

Nonlinear probability weighting in depression and anxiety: insights from healthy young adults

Supplementary material

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Table S1. The item structures of the seven factors underlying BDI and STAI-Y1 extracted from the principle component analysis (PCA)

| Domain | Anxiety | Anxiety/Depression | Depression | Depression | Depression | Depression | Anxiety |
|---------|-------------------|---------------------|-----------------|---------------|--------------|----------------|------------------|
| Factors | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 |
| Items | STAI-Y1 1 Calm | STAI-Y1 7 Worrying | STAI-Y1 6 Upset | BDI 3 Past | STAI-Y1 4 | BDI 4 Loss of | STAI-Y1 3 |
| | STAI-Y1 2 Secure | STAI-Y1 9 | BDI 1 Sadness | failure | Strained | pleasure | Tense |
| | STAI-Y1 5 At ease | Frightened | BDI 7 Self- | BDI 5 Guilty | BDI 2 | BDI 9 Suicidal | BDI 11 Agitation |
| | STAI-Y1 8 | STAI-Y1 12 Nervous | dislike | BDI 14 | Pessimism | thoughts | BDI 13 |
| | Satisfied | STAI-Y1 13 Jittery | BDI 21 Loss of | Worthlessness | BDI 16 Sleep | | Indecisiveness |
| | STAI-Y1 10 | STAI-Y1 14 | interest in sex | | | | |
| | Comfortable | Indecisive | | | | | |
| | STAI-Y1 11 Self- | BDI 6 Punishment | | | | | |
| | confident | feelings | | | | | |
| | STAI-Y1 15 | BDI 10 Crying | | | | | |
| | Relaxed | BDI 15 Loss of | | | | | |
| | STAI-Y1 16 | energy | | | | | |
| | Content | BDI 17 Irritability | | | | | |
| | STAI-Y1 17 | | | | | | |
| | Worried | | | | | | |
| | STAI-Y1 19 Steady | | | | | | |
| | STAI-Y1 20 | | | | | | |
| | Pleasant | | | | | | |

Items of depression and anxiety are shown in blue and red, respectively.

Table S2. Correlation between PCA extracted factors and risk parameters using the Prelec-1 parameter function

| Domain | Anxiety | Anxiety/Depression | Depression | Depression | Depression | Depression | Anxiety |
|--|---------------------|--------------------|-------------------------------------|----------------------|------------------------------------|----------------------|----------------------|
| Factors | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 |
| Sum of raw scores of items loading on the factor | | | | | | | |
| γ | r=0.094, p=0.505 | r=0.092, p=0.511 | r=0.275, p=0.046* | r=0.106, p=0.448 | r=0.274, p=0.047* | r=0.257, p=0.063 | r=0.114, p=0.416 |
| λ | r=0.205, p=0.141 | r=-0.170, p=0.225 | r=-0.112, p=0.424 | r=0.016, p=0.911 | r=0.137, p=0.328 | r=-0.222, p=0.110 | r=-0.164, p=0.241 |
| γ (partialling out mother education) | r=0.133, p=0.348 | r=0.108, p=0.445 | r=0.250, p=0.074 | r=0.150, p=0.288 | r=0.260, p=0.063 | r=0.252, p=0.072 | r=0.079, p=0.580 |
| λ (partialling out mother education) | r=0.194, p=0.169 | r=-0.179, p=0.204 | r=-0.107, p=0.451 | r=-0.005, p=0.974 | r=0.149, p=0.291 | r=-0.215, p=0.126 | r=-0.154, p=0.276 |
| Anderson-Rubin score | | | | | | | |
| γ | r=0.086, p=0.542 | r=-0.210, p=0.132 | r=0.278, p=0.044 * | r=-0.047, p=0.736 | r=0.249, p=0.072 | r=0.249, p=0.072 | r=0.110, p=0.433 |
| λ | r=0.251, p=0.070 | r=0.013, p=0.929 | r=-0.144, p=0.302 | r=-0.071, p=0.615 | r=0.194, p=0.164 | r=0.044, p=0.756 | r=-0.109, p=0.437 |
| γ (partialling out mother education) | r=0.114, p=0.420 | r=-0.232, p=0.098 | r=0.247, p=0.078 | r=-0.016, p=0.912 | r=0.215, p=0.126 | r=0.228, p=0.104 | r=0.119, p=0.399 |
| λ (partialling out mother education) | r=0.242, p=0.084 | r=0.018, p=0.902 | r=-0.129, p=0.361 | r=-0.088, p=0.533 | r=0.217, p=0.122 | r=0.060, p=0.673 | r=-0.114, p=0.422 |

* p<0.05. Coefficients are based on Spearman's rank order correlation due to non-normal distribution of the data.

Table S3. Number of correlations of individual items of BDI and STAI-Y1 with items from the other scale, respectively

| BDI items | Number of correlated items of STAI-Y1 | BDI items | Number of correlated items of STAI-Y1 | STAI-Y1 items | Number of correlated items of BDI | STAI-Y1 items | Number of correlated items of BDI |
|-------------------------------|--|---------------------|--|------------------|---|-----------------------|---|
| 16 Sleep | 1 | 7 Self-dislike | 6 | 2 Secure | 0 | 12 Nervous | 7 |
| 20 Fatigue | 1 | 3 Past failure | 6 | 18 Confused | 0 | 11 Self- confident | 9 |
| 18 Appetite | 3 | 2 Pessimism | 7 | 1 Calm | 1 | 13 Jittery | 9 |
| 21 Loss of interest in sex | 3 | 8 Self-criticalness | 8 | 3 Tense | 1 | 16 Content | 9 |
| 1 Sadness | 4 | 15 Loss of energy | 8 | 4 Strained | 2 | 10 Comfortable | 9 |
| 9 Suicidal thoughts | 4 | 11 Agitation | 8 | 5 At ease | 2 | 17 Worried | 11 |
| 12 Loss of interest | 4 | 4 Loss of pleasure | 9 | 8 Satisfied | 4 | 9 Frightened | 11 |
| 14 Worthlessness | 4 | 19 Concentration | 10 | 20 Pleasant | 4 | 6 Upset | 12 |
| 13 Indecisiveness | 5 | 17 Irritability | 12 | 15 Relaxed | 5 | 14 Indecisiveness | 12 |
| 10 Crying | 6 | 5 Guilty | 15 | 19 Steady | 6 | 7 Worrying | 16 |
| 6 Punishment feelings | 6 | | | | | | |

Selected items of depression and anxiety are shown in blue and red, respectively.

Table S4. Correlation between Depressed-selected/Anxiety-selected and risk parameters

| Factors | Depressed-selected | Anxiety-selected |
|--|--------------------------|-------------------|
| Prelec-1 parameter function | | |
| γ | r=0.329, p=0.016* | r=0.039, p=0.780 |
| λ | r=-0.074, p=0.597 | r=0.105, p=0.456 |
| γ (partialling out mother education) | r=0.331, p=0.017* | r=0.058, p=0.682 |
| λ (partialling out mother education) | r=-0.074, p=0.603 | r=0.098, p=0.488 |
| Prelec-2 parameter function | | |
| γ | r=0.290, p=0.035* | r=-0.061, p=0.666 |
| a | r=-0.239, p=0.085 | r=-0.119, p=0.395 |
| λ | r=-0.229, p=0.099 | r=0.022, p=0.875 |
| γ (partialling out mother education) | r=0.297, p=0.033* | r=-0.061, p=0.668 |
| a (partialling out mother education) | r=-0.241, p=0.085 | r=-0.131, p=0.353 |
| λ (partialling out mother education) | r=-0.228, p=0.104 | r=0.018, p=0.895 |
| One-parameter function with a log2 base | | |
| γ | r=0.282, p=0.041* | r=0.121, p=0.389 |
| λ | r=-0.065, p=0.645 | r=0.070, p=0.620 |
| γ (partialling out mother education) | r=0.293, p=0.035* | r=0.137, p=0.334 |
| λ (partialling out mother education) | r=-0.066, p=0.643 | r=0.066, p=0.641 |

* p<0.05. Coefficients are based on Spearman's rank order correlation due to non-normal distribution of the data.

Table S5. Additional computational models fitted

| Model No. | Model description | Equation | Free parameters | AIC |
|-----------|---|--|-----------------------------|--------------|
| 7 | Magnitude and Probability with probability weighting (Prelec-2) | $V(X) = r e^{-a(-\log p)^\gamma}$ | a, γ, β | 102.33 |
| 8 | Magnitude with utility function and Probability with probability weighting (Prelec-2) | $V(X) = r^\lambda e^{-a(-\log p)^\gamma}$ | $\lambda, a, \gamma, \beta$ | 90.75 |
| 9 | Magnitude and Probability with probability weighting (novel 1-parameter) | $V(X) = r 2^{-((- \log_2(p))^\gamma)}$ | γ, β | 148.31 |
| 10 | Magnitude with utility function and Probability with probability weighting (novel 1-parameter) | $V(X) = r^\lambda 2^{-((- \log_2(p))^\gamma)}$ | λ, γ, β | 95.96 |

Table S6. Results of the multiple linear regression using BDI with risk parameters using the Prelec-2 parameter function

| | Independent variables | Dependent variable: γ | | | Dependent variable: a | | | Dependent variable: λ | | |
|---------|-----------------------|------------------------------|-------------------|---------------|---------------------------|-------------------|-------|-------------------------------|-------------------|-------|
| | | Unstandardized B (95% CI) | Standardized beta | p | Unstandardized B (95% CI) | Standardized beta | p | Unstandardized B (95% CI) | Standardized beta | p |
| Model 1 | BDI | 0.033 (0.007, 0.059) | 0.429 | 0.015* | -0.003 (-0.098, 0.093) | -0.010 | 0.956 | -0.007 (-0.045, 0.030) | -0.071 | 0.692 |
| | STAI-Y1 | -0.012 (-0.034, 0.011) | -0.177 | 0.302 | -0.033 (-0.116, 0.050) | -0.144 | 0.425 | -0.007 (-0.039, 0.025) | -0.077 | 0.671 |
| Model 2 | BDI | 0.032 (0.006, 0.058) | 0.419 | 0.019* | 0.000 (-0.097, 0.098) | 0.001 | 0.996 | -0.008 (-0.046, 0.030) | -0.077 | 0.675 |
| | STAI-Y1 | -0.011 (-0.034, 0.012) | -0.166 | 0.340 | -0.036 (-0.120, 0.048) | -0.156 | 0.396 | -0.006 (-0.039, 0.026) | -0.070 | 0.111 |
| | Mother education | 0.051 (-0.168, 0.270) | 0.063 | 0.642 | -0.196 (-1.003, 0.610) | -0.070 | 0.627 | 0.040 (-0.274, 0.354) | 0.036 | 0.800 |

* p<0.05

Table S7. Results of the multiple linear regression using BDI-pure with risk parameters using the Prelec-2 parameter function

| | Independent variables | Dependent variable: γ | | | Dependent variable: a | | | Dependent variable: λ | | |
|---------|-----------------------|------------------------------|-------------------|----------------|---------------------------|-------------------|-------|-------------------------------|-------------------|-------|
| | | Unstandardized B (95% CI) | Standardized beta | p | Unstandardized B (95% CI) | Standardized beta | p | Unstandardized B (95% CI) | Standardized beta | p |
| Model 1 | BDI-pure | 0.037 (0.010, 0.065) | 0.447 | 0.009** | -0.003 (-0.106, 0.099) | -0.011 | 0.949 | -0.008 (-0.048, 0.032) | -0.071 | 0.688 |
| | STAI-Y1 | -0.012 (-0.034, 0.010) | -0.179 | 0.283 | -0.033 (-0.114, 0.048) | -0.143 | 0.417 | -0.007 (-0.038, 0.024) | -0.078 | 0.657 |
| Model 2 | BDI-pure | 0.036 (0.008, 0.065) | 0.438 | 0.012* | 0.000 (-0.104, 0.104) | 0.000 | 1.000 | -0.009 (-0.049, 0.032) | -0.077 | 0.669 |
| | STAI-Y1 | -0.011 (-0.033, 0.011) | -0.169 | 0.319 | -0.036 (-0.118, 0.047) | -0.155 | 0.388 | -0.006 (-0.039, 0.026) | -0.072 | 0.689 |
| | Mother education | 0.047 (-0.170, 0.264) | 0.058 | 0.665 | -0.196 (-1.003, 0.611) | -0.070 | 0.628 | 0.040 (-0.274, 0.355) | 0.037 | 0.798 |

* p<0.05, ** p<0.01

Table S8. Correlation between PCA extracted factors and risk parameters using the Prelec-2 parameter function

| Domain | Anxiety | Anxiety/Depression | Depression | Depression | Depression | Depression | Anxiety |
|--|---------------------------|---|---|---------------------------|---------------------------|---------------------------|---------------------------|
| Factors | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 |
| Sum of raw scores of items loading on the factor | | | | | | | |
| γ | $r=-0.015$, $p=0.915$ | $r=0.137$, $p=0.329$ | $r=0.378$, $p=0.005^{**}$ | $r=0.154$, $p=0.272$ | $r=0.220$, $p=0.114$ | $r=0.170$, $p=0.225$ | $r=-0.080$, $p=0.570$ |
| a | $r=-0.170$, $p=0.223$ | $r=-0.029$, $p=0.834$ | $r=-0.082$, $p=0.559$ | $r=-0.097$, $p=0.488$ | $r=-0.244$, $p=0.078$ | $r=-0.269$, $p=0.051$ | $r=-0.218$, $p=0.117$ |
| λ | $r=0.029$, $p=0.838$ | $r=0.003$, $p=0.982$ | $r=-0.165$, $p=0.237$ | $r=-0.037$, $p=0.792$ | $r=-0.129$, $p=0.356$ | $r=-0.231$, $p=0.096$ | $r=-0.114$, $p=0.418$ |
| γ (partialling out mother education) | $r=-0.008$, $p=0.953$ | $r=0.145$, $p=0.305$ | $r=0.381$, $p=0.005^{**}$ | $r=0.169$, $p=0.232$ | $r=0.219$, $p=0.119$ | $r=0.167$, $p=0.237$ | $r=-0.090$, $p=0.525$ |
| a (partialling out mother education) | $r=-0.200$, $p=0.154$ | $r=-0.035$, $p=0.807$ | $r=-0.059$, $p=0.677$ | $r=-0.130$, $p=0.359$ | $r=-0.237$, $p=0.091$ | $r=-0.263$, $p=0.060$ | $r=-0.190$, $p=0.178$ |
| λ (partialling out mother education) | $r=0.019$, $p=0.896$ | $r=0.002$, $p=0.988$ | $r=-0.155$, $p=0.272$ | $r=-0.052$, $p=0.714$ | $r=-0.121$, $p=0.391$ | $r=-0.228$, $p=0.105$ | $r=-0.100$, $p=0.481$ |
| Anderson-Rubin score | | | | | | | |
| γ | $r=-0.032$, $p=0.820$ | $r=-0.075$, $p=0.592$ | $r=0.305$, $p=0.026^*$ | $r=0.050$, $p=0.721$ | $r=0.207$, $p=0.137$ | $r=0.173$, $p=0.215$ | $r=-0.016$, $p=0.910$ |
| a | $r=-0.122$, $p=0.384$ | $r=0.290$, $p=0.035^*$ | $r=-0.027$, $p=0.847$ | $r=0.010$, $p=0.945$ | $r=-0.093$, $p=0.510$ | $r=-0.264$, $p=0.056$ | $r=-0.223$, $p=0.108$ |
| λ | $r=0.082$, $p=0.557$ | $r=0.300$, $p=0.029^*$ | $r=-0.209$, $p=0.134$ | $r=-0.057$, $p=0.685$ | $r=0.024$, $p=0.863$ | $r=-0.143$, $p=0.807$ | $r=-0.166$, $p=0.234$ |
| γ (partialling out mother education) | $r=-0.029$, $p=0.840$ | $r=-0.077$, $p=0.587$ | $r=0.303$, $p=0.029^*$ | $r=0.064$, $p=0.653$ | $r=0.204$, $p=0.147$ | $r=0.162$, $p=0.251$ | $r=-0.018$, $p=0.900$ |

| | | | | | | | |
|--|----------------------|--------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| a (partialling out mother education) | r=-0.143, p=0.312 | r=0.306, p=0.027* | r=0.005, p=0.997 | r=-0.017, p=0.905 | r=-0.063, p=0.659 | r=-0.249, p=0.075 | r=-0.223, p=0.113 |
| λ (partialling out mother education) | r=0.077, p=0.590 | r=0.308, p=0.026* | r=-0.200, p=0.155 | r=-0.073, p=0.607 | r=0.041, p=0.771 | r=-0.135, p=0.340 | r=-0.168, p=0.234 |

* p<0.05, ** p<0.01. Coefficients are based on Spearman's rank order correlation due to non-normal distribution of the data.

Table S9. Results of the multiple linear regression using BDI with risk parameters using the one-parameter probability weighting function having a log2 base

| | Independent variables | Dependent variable: γ | | | Dependent variable: λ | | |
|---------|-----------------------|------------------------------|-------------------|-------|-------------------------------|-------------------|-------|
| | | Unstandardized B (95% CI) | Standardized beta | p | Unstandardized B (95% CI) | Standardized beta | p |
| Model 1 | BDI | 0.009 (-0.008, 0.027) | 0.192 | 0.276 | -0.006 (-0.018, 0.006) | -0.184 | 0.305 |
| | STAI-Y1 | 0.004 (-0.011, 0.019) | 0.101 | 0.564 | 0.007 (-0.003, 0.017) | 0.237 | 0.190 |
| Model 2 | BDI | 0.008 (-0.009, 0.025) | 0.159 | 0.364 | -0.006 (-0.018,0.006) | -0.185 | 0.311 |
| | STAI-Y1 | 0.006 (-0.009, 0.021) | 0.138 | 0.431 | 0.007 (-0.004,0.017) | 0.237 | 0.196 |
| | Mother education | 0.111 (-0.031, 0.252) | 0.214 | 0.122 | 0.002 (-0.099,0.103) | 0.005 | 0.971 |

Table S10. Results of the multiple linear regression using BDI-pure with risk parameters using the one-parameter probability weighting function having a log2 base

| | Independent variables | Dependent variable: γ | | | Dependent variable: λ | | |
|---------|-----------------------|------------------------------|-------------------|-------|-------------------------------|-------------------|-------|
| | | Unstandardized B (95% CI) | Standardized beta | p | Unstandardized B (95% CI) | Standardized beta | p |
| Model 1 | BDI-pure | 0.010 (-0.009, 0.028) | 0.181 | 0.295 | -0.006 (-0.019, 0.007) | -0.156 | 0.377 |
| | STAI-Y1 | 0.005 (-0.010, 0.019) | 0.112 | 0.514 | 0.006 (-0.004, 0.016) | 0.215 | 0.224 |
| Model 2 | BDI-pure | 0.008 (-0.010, 0.026) | 0.147 | 0.392 | -0.006 (-0.019,0.007) | -0.156 | 0.384 |
| | STAI-Y1 | 0.006(-0.008, 0.021) | 0.149 | 0.387 | 0.006 (-0.004,0.017) | 0.216 | 0.231 |
| | Mother education | 0.111 (-0.031, 0.252) | 0.214 | 0.122 | 0.001 (-0.100,0.103) | 0.003 | 0.981 |

Table S11. Correlation between PCA extracted factors and risk parameters using the one-parameter probability weighting function having a log2 base

| Domain | Anxiety | Anxiety/Depression | Depression | Depression | Depression | Depression | Anxiety |
|--|---------------------|--------------------|------------------------------------|----------------------|------------------------------------|------------------------------------|----------------------|
| Factors | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 |
| Sum of raw scores of items loading on the factor | | | | | | | |
| γ | r=0.115, p=0.412 | r=0.159, p=0.256 | r=0.277, p=0.044* | r=0.089, p=0.525 | r=0.308, p=0.025* | r=0.282, p=0.041* | r=0.156, p=0.266 |
| λ | r=0.185, p=0.185 | r=-0.210, p=0.131 | r=-0.152, p=0.277 | r=-0.016, p=0.907 | r=0.140, p=0.317 | r=-0.220, p=0.113 | r=-0.171, p=0.220 |
| γ (partialling out mother education) | r=0.158, p=0.265 | r=0.173, p=0.221 | r=0.255, p=0.068 | r=0.137, p=0.334 | r=0.306, p=0.028* | r=0.281, p=0.044* | r=0.110, p=0.437 |
| λ (partialling out mother education) | r=0.182, p=0.198 | r=-0.221, p=0.116 | r=-0.151, p=0.285 | r=-0.026, p=0.855 | r=0.142, p=0.315 | r=-0.220, p=0.117 | r=-0.162, p=0.251 |
| Anderson-Rubin score | | | | | | | |
| γ | r=0.125, p=0.372 | r=-0.101, p=0.472 | r=0.306, p=0.026* | r=-0.108, p=0.440 | r=0.184, p=0.187 | r=0.249, p=0.073 | r=0.151, p=0.281 |
| λ | r=0.225, p=0.105 | r=-0.050, p=0.720 | r=-0.181, p=0.194 | r=-0.088, p=0.531 | r=0.245, p=0.077 | r=0.041, p=0.769 | r=-0.135, p=0.335 |
| γ (partialling out mother education) | r=0.156, p=0.271 | r=-0.117, p=0.408 | r=0.281, p=0.044* | r=-0.074, p=0.602 | r=0.150, p=0.288 | r=0.234, p=0.095 | r=0.147, p=0.300 |
| λ (partialling out mother education) | r=0.224, p=0.111 | r=-0.052, p=0.714 | r=-0.176, p=0.211 | r=-0.097, p=0.494 | r=0.262, p=0.061 | r=0.049, p=0.732 | r=-0.133, p=0.348 |

* p<0.05. Coefficients are based on Spearman's rank order correlation due to non-normal distribution of the data.

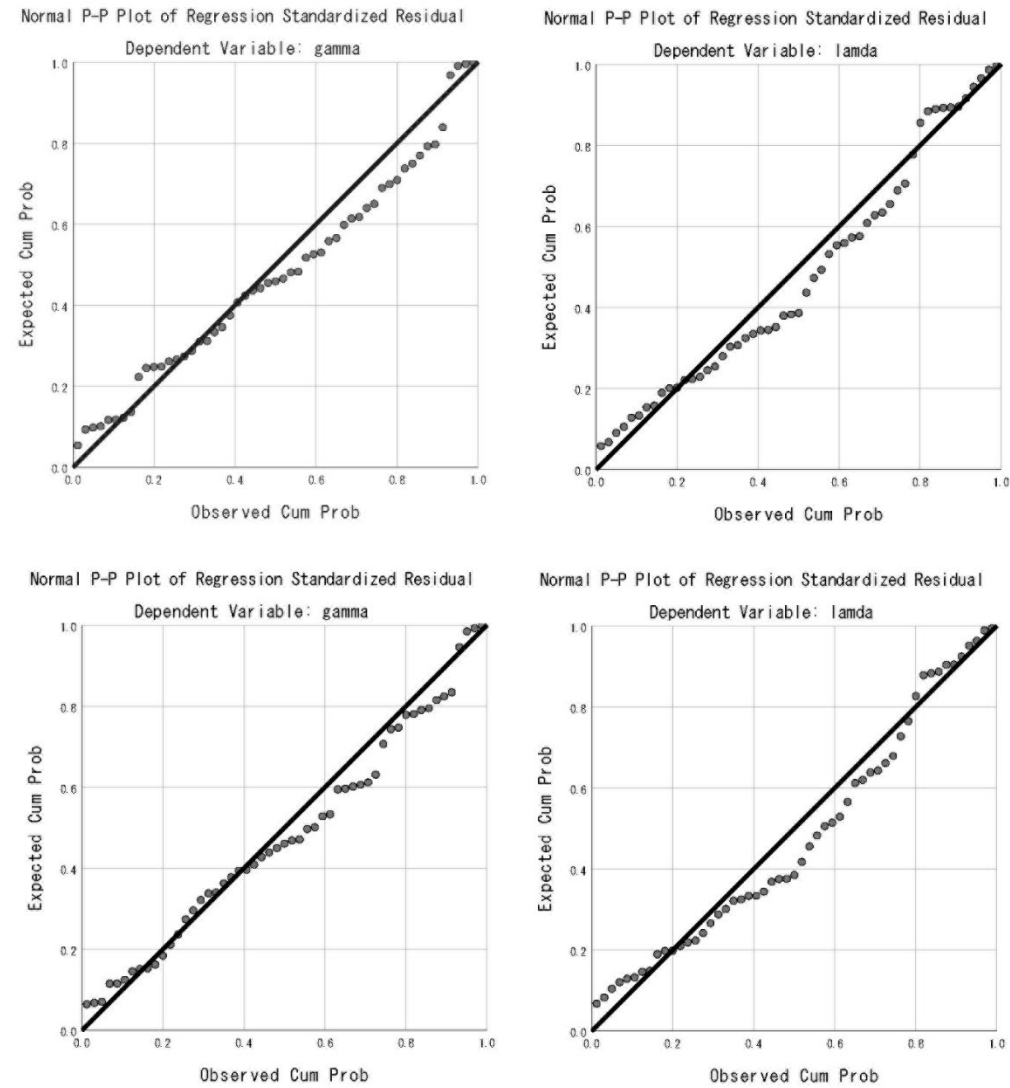


Figure S1. Normal P-P plot of regression standardized residual of multiple linear regressions shown in Table 2.

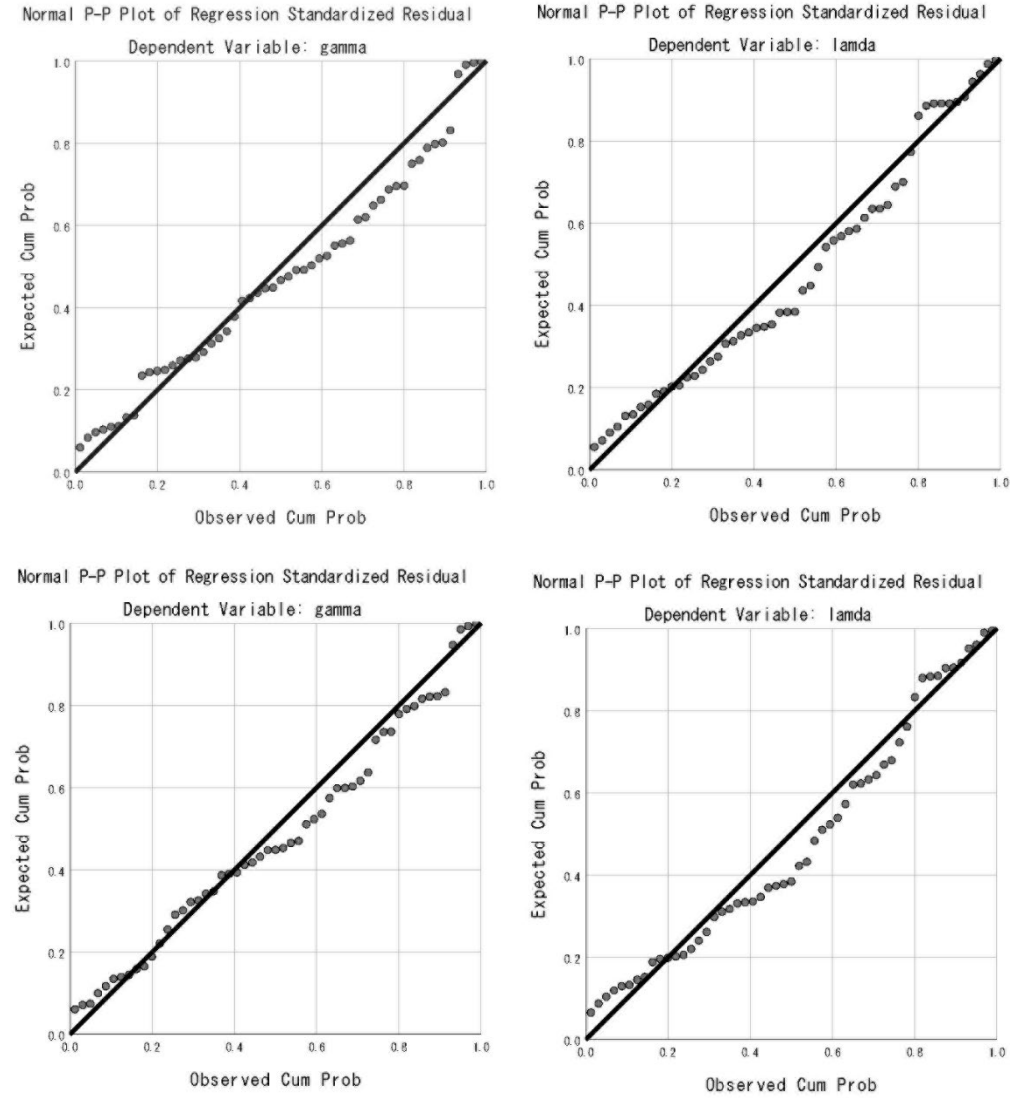


Figure S2. Normal P-P plot of regression standardized residual of multiple linear regressions shown in Table 3.

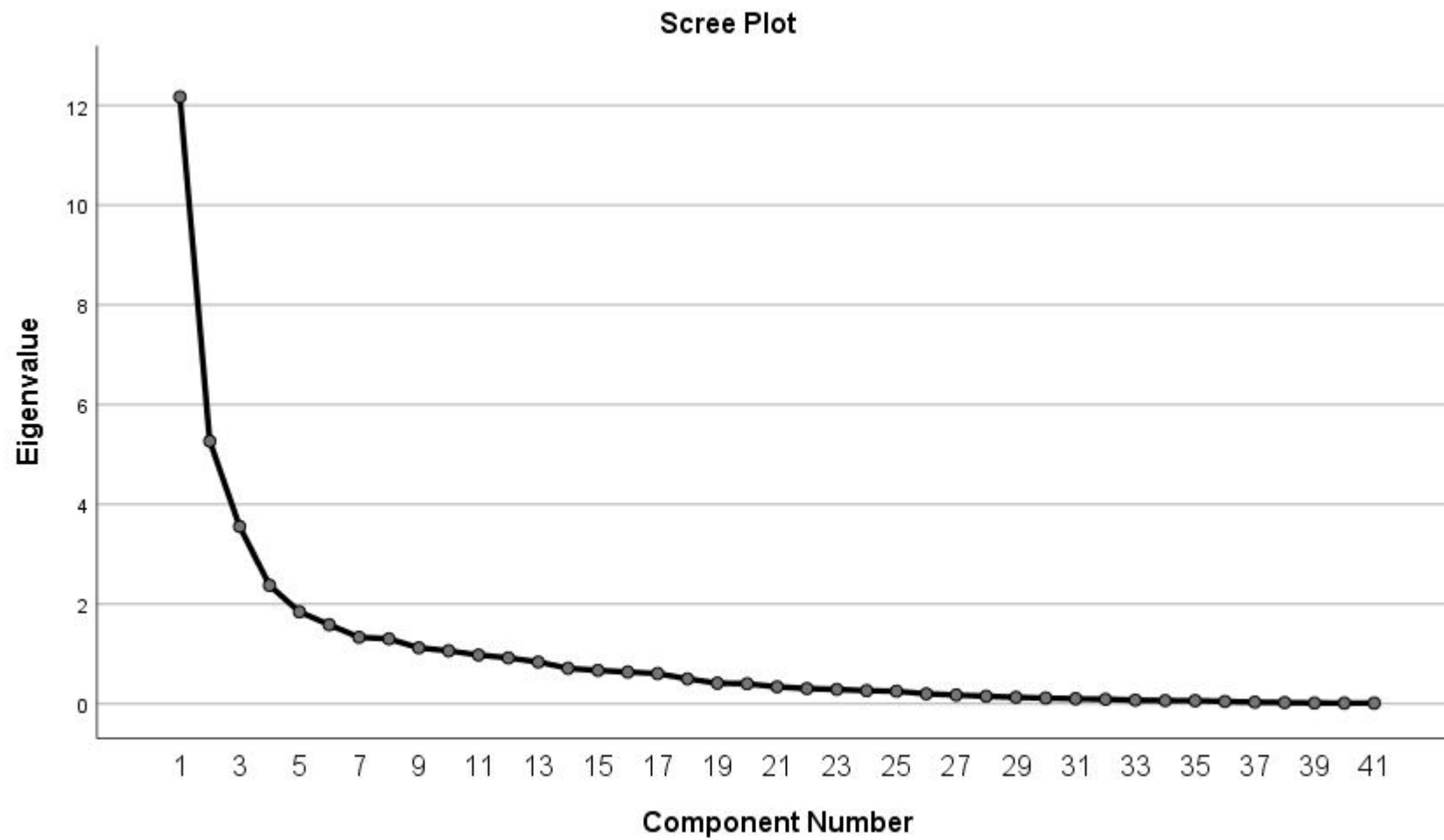


Figure S3. The scree plot of the principle component analysis (PCA). Seven factors were extracted, accounting for 64% of the total variance.

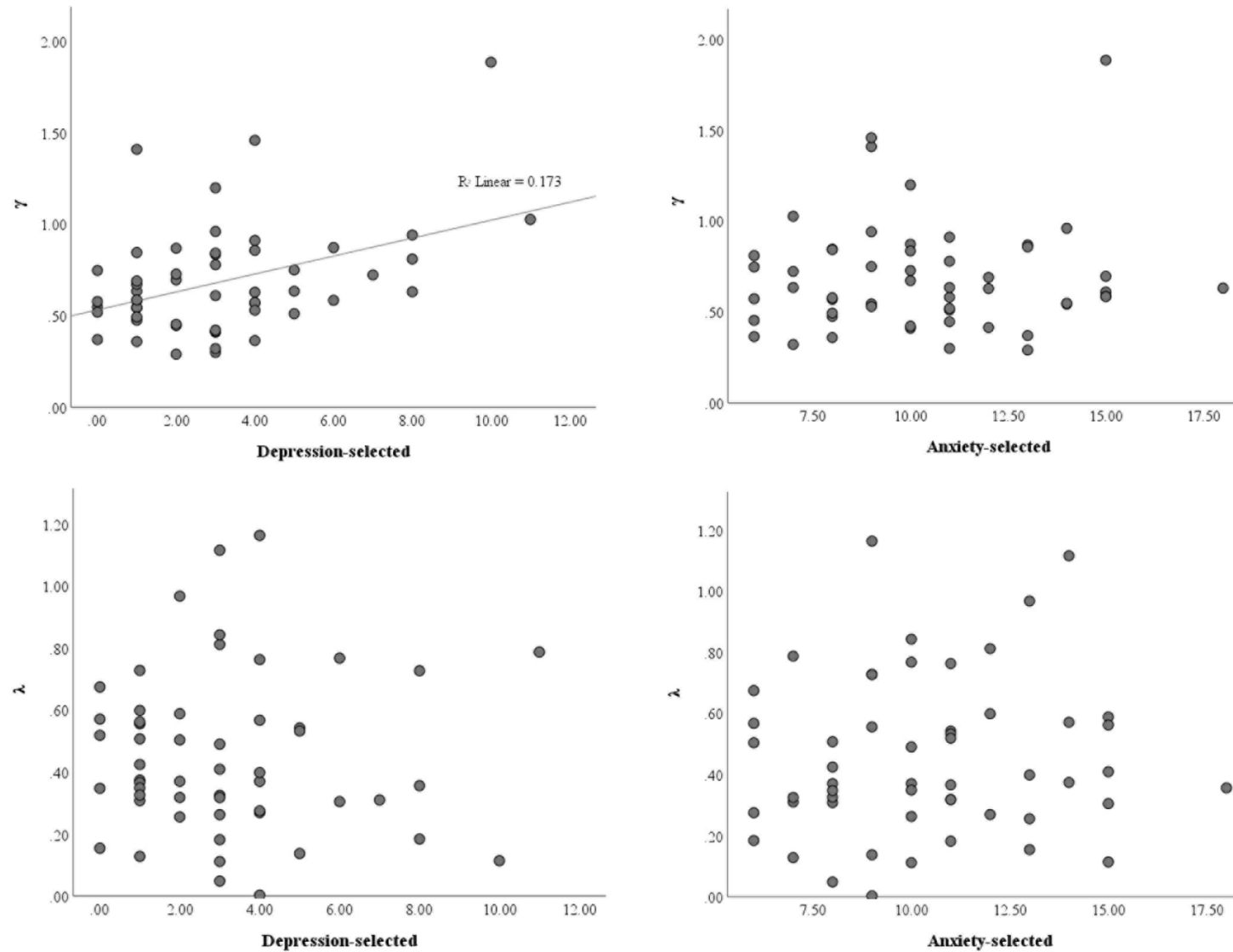


Figure S4. Scatterplot of the association between Depressed-selected/Anxiety-selected and risk parameters using the Prelec-1 parameter function