Supplementary Material

Persistence of anxiety/depression symptoms in early adolescence: A prospective study of daily life stress, rumination, and daytime sleepiness in a genetically informative cohort

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Supplementary Table S1. Linear regression analyses of potential fixed effect covariates at baseline (Time 1 (T1)) with family and zygosity included as random effects

			Outco	me Variable:	Anxiety/Dep	ression T1		
Fixed Effects		Full Sa	ample		Longitudinal Subsample Only			
(examined individualy*)	β	SE	<i>p</i> -value	R ² (marginal)	β	SE	<i>p</i> -value	R ² (marginal)
Sex (coded girls 0, boys 1)	.150	.105	.153	.006	.269	.120	.026	.018
Age at T1	163	.040	6.67e-05	.048	141	.049	.0043	.035
Puberty at T1	.006	.084	.947	1.1e-05	.062	.100	.537	.001
Neighbourhood SES at T1	057	.025	.021	.017	056	.030	.064	.015
Δσο T1 x SFS T1	- 002	017	885	000				

		Outcome Variable: Perceived Stress T1									
		Full Sa	mple		Longitudinal Subsample Only						
	β	SE	<i>p</i> -value	R ² (marginal)	β	SE	<i>p</i> -value	R ² (marginal)			
Sex	.163	.104	.118	.007	.171	.121	.160	.007			
Age at T1	092	.040	.023	.016	086	.049	.085	.013			
Puberty at T1	.058	.084	.485	.001	.156	.100	.117	.008			
Neighbourhood SES at T1	059	.024	.015	.019	047	.030	.124	.01			
Age T1 x SES T1	.005	.017	.750	.000							

	Outcome Variable: Rumination T1									
		Full Sa	mple		Longitudinal Subsample Only					
	β	SE	<i>p</i> -value	R ² (marginal)	β	SE	<i>p</i> -value	R ² (marginal)		
Sex	238	.104	.022	.014	200	.122	.101	.010		
Age at T1	112	.041	.0065	.023	100	.048	.040	.018		
Puberty at T1	009	.085	.916	2.8e-05	035	.101	.733	4.1e-04		
Neighbourhood SES at T1	013	.025	.585	9.4e-04	.000	.030	.989	8.8e-07		
Sex x Age T1	107	.075	.156	.005						

	Outcome Variable: Daytime Sleepiness T1									
		mple		l	Longitudinal Subsample Only					
	β	SE	<i>p</i> -value	R ² (marginal)	β	SE	<i>p</i> -value	R ² (marginal)		
Sex	039	.105	.707	3.9e-04	.020	.123	.163	1.0e-04		
Age at T1	032	.039	.410	.002	020	.047	.673	6.9e-04		
Puberty at T1	.068	.083	.414	.002	.068	.100	.498	.002		
Neighbourhood SES at T1	036	.023	.124	.007	001	.029	.826	1.9e-04		

*except for interactions (e.g. Age T1 x SES T1 includes Age and SES as well as the interaction – the R^2 represents the ΔR^2 when the interaction term is added). NOTE: Family and zygosity were included in the model as random effects. Nominally significant fixed effects are highlighted in **bold**. Supplementary Table S2. Linear Regression analyses of potential fixed effect covariates at follow-up (Time 2 (T2)) with family and zygosity included as random effects

	Outcome V	ariable: Ai	nxiety/Depre	ssion 12
Fixed Effects	β	SE	<i>p</i> -value	R^2
(examined individually*)	,			(marginal)
	270	110	020	010
Sex (coded girls 0, boys 1)	279	.119	.020	.019
Age at 12	.015	.045	./35	5.5e-04
Puberty at 12	.322	.086	.00023	.049
Neighbourhood SES at T2	004	.031	.896	8.3e-05
Baseline/Follow-up Interval	135	.233	.563	.002
Pre/Post Lockdown	.118	.149	.430	.003
Sex x Puberty T2	114	.169	.501	.000
	Outcome	Variables I	Domonized Str	
	Outcome	variable: r	ercerveu Su	p^2
	β	SE	<i>p</i> -value	R (marginal)
Sex (coded girls 0, boys 1)	037	.120	.760	3.4e-04
Age at T2	.053	.044	.233	.007
Puberty at T2	.207	.087	.018	.021
Neighbourhood SES at T2	.011	.030	.706	6.6e-04
Baseline/Follow-up Interval	.026	.229	.911	5.9e-05
Pre/Post Lockdown	.042	.147	.774	3.9e-04
	Outcor	ne Variable	: Rumination	n T2
	Outcor β	ne Variable SE	: Rumination <i>p</i> -value	n T2 <i>R</i> ² (marginal)
Sex (coded girls 0, boys 1)	Outcon β 421	ne Variable SE .120	: Rumination <i>p</i> -value .00058	n T2 <i>R</i> ² (marginal) .044
Sex (coded girls 0, boys 1) Age at T2	Outcor β 421 .070	ne Variable SE .120 .044	: Rumination <i>p</i> -value .00058 .113	n T2 <i>R²</i> (marginal) .044 .011
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2	Outcor β 421 .070 .358	ne Variable SE .120 .044 .086	: Rumination p-value .00058 .113 4.89e-05	n T2 <i>R</i> ² (marginal) .044 .011 .061
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2	Outcor β 421 .070 .358 .044	ne Variable SE .044 .086 .030	: Rumination <i>p</i> -value .00058 .113 4.89e-05 .145	n T2 <i>R</i> ² (marginal) .044 .011 .061 .010
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval	Outcor β 421 .070 .358 .044 .056	ne Variable SE .044 .086 .030 .228	Rumination <i>p</i> -value .00058 .113 4.89e-05 .145 .806	n T2 <i>R</i> ² (marginal) .044 .011 .061 .010 2.7e-04
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval Pre/Post Lockdown	Outcor β 421 .070 .358 .044 .056 080	ne Variable SE .120 .044 .086 .030 .228 .146	Rumination <i>p</i> -value .00058 .113 4.89e-05 .145 .806 .585	n T2 <i>R</i> ² (marginal) .044 .011 .061 .010 2.7e-04 .001
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval Pre/Post Lockdown Sex x Puberty T2	Outcor β 421 .070 .358 .044 .056 080 211	ne Variable SE .120 .044 .086 .030 .228 .146 .173	: Rumination <i>p</i> -value .00058 .113 4.89e-05 .145 .806 .585 .223	n T2 R ² (marginal) .044 .011 .010 2.7e-04 .001 .004
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval Pre/Post Lockdown Sex x Puberty T2	Outcor β421 .070 .358 .044 .056080211	ne Variable SE .120 .044 .086 .030 .228 .146 .173	: Rumination p-value .00058 .113 4.89e-05 .145 .806 .585 .223	n T2 R ² (marginal) .044 .011 .010 2.7e-04 .001 .004
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval Pre/Post Lockdown Sex x Puberty T2	Outcor β 421 .070 .358 .044 .056 080 211 Outcome	ne Variable SE .120 .044 .030 .228 .146 .173 Variable: Da	: Rumination p-value .00058 .113 4.89e-05 .145 .806 .585 .223 aytime Sleepi	n T2 R ² (marginal) .044 .011 .010 2.7e-04 .001 .004 mess T2
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval Pre/Post Lockdown Sex x Puberty T2	Outcor β 421 .070 .358 .044 .056 080 211 Outcome V β	ne Variable SE .120 .044 .030 .228 .146 .173 Variable: Da SE	: Rumination p-value .00058 .113 4.89e-05 .145 .806 .585 .223 sytime Sleepi p-value	n T2 R ² (marginal) .044 .011 .010 2.7e-04 .001 .004 iness T2 R ²
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval Pre/Post Lockdown Sex x Puberty T2	Outcor β 421 .070 .358 .044 .056 080 211 Outcome V β	ne Variable SE .120 .044 .030 .228 .146 .173 Variable: Da SE	: Rumination p-value .00058 .113 4.89e-05 .145 .806 .585 .223 aytime Sleepi p-value	n T2
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval Pre/Post Lockdown Sex x Puberty T2 Sex (coded girls 0, boys 1)	Outcor β 421 .070 .358 .044 .056 080 211 Outcome V β 220	ne Variable SE .044 .030 .228 .146 .173 Variable: Da SE .121	: Rumination p-value .00058 .113 4.89e-05 .145 .806 .585 .223 sytime Sleepi p-value .071	n T2
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval Pre/Post Lockdown Sex x Puberty T2 Sex (coded girls 0, boys 1) Age at T2	Outcor β 421 .070 .358 .044 .056 080 211 Outcome V β 220 .080	ne Variable SE .120 .044 .030 .228 .146 .173 Variable: Da SE .121 .045	: Rumination p-value .00058 .113 4.89e-05 .145 .806 .585 .223 sytime Sleepi p-value .071 .076	a T2 R^2 (marginal) .044 .011 .061 .010 2.7e-04 .001 .004 .004 .004 .005
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval Pre/Post Lockdown Sex x Puberty T2 Sex (coded girls 0, boys 1) Age at T2 Puberty at T2	Outcor β 421 .070 .358 .044 .056 080 211 Outcome V β 220 .080 .270	ne Variable SE .120 .044 .030 .228 .146 .173 Variable: De SE .121 .045 .087	: Rumination p-value .00058 .113 4.89e-05 .145 .806 .585 .223 sytime Sleepi p-value .071 .076 .002	a T2 R^2 (marginal) .044 .011 .061 .010 2.7e-04 .001 .004 iness T2 R^2 (marginal) .012 .015 .035
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval Pre/Post Lockdown Sex x Puberty T2 Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2	Outcor β 421 .070 .358 .044 .056 080 211 Outcome V β 220 .080 .270 .013	ne Variable SE .120 .044 .086 .030 .228 .146 .173 Variable: D: SE .121 .045 .087 .031	: Rumination p-value .00058 .113 4.89e-05 .145 .806 .585 .223 aytime Sleepi p-value .071 .076 .002 .675	a T2 R^2 (marginal) .044 .011 .061 .010 2.7e-04 .001 .004 iness T2 R^2 (marginal) .012 .015 .035 8.4e-04
Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval Pre/Post Lockdown Sex x Puberty T2 Sex (coded girls 0, boys 1) Age at T2 Puberty at T2 Neighbourhood SES at T2 Baseline/Follow-up Interval	Outcor β 421 .070 .358 .044 .056 080 211 Outcome V β 220 .080 .270 .013 .239	ne Variable SE .120 .044 .086 .030 .228 .146 .173 Variable: Dr SE .121 .045 .087 .031 .232	: Rumination p-value .00058 .113 4.89e-05 .145 .806 .585 .223 aytime Sleepi p-value .071 .076 .002 .675 .304	$\begin{array}{c} \mathbf{R}^2 \\ (marginal) \\ .044 \\ .011 \\ .061 \\ .010 \\ 2.7e-04 \\ .001 \\ .004 \\ \end{array}$

*except for interactions (e.g. Sex x Puberty T2 includes Sex and Puberty T2 as well as the interaction – the R^2 represents the ΔR^2 when the interaction term is added).

NOTE: Family and zygosity were included in the model as random effects. Nominally significant fixed effects are highlighted in **bold**.

Supplementary Table S3. Correlation coefficients for measures collected at baseline (Time 1 (T1)) and follow-up (Time 2 (T2)).

	Pearson Correlation Coefficient								
Anx/Dep Time 1	Stress Time 1	Rumination Time 1	Sleepiness Time 1	Anx/Dep Time 2	Stress Time 2	Rumination Time 2	Sleepiness Time 2		
.574**									
.532**	.593**								
.504**	.473**	.383**							
.416**	.363**	.331**	.336**						
.247**	.477**	.388**	.277**	.594**					
.275**	.270**	.404**	.268**	.553**	.628**				
.211**	.305**	.297**	.491**	.588**	.608**	.482**			
	Spearman's Rank Correlation Coefficient								
Anx/Dep Time 1	Stress Time 1	Rumination Time 1	Sleepiness Time 1	Anx/Dep Time 2	Stress Time 2	Rumination Time 2	Sleepiness Time 2		
0.048	0.075	127**	032	079	0.003	199**	114*		
238**	128**	172**	036	0.049	0.103	0.127*	0.115*		
025	0.007	003	0.055	0.149**	0.120*	0.124*	0.132*		
055	082	0.000	040	018	0.006	0.081	002		
204**	0.135*	165**	0.033	0.044	0.101	0.123*	0.114*		
056	053	020	0.058	0.199**	0.136*	0.233**	0.203**		
075	054	0.042	0.013	011	0.010	0.080	001		
172**	161**	163**	083	003	0.031	0.030	0.080		
0.183**	0.154**	0.179**	0.078	0.058	0.020	030	048		
	Anx/Dep Time 1 .574** .532** .504** .416** .247** .275** .211** Anx/Dep Time 1 0.048 238** 025 055 204** 056 075 172** 0.183**	Anx/Dep Time 1Stress Time 1 $574**$ $532**$ $593**$ $504**$ $473**$ $416**$ $363**$ $247**$ $477**$ $275**$ $270**$ $211**$ $305**$ $211**$ $305**$ $71**$ $71**$ $275**$ $270**$ $211**$ $305**$ $71**$ $71**$ $215**$ $270**$ $211**$ $305**$ $71**$ $71**$ $71**$ $71***$ $71**$ $71***$ $71***$ $7161**$ $0.183**$ $0.154**$	Anx/Dep Stress Rumination Time 1 Time 1 Time 1 .574** .532** .593** .504** .473** .383** .416** .363** .331** .247** .477** .388** .275** .270** .404** .211** .305** .297** Spear Maintaine Time 1 Time 1 Time 1 0.048 0.075 127** .238** 128** 172** .025 0.007 003 .055 082 0.000 .204** 0.135* 165** .056 053 020 .075 054 0.042 .172** 161** 163** 0.183** 0.154** 0.179**	Pearson Correl Anx/Dep Time 1 Stress Time 1 Rumination Time 1 Sleepiness Time 1 .574** .532** .593** .504** .71me 1 Time 1 .532** .593** .383** .416** .363** .331** .336** .416** .363** .331** .336** .247** .477** .388** .277** .247** .477** .388** .277** .268** .211** .305** .297** .491** Stress Rumination Sleepiness Time 1 0.048 0.075 127** 032 .238** .128** 172** 036 .025 0.007 .003 0.055 .055 082 0.000 040 .204** 0.135* 165** 0.033 .056 .053 .020 0.058 .075 .054 0.042 0.013 .172** .161** .163** .083	Anx/Dep Time 1 Stress Time 1 Rumination Time 1 Sleepiness Time 1 Anx/Dep Time 2 .574** .532** .593** .504** .71me 1 Time 1 Time 2 .504** .473** .383**	Anx/Dep Time 1Stress Time 1Rumination Time 1Sleepiness Time 1Anx/Dep Time 2Stress Stress.574**.532**.593**532**.593**	Anx/Dep Time 1 Stress Time 1 Rumination Time 1 Sleepiness Time 1 Anx/Dep Time 2 Stress Time 2 Rumination Time 2 .574** .532** .593** 504** .473** .383** 416** .363** .331** .336** . . .247** .477** .388** .277** .594** . .247** .477** .388** .277** .594** . .247** .477** .388** .277** .594** . .211** .305** .297** .491** .588** .608** .482** .211** .305** .297** .491** .588** .608** .482** .211** .305* .127** .032 .079 0.003 .199** .211** .0075 .127** .032 .079 0.003 .199** .238** .0075 .127** .036 0.049 <t< th=""></t<>		

** Significant at the 0.01 level (2-tailed)* Significant at the 0.05 level (2-tailed)

NOTE: Anxiety/depression, perceived stress, and rumination have been square root transformed to address minor positive skew with minor outliers winsorised to ± 3.3 SD. Transformations and correlations were conducted using IBM SPSS Statistics Version 27. Sample size ranged from 416 to 422 for Time 1 data correlations and from 303 to 304 for correlations including Time 2 data. All traits show moderate stability over time (*r* ranging 0.40 to 0.48). Perceived stress, rumination, and daytime sleepiness have moderate concurrent associations with anxiety/depression ((*r* ranging 0.50 to 0.57 at T1, and 0.55 to 0.60 at T2). Age is associated with anxiety/depression, perceived stress, and rumination at baseline, but puberty is more influential at follow-up. Note that associations between interval and lockdown with traits at Time 1 reflect associations with age at Time 1. That is, age at Time 1 correlates 0.59 with interval (i.e. younger participants had a shorter interval – an artificial construct driven by the practicalities of maximising sample size within our preferred age range). Age at Time 1 correlates - 0.56 with lockdown (post-lockdown participants were younger overall than pre-lockdown participants). These analyses do not include correction for twin relatedness.

Supplementary Table S4. Cross-sectional linear regression models with anxiety/depression symptoms at **Time 1** (T1) as the output variable: associations with perceived stress, rumination, and daytime sleepiness

	Anxiety/Depression at Time I as Output Variable									
Fixed Effects	Mod	el 1	Mod	el 2	Mod	el 3				
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value				
Perceived Stress T1	.568 (.040)	<2e-16								
Rumination T1			.521 (.041)	<2e-16						
Daytime Sleepiness T1					0.481 (.042)	<2e-16				
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC				
	.320	1016.3	.236	1056.8	.236	1056.8				
	Mod	el 4	Mod	el 5	Mod	el 6				
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value				
Perceived Stress T1	.388 (.048)	8.09e-15	.428 (.044)	<2e-16						
Rumination T1	.302 (.070)	3.60e-10			.398 (.041)	<2e-16				
Daytime Sleepiness T1			.297 (.043)	2.11e-11	.343 (.041)	1.09e-15				
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC				
	.380	976.3	.390	.967.8	.382	.972.0				
	Mod	el 7	Mod	el 8	Mode	el 9				
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value				
Perceived Stress T1	.289 (.049)	6.06e-09	.283(.048)	8.13e-09	.273 (.048)	2.97e-08				
Rumination T1	.262 (.045)	1.42e-08	.250 (.045)	5.35e-08	.254 (.045)	3.07e-08				
Daytime Sleepiness T1	.264 (.042)	7.65e-10	.266 (.041)	3.87e-10	.263 (.041)	4.91e-10				
Age at T1			095 (.031)	.002	094 (.030)	.0021				
Neighbourhood SES T1					027 (.018)	.129				
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC				
	.435	937.8	.453	930.3	.458	930.0				

Family and zygosity are included as random effects. Analyses are on the full baseline sample. Model 9 is the best-fitting model, although the AIC fit is almost identical to that of Model 8.

Supplementary Table S5. Cross-sectional linear regression models with anxiety/depression symptoms at **Time 2** (T2) as the output variable: associations with perceived stress, rumination, and daytime sleepiness

	Anxiety/Depression at Time 2 as Output Variable									
Fixed Effects	Mod	el 1	Mod	el 2	Mode	el 3				
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value				
Perceived Stress T2	.562 (.047)	<2e-16								
Rumination T2			.515 (.048)	<2e-16						
Daytime Sleepiness T2					0.563 (.047)	<2e-16				
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC				
	.326	726.7	.276	741.0	.326	725.2				
	Mod	el 4	Mod	el 5	Mod	el 6				
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value				
Perceived Stress T2	.381 (.057)	1.22e-10	.354 (.055)	3.55e-10						
Rumination T2	.295 (.056)	3.12e-07			.340 (.049)	1.69e-11				
Daytime Sleepiness T2			.359 (.055)	2.32e-10	.408 (.049)	4.35e-15				
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC				
	.384	702.5	.419	.688.6	.427	681.9				
	Mod	el 7	Mod	el 8	Mod	el 9				
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value				
Perceived Stress T2	.224 (.060)	.00023	.224 (.060)	.00024	.228 (.061)	.00023				
Rumination T2	.246 (.054)	7.71e-06	.233 (.055)	2.95e-05	.229 (.056)	5.35e-05				
Daytime Sleepiness T2	.321 (.054)	5.70e-09	.313 (.054)	1.89e-08	.311 (.054)	2.62e-08				
Puberty T2			.082 (.067)	.220	.076 (.069)	.273				
Sex					038 (.689)	.689				
	\mathbb{R}^2	AIC	\mathbf{R}^2	AIC	\mathbb{R}^2	AIC				
	.457	670.6	.459	664.8	.459	666.6				

NOTE: Family and zygosity are included as random effects. Model 8 is the best-fitting model.

Supplementary Table S6 (a). Linear regression analyses exploring bidirectional influences between perceived stress and anxiety/depression across times 1 and 2

		Output Variable: Anxiety/Depression T2								
Fixed Effects	Mod	lel 1	Mod	lel 2	Model 3					
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value				
Perceived Stress T1	.327 (.054)	3.57e-09*	.335 (.052)	6.38e-10*	.340 (.052)	3.28e-10*				
Puberty T2			.326 (.081)	7.15e-05*	.277 (.084)	.0012*				
Sex					226 (.116)	.052				
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC				
	.107	799.6	.158	776.8	.167	775.1				
	Out	tput Variable: I	Perceived Stress	T2						
	Mod	lel 4	Mod	lel 5						
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value						
Anxiety/Depression T1	.220 (.055)	7.63e-05*	.232 (.055)	2.89e-05*						
Puberty T2			.233 (.085)	.00062*						
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC						
	.049	824.3	.077	812.1						

NOTE: Family and zygosity were included as random effects in all models. Puberty and sex were significant covariates for anxiety/depression at follow-up, while puberty was a significant covariate for perceived stress at follow-up (Supp Table S2). Models are shown with and without sex and/or puberty as fixed effects. Sex (coded girls 0, boys 1) is not significant when perceived stress and puberty are included in the model (Model 3). Note that inclusion of covariates does not reduce the effect size of the predicting variable, rather, it causes a slight increase in the effect size.

*p-values less than the experiment-wide significance threshold (p<0.0085).

Supplementary Table S6 (b). Linear regression analyses exploring bidirectional influences between rumination and anxietv/depression across times 1 and 2

	Output Variable: Anxiety/Depression T2							
Fixed Effects	Model 1		Mod	lel 2	Model 3			
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value		
Rumination T1	.286 (.056)	6.24e-07*	.285 (.055)	3.86e-07*	.278 (.055)	8.32e-07*		
Puberty T2			.315 (.083)	.00018*	.293 (.087)	.00085*		
Sex					101 (.120)	.398		
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC		
	.076	810.5	.123	790.2	.125	791.5		
	0	utput Variable	e: Rumination T	2				
	Mod	lel 4	Mod	lel 5				
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value				
Anxiety/Depression T1	.254 (.055)	6e-06*	.274 (.054)	5.62e-07*				
Puberty T2			.387 (.083)	4.62e-06*				
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC				
	.065	830.0	.139	802.3				

NOTE: Family and zygosity were included as random effects in all models. Puberty and sex were significant covariates for anxiety/depression at follow-up, while puberty was a significant covariate for perceived stress at follow-up (Supp Table S2). Models are shown with and without sex and/or puberty as fixed effects. Sex (coded girls 0, boys 1) is not significant when perceived stress and puberty are included in the model (Model 3).

*p-values less than the experiment-wide significance threshold (p<0.0085).

Supplementary Table S6 (c). Linear regression analyses exploring bidirectional influences between *daytime* sleepiness and anxiety/depression across times 1 and 2

	Output Variable: Anxiety/Depression T2								
Fixed Effects	Model 1		Mod	lel 2	Model 3				
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value			
Daytime Sleepiness T1	.278 (.055)	2.1e-07*	.267 (.051)	3.79e-07*	.270 (.051)	2.63e-07*			
Puberty T2			.273 (.081)	.00084*	.235 (.085)	.0060*			
Sex					178 (.116)	.125			
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC			
	.078	796.8	.117	777.5	.124	777.1			
	Outp	ut Variable: D	aytime Sleepines	is T2					
	Mod	el 4	Mod	lel 5					
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value					
Anxiety/Depression T1	.166 (.055)	.0027*	.183 (.055)	.00089*					
Puberty T2			.299 (.086)	.00053*					
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC					
	.028	828.2	.074	813.1					

NOTE: Family and zygosity were included as random effects in Models 1 and 3-5. Model 2 was overfitted if both Family and Zygosity were included and so was run with only Family included as a Random Effect. Puberty and sex were significant covariates for anxiety/depression at follow-up, while puberty was a significant covariate for daytime sleepiness at follow-up (Supp Table S2). Models are shown with and without sex and/or puberty as fixed effects. Sex (coded girls 0, boys 1) is not significant when daytime sleepiness and puberty are included in the model (Model 3).

Supplementary Table S6 (d). Linear regression analyses exploring bidirectional influences between *perceived stress* and *rumination* across times 1 and 2

	Output Variable: Rumination T2								
Fixed Effects	Model 1		Mod	lel 2	Mod	lel 3			
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value			
Perceived Stress T1	.262 (.056)	4.51e-06*	.280 (.055)	5.44e-07*	.289 (.054)	1.85e-07*			
Puberty T2			.365 (.083)	1.74e-05*	.295 (.086)	.00073*			
Sex					338 (.120)	.0052*			
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC			
	.067	827.5	.135	800.9	.160	795.1			
	Out	put Variable: 1	Perceived Stress	T2					
	Mod	lel 4	Mod	lel 5					
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value					
Rumination T1	.356 (.053)	3.8e-10*	.362 (.054)	1.56e-10*					
Puberty T2			.200 (.081)	.014					
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC					
	.119	795.5	.143	784.3					

NOTE: Family and zygosity were included as random effects in all models. Puberty and sex (coded girls 0, boys 1) were significant covariates for rumination at follow-up, while puberty was a significant covariate for perceived stress at follow-up (Supp Table S2). Models are shown with and without sex and/or puberty as fixed effects.

*p-values less than the experiment-wide significance threshold (p<0.0085).

Supplementary Table S6 (e). Linear regression analyses exploring bidirectional influences between *perceived stress* and *daytime sleepiness* across times 1 and 2

	-	-				
	Outp	ut Variable: 1	Daytime Sleepiness T2			
Fixed Effects	Mod	lel 1	Model 2			
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value		
Perceived Stress T1	.297 (.053)	5.66e-08*	.302 (.053)	3.07e-08*		
Puberty T2			.252 (.083)	.0018*		
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC		
	.088 798.5		.122	785.6		
	Output Variable		: Perceived Stress T2			
	Out	put Variable:	Perceived Stress	T2		
	Out Mod	put Variable: lel 3	Perceived Stress Mod	T2 lel 4		
	Out Mod β (SE)	put Variable: lel 3 <i>p</i> -value	Perceived Stress Mod β (SE)	T2 lel 4 <i>p</i> -value		
Daytime Sleepiness T1	Out Mod β (SE) .235 (.055)	put Variable: lel 3 p-value 2.3e-05*	Perceived Stress Mod β (SE) .235 (.055)	T2 lel 4 p-value 2.42e-05*		
Daytime Sleepiness T1 Puberty T2	Out Mod β (SE) .235 (.055)	put Variable: lel 3 p-value 2.3e-05*	$\begin{array}{c} \mbox{Perceived Stress} \\ \mbox{Mod} \\ \beta \ (SE) \\ .235 \ (.055) \\ .179 \ (.085) \end{array}$	T2 lel 4 p-value 2.42e-05* .035		
Daytime Sleepiness T1 Puberty T2	$\begin{array}{c} & \text{Out} \\ & \text{Mod} \\ \beta \ (SE) \\ .235 \ (.055) \\ \\ & R^2 \end{array}$	put Variable: lel 3 p-value 2.3e-05* AIC	$\begin{array}{c} \mbox{Perceived Stress} \\ \mbox{Mod} \\ \beta (SE) \\ .235 (.055) \\ .179 (.085) \\ R^2 \end{array}$	T2 lel 4 <i>p</i> -value 2.42e-05* .035 AIC		

NOTE: Family and zygosity were included as random effects in all models. Puberty was the only significant covariate identified for perceived stress and daytime sleepiness at follow-up (Supp Table S2). Models are shown with and without puberty as a fixed effect. *p-values less than the experiment-wide significance threshold (p<0.0085).

Supplementary Table S6 (f). Linear regression analyses exploring bidirectional influences between *rumination* and *daytime sleepiness* across times 1 and 2

ruminution and unytime steepiness across times 1 and 2										
Output Variable: Daytime Sleepiness T2										
Fixed Effects	Model 1		Mod	el 2						
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value						
Rumination T1	.266 (.055)	2.63e-06*	.271 (.055)	1.4e-06*						
Puberty T2			.262 (.083)	.0017*						
	\mathbb{R}^2	AIC	\mathbb{R}^2	AIC						
	.066	804.7	.103	791.8						
		(Output Variable:	Rumination T	2					
	Mod	lel 3	Mod	el 4	Model 5					
	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value	β (SE)	<i>p</i> -value				
Daytime Sleepiness T1	β (SE) .272 (.055)	<i>p</i> -value 1.43e-06*	β (SE) .265 (.054)	<i>p</i> -value 1.88e-06*	β (SE) .267 (.054)	<i>p</i> -value 1.22e-06*				
Daytime Sleepiness T1 Puberty T2	β (SE) .272 (.055)	<i>p</i> -value 1.43e-06*	β (SE) .265 (.054) .323 (.084)	<i>p</i> -value 1.88e-06* .00016*	β (SE) .267 (.054) .261 (.087)	<i>p</i> -value 1.22e-06* .0030*				
Daytime Sleepiness T1 Puberty T2 Sex	β (SE) .272 (.055)	<i>p</i> -value 1.43e-06*	β (SE) .265 (.054) .323 (.084)	<i>p</i> -value 1.88e-06* .00016*	β (SE) .267 (.054) .261 (.087) 306 (.121)	<i>p</i> -value 1.22e-06* .0030* .013				
Daytime Sleepiness T1 Puberty T2 Sex	β (SE) .272 (.055) R ²	<i>p</i> -value 1.43e-06* AIC	β (SE) .265 (.054) .323 (.084) R ²	<i>p</i> -value 1.88e-06* .00016* AIC	$\begin{array}{c} \beta \text{ (SE)} \\ .267 (.054) \\ .261 (.087) \\306 (.121) \\ R^2 \end{array}$	<i>p</i> -value 1.22e-06* .0030* .013 AIC				

NOTE: Family and zygosity were included as random effects in all models. Puberty and sex (coded girls 0, boys 1) were significant covariates for rumination at follow-up, while puberty was a significant covariate for daytime sleepiness at follow-up (Supp Table S2). Models are shown with and without sex and/or puberty as fixed effects

*p-values less than the experiment-wide significance threshold (p<0.0085).

Supplementary Table S7. 8-Variable Cholesky decomposition parameter estimates for additive genetic (A), common (shared) environmental (C), and unique (non-shared) environmental (E) influences (95% confidence intervals shown for significant estimates)

	Additive Genetic Factor Estimates (shown as % of total variance)								
	A1	A2	A3	A4	A5	A6	A7	A8	Total A (Heritability)
Anx/Dep T1	23 (.04, 51)								23 (.04, 51)
Stress T1	09	12							20 (.04, 47)
Rumination T1	01	02	08						10
Sleepiness T1	10	00	01	18					29 (04, 48)
Anx/Dep T2	02	00	00	04	10				16
Stress T2	01	00	00	04	06	03			15
Rumination T2	00	09	09	01	08	10	00		28 (0.8, 58)
Sleepiness T2	00	00	01	22	02	18	00	00	44 (07, 66)
	C1	C2	Commor C3	n Environment C4	Factor Estimat C5	tes (shown as % C6	o of total varian C7	ce) C8	Total C
Any/Den T1	18	C2	0.5		0.5	Cu	CI	0	18
Stress T1	07	12							20 (.04, 40)
Rumination T1	11	11	01						23 (0.8, 40)
Sleepiness T1	04	02	00	00					06
Anx/Dep T2	27	02	06	00	00				35 (04, 56)
Stress T2	19	12	00	00	00	00			31 (01, 51)
Rumination T2	15	06	00	00	00	00	00		20 (0.3, 43)
Sleepiness T2	12	02	00	00	00	00	00	00	14
			Unique	Environment F	actor Estimate	es (shown as %	of total variand	e)	
	E1	E2	E3	E4	E5	E6	E7	E8	Total E
A /D /T1	50 (45 74)								EO (45 74)

			20					20	
Anx/Dep T1	59 (45, 74)								59 (45, 74)
Stress T1	13 (06, 24)	47 (36, 59)							60 (47, 75)
Rumination T1	18 (09, 30)	06 (02, 12)	43 (33, 54)						67 (52, 81)
Sleepiness T1	12 (05, 22)	03 (0.3, 09)	00	50 (39, 62)					65 (50, 80)
Anx/Dep T2	04 (0.4, 11)	01	00	00	43 (32, 57)				49 (36, 64)
Stress T2	03 (0.1, 10)	08 (02, 18)	00	00	04 (0.6, 12)	39 (28, 51)			54 (39, 71)
Rumination T2	03 (0.1, 11)	02	00	02	07 (02, 17)	07 (02, 15)	31 (21, 44)		52 (36, 72)
Sleepiness T2	01	06 (11, 37)	00	03 (0.4, 09)	07 (02, 14)	02 (0.1, 06)	00	24 (17, 34)	42 (30, 58)

Supplementary Table S8. Additive genetic (A), common environmental (C), unique environmental (E) and familial (A + C) contributions to phenotypic associations between Time 1 (T1) predictors and anxiety/depression symptoms at Time 2 (T2)

	T · · · · · · ·								
	Phenotypic r = A + C + E	A, C,	A, C, E additive components of phenotypic r				A, C, E as % of phenotypic r		
	(95% CI)	$A = a_{11}^* a_{21}$ (95% CI)	$C = c_{11} * c_{21}$ (95% CI)	$E = e_{11} * e_{21}$ (95% CI)	А	С	Е		
AnxDep T1 – AnxDep T2	0.41 (.31, .51)	0.10 (12, .40)	0.16 (08, .37)	0.15 (.04, .28)	24%	39%	37%		
Stress T1 – AnxDep T2	0.36 (.26, .46)	0.09 (16, .40)	0.13 (13, .36)	0.14 (.03, .27)	25%	36%	39%		
Rumination T1 – AnxDep T2	0.33 (.21, .43)	-0.08 (16, .19)	0.30 (.09, .39)	0.11 (01, .22)	16%	61%	23%		
Sleepiness T1 – AnxDep T2	0.32 (.21, .43)	0.17 (09, .38)	0.08 (09, .30)	0.07 (04, .20)	53%	25%	22%		
	Phenotypic r	(A + C) a	nd E additive com	ponents	(A + C) and E as %				
	$= (\mathbf{A} + \mathbf{C}) + \mathbf{E}$		of phenotypic r		pl	henotypio	e r		
	(95% CI)	A + C (9	5% CI)	E (95% CI)	A -	+ C	Е		
AnxDep T1 – AnxDep T2	0.41 (.31, .51)	0.26 (.1	2,.39)	0.15 (.04, .28)	63	3%	37%		
Stress T1 – AnxDep T2	0.36 (.26, .46)	0.22 (.0	8,.35)	0.14 (.03, .27)	61	.%	39%		
Rumination T1 – AnxDep T2	0.33 (.21, .43)	0.22 (.0	9,.35)	0.11 (01, .22)	77	1%	23%		
Sleepiness T1 – AnxDep T2	0.32(.21,.43)	0.25 (.1	1,.38)	0.07 (04, .20)	78	3%	22%		



Supplementary Figure S1. Path diagram of bivariate Cholesky decomposition (shown for only one twin). Factors A1, C1 and E1 represent the total additive genetic (A), common/shared environmental (C), and unique/non-shared environmental (E) influences on the predictor variable at baseline. a_{21} , c_{21} , and e_{21} indicate the extent to which A1, C1 and E1 account for variance in anxiety/depression symptoms at follow-up. Factors A2, C2, and E2 represent independent A, C, and E influences on anxiety/depression symptoms at follow-up. The phenotypic correlation between the predictor at baseline and anxiety/depression at follow-up is equivalent to $a_{11}*a_{21} + c_{11}*c_{21} + e_{11}*e_{21}$.



Supplementary Figure S2. Proportion of total variance influenced by additive genetic (A), common/shared environmental (C), and unique/non-shared environmental sources (E), as derived from multivariate Cholesky decomposition – **restricted to Time 2 sample for both timepoints**.