Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Journal of Psychiatric Research 148 (2022) 250–257

Contents lists available at ScienceDirect

Journal of Psychiatric Research

journal homepage: www.elsevier.com/locate/jpsychires

Investigating the relationships between resilience, autism-related quantitative traits, and mental health outcomes among adults during the COVID-19 pandemic

Sara C. Taylor [a,b,c], Zoe L. Smernoff [a,b], Maya Rajan [a,b], Samantha Steeman [a,b], Brielle N. Gehringer [a,b], Holly C. Dow [a,b], Ran Barzilay [a,d,e], Daniel J. Rader [b], Maja Bucan [a,b], Laura Almasy [b,e,f], Edward S. Brodkin [a,*]

[a] Department of Psychiatry, Perelman School of Medicine at the University of Pennsylvania, Translational Research Laboratory, 125 South 31st Street, Philadelphia, PA, 19104-3403, USA
[b] Department of Genetics, Perelman School of Medicine at the University of Pennsylvania, Clinical Research Building, 415 Curie Boulevard, Philadelphia, PA, 19104-6145, USA
[c] Neuroscience Graduate Group, Perelman School of Medicine at the University of Pennsylvania, 140 John Morgan Bldg., 3620 Hamilton Walk, Philadelphia, PA, 19104-6074, USA
[d] Department of Child and Adolescent Psychiatry and Behavioral Sciences, Children's Hospital of Philadelphia, 3401 Civic Center Blvd., Philadelphia, PA, 19104, USA
[e] Lifespan Brain Institute, Children's Hospital of Philadelphia, 3401 Civic Center Blvd., Philadelphia, PA, 19104, USA
[f] Department of Biomedical and Health Informatics, Children's Hospital of Philadelphia, 3401 Civic Center Blvd., Philadelphia, PA, 19104, USA

ARTICLE INFO

Keywords:
Autism spectrum
Adults
Resilience
Anxiety
Depression
COVID-19 pandemic

ABSTRACT

Resilience is a dynamic process through which people adjust to adversity and buffer anxiety and depression. The COVID-19 global pandemic has introduced a shared source of adversity for people across the world, with detrimental implications for mental health. Despite the pronounced vulnerability of autistic adults to anxiety and depression during the COVID-19 pandemic, relationships among autism-related quantitative traits, resilience, and mental health outcomes have not been examined. As such, we aimed to describe the relationships between these traits in a sample enriched in autism spectrum-related quantitative traits during the COVID-19 pandemic. We also aimed to investigate the impact of demographic and social factors on these relationships. Across three independent samples of adults, we assessed resilience factors, autism-related quantitative traits, anxiety symptoms, and depression symptoms during the COVID-19 pandemic. One sample (recruited via the Autism Spectrum Program of Excellence, n = 201) was enriched for autism traits while the other two (recruited via Amazon Mechanical Turk, n = 624 and Facebook, n = 929) drew from the general population. We found resilience factors and quantitative autism-related traits to be inversely related, regardless of the resilience measure used. Additionally, we found that resilience factors moderate the relationship between autism-related quantitative traits and depression symptoms such that resilience appears to be protective. Across the neurodiversity spectrum, resilience factors may be targets to improve mental health outcomes. This approach may be especially important during the ongoing COVID-19 pandemic and in its aftermath.

1. Introduction

Resilience is a dynamic process through which people adjust to adversity. It is multidimensional and shaped by multiple factors, including previous adverse experiences, external support, and individual traits (Luthar et al., 2000; Masten and Barnes, 2018; Ungar and Theron, 2020). At the individual level, resilience can be thought of as the capacity for success and well-being during and following adversity (Masten and Barnes, 2018). The COVID-19 global pandemic has introduced a shared source of adversity for people across the world. Given the potential immediate and lasting impacts of the pandemic on mental health outcomes (Pfefferbaum and North, 2020; Usher et al., 2020), it is important to investigate the processes (i.e., resilience factors) that buffer negative outcomes.

* Corresponding author. Translational Research Laboratory, 125 South 31st Street, Room 2202, Philadelphia, PA, 19104-3403, USA.
E-mail address: ebrodkin@pennmedicine.upenn.edu (E.S. Brodkin).

https://doi.org/10.1016/j.jpsychires.2022.01.046
Received 23 September 2021; Received in revised form 21 January 2022; Accepted 26 January 2022
Available online 29 January 2022

While the precise impact of the COVID-19 pandemic has yet to be quantified in the general population, estimates based on internet usage (content of searches) and expression (content of postings) make it clear that general mental health challenges, particularly depression, anxiety, and stress, have increased (Gianfredi et al., 2021; Saha et al., 2020). Certain populations may be especially vulnerable to these mental health impacts, for instance those on the autism spectrum, given the high co-occurrence of autism spectrum disorder (ASD) with anxiety and/or depression (Lai et al., 2019). In fact, a study across multiple countries found that increases in depression and anxiety due to the COVID-19 pandemic were heightened among autistic adults compared to non-autistic adults, suggesting this population may be especially vulnerable to mental health consequences of the crisis (Oomen et al., 2021). In a qualitative study focusing on experiences of autistic adults, researchers found that 55% of the participants experienced worsening mental health during the COVID-19 pandemic, many of whom highlighted the significance of the loss of in-person interaction (Stanley, 2021).

Previous work has established that having greater scores on surveys of resilience factors is associated with lower levels of anxiety and depression during the COVID-19 pandemic, although these studies did not specifically examine autism spectrum quantitative traits in their study populations (Barzilay et al., 2020; Mosheva et al., 2020; Ran et al., 2020). A recent study shows that these patterns extend to parents of children with and without autism spectrum disorder (ASD) diagnoses during the pandemic (Wang et al., 2021). Prior to the pandemic, a rare study of resilience among autistic individuals found that this buffering effect of resilience factors against anxiety and depression extended to autistic boys, though this study did not examine quantitative autism spectrum traits (Bitsika and Sharpley, 2014). In the current study, we sought to explore the degree to which resilience factors buffer against the psychological impacts of the COVID-19 pandemic in adults across the full spectrum of autism-related quantitative traits in population samples. To our knowledge, this is the first study to examine the relationships among quantitative autism-related traits, resilience, and mental health outcomes in adults. A better understanding of resilience may elucidate novel approaches to alleviate the burden of psychological disorders such as anxiety and depression for autistic individuals, as well as others high in autism-related quantitative traits.

2. Methods and materials

2.1. Sample

Adults high in autism spectrum traits and their family members were recruited through the University of Pennsylvania Autism Spectrum Program of Excellence (ASPE) study. Individuals high in autism spectrum traits were included in the study based on a clinical and developmental history in alignment with DSM-5 criteria for autism spectrum disorder and an intellectual quotient (IQ) $\geq$ 70 as measured by the Shipley-2 (Shipley et al., 2009). Clinical and developmental history was collected via phone screen, with questions on psychiatric history, social communication behavioral history (e.g. difficulty since early childhood with initiating conversation, making friends, eye contact, understanding nonliteral language and nonverbal social cues), repetitive behavioral history (e.g. strong interests, self-injurious behaviors, repetitive motor behaviors, routines, difficulty adjusting to change), sensory behavioral history (e.g. sensory sensitivity, hyper- or hypo-sensitivity to pain), treatment history, medication history, and genetic testing. Additionally, questions on development, including details on pregnancy and childhood behaviors (e.g. gaze following, mimicry of behavior, motor coordination, imaginative play, interest in other children, sensory sensitivity) were asked of an informant when possible and of the participant when an informant was not available. Information from the phone screen, in combination with the Social Communication Questionnaire (Berument et al., 1999), was reviewed in a case conference including the research team and the principal investigator, a psychiatrist specializing in ASD, to determine if the individual met DSM-V criteria for ASD and therefore were eligible for enrollment. Participants were excluded based on 1) a recent history of self-harm, aggressive behavior, or severe mood or psychotic symptoms and 2) a history of intellectual disability or severe neurological disorder (e.g. dementia, epilepsy, etc.), or IQ below 70 as measured by the Shipley-2 (Shipley et al., 2009). Family members of the ASPE participants were included based on their relationship and included first-, second-, third-, and fourth-degree relatives.

In addition to the ASPE sample enriched in autism spectrum traits, a population-based sample was ascertained through two online methods: 1) Facebook and 2) Amazon Mechanical Turk (MTurk). Participation was contingent on being over 18 years old. All procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. All study methods and procedures were approved by the appropriate Institutional Review Board, and all participants underwent an informed consent process. Study data were collected and managed using Research Electronic Data Capture (REDCap) tools hosted at the University of Pennsylvania (Harris et al., 2009, 2019). Sample demographics, separated by ascertainment method, are reported in Supplement Table 1.

2.2. Measures

Demographic characteristics. Demographic characteristics were collected either via a phone interview or an online questionnaire. They included, but were not limited to, age, sex, highest education level achieved, and household income. Using an index numbering system, each education and income level was assigned a numerical value and summed to calculate a value for socioeconomic status (possible range 0–13). The education levels and corresponding numeric value were as follows: less than high school (0), high school graduate (1), some college (2), undergraduate degree (3), master's degree (4), and doctoral degree (5). The household income levels and corresponding numeric value were as follows: less than $10,000 (0), $10,000 - $14,999 (1), $15,000-$24,999 (2), $25,000-$34,999 (3), $35,000-$49,999 (4), $50,000-$74,999 (5), $75,000-$99,999 (6), $100,000-$149,999 (7), and $150,000 or more (8). Additionally, participants were given the option to indicate which, if any, of ten adverse childhood experiences (ACE) they had experienced. ACE questions were adapted from the BRFSS Adverse Childhood Experience Module (Centers for Disease Control and Prevention (CDC), 2019; Felitti et al., 1998). The categories for ACE included: verbal, physical, or sexual abuse; neglect; parental divorce or separation; witnessing the physical abuse of a parent; living with someone struggling with addiction or mental health issues; and the incarceration of a household member. The ACE score was a count of how many ACE categories they indicated that they experienced (possible range 0–10).

Social Responsiveness Scale – 2 Adult (SRS-2A). The self-report version of SRS-2A was used to assess the level of autism spectrum-related quantitative traits. The SRS-2A has been used previously to quantify autism spectrum traits among people on and off the autism spectrum (Constantino et al., 2003; Constantino and Todd, 2003). The SRS-2A is a 60-item questionnaire covering social communication, restricted interests and repetitive behavior, social motivation, social awareness, and social cognition. The SRS has good convergent validity for adults, independent of IQ, and good inter-rater reliability (Chan et al., 2017; Constantino et al., 2003).

Patient Health Questionnaire 2 (PHQ-2). The PHQ-2 is composed of the first two questions of the PHQ-9 and is designed to efficiently assess depression severity (Arroll et al., 2010). It has high sensitivity (0.92) and moderate specificity (0.61) for major depression (Arroll et al., 2010).

Generalized Anxiety Disorder 7 (GAD-7). The GAD-7 is a 7-item

questionnaire that assesses symptoms associated with generalized anxiety disorder based on the frequency of occurrence (Spitzer et al., 2006). Participants indicate whether they have experienced the symptom described in each item "not at all", "several days", "more than half the days", or "nearly every day" over the previous two weeks. The GAD-7 has good convergent validity, with strong correlations with other anxiety measures and with depression measures (Spitzer et al., 2006).

Penn Resilience Survey. This questionnaire was developed by a research group at the University of Pennsylvania and Children's Hospital of Philadelphia led by co-author Ran Barzilay. Resilience is assessed in this 21-item questionnaire based on self-reliance, emotion regulation, and positive and negative relationships (Barzilay et al., 2020; Moore et al., 2020). Statements include "When I'm in a difficult situation, I can usually find my way out of it" and "When I'm upset, I have difficulty focusing on other things". Participants indicated either the degree to which they agree with each statement or how often the statement applies to them, depending on the statement. This questionnaire has good internal consistency, with Cronbach's α ranging from 0.85 to 0.96 (Moore et al., 2020).

Connor-Davidson Resilience Questionnaire (CD-RISC). The CD-RISC is a self-report questionnaire that evaluates resilience as defined by several attributes: personal competence, trust/tolerance/strengthening effects of stress, acceptance of changes, secure relationships, realistic sense of control over one's situation, and spiritual influences (Connor and Davidson, 2003). Questions asked how much participants agree to statements including "I am able to adapt when changes occur" and "Past successes give me confidence in dealing with new challenges and difficulties". The 25-question version of this questionnaire was used. The questionnaire has good internal consistency (Cronbach's $\alpha = 0.89$), test-retest reliability ($r = 0.87$), and convergent validity with the Kobasa hardiness measure ($r = 0.83$) as well as inverse relationships with stress questionnaires ($r = -0.32$ to -0.76) (Connor and Davidson, 2003).

We used two measures of resilience factors for several reasons. First, we wanted to include resilience measures that address relationships with others to varying degrees to insure that, especially among individuals high in autism spectrum traits, we are still assessing resilience factors and not an aspect of the autism phenotype. Given that the Penn Resilience Survey heavily emphasizes relationships as two out of its four factors, the CD-RISC is valuable as a resilience measure less focused on social aspects. Second, resilience is a dynamic, complex construct. Including more than one measure of resilience can establish with greater confidence that the relationships we find are between constructs and are not limited to the peculiarities of a specific measure.

2.3. Relationships between anxiety and depression symptoms, autism-related quantitative traits, and resilience factors

The relationships between anxiety, depression, autism-related quantitative traits, and resilience factors were evaluated using correlational analysis with Spearman coefficients in a pooled sample including participants recruited through ASPE, Facebook, and MTurk. Spearman rank-based coefficients were used to account for the ordinal distributions of the PHQ-2 and ACE scores (Fig. 1). Spearman's correlation analysis is non-parametric and allows for the test of association between continuous and ordinal data. As this is the first time the relationship between autism spectrum-related quantitative traits and resilience has been examined in a sample of adults, we completed exploratory correlation analyses between the subscales of the Penn Resilience Survey and the SRS-2A. Follow-up Fisher r-to-z transformation was used to determine if there were differences in the magnitude of the relationships. Fisher r-to-z transformation has been shown to be appropriate to compare correlations of different variables from the same sample that are therefore dependent (Steiger, 1980). The relationships between each measure (total scores only) were additionally assessed using

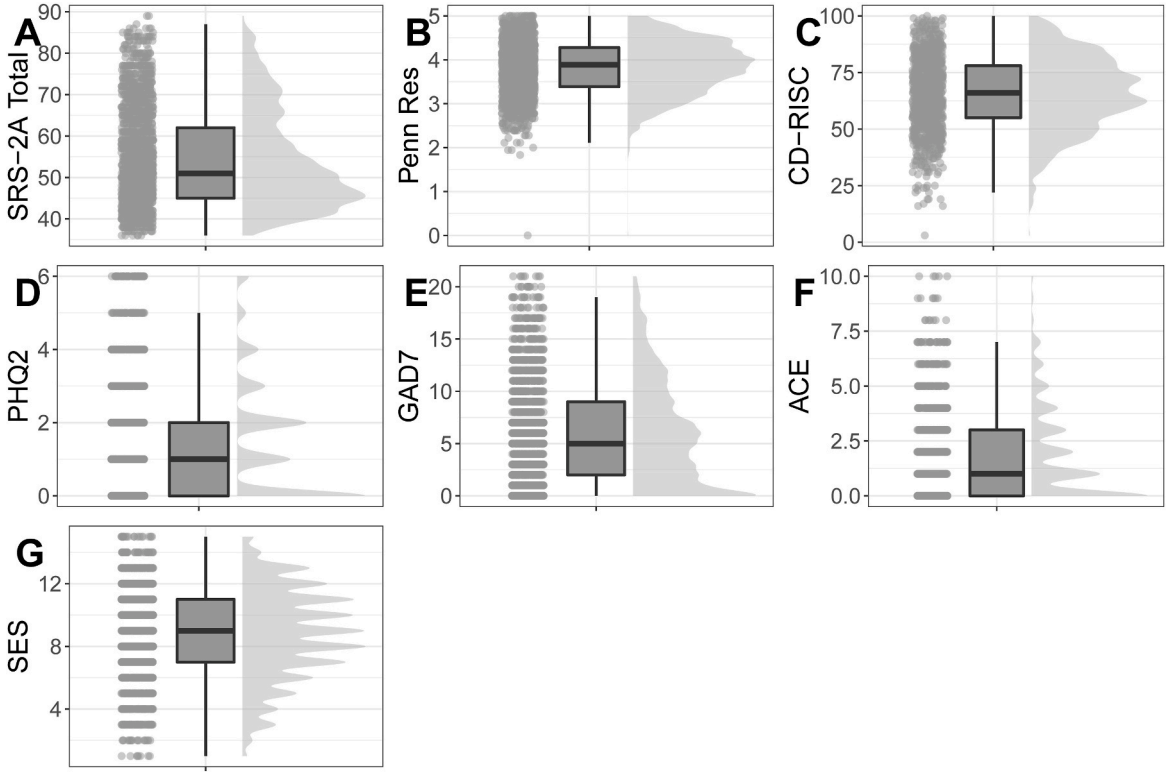

Fig. 1. Distribution of Data for the Measures Used. All measure scores with the exception of PHQ2 and ACE are distributed continuously across the sample. The data are shown as a scatterplot, boxplot, and histogram for each measure. SRS-2A Total = Social Responsiveness Scale-2A self-report total, Penn Res = Penn resilience survey mean score, CD-RISC = Connor-Davidson Resilience questionnaire total, PHQ2 = Personal Health Questionnaire-2 depression total score, GAD7 = General Anxiety Disorder-7 anxiety total score, ACE = adverse childhood experiences, SES = socioeconomic status.

multivariable linear regression in the pooled sample. The contributions of demographic variables (age, sex, ACE, and SES) as well as the date of completion of the resilience survey were evaluated in model 1 and controlled for in the following models. The date of completion of the resilience survey was included in the analysis because the stresses of the pandemic may have varied over time. The model comparison approach of hierarchical regression was used with an initial model assessing the impact of demographic variables (model 1), followed by models incorporating one of the other measures in order to assess their effects independently. Specifically, a measure of anxiety (GAD7) and a measure of depression (PHQ2) were each used as outcome variables with the contribution of demographic variables assessed in the first model, the contribution of a measure of autism-related quantitative traits (SRS-2A) assessed in the second model, and the contribution of measures of resilience assessed in the third model using CD-RISC and in the fourth model using the Penn resilience survey. Separately, SRS-2A was used as an outcome variable with demographic variables evaluated in model 1, CD-RISC evaluated in model 2, and Penn resilience survey total evaluated in model 3.

2.4. The moderating impact of resilience on the relationship between autism-related traits and anxiety and depression

The ability of resilience to moderate the relationship between autism-related quantitative traits and anxiety and depression was evaluated using multivariable linear regression in a pooled sample, including participants recruited through ASPE, Facebook, and MTurk. The outcome variables were GAD7 and PHQ2, with two different sets of input variables. The input variables were either SRS-2A, CD-RISC, and the interaction between SRS-2A and CD-RISC or SRS-2A, resilience survey total, and the interaction between SRS-2A and Penn resilience survey total.

3. Results

All tested measures (SRS-2A, GAD7, PHQ2, CD-RISC, and Penn resilience survey) were significantly correlated with each other (Fig. 2). The Penn resilience survey total was negatively related to anxiety ($r = -0.67$, $p < 0.01$), depression ($r = -0.66$, $p < 0.01$), and autism-related quantitative traits ($r = -0.74$, $p < 0.01$), as was resilience measured by the CD-RISC (anxiety, $r = -0.49$, $p < 0.01$; depression, $r = -0.49$, $p < 0.01$; autism-related traits, $r = -0.55$, $p < 0.01$). Additionally, autism-related quantitative traits were inversely related to each of the four subscales of the Penn Resilience Survey (self-reliance $r = -0.57$, $p < 0.01$; emotion regulation $r = -0.58$, $p < 0.01$; negative relationships $r = -0.41$, $p < 0.01$; positive relationships $r = -0.35$, $p < 0.01$). Fisher r to z transformation showed that the correlation between the SRS-2A and self-reliance was stronger in magnitude than that between the SRS-2A and the positive relationship subscale ($z = 8.20$, $p < 0.01$) and between the SRS-2A and the negative relationship subscales ($z = 6.16$, $p < 0.01$). The strength of the correlation between SRS-2A and the emotion regulation subscale was stronger in magnitude than that between SRS-2A and positive relationship subscale ($z = 8.64$, $p < 0.01$) and that between SRS-2A and negative relationship subscale ($z = 6.60$, $p < 0.01$). Autism-related traits were positively correlated with anxiety ($r = 0.59$, $p < 0.01$) and depression ($r = 0.57$, $p < 0.01$). The resilience measures were positively correlated with each other ($r = 0.67$, $p < 0.01$). All p-values passed Benjamini-Hochberg correction for multiple testing.

Among demographic variables, anxiety symptoms were partially predicted by age ($\beta = -0.22$), ACE ($\beta = 0.37$), and date of questionnaire completion ($\beta = -0.15$; $F(5,519) = 24.22$, $p < 0.001$) (see Table 1). Depression severity was predicted by only age ($\beta = -0.20$) and ACE ($\beta = 0.34$; $F(5,519) = 20.45$, $p < 0.001$) (see Table 2). Autism-related quantitative traits were partially predicted by age ($\beta = -0.33$), sex ($\beta = 0.10$), ACE ($\beta = 0.37$), and SES ($\beta = -0.08$; $F(5,519) = 44.2$, $p < 0.001$) (see Table 3). When analyzing the impact of resilience factors and

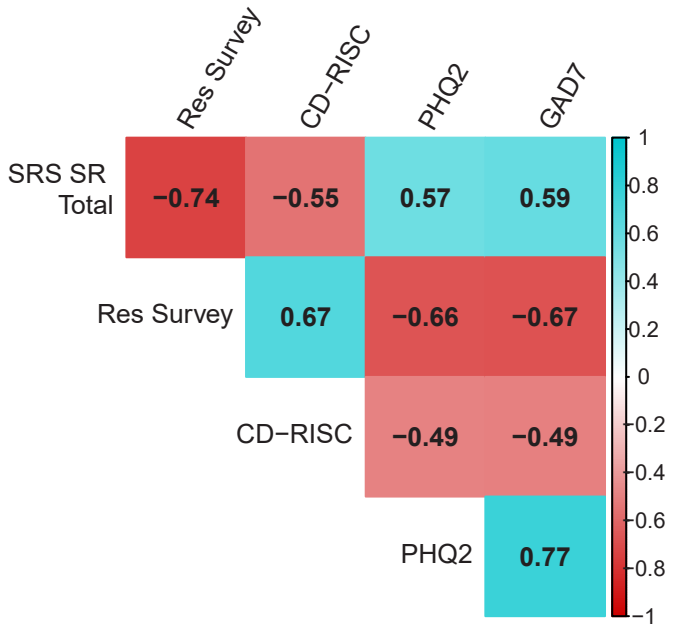

Fig. 2. Resilience factors' scores are negatively correlated to anxiety, depression, and autistic traits. Correlation coefficient (Spearman's rho) values for each pair of traits shown in text and represented using color (color intensity greater with stronger correlation, red for negative correlation, and blue for positive correlation).
SRS SR Total = Social Responsiveness Scale-2A self-report total, COVID-19 Res = Penn resilience survey mean score, CD-RISC = Connor-Davidson Resilience questionnaire total, PHQ2 = Personal Health Questionnaire-2 depression total score, GAD7 = General Anxiety Disorder-7 anxiety total score.

Table 1
Anxiety is partially predicted by age, adverse childhood experiences, date of questionnaire completion, autism-related quantitative traits, and resilience.

GAD-7				
	Model 1	Model 2	Model 3	Model 4
Age	−0.22***	−0.06	−0.14***	−0.09*
Sex	−0.02	−0.07	−0.01	−0.06
Date	−0.15**	−0.16***	−0.10*	−0.07
ACE	0.37***	0.19***	0.32***	0.16***
SES	−0.02	0.02	0.03	0
SRS-2A		0.49***		
CD-RISC			−0.35***	
Penn resilience survey				−0.55***
R^2 change	0.19	0.17	0.11	0.25
Adjusted R^2	0.18	0.35	0.29	0.43
F	24.22***	47.9***	36.91***	66.28***

For each model, values for the overall significance of the model (F), the explanatory power of the model adjusted for what would occur randomly (adjusted R^2), and the explanatory power of the model in comparison to a previous model (R^2 change) are reported. R^2 change for models 2, 3, and 4 are in comparison to model 1. R^2 change for model 1 is in comparison to a null model. Additionally, for each predictor variable included in the models, beta coefficients representing the degree of change in the outcome variable for every unit of the predictor variable are reported.
The outcome variable for each model is the GAD-7 total score, a measure of anxiety symptoms. Model 1 predictor variables are demographic. In addition to the predictor variables for Model 1, Model 2 includes autism-related quantitative traits (SRS-2A) as a predictor variable, Model 3 includes a resilience measure (CD-RISC), and Model 4 includes a different resilience measure (Penn resilience survey).
Date = date of resilience survey completion, ACE = adverse childhood experiences, SES = socioeconomic status, SRS-2A = Social Responsiveness Scale-2 Adult, CD-RISC = Connor-Davidson Resilience Questionnaire.
***p < 0.0001, **p < 0.01, *p < 0.05.

Table 2
Depression is partially predicted by age, adverse childhood experiences, autism-related quantitative traits, and resilience.

PHQ-2				
	Model 1	Model 2	Model 3	Model 4
Age	−0.20***	−0.05	−0.10**	−0.06
Sex	0.05	0.01	0.07	0.01
Date	−0.08	−0.09*	−0.03	−0.01
ACE	0.34***	0.17***	0.29***	0.13***
SES	−0.08	−0.04	−0.03	−0.06
SRS-2A		0.46***		
CD-RISC			−0.37***	
Penn resilience survey				−0.57***
R^2 change	0.16	0.15	0.13	0.26
Adjusted R^2	0.16	0.30	0.28	0.42
F	20.45***	38.82***	35.26***	64.26***

For each model, values for the overall significance of the model (F), the explanatory power of the model adjusted for what would occur randomly (adjusted R^2), and the explanatory power of the model in comparison to a previous model (R^2 change) are reported. R^2 change for models 2, 3, and 4 are in comparison to model 1. R^2 change for model 1 is in comparison to a null model. Additionally, for each predictor variable included in the models, beta coefficients representing the degree of change in the outcome variable for every unit of the predictor variable are reported.
The outcome variable for each model is the PHQ-2 total score, a measure of depression symptoms. Model 1 predictor variables are demographic. In addition to the predictor variables for Model 1, Model 2 includes autism-related quantitative traits (SRS-2A) as a predictor variable, Model 3 includes a resilience measure (CD-RISC), and Model 4 includes a different resilience measure (Penn resilience survey).
Date = date of resilience survey completion, ACE = adverse childhood experiences, SES = socioeconomic status, SRS-2A = Social Responsiveness Scale-2 Adult, CD-RISC = Connor-Davidson Resilience Questionnaire.
***p < 0.0001, **p < 0.01, *p < 0.05.

Table 3
Autism-related quantitative traits are partially predicted by age, sex, adverse childhood experiences, socioeconomic status, and resilience.

SRS-2A			
	Model 1	Model 2	Model 3
Age	−0.33***	−0.26***	−0.20***
Sex	0.10*	0.11**	0.06
Date	0.03	0.07	0.10**
ACE	0.37***	0.33***	0.17***
SES	−0.08*	−0.04	−0.07*
CD-RISC		−0.30***	
Penn resilience survey			−0.53***
R^2 change	0.30	0.08	0.22
Adjusted R^2	0.29	0.37	0.52
F	44.2***	53.13***	94.8***

For each model, values for the overall significance of the model (F), the explanatory power of the model adjusted for what would occur randomly (adjusted R^2), and the explanatory power of the model in comparison to a previous model (R^2 change) are reported. R^2 change for models 2 and 3 are in comparison to model 1. R^2 change for model 1 is in comparison to a null model. Additionally, for each predictor variable included in the models, beta coefficients representing the degree of change in the outcome variable for every unit of the predictor variable are reported.
The outcome variable for each model is the SRS-2A total score, a measure of autism-related quantitative traits. Model 1 predictor variables are demographic. In addition to the predictor variables for Model 1, Model 2 includes a resilience measure (CD-RISC) and Model 3 includes a different resilience measure (Penn resilience survey).
Date = date of resilience survey completion, ACE = adverse childhood experiences, SES = socioeconomic status, SRS-2A = Social Responsiveness Scale-2 Adult, CD-RISC = Connor-Davidson Resilience Questionnaire.
***p < 0.0001, **p < 0.01, *p < 0.05.

autism-related quantitative traits on anxiety severity, we found that more autism-related traits were associated with higher anxiety (β = 0.49; $F(6,518) = 47.9$, $p < 0.001$), while higher scores in either CD-RISC or Penn Resilience Survey, were associated with lower anxiety (β = −0.35, $F(6,518) = 36.91$, $p < 0.001$; β = −0.55, $F(6,518) = 66.28$, $p <$ 0.001, respectively). The same pattern held true for depression severity, with each unit (point) of SRS-2A predicting 46% more severe depression ($F(6,518) = 38.82$, $p < 0.001$), each unit of CD-RISC score predicting 37% less severe depression ($F(6,518) = 35.26$, $p < 0.001$), and each unit of Penn Resilience Survey score predicting 57% less severe depression (F (6,518) = 64.26, $p < 0.001$). Another shared pattern between anxiety and depression symptom prediction was that ACE predicted a significant portion of variance in anxiety and depression with SRS-2A (anxiety, β = 0.19; depression, $\beta = 0.17$), CD-RISC (anxiety, $\beta = 0.32$; depression, β = 0.29), or Penn Resilience Survey total (anxiety, $\beta = 0.16$; depression β = 0.13) (see Tables 1 and 2). Additionally, autism-related quantitative traits were partially predicted by CD-RISC ($\beta = -0.30$; $F(6,518) = 53.13$, $p < 0.001$) and Penn Resilience Survey total (β = −0.53; $F(6,518)$ = 94.8, $p < 0.001$) such that higher resilience levels were associated with fewer autism-related quantitative traits (see Table 3).

In addition to the individual effects of resilience and autism-related quantitative traits on anxiety, there was a positive moderating effect of resilience measured by CD-RISC (β = 0.002, $p < 0.01$; $F(3,987)$ = 188.36, $p < 0.01$) and by the Penn Resilience Survey (β = 0.035, $p <$ 0.05; $F(3,1677) = 327.24$, $p < 0.01$) on the relationship between autism-related quantitative traits and anxiety. A positive moderating effect indicates that higher resilience predicts a strengthened relationship between autism-related quantitative traits and anxiety. In addition to the individual effects of resilience and autism-related quantitative traits on depression, there was a negative moderating effect of Penn Resilience Survey total on the relationship between autism-related quantitative traits and depression (β = −0.010, $p < 0.01$; $F(3,1677)$ = 319.83, $p <$ 0.01), but not of CD-RISC resilience ($\beta = 0.0002$, $p > 0.05$). A negative moderating effect indicates that higher resilience predicts a weakened relationship between autism-related quantitative traits and depression.

4. Discussion

To our knowledge, this is first study to investigate the dimensional relationship between resilience factors and autism-related quantitative traits among adults. Moreover, this study was conducted during the unique, stressful circumstances of the COVID-19 pandemic. We found resilience factors and autism-related quantitative traits to be inversely related, using two different resilience measures. After accounting for the effects of the demographic variables, these relationships were still significant. In exploratory analyses, we found that the resilience factors that were more strongly related to autism-related quantitative traits were self-reliance and emotion regulation rather than positive or negative relationships. In replication of previous studies' results among neurotypical individuals (Barzilay et al., 2020; Mosheva et al., 2020; Ran et al., 2020; Wang et al., 2021), we found that resilience was negatively associated with anxiety and depression, such that higher resilience was associated with fewer symptoms for both. These relationships were maintained after accounting for demographic variables. As expected, given the high co-occurrence of ASD with anxiety and/or depression (Lai et al., 2019), we found that having more autism-related quantitative traits was associated with a greater severity of anxiety and depression. These effects were also robust to demographic differences.

We also found that resilience factors moderated the relationship between autism-related quantitative traits and depression severity, suggesting that improving resilience could be an especially effective strategy for reducing depression symptoms among individuals on the autism spectrum. Multiple programs designed for neurotypical adults to enhance resilience have been shown to be effective (e.g. Litvin et al., 2020; Millear et al., 2008) and could be modified to suit the diverse

needs of autistic individuals. Our results suggest that some resilience factors may be more closely related to the overall autism spectrum phenotype than others. This suggests that assessing resilience with some granularity (e.g. by separating out interpersonal vs. intrapersonal factors) could be helpful in focusing strategies to improve resilience in this population.

Resilience factors also moderated the relationship between anxiety and autism-related quantitative traits, but in a surprising direction. The pattern we observed suggests that greater resilience strengthens the relationship between anxiety and autism-related quantitative traits. The interpretation of this finding is complicated by the complexities of the sources of anxiety during the COVID-19 pandemic. In the general population, it is clear that the focus of anxiety and stress has shifted over time as the COVID-19 pandemic has progressed (e.g. from early concerns about access to health insurance and uncertainty about how the virus is transmitted to concerns about the impacts of social isolation) (Saha et al., 2020). Among autistic adults, there has not been a uniform increase across all domains of anxiety during the pandemic, with evidence of some reported reduction of social stress (Oomen et al., 2021; Stanley, 2021). While we did not investigate specific sources of anxiety in the present study, we found that overall, anxiety (but not depression or autism-related quantitative traits) gradually decreased over the course of the pandemic in our participants, as indicated by the fact that the date of completion of the surveys predicted anxiety, with later date of completion predicting lower anxiety levels. It is possible that these dynamic complexities of anxiety sources and triggers contribute to the direction of the moderating effect of resilience on the relationship between anxiety and autism spectrum-related quantitative traits.

The current study also contributes to extensive past literature examining the effects of ACE and SES on mental health outcomes. Previous work has shown that autistic children have a higher number of ACE than their neurotypical peers (Hoover and Kaufman, 2018; Kerns et al., 2017). We show that this relationship extends to a quantitative relationship between autism-related traits and the number of ACEs among adults, with higher number of ACEs predicting more autism-related quantitative traits. We also show that the inverse relationship exists for SES, with lower SES predicting more autism-related quantitative traits. Previous work in a sample of autistic children suggests that there may also be an interactive effect of SES and ACE on ASD traits such that the relationship between ACE and ASD is more pronounced among individuals in a lower income bracket (Kerns et al., 2017). The high incidence of ACE and trauma continuing into adolescence and adulthood among the autistic community should continue to be rigorously examined in order to identify preventative and protective mechanisms against trauma and its detrimental effects on mental health (Hoover, 2015; Peterson et al., 2019; Rumball et al., 2020, 2021). Moreover, our results suggest that mental health treatments for autistic individuals needs to be trauma-informed (Benevides et al., 2020; Peterson et al., 2019; Rumball et al., 2020, 2021).

4.1. Limitations

There are several limitations to the interpretation of the current study. It is worth noting that, while we observed moderate to strong relationships between many of the constructs studied, our data do not indicate causal mechanisms or direction(s) of causation. More work needs to be done in order to evaluate causation between the constructs studied here – namely autism-related quantitative traits, mental health outcomes, resilience, ACE, and SES. Also, the relationships between these constructs need to be further explored by looking at factors such as degree and quality of exposures to different types of stressors (COVID-19 specific or otherwise) and looking at social support access in more detail than in the present study. Additionally, the use of a general anxiety measure limited our ability to explore potential nuances in the relationships between autism-related quantitative traits, specific types of anxiety symptoms, and resilience. Finally, the ordinal nature of the distribution of the measure for depression symptoms and the ACE scores in our sample may limit the interpretability of the hierarchical regression and moderation results using those variables. These analyses assume continuous distributions of the variables and therefore equal distance between each unit of measurement.

4.2. Conclusions

Resilience is a construct that should be further explored in order to better understand the relationships between autism-related quantitative traits and co-occurring anxiety/depression. Across the autism spectrum and individuals high in autism-related quantitative traits, bolstering resilience may be a feasible strategy for improving mental health outcomes. This approach may be especially important during the severe stresses of the ongoing COVID-19 pandemic and in its aftermath.

5. Citation diversity statement

Recent work in several fields of science has identified a bias in citation practices such that papers from women and other minority scholars are under-cited relative to the number of such papers in the field (e.g. Dworkin et al., 2020). Here we sought to proactively consider choosing references that reflect the diversity of the field in thought, form of contribution, gender, race, ethnicity, and other factors. First, we obtained the predicted gender of the first and last author of each reference by using databases that store the probability of a first name being carried by a woman (Dworkin et al., 2020; Zhou et al., 2020). By this measure (and excluding self-citations to the first and last authors of our current paper), our references contain 14.29% woman(first)/woman(last), 23.94% man/woman, 34.29% woman/man, and 27.49% man/man. This method is limited in that a) names, pronouns, and social media profiles used to construct the databases may not, in every case, be indicative of gender identity and b) it cannot account for intersex, non-binary, or transgender people. Second, we obtained predicted racial/ethnic category of the first and last author of each reference by databases that store the probability of a first and last name being carried by an author of color (Ambekar et al., 2009; Sood and Laohaprapanon, 2018). By this measure (and excluding self-citations), our references contain 9.98% author of color(first)/author of color(last), 20.09% white author/author of color, 16.56% author of color/white author, and 53.37% white author/white author. This method is limited in that a) names and Florida Voter Data to make the predictions may not be indicative of racial/ethnic identity, and b) it cannot account for Indigenous and mixed-race authors, or those who may face differential biases due to the ambiguous racialization or ethnicization of their names. We look forward to future work that could help us to better understand how to support equitable practices in science.

Author contributions

Sara C. Taylor: Conceptualization, Formal analysis, Software, Writing – Original Draft, Writing – Review & Editing. **Zoe L. Smernoff:** Conceptualization, Resources, Data curation, Writing – Review & Editing. **Maya Rajan:** Validation, Writing – Review & Editing. **Samantha Steeman:** Resources, Validation, Writing – Review & Editing. **Brielle N. Gehringer:** Resources, Project administration. **Holly C. Dow:** Resources. **Ran Barzilay:** Writing – Review & Editing. **Daniel J. Rader:** Funding acquisition, Project administration. **Maja Bucan:** Funding acquisition, Supervision. **Laura Almasy:** Supervision. **Edward S. Brodkin:** Conceptualization, Supervision, Funding acquisition, Project administration, Writing – Review & Editing.

Funding statement

This study was financially supported by the Autism Spectrum Program of Excellence at the University of Pennsylvania as well as the

National Institute of Mental Health (S.C.T., grant number F31MH125539).

Declaration of competing interest

None.

Acknowledgements

We would like to thank Allison Langer, Eric Rawot, Leat S. Perez, Matthew Goodman, Mahip Grewal, Oceania Eshraghi, and Ashley A. Pallathra for their contributions to data collection. We would like to thank Maria Fasolino for the encouragement to investigate the relationships between the Penn Resilience Survey subscales and autism-related quantitative traits. Finally, we would like to thank the participants for their efforts which made this study possible.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpsychires.2022.01.046.

References

Ambekar, A., Ward, C., Mohammed, J., Male, S., Skiena, S., 2009. Name-ethnicity classification from open sources. In: Proceedings of the 15th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, pp. 49–58.

Arroll, B., Goodyear-Smith, F., Crengle, S., Gunn, J., Kerse, N., Fishman, T., Falloon, K., Hatcher, S., 2010. Validation of PHQ-2 and PHQ-9 to screen for major depression in the primary care population. Ann. Fam. Med. 8, 348–353. https://doi.org/10.1370/afm.1139.

Barzilay, R., Moore, T.M., Greenberg, D.M., DiDomenico, G.E., Brown, L.A., White, L.K., Gur, R.C., Gur, R.E., 2020. Resilience, COVID-19-related stress, anxiety and depression during the pandemic in a large population enriched for healthcare providers. Transl. Psychiatry 10. https://doi.org/10.1038/s41398-020-00982-4.

Benevides, T.W., Shore, S.M., Palmer, K., Duncan, P., Plank, A., Andresen, M.L., Caplan, R., Cook, B., Gassner, D., Hector, B.L., Morgan, L., Nebeker, L., Purkis, Y., Rankowski, B., Wittig, K., Coughlin, S.S., 2020. Listening to the autistic voice: mental health priorities to guide research and practice in autism from a stakeholder-driven project. Autism 24, 822–833. https://doi.org/10.1177/1362361320908410.

Berument, S.K., Rutter, M., Lord, C., Pickles, A., Bailey, A., 1999. Autism screening questionnaire : diagnostic validity. Br. J. Psychiatry 175, 444–451.

Bitsika, V., Sharpley, C.F., 2014. Which psychological resilience attributes are associated with lower aspects of anxiety in boys with an autism spectrum disorder? Implications for guidance and counselling interventions. Br. J. Guid. Counsell. 42, 544–556. https://doi.org/10.1080/03069885.2014.931929.

Centers for Disease Control and Prevention (CDC), 2019. Behavioral Risk Factor Surveillance System Survey Questionnaire. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Atlanta, Georgia.

Chan, W., Smith, L.E., Hong, J., Greenberg, J.S., Mailick, M.R., 2017. Validating the social responsiveness scale for adults with autism. Autism Res. 10, 1663–1671. https://doi.org/10.1002/aur.1813.

Connor, K.M., Davidson, J.R.T., 2003. Development of a new resilience scale: the connor-davidson resilience scale (CD-RISC). Depress. Anxiety 18, 76–82. https://doi.org/10.1002/da.10113.

Constantino, J.N., Davis, S.A., Todd, R.D., Schindler, M.K., Gross, M.M., Brophy, S.L., Metzger, L.M., Shoushtari, C.S., Splinter, R., Reich, W., 2003. Validation of a brief quantitative measure of autistic traits: comparison of the social responsiveness scale with the Autism Diagnostic Interview-Revised. J. Autism Dev. Disord. 33, 427–433. https://doi.org/10.1023/A:1025014929212.

Constantino, J.N., Todd, R.D., 2003. Autistic traits in the general population: a twin study. Arch. Gen. Psychiatr. 60, 524–530. https://doi.org/10.1001/archpsyc.60.5.524.

Dworkin, J.D., Linn, K.A., Teich, E.G., Zurn, P., Shinohara, R.T., Bassett, D.S., 2020. The extent and drivers of gender imbalance in neuroscience reference lists. Nat. Neurosci. 23, 918–926. https://doi.org/10.1038/s41593-020-0658-y.

Felitti, V.J., Anda, R.F., Nordenberg, D., Williamson, D.F., Spitz, A.M., Edwards, V., Koss, M.P., Marks, J.S., 1998. Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults: the adverse childhood experiences (ACE) study. Am. J. Prev. Med. 14, 245–258. https://doi.org/10.1016/S0749-3797(98)00017-8.

Gianfredi, V., Sandro, P., Santangelo, O.E., 2021. What can internet users' behaviours reveal about the mental health impacts of the COVID-19 pandemic? A systematic review. Public Health 198, 44–52. https://doi.org/10.1016/j.puhe.2021.06.024.

Harris, P.A., Taylor, R., Minor, B.L., Elliott, V., Fernandez, M., Neal, L.O., Mcleod, L., Delacqua, G., Delacqua, F., Duda, S.N., REDCapConsortium, 2019. The REDCap Consortium: building an international community of software platform partners. J. Biomed. Inf. 95, 103208. https://doi.org/10.1016/j.jbi.2019.103208.

Harris, P.A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., Conde, J.G., 2009. Research electronic data capture (REDCap)-A metadata-driven methodology and workflow process for providing translational research informatics support. J. Biomed. Inf. 42, 377–381. https://doi.org/10.1016/j.jbi.2008.08.010.

Hoover, D.W., 2015. The effects of psychological trauma on children with autism spectrum disorders: a research review. Rev. J. Autism Dev. Disord. 2, 287–299. https://doi.org/10.1007/s40489-015-0052-y.

Hoover, D.W., Kaufman, J., 2018. Adverse childhood experiences in children with autism spectrum disorder. Curr. Opin. Psychiatr. 31, 128–132. https://doi.org/10.1097/YCO.0000000000000390.

Kerns, C.M., Newschaffer, C.J., Berkowitz, S., Lee, B.K., 2017. Examining the association of autism and adverse childhood experiences in the National Survey of Children's Health: the important role of income and co-occurring mental health conditions. J. Autism Dev. Disord. 47, 2275–2281. https://doi.org/10.1007/s10803-017-3111-7.

Lai, M.-C., Kassee, C., Besney, R., Bonato, S., Hull, L., Mandy, W., Szatmari, P., Ameis, S. H., 2019. Prevalence of co-occurring mental health diagnoses in the autism population: a systematic review and meta-analysis. Lancet Psychiatr. 6, 819–829. https://doi.org/10.1016/S2215-0366(19)30289-5.

Litvin, S., Saunders, R., Maier, M.A., Lüttke, S., 2020. Gamification as an approach to improve resilience and reduce attrition in mobile mental health interventions: a randomized controlled trial. PLoS One 15, e0237220. https://doi.org/10.1371/journal.pone.0237220.

Luthar, S.S., Cicchetti, D., Becker, B., 2000. The construct of resilience: a critical evaluation and guidelines for future work. Child Dev. 71, 543–562.

Masten, A., Barnes, A., 2018. Resilience in children: developmental perspectives. Children 5, 98. https://doi.org/10.3390/children5070098.

Millear, P.M., Liossis, P.L., Shochet, I.M., Biggs, H., Donald, M., 2008. Being on PAR: outcomes of a pilot trial to improve meantal health and wellbeing in the workplace with the Promoting Adult Resilience (PAR) Program. Behav. Change 25, 215–228. https://doi.org/10.1375/bech.25.4.215.

Moore, T.M., White, L.K., Barzilay, R., Calkins, M.E., Jones, J.D., Young, J.F., Gur, R.C., Gur, R.E., 2020. Development of a scale battery for rapid assessment of risk and resilience. Psychiatr. Res. 288, 112996. https://doi.org/10.1016/j.psychres.2020.112996.

Mosheva, M., Hertz-Palmor, N., Dorman Ilan, S., Matalon, N., Pessach, I.M., Afek, A., Ziv, A., Kreiss, Y., Gross, R., Gothelf, D., 2020. Anxiety, pandemic-related stress and resilience among physicians during the COVID-19 pandemic. Depress. Anxiety 37, 965–971. https://doi.org/10.1002/da.23085.

Oomen, D., Nijhof, A.D., Wiersema, J.R., 2021. The psychological impact of the COVID-19 pandemic on adults with autism: a survey study across three countries. Mol. Autism. 12, 21. https://doi.org/10.1186/s13229-021-00424-y.

Peterson, J.L., Earl, R.K., Fox, E.A., Ma, R., Haidar, G., Pepper, M., Berliner, L., Wallace, A.S., Bernier, R.A., 2019. Trauma and autism spectrum disorder: review, proposed treatment adaptations and future directions. J. Child Adolesc. Trauma 12, 529–547. https://doi.org/10.1007/s40653-019-00253-5.

Pfefferbaum, B., North, C.S., 2020. Mental health and the Covid-19 pandemic. N. Engl. J. Med. 383, 508–510. https://doi.org/10.1056/NEJMp2008017.

Ran, L., Wang, W., Ai, M., Kong, Y., Chen, J., Kuang, L., 2020. Psychological resilience, depression, anxiety, and somatization symptoms in response to COVID-19: a study of the general population in China at the peak of its epidemic. Soc. Sci. Med. 262, 113261. https://doi.org/10.1016/j.socscimed.2020.113261.

Rumball, F., Brook, L., Happé, F., Karl, A., 2021. Heightened risk of posttraumatic stress disorder in adults with autism spectrum disorder: the role of cumulative trauma and memory deficits. Res. Dev. Disabil. 110, 103848. https://doi.org/10.1016/j.ridd.2020.103848.

Rumball, F., Happé, F., Grey, N., 2020. Experience of trauma and PTSD symptoms in autistic adults: risk of PTSD development following DSM-5 and non-DSM-5 traumatic life events. Autism Res. 13, 2122–2132. https://doi.org/10.1002/aur.2306.

Saha, K., Torous, J., Caine, E.D., de Choudhury, M., 2020. Psychosocial effects of the COVID-19 pandemic: large-scale quasi-experimental study on social media. J. Med. Internet Res. 22, e22600 https://doi.org/10.2196/22600.

Shipley, W.C., Gruber, C.P., Martin, T.A., Klein, A.M., 2009. Shipley-2 Manual. Western Psychological Services, Los Angeles, CA.

Sood, G., Laohaprapanon, S., 2018. Predicting Race and Ethnicity from the Sequence of Characters in a Name. arXiv: Applications.

Spitzer, R.L., Kroenke, K., Williams, J.B.W., Löwe, B., 2006. A brief measure for assessing generalized anxiety disorder: the GAD-7. Arch. Intern. Med. 166, 1092–1097. https://doi.org/10.1001/archinte.166.10.1092.

Stanley, R.E., 2021. "Listen, I've been thriving" vs. "This is the worst I've ever felt!": an exploratory study of autistic experiences with in-person and online social interaction during the COVID-19 pandemic. In: International Society for Autism Research Annual Meeting.

Steiger, J.H., 1980. Tests for comparing elements of a correlation matrix. Psychol. Bull. 87, 245–251. https://doi.org/10.1037//0033-2909.87.2.245.

Ungar, M., Theron, L., 2020. Resilience and mental health: how multisystemic processes contribute to positive outcomes. Lancet Psychiatr. 7, 441–448. https://doi.org/10.1016/S2215-0366(19)30434-1.

Usher, K., Durkin, J., Bhullar, N., 2020. The COVID-19 pandemic and mental health impacts. Int. J. Ment. Health Nurs. 29, 315–318. https://doi.org/10.1111/inm.12726.

Wang, L., Li, D., Pan, S., Zhai, J., Xia, W., Sun, C., Zou, M., 2021. The relationship between 2019-nCoV and psychological distress among parents of children with autism spectrum disorder. Glob. Health 17, 23. https://doi.org/10.1186/s12992-021-00674-8.

Zhou, D., Bertolero, M.A., Stiso, J., Cornblath, E.J., Teich, E.G., Blevins, A.S., Virtualmario, Camp, C., Dworkin, J.D., Bassett, D.S., 2020. Gender Diversity Statement and Code Notebook v1.1.