COVID-19 pandemic. This was not in line with our hypothesis but is in line with the positive association as found outside lockdown circumstances (Buecker et al., 2020). This may be due to the fact that the data collection happened at the beginning of the lockdown. Thus, the effects on mental health are not that pronounced yet (Hawryluck et al., 2004). Additionally, we observed a main effect of communication on loneliness. Individuals who had more in person interactions during the pandemic experienced less loneliness compared to people having no interactions or online interactions. This is in line with the friendship protection hypothesis (Espinoza & Hernandez, 2022). Concretely, personal contact during the lockdown seemed to protect people from feeling lonely. The results also showed evidence for the moderating role of in person interactions on the relationship between extraversion and loneliness. People who score higher on extraversion and who had more in person interactions reported less loneliness than extraverted people without interaction, compared to less extraverted people. These findings indicate that especially for extraverted people, direct contacts can help reduce loneliness because it fulfils their higher need for social contact.

Mediation

Since our mediator is a within-subjects categorical variable with three levels, we ran into a problem wanting to perform a mediation analysis on the entire dataset. Therefore, we opted to split the dataset and look at the mediating role of in person communication and online communication separately. Our analysis for in person communication using linear regression yielded significance in all four steps of the Baron and Kenny method. This

indicates that in person communication has a partially suppressing effect on the negative relation between extraversion and loneliness, although we should be cautious about drawing conclusions about partial mediation due to power issues (Kenny, 2021). Surprisingly, people scoring higher on extraversion reported significantly fewer in person interactions. Moreover, there was a significant positive effect of no interactions on loneliness, indicating that having no interactions increased loneliness. This latter is in line with the existing literature. However, we did not expect more extraverted people to report fewer interactions (Alt et al., 2021; Bellingtier et al., 2021; Entringer & Gosling, 2022; Gubler et al., 2021; Zager Kocjan et al., 2021). Overall, researchers agree that extravert people have an innate higher need for social contact and that they experience more loneliness during the COVID-19 pandemic because of the restrictions on social contact. The fact that they report fewer interactions but still feel less lonely than less extraverted individuals may be explained by the fact that they place a higher value on those interactions, which reduces feelings of loneliness; however, this is merely speculation. Since the effect $c' - c$ was rather small, having fewer in person interactions may not fully explain the fact that extraverted people experience less loneliness during the corona pandemic.

Finally, no significant mediating role was found for online interactions. However, we found a significant negative effect of extraversion on online interactions, which indicates that higher scores on extraversion were related to fewer online interactions. Again, this is not in line with existing literature showing evidence for the higher need for social interactions among people scoring high on extraversion (Alt et al., 2021; Bellingtier et al., 2021; Entringer & Gosling, 2022; Gubler et al., 2021; Zager Kocjan et al., 2021).

For both in person and online communication we obtained the same results for the linear regression mediation analyses with the mediation package, as this implements the

Baron and Kenny method, as well as with the Structural Equation Modelling with the lavaan package.

Linear Mixed Models

Because we wanted to take the within-subject variability of the communication variable into account, we also implemented linear mixed models to test the moderation and mediation model. Similar as with the linear models, we applied the Baron and Kenny method (Baron & Kenny, 1986) and used the mediation package. The lavaan package was not suited for a mediation analysis with linear mixed models, so this was not implemented. In the second step of the Baron and Kenny method (Baron & Kenny, 1986) a binary logistic regression is fitted. However, we are aware that the coefficient estimates are not comparable to the ones of linear regression because logistic regression uses a log-odds scale.

None of our hypotheses could be confirmed with the linear mixed models. There was a significant main effect of extraversion on loneliness, in the sense that higher scores on extraversion were related to less loneliness. There was no evidence that this relationship is moderated or mediated by direct or indirect interactions. Concretely, we could not confirm our hypotheses that higher scores on extraversion related to higher loneliness (H1); that direct (in person) and indirect (chat/phone) interactions moderate this relationship in a way that they decrease the negative impact of extraversion on loneliness (H2 + H3); and that extraverts seek more direct and/or indirect contact which in turn decreases loneliness (H4 + H5). However, this mixed model approach may be more accurate as it reflects the structure of the repeated measures.

Limitations

Besides our findings, this study also encountered some limitations. For example, it is important to be cautious regarding the interpretation of the mediation analysis. The Baron and Kenny method has several limitations (Moerkerke, 2020). Because multiple tests are

conducted consecutively, the chance of a Type I error increases, which can in turn decrease the power (MacKinnon et al., 2002). The results may be inconsistent over regressions, which is the case for the in person mediation with linear models. Path a and b are significant, while c’ and c are nearly equal. Thus, the mediated effect c – c' is nearly zero. Furthermore, c’ was larger than c instead of smaller, although very minimal. Lastly, other models may be possible, for example, where the mediator and the outcome variable switch places.

Since working with a categorical mediator with more than two categories is more difficult to work with, we propose the possibility to convert the communication variable into two continuous variables for future analysis. These variables would represent the proportion of direct and indirect interactions one person had.

Furthermore, assumption checks for the linear mixed models appeared to reveal minor violations of normality, homoscedasticity and linearity. Log-transforming the data did not lead to improvement. Other measures, such as redefining variables or applying weighted regression, should be implemented in further analysis in order to obtain more reliable results.

In conclusion, we only found evidence for moderation of in person communication, as compared to no communication, and mediation of in person communication on the negative relation between extraversion and loneliness with the regular linear regression approach. However, these effects were not present when using a mixed models approach. As this approach takes the structure of the repeated measures into account, we believe that the linear mixed models are more accurate to test moderation and mediation. Concerning the Baron and Kenny method (1986) for mediation analysis, we have doubts about whether this is the best way to test mediation as there are some limitations.

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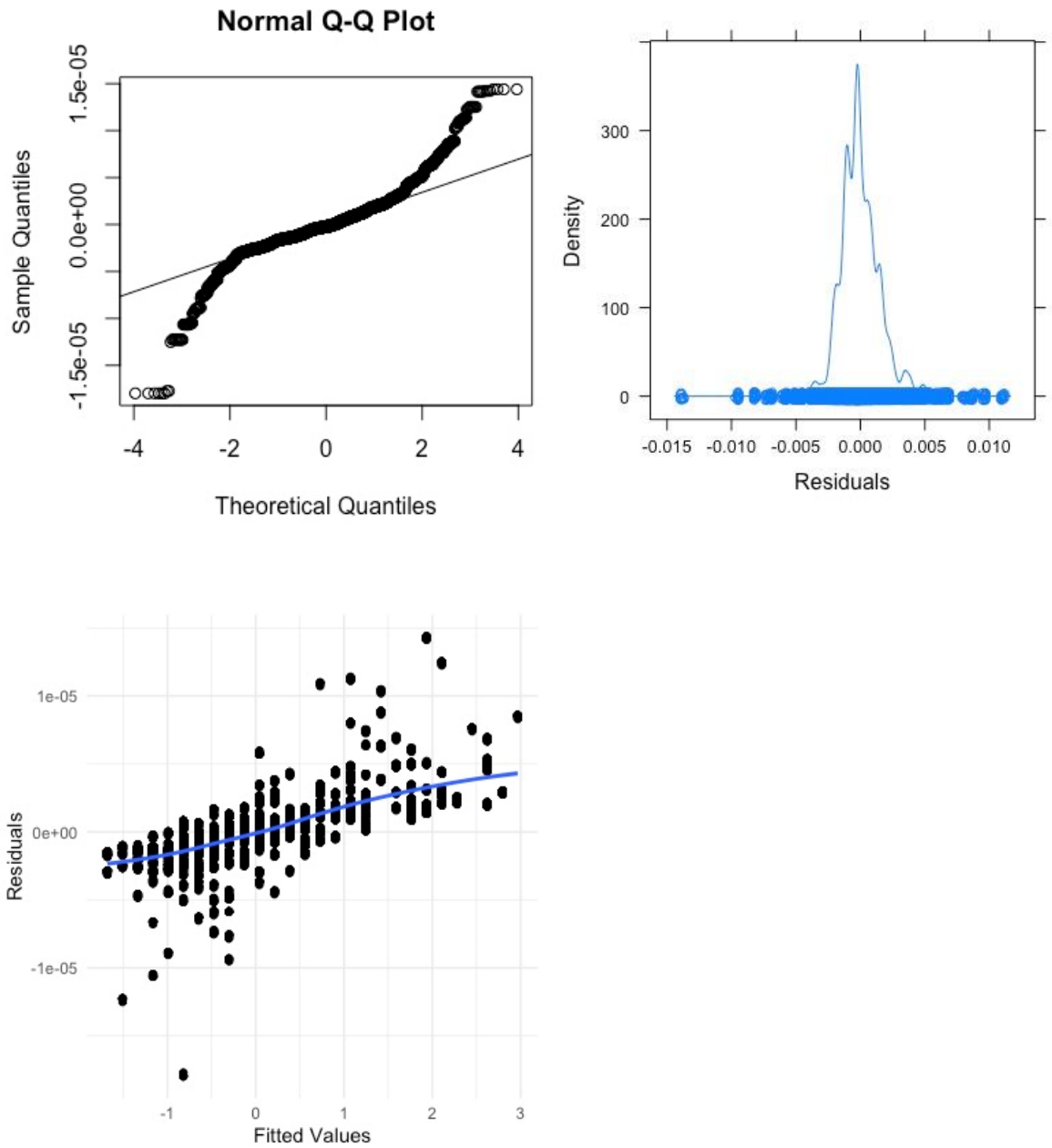
Appendix A

QQ-plots, density plots and residuals vs. fitted values for linear mixed models used in the moderation and mediation analysis.

Figure 8

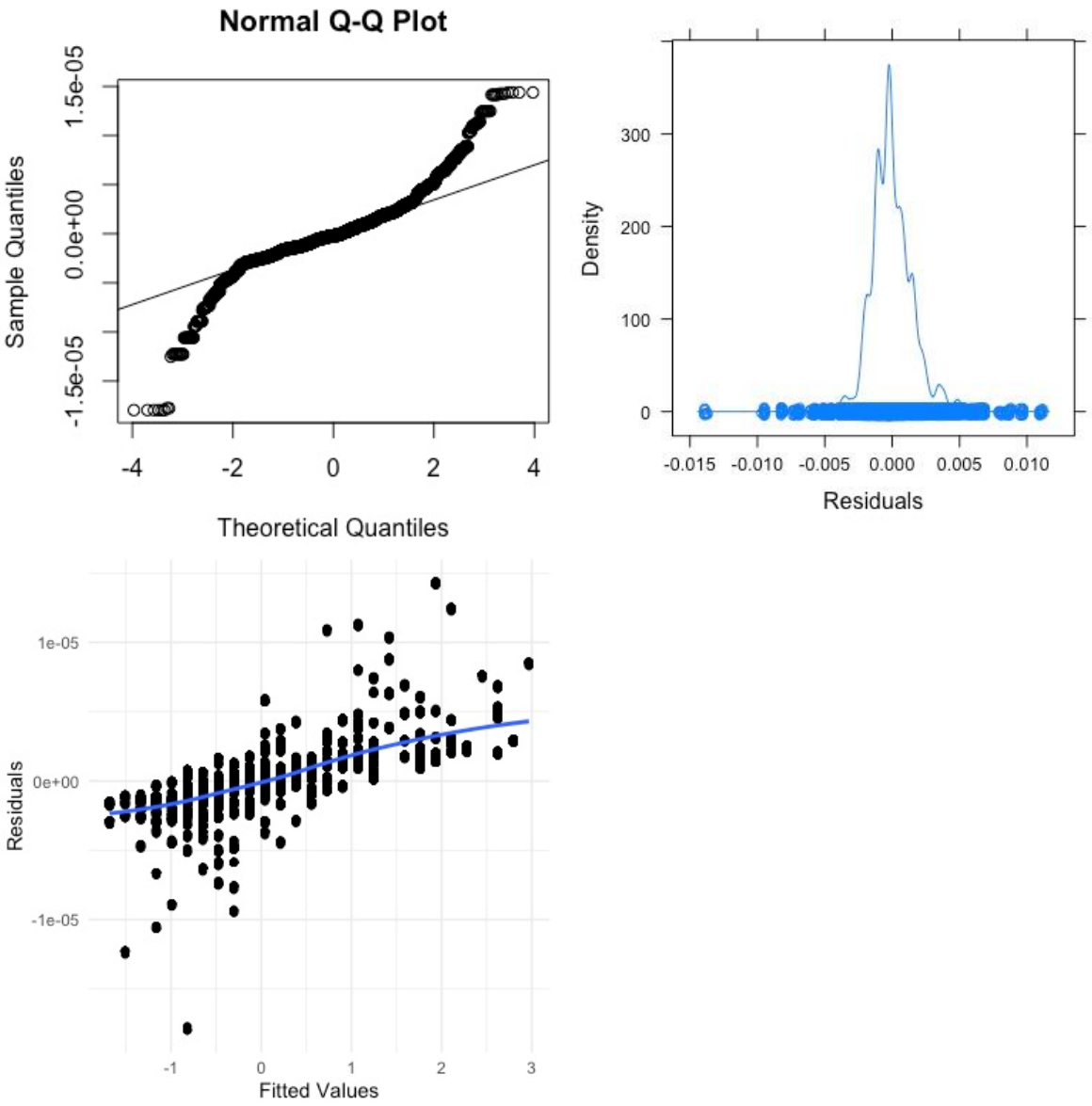
Plots for assumption checks of model 1 of the moderation analysis



Note. These are the plots to check the assumptions of the model lmer(Loneliness ~ communication + extraversion.

Figure 9

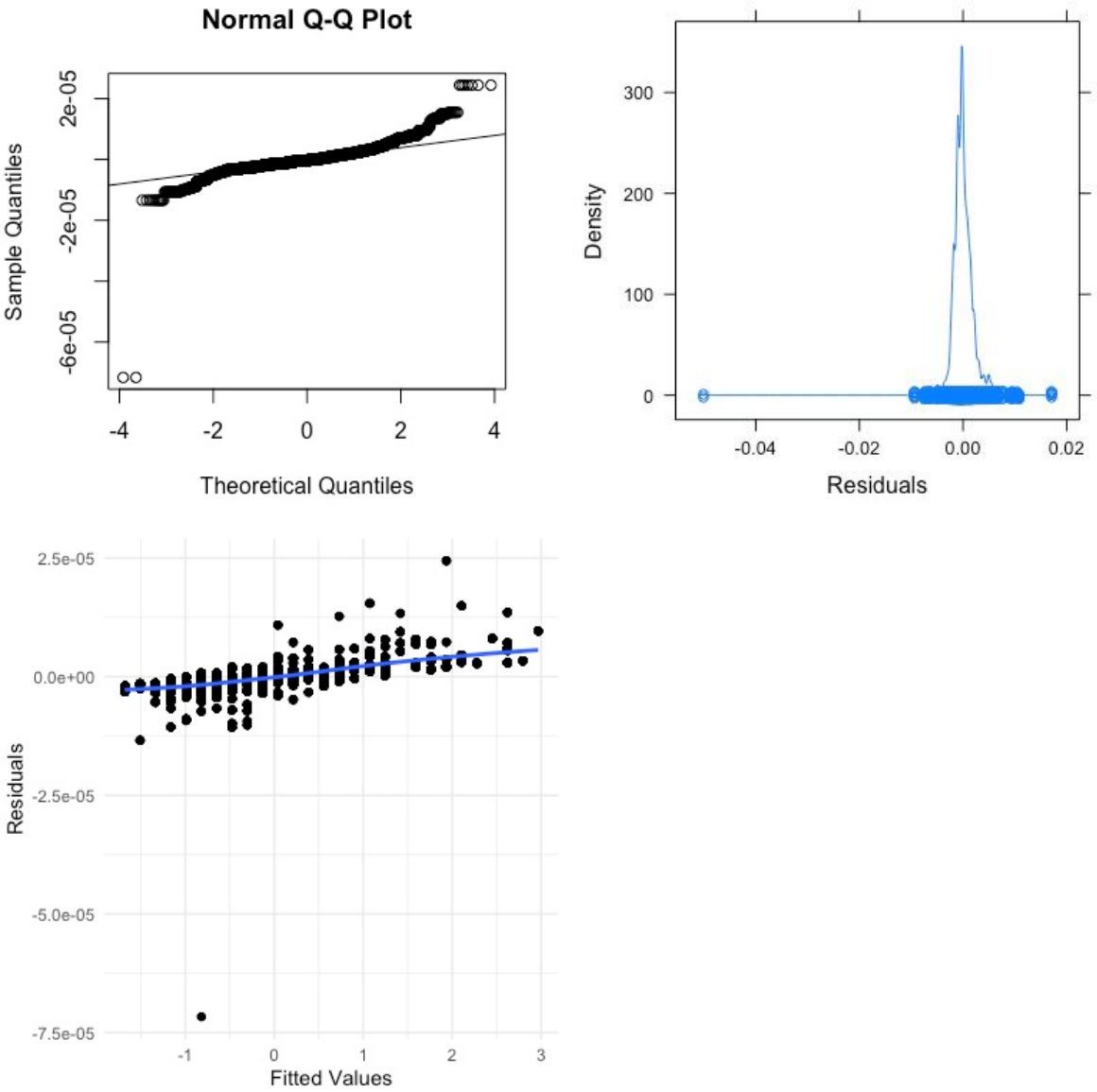
Plots for assumption checks of model 2 of the moderation analysis



Note. These are the plots to check the assumptions of the model lmer(Loneliness ~ communication * extraversion, data = data).

Figure 10

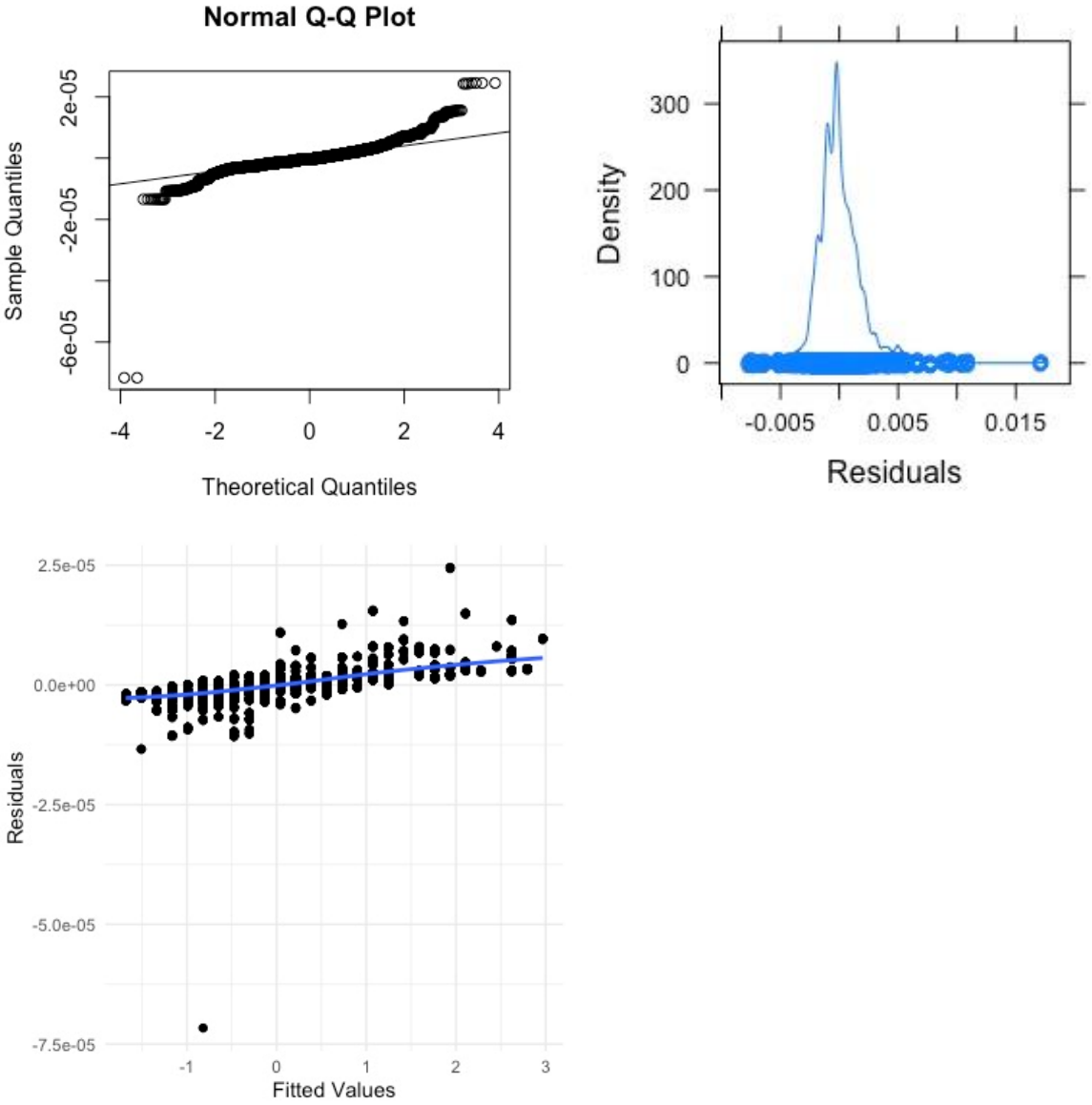
Plots for assumption checks of model 1 of the mediation analysis of in person communication



Note. These are the plots to check the assumptions of the model lmer(Loneliness ~ extraversion, data = data_inperson).

Figure 11

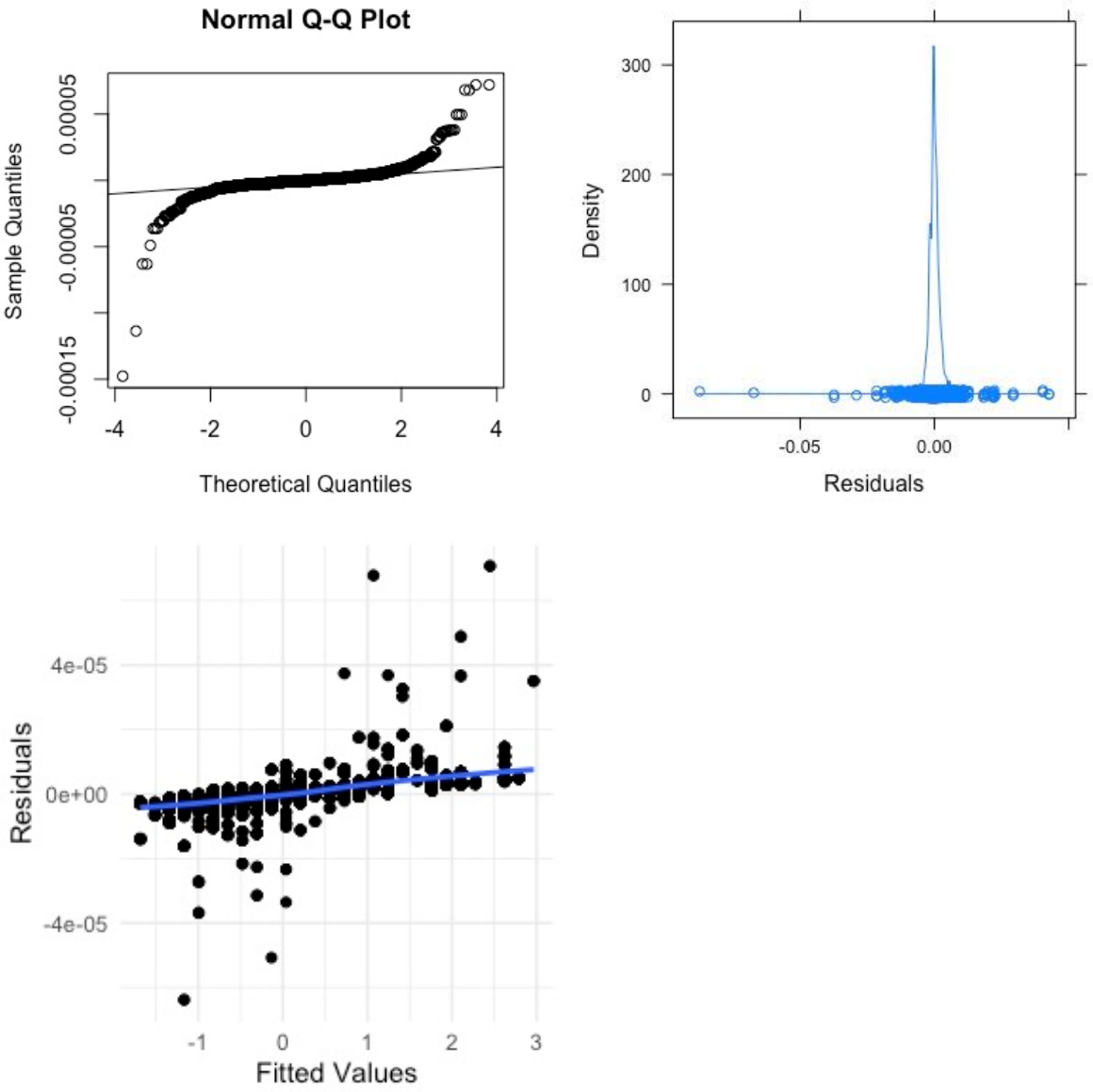
Plots for assumption checks of model 3 of the mediation analysis of in person communication



Note. These are the plots to check the assumptions of the model lmer(Loneliness ~ communication + extraversion, data = data_inperson).

Figure 12

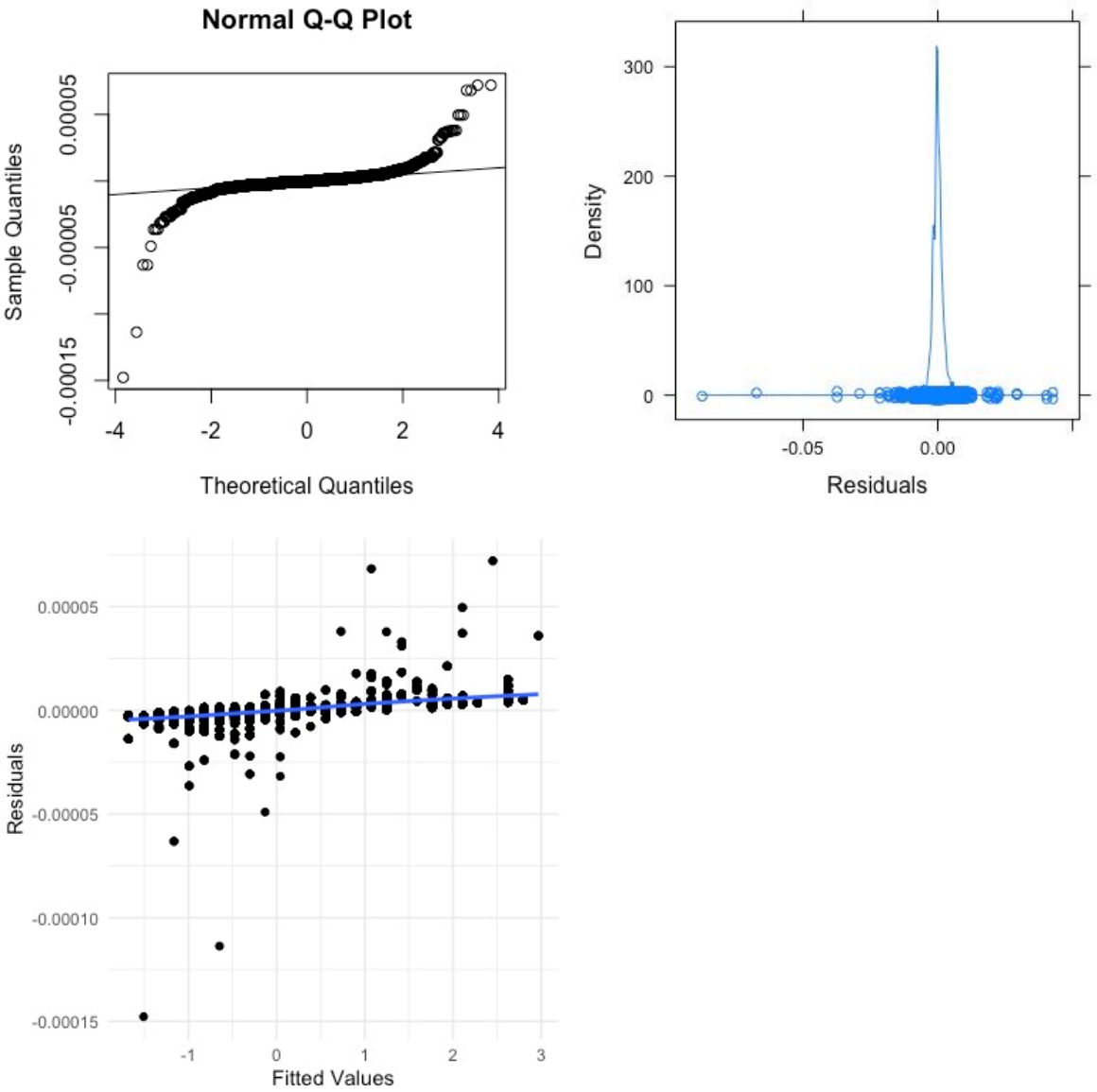
Plots for assumption checks of model 1 of the mediation analysis of online communication



Note. These are the plots to check the assumptions of the model lmer(Loneliness ~ extraversion, data = data_chatphone).

Figure 13

Plots for assumption checks of model 3 of the mediation analysis of online communication



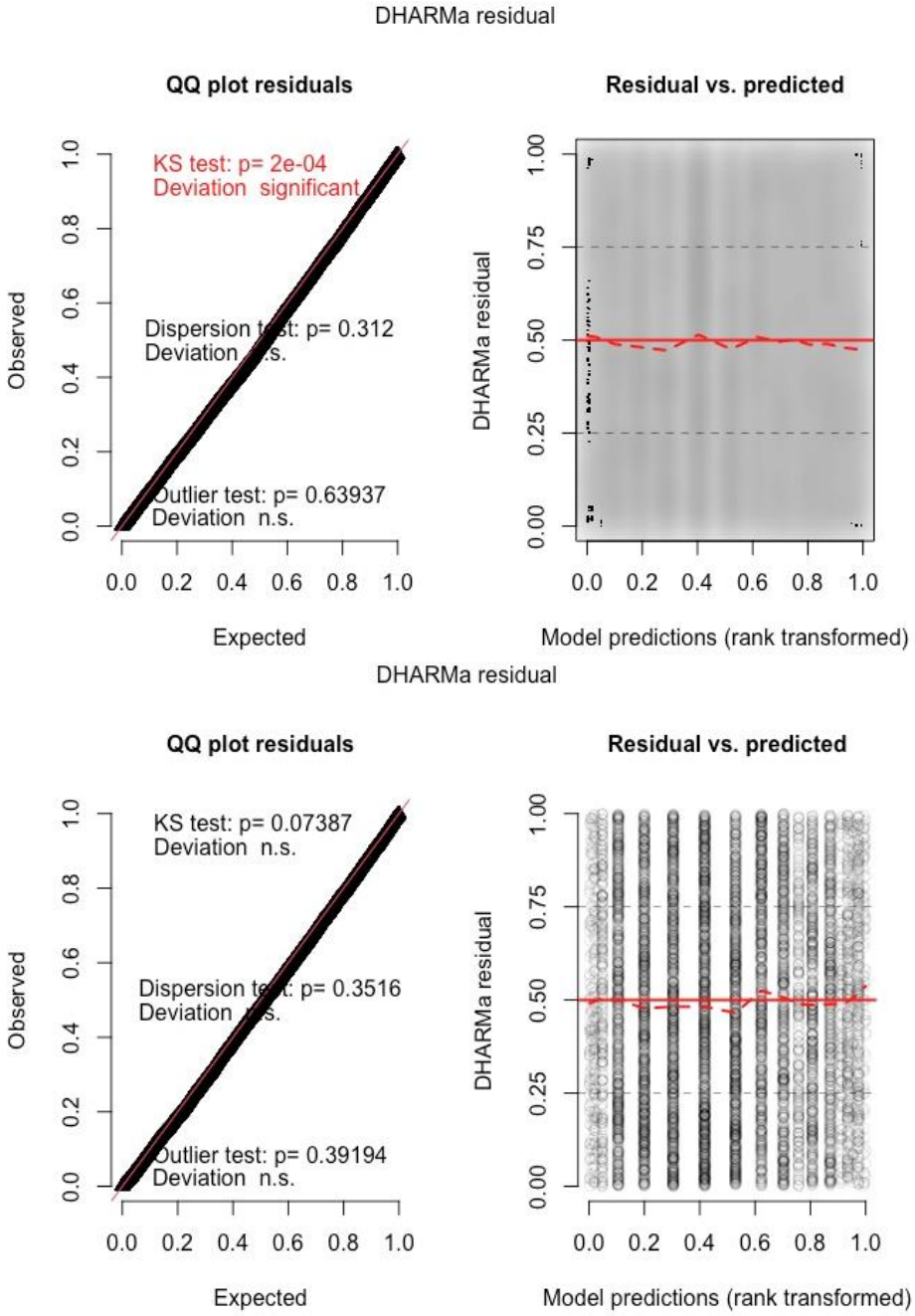
Note. These are the plots to check the assumptions of the model lmer(Loneliness ~ communication + extraversion, data = data_chatphone).

Appendix B

QQ-plots and residuals vs. fitted values for generalized linear mixed models used in the mediation analysis.

Figure 14

Plots for assumption checks of model 2 of the mediation analysis of in person communication and online communication



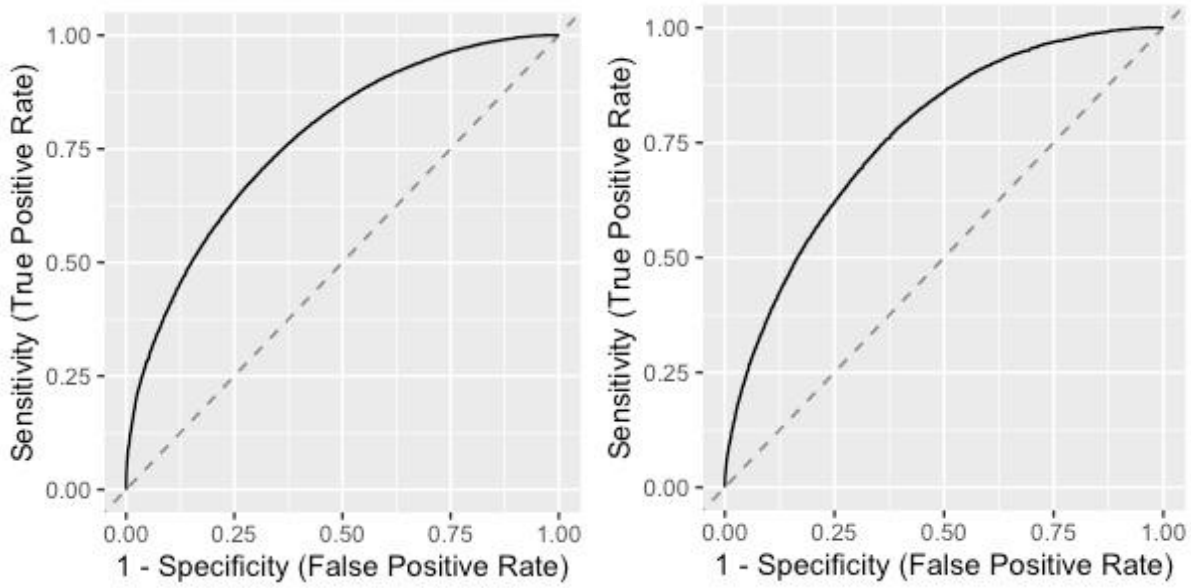
Note. These are the plots to check the assumptions of the model glmer(communication ~ extraversion, data = data_inperson) (**A**) and glmer(communication ~ extraversion, data = data_chatphone) (**B**).

Appendix C

ROC-curves of the generalized linear mixed models used in the mediation analysis.

Figure 15

ROC-curves of the generalized linear mixed models used in the mediation analysis.



Note. These plots represent the ROC-curves of the generalized linear mixed models used in the mediation analysis of in person and online communication. These models look as follows: glmer(communication ~ extraversion, data = data_inperson) (**A**) and glmer(communication ~ extraversion, data = data_chatphone) (**B**).