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A Quantitative Simulation Study of the Relationship Between Anxiety, Psychological Resilience, and Life Satisfaction Using Graph-Theoretic and Statistical Models

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ABSTRACT
This paper investigates the relationship between anxiety, psychological resilience and life satisfaction with each other using Monte Carlo simulation. Latent population values for the dataset were obtained by the correlations provided by Sarid et al. (2024), and from these, the item responses for the GAD-7, CD-RISC-10 and the SWLS were simulated for 500 cases. Pearson correlation, hierarchical regression, bootstrapped mediation and moderated regression were used and a Monte Carlo experiment (2 000 replications at each of five sample sizes) was conducted to examine the performance of the mediation analysis. Anxiety was negatively related to life satisfaction ($r = -.29$) and resilience positively ($r = .43$). The indirect effect with resilience as the first step in the chain proved significant ($ab = -.082$, 95% CI [−.117, −.049]), as did the indirect effect with the order reversed, and the two models fit equally well. No buffering interaction was found, and a data-generating model without any buffering interaction is consistent with this. Measurement error reduced the true indirect effect by approximately 27%, and at $N = 500$, the intervals only contained the latent indirect effect 52% of the time. The findings indicate that cross-sectional mediation analysis does not allow determining the sequence of effects, and measurement errors affect indirect effects, even if the scales are highly reliable.
Keywords: anxiety, psychological resilience, life satisfaction, mediation, Monte Carlo simulation

1. INTRODUCTION

Life satisfaction is a person's overall evaluation of her/her life in comparison to her or his own personal standards (Diener et al., 1985; Pavot & Diener, 2008). It's a judgement and not a passing mood and serves as a helpful guideline that the distress is beginning to pervade the person's overall life appraisal. Anxiety immediately comes to mind as one area of distress for this reason; as persistent worrying and tension is common and does affect day to day functioning (Spitzer et al., 2006). A major difference between satisfaction with or without anxiety is posited to be resilience; the capacity to cope with stress and adversity (Connor & Davidson, 2003). Positive emotion appears to be a booster in the recovery from the negative emotion and resilient individuals appear to cope with negative experiences more quickly (Tugade & Fredrickson, 2004).

This is an approximately universal rule of thumb. Hu et al., (2015) did a meta-analysis on 60 studies and found that trait resilience was negatively correlated with negative mental health indices, and positively correlated with positive mental health indices. Sarid et al. (2024) showed −.37 for the association between anxiety and life satisfaction, .54 for the association between resilience and life satisfaction and −.32 for the association between anxiety and resilience based on 993 Israelis. Further research in the area of mediation. As a mediator, it was observed that resilience partially mediated the relationship between mindfulness and life satisfaction with Indian undergraduates (Bajaj & Pande, 2016), partially mediated the relationship between personality and anxiety in Chinese medical undergraduates (Shi et al., 2015), and acted as a mediator in the relationship between academic burnout and life dissatisfaction in Chinese's three wave data (Wang et al., 2022).

These paths are less stable than the correlations; that is, it is less clear in which direction they are pointing. It can be reversed though, as Samani et al. (2007) said that there can be a decrease in negative emotions such as anxiety, resilience works to increase life satisfaction. Both orders of the data in this case are defensible based on the same cross sectional data, and can dramatically misrepresent the longitudinal processes (Maxwell & Cole, 2007). One issue is that the "true value" (that is, what the survey researcher believes the value is) is not known to the researcher and he/she therefore does not know by how much the measurement error has pushed him/her.

The second problem is overcome by simulation since the truth is defined by the researcher (Morris et al., 2019). This paper therefore builds up a graph-theoretic model for the three variables from published data of their values, generates questionnaire type data from this model and applies the statistical models in this literature. You are able to compare the analysis to the correct answer as you know what this is. Four models hypotheses can be formulated from the model:

H1: Anxiety is negatively, and resilience positively, associated with life satisfaction.
H2: Resilience has a significant indirect role in the association between anxiety and life satisfaction.
H3: Resilience does not moderate the association, because no interaction is built into the model.
H4: Scale-based estimates of the indirect effect are smaller in size than the latent value set in the model.

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2.METHOD

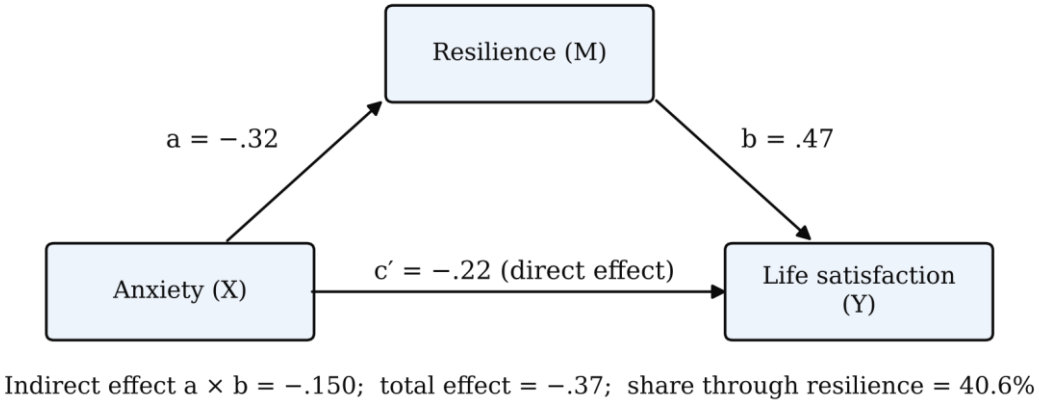
Design and Ethics

This is a quantitative simulation study. All cases were generated by computer from a calibrated statistical model, so participant recruitment, informed consent and ethical review were not required. The analysis was written in Python using NumPy and SciPy, with a fixed random seed (20261105) so that each result can be reproduced.

Graph-Theoretic Model

Anxiety (X), resilience (M) and life satisfaction (Y) were defined as standard normal latent variables whose correlations equal the values reported by Sarid et al. (2024): −.32 between anxiety and resilience, −.37 between anxiety and life satisfaction, and .54 between resilience and life satisfaction. The published values describe observed scores, and treating them as latent is an assumption of this study. Figure 1 shows the model that these correlations imply, which is the model used to generate the data.

Figure 1 True Model Built Into the Simulation



Note. Standardised path values implied by the correlations in Sarid et al. (2024). These are set values, not estimates. Compiled by the author.

Each arrow shows a direct effect. Higher anxiety lowers resilience (path a = −.32), higher resilience raises life satisfaction (path b = .47), and anxiety also lowers life satisfaction directly (path c′ = −.22). Because part of the effect of anxiety travels through resilience, there is also an indirect effect, found by multiplying a by b, which equals −.150. This is 40.6% of the total effect of anxiety on life satisfaction (−.37). Together, anxiety and resilience explain 33.5% of the variance in life satisfaction. These set values are the correct answers against which every analysis in this study is judged.

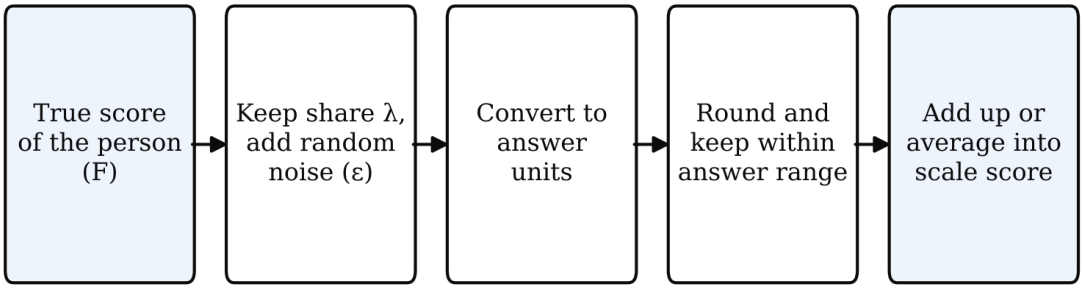
In graph-theoretic terms, Figure 1 is a directed acyclic graph. Each variable is a node, each arrow is a directed edge carrying a weight (its path coefficient), and no sequence of arrows leads back to its starting point. This structure allows effects to be read directly from the graph using the path-tracing rules of Wright (1934). The effect carried along any route from one node to another equals the product of the edge weights on that route, and the total effect equals the sum over all routes. Anxiety reaches life satisfaction by two routes, the direct edge (−.22) and the route through resilience (−.32 × .47 = −.150), and their sum gives the total effect of −.37. The graph also states which variables are assumed not to affect one another, which is the basis of modern graphical approaches to cause and effect (Pearl, 2009). Its main limit is that the direction of each arrow is an assumption made by the researcher. As the Results show, a graph with resilience placed before anxiety fits the same data equally well.

Simulated Measures

Item responses were generated for three established instruments: the seven-item GAD-7, scored 0–3 (Spitzer et al., 2006; Löwe et al., 2008); the ten-item CD-RISC-10 (Campbell-Sills & Stein, 2007); and the five-item SWLS, scored 1–7 (Diener et al., 1985). The CD-RISC-10 is normally scored 0–4, but the items here were coded 1–5 as an assumption, because the published mean of 3.72 was the calibration target and the source consulted did not state the range. No questionnaire was given to any person. Figure 2 shows how each simulated answer was produced.

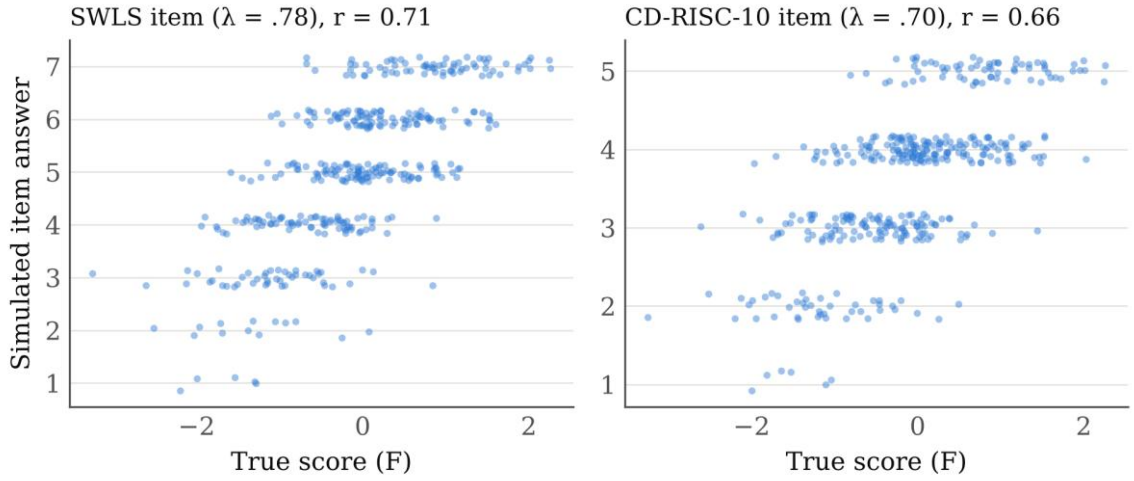
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Figure 2 How Each Simulated Item Answer Was Generated



Note. Compiled by the author.
Each simulated person starts with a true score (F) on each of the three variables. For every questionnaire item, part of that true score is kept, set by the loading λ, and the rest is replaced by random noise (ε), so that no single item measures the trait perfectly. The result is converted to the questionnaire's units, rounded to a whole answer and kept within the allowed range, such as 0 to 3 for the GAD-7. The item answers are then added up (GAD-7) or averaged (CD-RISC-10 and SWLS) into a scale score. The loadings were .78 for the GAD-7 and SWLS and .70 for the CD-RISC-10; these were analyst choices, not published values.

Figure 3 How the Loading Affects the Link Between True Scores and Item Answers



Note. Each point is one of 400 illustrative simulated cases, produced with the same procedure as the study data. Points are spread vertically so that overlapping answers are visible. r = correlation between true score and item answer.
Figure 3 shows the effect of the loading in practice. People with higher true scores tend to give higher answers, but the points are widely spread, and the spread is larger when the loading is lower (.70 compared with .78). This spread is measurement error. It is the reason why estimates based on scale scores are expected to fall short of the true values in Figure 1, which H4 tests. Scaling constants were tuned so that large-sample means and standard deviations matched Sarid et al. (2024). A check on 2,000,000 simulated cases gave 5.39 (5.65), 3.72 (0.66) and 5.19 (1.22), against published values of 5.40 (5.66), 3.72 (0.66) and 5.19 (1.22). The same check supplied the scale-level values towards which estimates should move: an indirect effect of −.110 and a true interaction of essentially zero (.003).
Statistical Analysis
One dataset of N = 500 was analysed in full. Reliability was estimated with Cronbach's alpha. Pearson correlations carried Fisher z confidence intervals, with Spearman coefficients as a check against skew. Hierarchical regression on standardised scores entered anxiety, then resilience, then their product. Variance inflation, residual normality

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(Shapiro–Wilk) and homoscedasticity (Breusch–Pagan) were examined, and HC3 robust standard errors were computed as a sensitivity check. The indirect effect was tested with 5,000 percentile bootstrap resamples (Preacher & Hayes, 2008). A second mediation model reversed the order of anxiety and resilience so that the two accounts could be compared directly.

Monte Carlo Experiment

The experiment follows the structure recommended by Morris et al. (2019). The aim was to evaluate the bootstrapped mediation test. Data were generated at N = 30, 50, 100, 200 and 500, under two conditions: item-based scale scores and error-free latent scores. The main estimand was the true latent indirect effect (−.150). Each of the 10 cells used 2,000 replications with 1,000 bootstrap resamples per replication. Performance measures were mean estimate, empirical standard error, 95% interval coverage, power and the false-positive rate of the interaction test. The Monte Carlo standard error is about .005 for a rate near .95 and at most .011 for power.

3.RESULTS

Descriptive Statistics and Correlations

Table 1 shows that means and standard deviations sat close to their calibration targets. Anxiety was positively skewed, as expected for a symptom scale in a general population, and all three scales reached alpha values of .85 or higher. Table 2 supports H1. Anxiety correlated negatively with life satisfaction and resilience, and resilience correlated positively with life satisfaction (all $p < .001$). Spearman coefficients were nearly identical, so skew did not distort the linear estimates.

Table 1 Descriptive Statistics and Reliability of the Simulated Scales (N = 500)

Variable	M	SD	Range	Skew	Kurtosis	α
Anxiety (GAD-7, sum)	5.52	5.66	0–21	.97	−.09	.87
Resilience (CD-RISC-10, item mean)	3.70	0.67	1.90–5.00	−.28	−.36	.89
Life satisfaction (SWLS, item mean)	5.27	1.15	1.20–7.00	−.53	.03	.85

Table 2 Correlations Among the Simulated Variables (N = 500)

Variable	1	2	3
1. Anxiety	—	−.20	−.30
2. Resilience	−.22 [−.30, −.13]	—	.43
3. Life satisfaction	−.29 [−.37, −.21]	.43 [.35, .49]	—

Note. Pearson r with 95% CI appears below the diagonal and Spearman ρ above it. All $p < .001$.

Hierarchical Regression

Anxiety alone explained 8.4% of the variance in life satisfaction, $F(1, 498) = 45.91$, $p < .001$. Adding resilience raised this to 22.3%, $F_{change}(1, 497) = 88.40$, $p < .001$ (Table 3). In raw units, each additional GAD-7 point was associated with a life satisfaction score lower by 0.042 points, 95% CI [−0.058, −0.026], while each additional resilience point was associated with a score higher by 0.65, 95% CI [0.52, 0.79]. Multicollinearity was negligible (VIF = 1.05). Heteroscedasticity was borderline, $\chi^2(2) = 5.88$, $p = .053$, and residuals departed from normality, $W = .98$, $p < .001$, reflecting rounded and bounded scores, though the departure was mild (skew = −.53). HC3 errors altered no conclusion: the 95% CI for the anxiety coefficient became [−.29, −.12].

Table 3 Hierarchical Regression Predicting Life Satisfaction (N = 500)

Predictor	β	SE	t	p	95% CI
Step 1: $R^2 = .084$					
Anxiety	−.29	.04	−6.78	<.001	[−.37, −.21]
Step 2: $\Delta R^2 = .138$, $R^2 = .223$					

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Predictor	β	SE	t	p	95% CI
Anxiety	−.21	.04	−5.15	<.001	[−.29, −.13]
Resilience	.38	.04	9.40	<.001	[.30, .46]
Step 3: ΔR^2 = .002, R^2 = .225					
Anxiety	−.22	.04	−5.27	<.001	[−.30, −.14]
Resilience	.38	.04	9.39	<.001	[.30, .46]
Anxiety × Resilience	−.04	.04	−1.11	.269	[−.12, .03]

Note. All variables were standardised before analysis.

Moderation

The interaction term was small and non-significant, β = −.04, p = .269 (HC3 p = .345), adding 0.2% of explained variance, which supports H3. Simple slopes of anxiety were −.17, 95% CI [−.27, −.07], at low resilience and −.26, 95% CI [−.39, −.14], at high resilience. These overlapping intervals give no indication of a buffering pattern, correctly reflecting a model without one.

Mediation and the Reversed Model

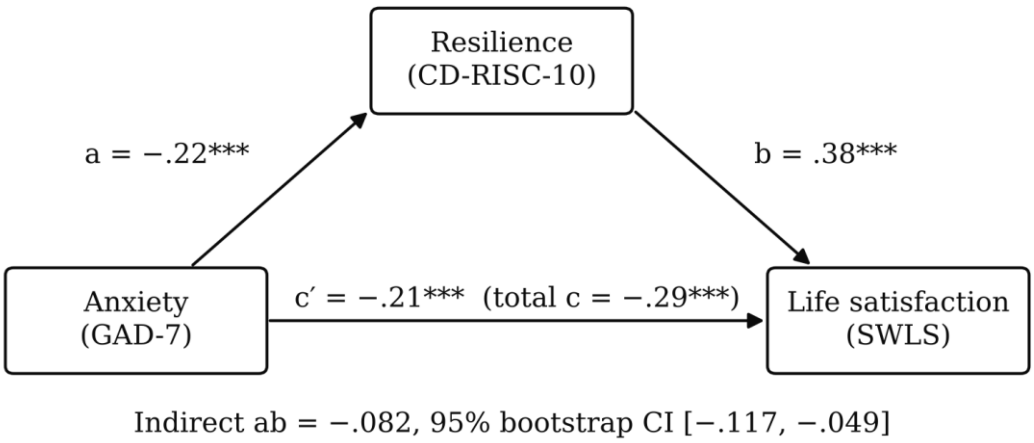
In Model A (Table 4; Figure 4), the indirect effect through resilience was significant, ab = −.082, 95% CI [−.117, −.049], and accounted for 28% of the total effect, supporting H2. A significant direct effect remained. Model B reversed the order and also produced a significant indirect effect, ab = .045, 95% CI [.022, .072]. The two models explain exactly the same variance in life satisfaction, because they contain the same predictors. The data therefore cannot choose between them, even though Model A is, by construction, the model that generated the data.

Table 4 Standardised Mediation Estimates for Two Orderings, With 95% CIs (N = 500)

Effect	Model A: Anxiety → Resilience → Life satisfaction	Model B: Resilience → Anxiety → Life satisfaction
a path	−.22 [−.30, −.13]	−.22 [−.30, −.13]
b path	.38 [.30, .46]	−.21 [−.29, −.13]
Direct effect (c′)	−.21 [−.29, −.13]	.38 [.30, .46]
Total effect (c)	−.29 [−.37, −.21]	.43 [.35, .51]
Indirect effect (ab)	−.082 [−.117, −.049]	.045 [.022, .072]
Proportion of total effect	.28	.11
Variance in life satisfaction (R^2)	.223	.223

Note. The indirect-effect CIs are percentile bootstrap intervals from 5,000 resamples.

Figure 4 Standardised Path Estimates for Model A (Simulated Data, N = 500)



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Note. Three asterisks indicate p < .001.

Monte Carlo Performance

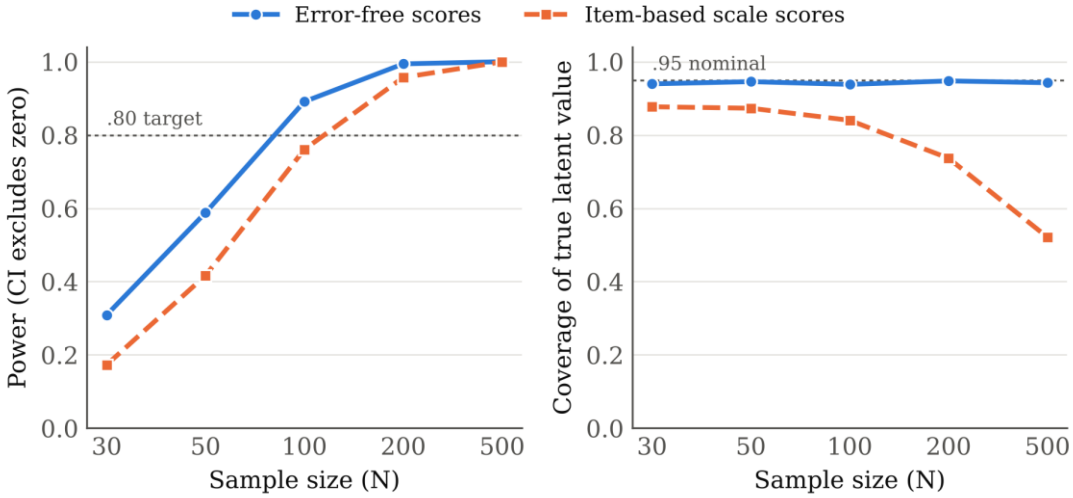
The effect of measurement error is shown in Table 5 and Figure 5, supporting H4. All mean estimates were within .004 of the true value of −.150 with error free scores and the coverage ranged from .938 to .948, close to the nominal .95 at all sample sizes. In the case of item-based scale scores, the estimates averaged about −.110, a value that is about 27% too low, with no reduction in this underestimation as N increased. As the width of the intervals becomes smaller (with larger samples), the probability of them missing the truth increases, so coverage of the latent value deteriorates as the sample size increases, from .877 at N = 30 to .521 at N = 500. This can be seen in the estimate for the main dataset; there is a larger interval which includes the value of the scale-level (−.110), but not the latent interval (−.150). Coverage of the scale-level value itself ran from .919 at N = 30 to .953 at N = 500 Power reached .80 between N = 100 and 200 for scale scores (.760 and .957) and by N = 100 for error-free scores (.891). These figures agree with Fritz and MacKinnon (2007), whose percentile bootstrap table requires N = 126 for paths of .26 and .39, close to the scale-level paths found here (−.26 and .42). False-positive rates for the interaction ranged from .039 to .056, near the 5% level, so neither skew nor discrete responses manufactured a spurious buffering effect.

Table 5 Monte Carlo Performance of the Mediation Analysis (2,000 Replications per Cell)

N	Mean ab	Empirical SE	Coverage	Power	Interaction false positives
Item-based scale scores					
30	−.107	.091	.877	.173	.053
50	−.112	.067	.873	.416	.048
100	−.110	.046	.840	.760	.056
200	−.109	.033	.737	.957	.046
500	−.110	.020	.521	1.000	.054
Error-free scores					
30	−.147	.096	.940	.309	.051
50	−.146	.072	.946	.588	.052
100	−.148	.050	.938	.891	.051
200	−.148	.034	.948	.994	.051
500	−.150	.022	.943	1.000	.039

Note. Coverage refers to the true latent value of −.150. Power is the share of intervals excluding zero. The final column is the rejection rate of the interaction test at α = .05.

Figure 5 Power and Coverage of the Indirect Effect by Sample Size and Measurement Condition



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Note. Dashed reference lines mark the .80 power target and .95 nominal coverage.

4.DISCUSSION

The results of the study confirmed the expected trend of oppositionality between anxiety and life satisfaction in this literature, high and positive relationship between resilience and life satisfaction, and substantial level of variance accounted for by resilience. This agreement should not be considered as the confirmation of previous work. These data were artificially invented using published correlation matrix and both H1 and H2 would be expected to hold true if the size of the sample were sufficiently large. What's more fascinating has to do with what the methods can and cannot obtain, knowing the truth.

The first of these is that the so-called 'reversed model'. Aresearcher who analyzed this data may conclude that resilience is a mediator between anxiety and satisfaction, or that anxiety is a mediator between resilience and satisfaction as per Samani et al. (2007). Both claims would explain a given amount of variance and have a large and significant bootstrap interval, but one is a process that produced the data, and the other is not. A large indirect effect in a cross sectional data analysis therefore would only suggest that the effect is consistent with a proposed mechanism. Great reminder of the importance of Maxwell and Cole (2007) and Longitudinal designs like Wang et al. (2022) having more weight on Questions involving ordering.

The second one is a measurement one. All three scales simulated groups met the alpha that one would assume as a rule of thumb, but the indirect effect was still under-estimated by about a quarter. The direct effect decreased less so that the proportion mediated decreased from 40.6% in the model to 36.4% at the scale level. Bigger samples didn't help. They demonstrated their ability to only reduce the width of intervals around a biased value, in opposition to the "more data equals better estimation" approach. If it is not just the direction of the effect that is relevant, but also the magnitude, latent-variable models or reliability corrections would be appropriate. It is, however, important to note that the amount of attenuation here depends on loadings applied in this model.

Third is that it is useful to have a null moderation result. Moderation, using skewed and bounded scales has been suggested in the resilience literature as a possible interaction may seem like that in reality. In such cases, they would and the false-positive rate would be around 5%. This simulation was not performed to test power for interactions; if there were a true buffering effect a separate simulation would be needed.

With respect to study planning, assuming scale scores would provide a sample of ~200 respondents to result in a level of power to detect an indirect effect of this order of size, and a sample of 100 would be just a bit less. The recommendation is based on the assumption that the effect of real effects is similar to that assumed here: a smaller effect would mean a larger number of samples. (Fritz & MacKinnon, 2007).

5.LIMITATIONS

The major drawback is inherent in the design – simulated data reflect the behaviour of analytic approaches and cannot be used to answer any new questions about the functioning of anxiety, resilience and life satisfaction in real humans. All parameters were based on one cross sectional study in one national context at one time and observed correlations were used as latent values - true latent values may be even higher. The loadings of the items within each scale were set equal and no missing data, no response styles, no unmeasured confounders or no demographic differences were modelled. As well, the results for the resilience scale rely on the 1-5 coding assumption. A real survey with these instruments is the next step that would be needed.

6.CONCLUSION

Following the modelling of the above relationships, based on published data, this study illustrated two boundaries there are when reading the outcomes from such models. Mediation analysis revealed that there were significant indirect effects in both directions of the variables and therefore could not determine which was the correct relationship. Even reliable scales underestimated the actual indirect effect by approximately 27% and larger samples were more likely to underestimate. When such effects are anticipated, future empirical studies should use at least 200 participants and try to assess measurement error, as well as make the measurement a longitudinal one.

Three further points follow from these results. First, the significant indirect effects found in both directions show that a bootstrapped confidence interval, however accurate it is as a test (MacKinnon et al., 2004), cannot settle the order of causes; designs that measure each variable at several time points are needed for that purpose (Cole & Maxwell, 2003). Second, the shortfall in the indirect effect is an example of attenuation, the weakening of associations by measurement error that Spearman (1904) first described, and the same error can also make statistical control of other variables unreliable (Westfall & Yarkoni, 2016). Researchers should therefore report the reliability of every scale and, where possible, use latent-variable models. Third, the choice of resilience measure matters, because resilience scales differ considerably in their psychometric quality (Windle et al., 2011).

Finally, the strong positive link between resilience and life satisfaction is consistent with the broaden-and-build theory, in which positive emotions help people build lasting personal resources (Fredrickson, 2001). This theory

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offers a basis for testing resilience-building programmes in future studies with real participants, which would show whether the relationships modelled here hold in practice.

Data Availability

The dataset and Python code accompany this paper.

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