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A Dynamic Bidirectional System of Stress Processes: Feedback Loops Between Stressors, Psychological Distress, and Physical Symptoms

Xiaohui Luo, Jingwei Ma, and Yueqin Hu
Beijing Key Laboratory of Applied Experimental Psychology, National Demonstration Center for Experimental Psychology Education (Beijing Normal University), Faculty of Psychology, Beijing Normal University

Objective: Stress processes have long been of interest to researchers. A growing body of research explores the bidirectional relations between stressors, psychological and physical states. However, research on stress processes and their individual differences from a dynamic systems perspective is still lacking. This study examined dynamic feedback loops between stressors, psychological distress, and physical symptoms simultaneously using ecological momentary assessment. ***Method:*** Three hundred and fifty-six participants completed five momentary assessments on stressors, psychological distress, and physical symptoms per day for 7 days in 2023. They also completed measures of their Big Five personality traits, depressive symptoms, and anxiety symptoms. ***Results:*** Dynamic structural equation models showed positive cross-lagged and feedback effects of stressors with psychological distress and physical symptoms, suggesting their self-perpetuating loops. Agreeableness and conscientiousness were protective factors, and neuroticism was a risk factor for the stressor–psychological loop. Individuals with depressive and/or anxiety symptoms were characterized by (a) greater inertia of psychological distress and physical symptoms, (b) stronger reverse effects of psychological distress and physical symptoms on subsequent stressors, (c) significant reciprocal effects between psychological distress and physical symptoms, and (d) stronger self-perpetuating loops of stressors with psychological distress and physical symptoms. ***Conclusions:*** Our findings highlight the importance of analyzing feedback loops to understand bidirectional relations and individual differences in dynamic stress processes, providing insights for relevant personalized interventions.

Public Significance Statement
This study uncovers self-perpetuating loops of stressors with psychological distress and physical symptoms; as individuals encounter more stressors, they subsequently experience higher levels of psychological distress and more physical symptoms, which leads to more stressors later. These effects are amplified in individuals with low agreeableness and conscientiousness, high neuroticism, and depressive and/or anxiety symptoms. Relevant prevention and intervention strategies should consider specific stress processes and different individual vulnerabilities.

Keywords: stress, psychological distress, physical symptoms, dynamic structural equation models, feedback loop

Researchers have long been interested in the relations between stressors, psychological well-being, and physical well-being. Traditional stress research mainly focused on major life events that led to substantial changes in people's lives, while in the past few decades, there has been increasing attention to minor stressful events that are more frequent and inevitable in our daily lives (Almeida, 2005; Flook, 2011; Zhaoyang et al., 2020). Moreover, considering the dynamic nature of stress and well-being, researchers have emphasized the importance of examining not only the between-person differences in stress responses but also within-person stress processes (Zawadzki et al., 2022). Due to recent developments in technology and analysis methods, an increasing number of studies have explored stress processes using data collected through daily diaries (Kiang & Buchanan, 2014) and ecological momentary

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Yueqin Hu https://orcid.org/0000-0002-5533-9277
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Xiaohui Luo served as lead for investigation, methodology, visualization, and writing–original draft. Jingwei Ma served in a supporting role for investigation, methodology, and writing–original draft. Yueqin Hu served as lead for funding acquisition, project administration, supervision, and writing–review and editing. Xiaohui Luo and Yueqin Hu contributed equally to conceptualization. Xiaohui Luo and Jingwei Ma contributed equally to formal analysis.

Correspondence concerning this article should be addressed to Yueqin Hu, Beijing Key Laboratory of Applied Experimental Psychology, National Demonstration Center for Experimental Psychology Education (Beijing Normal University), Faculty of Psychology, Beijing Normal University, No. 19, Xin Jie Kou Wai Street, Hai Dian District, Beijing 100875, People's Republic of China. Email: yueqinhu@bnu.edu.cn

assessments (EMAs; Kang et al., 2024; Schultchen et al., 2019), which enables us to gain deeper insights into the dynamic relations between stressors and psychological well-being, and physical well-being.

Research using ecologically valid data has consistently shown concurrent associations of stressors with psychological and physical well-being (Flook, 2011; Kiang & Buchanan, 2014; Zawadzki et al., 2022; Zhaoyang et al., 2020). Researchers have also found positive temporal or lagged effects of stressors on subsequent negative emotions (Kang et al., 2024; Mey et al., 2020) and physical symptoms (Cichy et al., 2012). More importantly, others revealed reversed lagged effects of psychological distress (Kiang & Buchanan, 2014) and physical symptoms (Chan et al., 2019) on subsequent stress. In fact, the bidirectional relations of stressors with psychological and physical well-being have been theoretically discussed (Almeida, 2005) and empirically tested (Calvete et al., 2013; Gordon et al., 2020; Martinez & Bámaca-Colbert, 2019). There were also studies suggesting a bidirectional relation between psychological well-being and physical well-being (Charles & Almeida, 2006; Goldring & Bolger, 2021; Long et al., 2018).

Although there are studies that have investigated bidirectional lagged effects between stressors, psychological well-being, and physical well-being, most of them collect data at only a few time points, each spanning several months or years (Calvete et al., 2013; Long et al., 2018; Martinez & Bámaca-Colbert, 2019). Given that stressors and well-being can change from day to day and even within a day, it is crucial to investigate their bidirectional lagged relations on a denser time scale (i.e., at daily or hourly levels). Moreover, the few studies that have explored the dynamic interplay between stressors, psychological well-being, and physical well-being in everyday contexts have focused only on the lagged effects from one variable to another (Chan et al., 2019; Kiang & Buchanan, 2014), rather than the overall bidirectional relation between the two variables. It is worth noting that focusing only on lagged effects in either direction between stressors, psychological well-being, and physical well-being may overlook broader features of their dynamic interplay. In fact, the bidirectional relation between stressors and well-being (i.e., stressors lead to poorer subsequent well-being, which in turn leads to more stressors) implies the presence of specific patterns of individuals' stress processes. This suggests that the bidirectional relations in stress processes should be viewed as an integrated whole, which illuminates a dynamic systems perspective of the bidirectional relations among stressors, psychological well-being, and physical well-being.

From a dynamic systems perspective, the bidirectional relations between stressors, psychological well-being, and physical well-being can be viewed as feedback loops and quantified as feedback effects (Almeida, 2005). Feedback effects can be calculated by multiplying the corresponding bidirectional effects (i.e., cross-lagged effects), and the feedback effect between two variables describes how the prior state of one variable affects its subsequent state through its dynamic interaction with the other variable (X. Luo et al., 2024). There are two types of feedback loops: self-perpetuating loops, where two components mutually reinforce each other, resulting in reciprocal effects in the same direction, and self-regulating loops, composed of two components mutually inhibiting each other, leading to reciprocal effects in the opposite direction. For example, a self-perpetuating loop between stressors and psychological distress suggests that stressors increase individuals' subsequent distress levels, which in turn exposes them to more stressors. In contrast, a self-regulating loop involves stressors leading to greater distress, which subsequently reduces exposure to further stressors. These two types of feedback loops suggest variations in stress reactivity and recovery processes among individuals, which motivated us to explore individual differences in feedback loops between stressors, psychological well-being, and physiological well-being.

Many researchers have noted individual differences in stress processes and have explored possible correlates. As a possible dispositional source of individual differences, the Big Five personality traits have received much attention in stress research (J. Luo et al., 2023). For example, Leger et al. (2016) found that the predictive effect of daily stressors on negative affect on the same day was weaker for individuals with higher levels of extraversion, conscientiousness, and openness and lower levels of neuroticism. However, Joshanloo (2023) found only neuroticism, but not the other Big Five personality traits, moderated the concurrent effects of daily stressors on negative affect. There were also other studies that supported a stronger association between daily stressors and daily well-being among individuals high in neuroticism (Mroczek & Almeida, 2004; Weber & Hülür, 2023). However, further examining the concurrent and lagged effects of stressors, Wickham et al. (2016) found that neuroticism only moderated the concurrent effect of daily stressors on subjective well-being, but not the lagged effect. Moreover, Mey et al. (2020) failed to find moderating effects of neuroticism on the concurrent as well as the lagged effects of stressors on negative affect. Although previous studies have examined the moderating effect of neuroticism on the lagged effects of stressors on daily well-being, less attention has been paid to the moderating effects of the other dimensions of the Big Five personality. More importantly, research on the moderating effects of the Big Five personality traits on the reverse lagged effects is still lacking. It remains unclear how the psychological and physical states of individuals with different levels of the Big Five personality traits predict their subsequent stress exposure. Considering that stress processes are integrated dynamic systems consisting of bidirectional relations between stressors and individuals' psychological and physical states, the associations between the Big Five personality traits and individuals' dynamic stress systems remain to be explored.

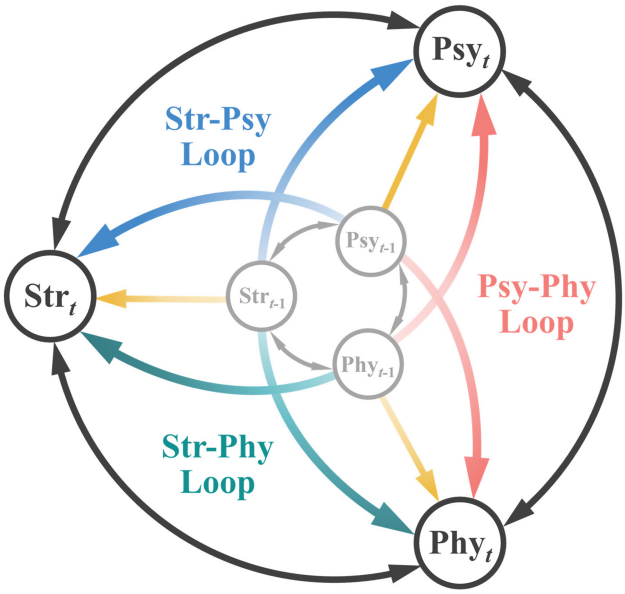
In addition, researchers have been concerned with how dynamic stress processes differ in people with different levels of clinical characteristics, particularly different levels of depressive and anxiety symptoms. A large number of studies have found that compared to people without clinical symptoms, people with higher levels of depressive and anxiety symptoms have stronger negative emotional reactivity (Booij et al., 2018; Sheets & Armey, 2020) and physical reactivity (Meier et al., 2014) to stressful life events. Furthermore, for the reverse effect, stress generation theory originally suggested that individuals with depressive symptoms actively interact with their environment and trigger more negative, dependent (i.e., controllable rather than fateful) events (Hammen, 1991). A recent meta-analytic review further revealed stress generation across a broad range of psychopathology (including depression and anxiety) and different types of stressful events (i.e., dependent and independent stressors) (Rnic et al., 2023). This suggests that for individuals with different levels of depressive and anxiety symptoms, their psychological and physical states may have different impacts on their subsequent stress. Although many

studies have explored the associations of depressive and anxiety symptoms with daily stress processes, most have focused on the emotional processes of stress, particularly the emotional reactivity of stress (Booij et al., 2018; Sheets & Armey, 2020). The relations between depressive and anxiety symptoms and the dynamic interplay among daily stressors and individuals' psychological and physical states (especially their dynamic bidirectional effects), remains understudied. Considering that psychological and physical health issues often cooccur, there is a need to comprehensively consider the overall characteristics of dynamic stress processes (e.g., feedback effects among stressors, psychological well-being, and physical well-being) to further our understanding of the associations between individuals' depressive and anxiety symptoms and their dynamic stress systems.

The main purpose of this study was to examine the dynamic feedback loops between stressors, psychological distress, and physical symptoms from a dynamic systems perspective (see Figure 1). We conducted EMAs, measuring five times a day across 7 days. Using dynamic structural equation modeling (DSEM, Asparouhov et al., 2018), we explored the within-person processes (i.e., autoregressive, cross-lagged, and feedback effects) of stressors, psychological distress, and physical symptoms. More importantly, we investigated whether their dynamic bidirectional relations were associated with individuals' Big Five personality traits, and depressive and anxiety symptoms to further examine the individual differences of the dynamic stress system.

Figure 1

Schematic Diagram of the Dynamic Bidirectional System of Stressors, Psychological Distress, and Physical Symptoms



Note. The double-arrowed lines indicate contemporaneous relations between the variables, and the single-arrowed paths indicate lagged effects (i.e., the effect of a variable at $t - 1$ on a variable at t). Specifically, the yellow paths (dark gray paths) indicate the autoregressive effects of the variables, and the blue, green, and red paths (gradient gray paths) indicate the three sets of cross-lagged effects and form three feedback loops, respectively. Str = stressors; Psy = psychological distress; Phy = physical symptoms. See the online article for the color version of this figure.

Method

Transparency and Openness

We report how we determined our sample size and all measures in the study. This study was not preregistered. All data, Mplus syntax, and R code are available at https://osf.io/gkrjw/ (X. Luo, 2024).

Participants and Procedure

A total of 356 Chinese college students (75.84% female) with a mean age of 20.658 years (ranged from 17 to 25, $SD = 1.642$) participated in this study in September 2023. About 84.884% of them were undergraduate students. The sample size was determined according to previous empirical studies based on DSEMs (X. Luo et al., 2024). First, informed consent was obtained from each participant. Then, they provided demographics and completed measures on the Big Five personality traits and depressive and anxiety symptoms. These measures were completed online. Over the next 7 days, a smartphone message with a questionnaire link was sent to each participant at 11 a.m., 2 p.m., 5 p.m., 8 p.m., and 11 p.m. each day, and participants reported their momentary stressors, psychological distress, and physical symptoms. The final compliance was satisfactory, with 90.594% ($n = 11{,}288$) of all questionnaires ($N = 12{,}460$; 356 Participants × 35 Questionnaires) being completed. The study was approved by the university's ethics committee.

Measures

Stressors

The nine-item stressors checklist (Baker et al., 2020) was used to assess the stressors relevant to the lives of college students (e.g., too much school work and preparing for your future/career path). Participants were asked to report whether they had experienced the stressors since they completed the last questionnaire with 0 (*no*) or 1 (*yes*). The total score was calculated.

Psychological Distress

The four-item Patient Health Questionnaire (Kroenke et al., 2009; Löwe et al., 2010) was used to assess psychological distress (example item: "feeling down, depressed, or hopeless"). Items were rated on a 5-point scale (1 = *not at all*, 5 = *very much*). The average score of the four items was calculated.

Physical Symptoms

A 10-item checklist of physical symptoms was adapted from previous studies (Goldring & Bolger, 2021; Larsen & Kasimatis, 1991). Participants were asked to report whether they had experienced the listed physical symptoms that day (e.g., any aches such as headaches, gastrointestinal symptoms such as diarrhea, etc.). Responses were 0 (*no*) or 1 (*yes*). The total score of the 10 items was calculated.

Big Five Personality

The Big Five personality traits were assessed by the Big Five Inventory-2 (Soto & John, 2017). The Chinese version of Big Five Inventory-2 (B. Zhang et al., 2022) was used in this study. The 60-item inventory includes five dimensions: extraversion,

agreeableness, conscientiousness, neuroticism, and openness. Participants need to report to what extent that they agree with each item on a 5-point scale (1 = *strongly disagree*, 5 = *strongly agree*). The average score of each dimension was calculated.

Depressive and Anxiety Symptoms

Depressive symptoms were assessed using the nine-item Patient Health Questionnaire (Kroenke et al., 2001). Participants rated the frequency of the symptom in each item over the preceding 2 weeks on a 4-point Likert scale (0 = *not at all*, 3 = *nearly every day*). The total scores of depressive symptoms were calculated. Based on previous studies, 109 participants scored ≥ 10 on the nine-item Patient Health Questionnaire, indicating clinically significant depressive symptoms (Kroenke et al., 2002).

Anxiety symptoms were assessed using the seven-item Generalized Anxiety Disorder scale (Spitzer et al., 2006). Participants rated the frequency of the symptom in each item over the preceding 2 weeks on a 4-point Likert scale (0 = *not at all*, 3 = *nearly every day*). The total scores of anxiety symptoms were calculated. Based on previous studies, 101 participants scored ≥ 10 on the seven-item Generalized Anxiety Disorder scale indicating significant moderate anxiety symptoms (Spitzer et al., 2006).

Considering the high number of people (i.e., $n = 75$) with both depressive symptoms and anxiety symptoms, we divided the sample into two groups, that is, people with ($n = 135$) and without ($n = 221$) depressive and/or anxiety symptoms, to explore the differences in dynamic stress processes between the two groups.

Analytic Strategy

Descriptive statistics, intraclass correlations, and between- and within-person correlations were calculated in R Version 4.2.2 (R Core Team, 2021) with the psych (Revelle, 2017) package. The dynamic bidirectional system of stressors, psychological distress, and physical symptoms (see Figure 2) was estimated in Mplus 8.3 (Muthén & Muthén, 2017). We used Bayesian estimation and two Markov Chain Monte Carlo chains with 5,000 iterations each, 50% burn-in, and a thinning value of 10. The variables are first decomposed into within-person components (i.e., $Str_t^{(w)}$, $Psy_t^{(w)}$, and $Phy_t^{(w)}$) and between-person components (i.e., μ_{Str}, μ_{Psy}, and μ_{Phy}). The between-person components are the person-specific average levels of each variable across all measurement occasions, which indicate the trait components that are stable over this period. The within-person components are the deviations of the observed scores from the average levels for each person, which represent the state components that vary over time. At the within-person level, we estimated three autoregressive effects (i.e., φ_{00}, φ_{11}, and φ_{22}) and six cross-lagged effects (i.e., φ_{01}, φ_{02}, φ_{10}, φ_{20}, φ_{12}, and φ_{21}) for each participant. The variances and covariance of the within-person residuals for stressors, psychological distress, and physical symptoms were fixed to be equal for all individuals. At the between-person level, the correlations between stressors, psychological distress, and physical symptoms were estimated. In addition, we specified a timing variable using the TINTERVAL command in Mplus, setting a 3-hr time interval of within-person estimates. The default Kalman filter method was used to handle the missingness (Asparouhov et al., 2018).

To further examine the feedback effects between stressors and psychological distress (i.e., FE_1), between stressors and physical symptoms (i.e., FE_2), and between psychological distress and physical symptoms (i.e., FE_3), we used the MODEL CONSTRAINT command in Mplus to obtain the products of the corresponding cross-lagged effects. For example, the feedback effect between stressors and psychological distress for the average person was calculated by multiplying the cross-lagged effects between stressors and psychological distress ($FE_1 = \varphi_{01} \times \varphi_{10}$; X. Luo et al., 2024). This feedback effect from the perspective of stressors can be interpreted as how the prior state of stressors affects its subsequent state through its dynamic interaction with psychological distress (X. Luo et al., 2024). A similar interpretation of this feedback effect can be made from the perspective of psychological distress.

Furthermore, we explored the individual differences in the dynamic bidirectional system of stress processes. To examine the associations between the Big Five personality traits and the characteristics of the dynamic system, we first saved person-specific standardized cross-lagged effects using the STDRESULTS command in Mplus and then calculated the products of corresponding cross-lagged effects to obtain the person-specific feedback effects in R. For example, the person-specific feedback effect between stressors and psychological distress was calculated by multiplying the saved person-specific cross-lagged effects between stressors and psychological distress. Then, we computed the correlations between the Big Five personality traits and person-specific cross-lagged and feedback effects. In addition, to test whether the dynamic stress processes of people with depressive and/or anxiety symptoms differed from those without, we estimated the DSEMs for both groups and compared their dynamic features.

Results

Descriptive Analysis

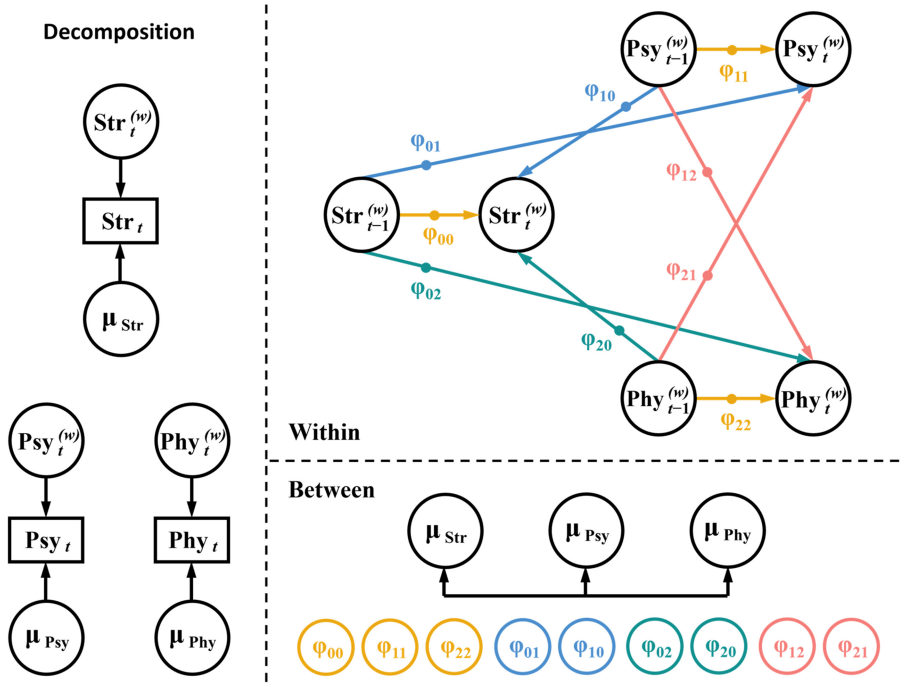
The descriptive statistics and correlations among stressors, psychological distress, physical symptoms, and individual difference factors are shown in Table 1. The intraclass correlations for stressors, psychological distress, and physical symptoms were .616, .672, and .606, respectively, suggesting that approximately 40% of their variance were within-person. There were positive associations among three components of the dynamic bidirectional system at both within- and between-person levels. In addition, they were negatively associated with extraversion, agreeableness, conscientiousness, and openness, while positively associated with neuroticism, depressive symptoms, and anxiety symptoms at the between-person level. People with clinically significant depressive and/or anxiety symptoms had more stressors, higher levels of psychological distress, and more physical symptoms than those without clinical symptoms.

Within-Person Processes

The parameter estimation results of the dynamic system are presented in Table 2. There were positive autoregressive effects of stressors, psychological distress, and physical symptoms. The cross-lagged effects between stressors and psychological distress ($\varphi_{01} = .070$, 95% credible interval [CI] [.045, .093]; $\varphi_{10} = .072$, 95% CI [.043, .101]) and between stressors and physical symptoms ($\varphi_{02} = .063$, 95% CI [.033, .092]; $\varphi_{20} = .061$, 95% CI [.034, .090]) as well as their feedback effects ($FE_1 = .005$, 95% CI [.002, .009], standardized effect = .0050; $FE_2 = .004$, 95% CI [.001, .008], standardized effect

Figure 2

DSEM of Stressors, Psychological Distress, and Physical Symptoms



Note. The superscript of (*w*) refers to the within-person component (i.e., deviation from the person-specific mean) of the variable and μ refers to the between-person component (i.e., the person-specific mean) of the variable. φ_{00}, φ_{11}, and φ_{22} denote the autoregressive effects of stressors, psychological distress, and physical symptoms, respectively. φ_{01}, φ_{02}, φ_{10}, φ_{20}, φ_{12}, and φ_{21} denote the cross-lagged effects between stressors, psychological distress, and physical symptoms. Solid dots indicate person-specific autoregressive and cross-lagged effects. DSEM = dynamic structural equation model; Str = stressors; Psy = psychological distress; Phy = physical symptoms. See the online article for the color version of this figure.

= .0038) were significant. Both feedback effects were considered medium to large effects according to the empirical benchmarks for feedback effects (X. Luo et al., 2024). In addition, there was significant cross-lagged effect of psychological distress on subsequent physical symptoms (φ_{12} = .029, 95% CI [.003, .055]), but not of physical symptoms on subsequent psychological distress (φ_{21} = .018, 95% CI [−.009, .044]). The feedback effect between psychological distress and physical symptoms was nonsignificant (FE_3 = .000, 95% CI [−.001, .002], standardized effect = .0005) and was a small feedback effect (X. Luo et al., 2024). The model explained 24.6% of the within-person variance in stressors, 19.6% of the within-person variance in psychological distress, and 20.9% of the within-person variance in physical symptoms.

Between-Person Differences

To explore the between-person differences of the dynamic bidirectional system, we first tested the correlations of the Big Five personality traits with the cross-lagged effects and feedback effects among stressors, psychological distress, and physical symptoms (see Table 3). We found that agreeableness and conscientiousness were protective factors for the dynamic interplay between stressors and psychological distress. Higher levels of agreeableness were negatively associated with the cross-lagged effect of stressors on subsequent psychological distress (r = −.135, p = .011). More importantly, agreeableness (r = −.165, p = .002) and conscientiousness (r = −.133, p = .012) were associated with a weaker self-perpetuating feedback loop between stressors and psychological distress, which suggested that people with higher levels of agreeableness and conscientiousness were less likely to get stuck in this loop. In addition, people with higher levels of neuroticism were more psychologically (r = .140, p = .008) and physically (r = .121, p = .022) affected by stressors and had stronger feedback effects between stressors and psychological distress (r = .142, p = .007) and between psychological distress and physical symptoms (r = .131, p = .014). This suggested that neuroticism was a risk factor that exacerbated and prolonged negative emotional and physical processes of daily stress.

One thing that should be noted is that the significant correlations between agreeableness and neuroticism and the feedback effect between stressors and psychological distress may be attributed to the fact that the feedback effect was the product of corresponding cross-lagged effects. Therefore, we tested the partial correlations between agreeableness and neuroticism and the feedback effect between stressors and psychological distress by controlling for the corresponding cross-lagged effects. The result showed that the partial correlations of agreeableness (r = −.149, p = .005) and neuroticism (r = .110, p = .038) with the feedback effect remained significant, suggesting that people with higher levels of agreeableness or lower levels of neuroticism were indeed less likely to have

Table 1

Descriptive Statistics and Correlations Among Stressors, Psychological Distress, Physical Symptoms, and Individual Difference Factors (n = 356)

Variable	*M* (*SD*)	ICC	1	2	3	4	5	6	7	8	9	10
1. Stressors	1.260 (1.025)	.616	—	.240***	.330***							
2. Psychological distress	1.732 (0.737)	.672	.432**	—	.239***							
3. Physical symptoms	0.899 (0.950)	.606	.568**	.525**	—							
4. Extraversion	3.079 (0.716)		−.219**	−.352**	−.294**	—						
5. Agreeableness	3.733 (0.592)		−.277**	−.486**	−.226**	.435**	—					
6. Conscientiousness	3.469 (0.719)		−.204**	−.408**	−.245**	.593**	.649**	—				
7. Neuroticism	2.775 (0.809)		.297**	.532**	.364**	−.681**	−.658**	−.675**	—			
8. Openness	3.427 (0.676)		−.158**	−.262**	−.134*	.459**	.441**	.430**	−.399**	—		
9. Depressive symptoms	8.000 (5.830)		.262**	.619**	.353**	−.460**	−.516**	−.522**	.656**	−.343**	—	
10. Anxiety symptoms	6.666 (5.127)		.300**	.632**	.347**	−.434**	−.522**	−.482**	.691**	−.342**	.843**	—
11. DA group	0.379 (0.486)		.245**	.539**	.362**	−.411**	−.484**	−.417**	.617**	−.301**	.789**	.788**

Note. Between-person correlations are presented below the diagonal, and within-person correlations are presented above the diagonal; ICC = intraclass correlation; DA group = 0 indicates participants without depressive or anxiety symptoms; DA group = 1 indicates participants with depressive and/or anxiety symptoms.

* $p < .05$. ** $p < .01$. *** $p < .001$.

the self-perpetuating loop between stressors and psychological distress.

In addition, we compared the dynamic stress systems between individuals with and without depressive and/or anxiety symptoms. As revealed in Table 4, the autoregressive effects of psychological distress and physical symptoms were stronger in individuals with depressive and/or anxiety symptoms, suggesting their stronger inertia in negative psychological and physical states. For the bidirectional relation between stressors and psychological distress, the cross-lagged effects were significant in both groups, but the cross-lagged effect of psychological distress on subsequent stressors was twice as large for individuals with depressive and/or anxiety symptoms than for those without depressive and anxiety symptoms. More importantly, the feedback effect was significant only for individuals with depressive and/or anxiety symptoms ($FE_1 = .004$, 95% CI [.001, .009]), and the feedback effect was a medium to large effect according to the empirical benchmarks for feedback effects (X. Luo et al., 2024). For the bidirectional relation between stressors and physical symptoms, both groups had the significant cross-lagged effects of stressors on subsequent physical symptoms, but only individuals with depressive and/or anxiety symptoms had significant and much stronger cross-lagged effect of physical symptoms on subsequent stressors ($\varphi_{20} = .130$, 95% CI [.082, .175]). Similarly, the feedback effect between stressors and physical symptoms was significant only for individuals with depressive and/or anxiety symptoms ($FE_2 = .009$, 95% CI [.001, .019]), and this feedback effect was a large effect according to the empirical benchmarks for feedback effects (X. Luo et al., 2024). These results suggested that individuals with depressive and/or anxiety symptoms were more susceptible to the self-perpetuating loops of stressors with psychological distress

Table 2

Within-Person Process of Stressors, Psychological Distress, and Physical Symptoms

Within-person effects	Notation	Unstandardized estimates: Fixed effects	Unstandardized estimates: Random variances	Standardized estimates: fixed effects
Str → Str	φ_{00}	**.271 [.232, .309]**	.053 [.042, .067]	**.271 [.240, .300]**
Psy → Psy	φ_{11}	**.216 [.181, .250]**	.054 [.043, .067]	**.216 [.189, .242]**
Phy → Phy	φ_{22}	**.240 [.202, .277]**	.055 [.043, .070]	**.239 [.211, .268]**
Str → Psy	φ_{01}	**.044 [.025, .062]**	.011 [.006, .016]	**.070 [.045, .093]**
Str → Phy	φ_{02}	**.062 [.023, .098]**	.048 [.036, .062]	**.063 [.033, .092]**
Psy → Str	φ_{10}	**.120 [.057, .187]**	.108 [.035, .178]	**.072 [.043, .101]**
Phy → Str	φ_{20}	**.067 [.027, .109]**	.057 [.034, .084]	**.061 [.034, .090]**
Psy → Phy	φ_{12}	.042 [−.006, .089]	.055 [.025, .108]	**.029 [.003, .055]**
Phy → Psy	φ_{21}	.011 [−.013, .035]	.022 [.014,.031]	.018 [−.009, .044]
Str–Psy loop	FE_1	**.005 [.002, .009]**		.005040[a]
Str–Phy loop	FE_2	**.004 [.001, .008]**		.003843[a]
Psy–Phy loop	FE_3	.000 [−.001, .002]		.000522[a]

Note. φ_{00}, φ_{11}, and φ_{22} denote the autoregressive effects of stressors, psychological distress, and physical symptoms. φ_{01} and φ_{10} denote the cross-lagged effects between stressors and psychological distress, and φ_{02} and φ_{02} denote the cross-lagged effects between stressors and physical symptoms, and φ_{12} and φ_{21} denote the cross-lagged effects between psychological distress and physical symptoms. FE_1, FE_2, and FE_3 denote the feedback loops between stressors and psychological distress, stressors and physical symptoms, and psychological distress and physical symptoms, respectively. 95% CIs are in the brackets. Significant effects (zero is not within the 95% CIs) are bolded. Str = stressors; Psy = psychological distress; Phy = physical symptoms; CI = credible interval.

[a] The standardized feedback effects are the products of two corresponding standardized cross-lagged effects.

Table 3
Correlations of the Big Five Personality Traits With Cross-Lagged Effects and Feedback Effects Among Stressor, Psychological Distress, and Physical Symptoms

	Str–Psy loop			Str–Phy loop			Psy–Phy loop		
Correlations	φ_{01}	φ_{10}	FE_1	φ_{02}	φ_{20}	FE_2	φ_{12}	φ_{21}	FE_3
Extraversion									
r	−.076	.008	−.102	−.050	−.010	−.047	−.031	−.075	−.104
p	.152	.882	.055	.344	.855	.377	.564	.159	.050
Agreeableness									
r	−.135*	−.007	−.165** (−.149**)	−.090	−.007	−.050	−.005	.067	.006
p	.011	.901	.002 (.005)	.089	.900	.349	.926	.209	.907
Conscientiousness									
r	−.097	−.057	−.133*	−.033	.035	−.010	.017	−.016	−.013
p	.068	.286	.012	.537	.507	.853	.756	.765	.814
Neuroticism									
r	.140**	.013	.142** (.110*)	.121*	−.040	.047	.097	.040	.131*
p	.008	.807	.007 (.038)	.022	.455	.375	.067	.457	.014
Openness									
r	−.092	.024	−.059	.094	.003	.016	−.019	−.041	−.094
p	.084	.646	.270	.075	.949	.768	.726	.444	.077

Note. φ_{01} and φ_{10} denote the cross-lagged effects between stressors and psychological distress, and φ_{02} and φ_{20} denote the cross-lagged effects between stressors and physical symptoms, and φ_{20} and φ_{20} denote the cross-lagged effects between psychological distress and physical symptoms. FE_1, FE_2, and FE_3 denote the feedback loops between stressors and psychological distress, stressors and physical symptoms, and psychological distress and physical symptoms, respectively. The partial correlations between agreeableness and neuroticism and the feedback effect between stressors and psychological distress (after controlling for the impacts of two corresponding cross-lagged effects) is calculated and presented in parentheses. Str = stressors; Psy = psychological distress; Phy = physical symptoms.
* $p < .05$. ** $p < .01$.

and physical symptoms. In addition, for the bidirectional relation between psychological distress and physical symptoms, only individuals with depressive and/or anxiety symptoms showed significant though relatively small cross-lagged effects between psychological distress and physical symptoms ($\varphi_{12} = .046$, 95% CI [.004, .085]; $\varphi_{21} = .043$, 95% CI [.003, .083]). The feedback effect between psychological distress and physical symptoms was nonsignificant in both groups.

Discussion

This study examined the dynamic stress processes and their individual differences in everyday contexts using EMA data, which expanded previous research on stress processes by taking a dynamic systems perspective. First, we simultaneously examined stressors, psychological distress, and physical symptoms to gain a more comprehensive understanding of the entire system consisting of stressors

Table 4
The Dynamic System of Stressors, Psychological Distress, and Physical Symptoms of People With and Without Clinically Significant Depressive and/or Anxiety Symptoms

Within-person effects	Notation	Without depressive and anxiety symptoms ($n = 221$)	With depressive and/or anxiety symptoms ($n = 135$)
Str → Str	φ_{00}	**.273 [.239, .306]**	**.256 [.211, .300]**
Psy → Psy	φ_{11}	**.158 [.128, .191]**	**.282 [.242, .323]**
Phy → Phy	φ_{22}	**.220 [.187, .253]**	**.300 [.254, .341]**
Str → Psy	φ_{01}	**.052 [.025, .082]**	**.058 [.019, .094]**
Str → Phy	φ_{02}	**.034 [.002, .067]**	**.064 [.018, .110]**
Psy → Str	φ_{10}	**.032 [.001, .065]**	**.071 [.030, .110]**
Phy → Str	φ_{20}	.025 [−.015, .065]	**.130 [.082, .175]**
Psy → Phy	φ_{12}	−.010 [−.047, .029]	**.046 [.004, .085]**
Phy → Psy	φ_{21}	.021 [−.012, .054]	**.043 [.003, .083]**
Str–Psy loop	FE_1	.002 [.000, .005]	**.004 [.001, .009]**
Str–Phy loop	FE_2	.001 [−.002, .004]	**.009 [.001, .019]**
Psy–Phy loop	FE_3	.000 [−.003, .002]	.002 [−.001, .005]

Note. φ_{00}, φ_{11}, and φ_{22} denote the autoregressive effects of stressors, psychological distress, and physical symptoms. φ_{01} and φ_{10} denote the cross-lagged effects between stressors and psychological distress, and φ_{02} and φ_{20} denote the cross-lagged effects between stressors and physical symptoms, and φ_{12} and φ_{21} denote the cross-lagged effects between psychological distress and physical symptoms. FE_1, FE_2, and FE_3 denote the feedback loops between stressors and psychological distress, stressors and physical symptoms, and psychological distress and physical symptoms, respectively. 95% CIs are in the brackets. Significant values (zero is not within the 95% CIs) are bolded. Str = stressors; Psy = psychological distress; Phy = physical symptoms; CI = credible interval.

and individuals' psychological and physical states. Second, instead of focusing only on the effects of one component on another (i.e., cross-lagged effects) as previous studies have done, we further examined the overall effects (i.e., feedback effects) between components in the dynamic system to examine the bidirectional relations as a whole (X. Luo et al., 2024). This helped us to quantify and understand the dynamic bidirectional relations in stress processes in a more integrated way. Third, we used DSEM to model the between-person variability in the dynamic bidirectional system and obtain person-specific autoregressive, cross-lagged, and feedback effects in stress processes. By exploring individual difference factors that may be associated with the between-person variability in stress processes, we found that individuals with different levels of the Big Five personality traits and different levels of depressive and/or anxiety symptoms exhibited different dynamic stress processes. In addition, the overall properties of the dynamic system (i.e., feedback effects) made an important contribution to a better understanding of the individual differences in stress processes. Taken together, moving from focusing on one variable or one local effect in stress processes to considering the entire system consisting of stressors and related components and the overall properties of the system helped us to further explore person-specific dynamic stress systems. In addition, using a person-centered approach to study individual-based dynamic stress processes can provide valuable insights into relevant personalized prevention and intervention practices.

Within-Person Processes of the Dynamic Stress System

For the within-person processes of the dynamic stress system, we found bidirectional lagged effects between individuals' stressors and their psychological distress and physical symptoms in both studies. When people encountered more stressors than usual, they subsequently experienced higher levels of psychological distress and had more physical symptoms, which in turn led to more stressors. This suggested the dynamic interactions between individuals' stressors and their psychological and physical states occurred over several hours. Kiang and Buchanan (2014) examined the bidirectional lagged relations between stressors and emotional well-being on a daily basis and found that the lagged effects were small or nonsignificant. However, our findings suggested that the dynamic interactions between stressors and individuals' psychological and physical states were stronger on a denser time scale (e.g., several hours), which deepened our understanding of how stress and well-being processes unfolded from hours to hours.

In addition, previous research on bidirectional relations in stress processes has mainly focused on the reciprocal effects between stressors and one type of individuals' state (e.g., emotional well-being; Flook, 2011), with less attention paid to the associations between multiple states of an individual, especially between an individual's psychological and physical states. Considering the complex interplay between individuals' psychological and physical states and the stressors they encounter, we adopted a dynamic systems perspective by simultaneously incorporating multiple key variables in stress processes to test their bidirectional relations, which helped to better reflect and understand real-world dynamic stress processes with multiple interconnected components.

Furthermore, the bidirectional feedback loops between stressors and psychological distress and physical symptoms found in our study provided empirical evidence for previous theoretical perspectives. Hammen (2006) argued that people not only passively receive and respond to stressors but also actively elicit and contribute to the occurrence of stressful events. Other researchers have also suggested that people who are negatively affected by stressful events may be selectively exposed to more stressful events, leading to a self-perpetuating loop between stressors and daily well-being (Almeida, 2005; Goldring & Bolger, 2021). In this study, we empirically supported the bidirectional lagged relations of stressors with psychological distress and physical symptoms in everyday contexts. More importantly, we examined the feedback loops in stress processes and estimated feedback effects, thus quantitatively analyzing the bidirectional relations as a whole. We found that the feedback effects between stressors and psychological distress as well as between stressors and physical symptoms were statistically significant and that the magnitude of these feedback effects was medium to large according to the empirical criteria of feedback effects (X. Luo et al., 2024), providing further support for previous theoretical perspectives on stress processes.

In contrast to the effects of stressors on psychological distress and physical symptoms, the cross-lagged and feedback effects between psychological distress and physical symptoms in both studies were either nonsignificant or quite small. Thus, we did not find sufficient evidence to support a bidirectional lagged relation between psychological distress and physical symptoms. However, it is worth noting that this does not necessarily suggest that there is no reciprocal relation between psychological distress and physical symptoms. In fact, it may imply a more frequent, or even contemporaneous, dynamic interaction between individuals' psychological and physical states. In other words, their bidirectional lagged effects may occur on even denser time scales (e.g., time scales at the minute level when measured with physiological sensors), so the effects across hours in this study were rather weak. Another possible explanation was that different psychological and physical states interacted with each other on different time scales. For example, Charles and Almeida (2006) conducted a daily diary study for eight consecutive days and found bidirectional lagged effects between negative affect and pain symptoms, a unidirectional lagged effect of negative affect on gastrointestinal symptoms, and no lagged effect between negative affect and respiratory symptoms. In addition, model selection may also be the reason why we did not find bidirectional lagged effects between physical symptoms and psychological distress. The DSEM used in this study is a linear model, whereas there may be nonlinear dynamic associations between an individual's physical and psychological states. Nevertheless, these possibilities remain to be further explored in future studies that comprehensively consider different time intervals, multiple psychological and physical states, and alternative modeling approaches (e.g., multilevel vector autoregressive network analysis; Bringmann et al., 2013; coupled latent differential equation model; Hu et al., 2014).

Between-Person Differences of the Dynamic Stress System

For the between-person differences of the dynamic stress system, we first found significant moderating effects of agreeableness, conscientiousness, and neuroticism on different stress processes. Previous stress research on the moderating roles of agreeableness and conscientiousness was limited (Leger et al., 2016). The few studies that investigated the concurrent effect of stressors on

psychological well-being did not find significant moderating effects of agreeableness (Joshanloo, 2023; Leger et al., 2016) and conscientiousness (Gartland et al., 2014). This study explored the bidirectional lagged relation between stressors and psychological distress from a dynamic systems perspective and found that agreeableness not only reduced psychological reactions to daily stressors but also weakened the self-perpetuating loop between stressors and psychological distress. Furthermore, although conscientiousness could not affect the direct reciprocal effects (i.e., cross-lagged effects) between stressors and psychological distress, it could buffer the self-perpetuating loop between them. This may be due to the fact that people high in conscientiousness are more self-disciplined (Costa & McCrae, 1995), more resilience to negative stimuli (Javaras et al., 2012), and more focused on dealing with current stressful events, thus weakening the dynamic mutual reinforcement between stressors and negative psychological states. These results also reminded us that when examining bidirectional relations between variables, it was important to consider not only cross-lagged effects but also feedback effects to better understand bidirectional relations as a whole.

In addition, neuroticism increased the psychological and physical impacts of stressors on individuals, which suggests that neuroticism exerts an influence on individuals' daily well-being by exacerbating individuals' reactivity to stress (Bolger & Schilling, 1991; Lahey, 2009). Neuroticism also amplified the self-perpetuating loop between stressors and psychological distress. Moreover, neuroticism strengthened the reciprocal effects between individuals' psychological and physical states. A previous study examined the bidirectional lagged effects between negative affect and physical symptoms but failed to find significant moderating of neuroticism on either effect (J. Zhang & Zheng, 2019). In contrast, this study further examined feedback effects between psychological distress and physical symptoms to better reflect their bidirectional relation as a whole, and revealed a significant association between neuroticism and the feedback effect between psychological distress and physical symptoms. This again suggests that focusing only on cross-lagged in bidirectional relations may overlook individual difference factors related to bidirectional relations, and that a further examination of feedback effects from a dynamic systems perspective could make a valuable contribution to explaining individual differences in dynamic stress processes.

Comparing individuals with and without depressive and/or anxiety symptoms revealed the following four main differences in the dynamic stress processes between the two groups. First, individuals with depressive and/or anxiety symptoms had stronger inertia in both psychological distress and physical symptoms, suggesting that negative psychological and physical states may be more persistent in these individuals. Second, the positive predictive effect of psychological distress on subsequent stressors was stronger in individuals with depressive and/or anxiety symptoms compared to those without. Moreover, the positive predictive effect of physical symptoms on subsequent stressors was only significant in individuals with depressive and/or anxiety symptoms and was much stronger than those without. This suggested that although individuals with and without depressive and/or anxiety symptoms may both have more negative psychological and physical states after experiencing stress, whether such psychological and physical states further bring about more subsequent stressors was a key difference between the two groups. This also provided insight into stress interventions for individuals with depressive and/or anxiety symptoms, which should focus on reducing the risk of an individual's negative psychological and physical state triggering more subsequent stressors. Third, there were relatively small but statistically significant bidirectional effects between psychological distress and physical symptoms in individuals with depressive and/or anxiety symptoms. This indicated that their negative psychological and physical states may reinforce each other. Therefore, both psychological and physical aspects need to be considered in an integrated way to enhance the effectiveness of relevant prevention and intervention practices. Fourth, self-perpetuating loops between stressors and psychological distress as well as physical symptoms were found only in individuals with depressive and/or anxiety symptoms. The feedback effect between stressors and psychological distress was moderate in size, and the feedback effect between stressors and physical symptoms even exceeded the benchmark for large effects in the empirical criteria for feedback effects (X. Luo et al., 2024). This suggested that the psychological and physical effects of stressors on individuals with depressive and/or anxiety symptoms could have further and lasting impacts on individuals through the dynamic interaction between their state and the external environment. These dynamic features highlighted the importance of providing daily stress management and coping interventions for individuals with depressive and/or anxiety symptoms.

In addition, although the above results suggest that feedback effects in the dynamic stress system were related to some personality traits and clinical characteristics, it is worth noting that feedback effects are a feature of dynamic systems and their interpretation requires special attention. For example, the positive feedback effect between stressors and psychological distress reflects their mutually reinforcing relation. This suggests that changes in individuals' stressors promote subsequent changes in their levels of psychological distress in the same direction, which in turn brings about changes in stressors in the same direction. However, this mutually reinforcing relation does not mean that their changes will continue to develop forever. Rather, feedback effects can be better understood using attractor basins in dynamic systems theory (Kunnen et al., 2019). For example, strong feedback effects of stressors with psychological distress and physical symptoms may reflect a steep attractor basin for stressors. This suggested that individuals facing changes in stressors are prone to get stuck in this basin because of the mutual reinforcement of stressors and psychological and physical states, making it difficult to return to their general states (i.e., average levels). Based on this interpretation of the feedback effect, the correlates of the feedback effect found in this study suggest that the attractor basins in the dynamic stress system may be steeper for individuals with certain personality and clinical characteristics, making it more difficult for these individuals to return to their typical levels when exposed to stress-related influences.

Taken together, the individual differences in the dynamic stress system and its correlates revealed in this study can provide insights into stress intervention practices. Using daily diaries and EMAs, we found different characteristics of individuals' dynamic stress processes. Future studies and practices could also adopt these high ecological validity methods to identify individuals who are more vulnerable to stressful life events and design more personalized intervention programs. In addition, this study found protective (i.e., agreeableness and conscientiousness) and risk (i.e., neuroticism) personality factors in stress dynamics, which helped to better

understand how individuals with different personality traits respond to and recover from daily stressors and to better identify individuals in need of stress-related interventions. More importantly, this study summarizes key features of the dynamic stress process in individuals with depressive and/or anxiety symptoms. Future interventions for individuals with depressive and/or anxiety symptoms could target specific features of individuals' dynamic stress processes to improve treatment effectiveness.

There are several limitations of the current study that should be noted. First, the generality of this study may be limited by the participants and measures. The participants in this study were college students and most of them were female. More importantly, the stressors checklist (Baker et al., 2020) used in this study was adapted for college students. Considering that there may be differences in the major stressors in daily life among different groups, the measure of stressors used in this study may not adequately capture the stressful life events of other groups. Therefore, further investigations are needed to explore whether our findings can be generalized to more diverse samples.

Second, individuals' stressors, psychological and physical states were assessed using self-report measures. Therefore, our findings may be influenced by common method variance. Considering that there are an increasing number of wearable sensors (e.g., heart rate monitors) and corresponding metrics (e.g., heart rate variability as a measure of stress) that can be used for more objective and dynamic assessments, future studies could combine subjective reports and objective physiological measures to better explore the dynamic processes of stress.

Third, when examining the associations between dynamic stress processes and depressive and/or anxiety symptoms, we did not focus on individuals who were clinically diagnosed with depression or anxiety disorders. Future research could focus on clinically diagnosed individuals to examine the characteristics of the dynamic stress processes in their daily lives.

Finally, specific variables were used to construct individuals' dynamic stress systems. For stress, further consideration could be given to the stressors in a specific domain (e.g., interpersonal stressors) as well as possible differences in the dynamic processes of stressors in different domains. For individuals' psychological states, the dynamic bidirectional relations of stress with other emotional (e.g., positive affect and negative affect) or cognitive factors (e.g., rumination) can also be explored. For individuals' physical states, for example, physical activity is one of the focuses in clinical and health-related behavioral interventions (Difrancesco et al., 2022). Future research could further examine its positive role in daily stress processes from a dynamic systems perspective.

Resumen

Objetivo: Los procesos de estrés han sido de interés para los investigadores durante mucho tiempo. Una creciente colección de estudios explora las relaciones bidireccionales entre los factores estresantes y los estados psicológicos y físicos. Sin embargo, aún faltan investigaciones sobre los procesos de estrés y sus diferencias individuales desde una perspectiva de sistemas dinámicos. Este estudio examinó los circuitos de retroalimentación dinámica entre factores estresantes, angustia psicológica y síntomas físicos simultáneamente utilizando una evaluación ecológica momentánea (EMA, por sus siglas en inglés). ***Métodos:*** 356 participantes completaron cinco evaluaciones momentáneas sobre factores estresantes, angustia psicológica y síntomas físicos por día durante siete días en 2023. También completaron medidas de sus cinco grandes rasgos de personalidad, síntomas depresivos y síntomas de ansiedad. ***Resultados:*** Los modelos de ecuaciones estructurales dinámicas mostraron efectos positivos de retraso cruzado y retroalimentación de los factores estresantes con angustia psicológica y síntomas físicos, lo que sugiere sus bucles que se perpetúan a sí mismos. La amabilidad y la escrupulosidad fueron factores protectores, y el neuroticismo fue un factor de riesgo para el ciclo estresante-psicológico. Los individuos con síntomas depresivos y/o de ansiedad se caracterizaron por (a) una mayor inercia de la angustia psicológica y los síntomas físicos, (b) efectos inversos más fuertes de la angustia psicológica y los síntomas físicos sobre los estresores posteriores, (c) efectos recíprocos significativos entre la angustia psicológica y los síntomas físicos. síntomas, y (d) bucles de factores estresantes que se perpetúan a sí mismos más fuertes con angustia psicológica y síntomas físicos. ***Conclusiones:*** Nuestros hallazgos resaltan la importancia de analizar los ciclos de retroalimentación para comprender las relaciones bidireccionales y las diferencias individuales en los procesos dinámicos de estrés, proporcionando información para intervenciones personalizadas relevantes.

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