# Evidence for a causal-mechanistic role for positive appraisal style in stress resilience

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**Abstract**

Stress resilience is the maintenance of mental health despite adversity. We have predicted that a tendency to appraise stressors in a realistic to slightly unrealistically positive fashion (positive appraisal style, PAS) is prospectively associated with more resilient outcomes; that PAS is a proximal and integrative resilience factor, mediating the pro-resilience effects of other protective factors (e.g., social support); and that PAS is modifiable, with changes in PAS leading to corresponding changes in resilience. In two independent observational samples (N=132 and N=1034), we find PAS to predict resilience over three and more years and to mediate the positive effects of social support. Analyzing the effects of a multi-component intervention (N=232) that targets a broad set of resilience factors, we find that the intervention increases PAS and that this prospectively mediates the intervention-induced increases in resilience. This establishes PAS as a proximal and plastic resilience factor with likely causal effects on resilience.

Mental health conditions such as anxiety, depression, or post-traumatic stress disorder are partly caused by exposure to stressors, including adverse life events, longer-term difficult life circumstances, or challenging life transitions[1–4]. However, not all individuals exposed to stressors develop mental health problems, a phenomenon known as stress resilience[5]. In times of multiplying global crises and a high and rising disease burden from stress-related disorders[6], this observation is raising increasing interest as an anchor point to develop new strategies in the combat for mental health[5,7]. Specifically, it is hoped that the identification of social, psychological, or biological resilience-predictive factors, along with their causal links to resilient outcomes, can inspire prevention programs for particularly vulnerable groups.

Appraisal is the evaluation of a stimulus or situation in terms of its meaning for the needs and goals of the individual and is considered by appraisal theories as the determinant of the emotional reaction to the stimulus/situation (e.g., [8–11]). Stressors are stimuli that are appraised as potential threats to one's needs or goals. Positive appraisal style theory of resilience (PASTOR)[12] builds on these concepts by claiming that a general tendency to appraise stressors in a realistic to mildly illusionary positive fashion is a key resilience factor. Compared to an overly (delusionally) positive appraisal tendency, such a 'positive appraisal style' (PAS) is supposed to make it likelier that individuals will mount stress reactions when necessary to cope with potentially threatening situations. Conversely, compared to an unrealistically negative appraisal tendency[13], individuals with a PAS will be more likely to avoid unnecessary stress reactions or over-reactions. They will thereby be better protected against resource depletion and allostatic load effects and have more room for learning, exploration, creativity, restoration, and resource-building. In situations of adversity or longer-lasting stressor exposure, this beneficial stress response profile will eventually reduce an individual's risk of developing mental health problems[12,14].

Initial studies have shown that PAS was linked with relatively better resilience during the first phases of the COVID-19 pandemic. This was observed cross-sectionally in 16,000 European adults[15] and in 570 mental health practitioners from various countries[16] and also prospectively over five weeks in 200 European adults[17] and over six months in 350 Dutch patients with Parkinson's Disease[18]. These studies measured PAS with an early version of the PASS-process instrument[15], a self-report questionnaire developed during the beginning of the pandemic to assess cognitive processes and strategies that individuals employ under stress to produce positive appraisals, that is, to view a difficult situation more positively. Questionnaire items mainly represent different variants of positive cognitive reappraisal.

The first goal of the present work is to ask whether PASS-process scores, now obtained from a fully validated version of the instrument[19], prospectively predict resilience across much longer timeframes. This is done in data from two German longitudinal observational studies: the Mainz Resilience Project (MARP)[20,21], where healthy young adults confronted with the challenges of transitioning into adulthood and pre-selected for having experienced at least three prior negative life events have been reporting their exposure to stressors and potential internalizing (negative mood and affective) symptoms every three months over 3.7 years, and the population-based Longitudinal Resilience Assessment (LORA) study on resilience to everyday modern-life stressors[22], where corresponding three-monthly reports have been obtained from adult participants over three years. In both samples, the baseline PASS-process measurement is complemented with an additional recently validated instrument that has individuals report to what extent they generate positive appraisals when under stress (PASS-content)[19]. By focusing on appraisal contents, rather than on the cognitive processes that can generate these contents (as in PASS-process), the PASS-content scale more directly targets the PAS construct.

As in the initial studies with PASS-process[15–18], resilience in these samples is defined as the maintenance or quick recovery of mental health during and after stressor exposure, that is, as a good long-term mental health outcome despite adversity[5]. Resilience is quantified by first regressing participants' scores for internalizing mental health problems on their stressor exposure scores. The regression line describes the normative reactivity of participants' mental health to the reported stressors in the given sample. We then express an individual participant's 'stressor reactivity' at each reporting time point by their residualized mental health problem score, that is, the distance of the mental health problem score from the normative regression line. We thus obtain a continuous stressor reactivity score (SR score), where a smaller value indicates that the participant is relatively less affected by the stressors[23]. The residualization approach (see also[24–29]) has several advantages. Most importantly, stressor exposure can differ between individuals, and classifying an individual as resilient merely based on low raw mental health problems ignores that a person may show good mental health for the trivial reason that they experience less adversity[23,30]. By contrast, by taking into account between-person differences in exposure, the SR score can be compared between participants with different exposure levels, such that relatively lower SR in a participant corresponds to relatively better mental health despite adversity[23]. Resilience as 'good long-term mental health despite adversity'[5] is operationalized even better when a stressor-exposed individual shows low SR over longer time frames[23], such as now available in MARP and LORA.

PASTOR also claims that PAS is an integrative resilience factor that mediates the effects of other (social, psychological, or biological) resilience factors, in that these shape the way an individual typically perceives stressors. In turn, this will determine how much an individual typically reacts to them and, eventually, how resilient they are[12,31]. Thus, PAS acts proximally on resilience, compared to other factors. In the four previous studies conducted during the COVID-19 pandemic[15–18], we found that negative associations of the well-established resilience factor perceived social support[32–35] with SR were mediated by PASS-process, in line with the idea that individuals who trust more in the availability of assistance from their social networks also perceive difficult situations as more easily controllable or less impactful and therefore show more resilience[15,34]. We also observed that negative associations of PASS-process with SR were mediated by a self-assessment of participants' stress recovery, such that participants with a higher PAS also reported to more easily recover from stressors and showed correspondingly lower SR[15–17]. The second goal of the present work was therefore to test the generalizability of these observations from samples primarily challenged by the pandemic to samples primarily exposed to other modern-life stressors (MARP and LORA). We also tested whether mediations are observed not only for PASS-process, but also for PASS-content.

The idea of PAS as an integrative and proximal mediator of other resilience factors implies that PAS may be enhanced even by interventions that do not target it directly. For instance, interventions trying to boost other (more distal) resilience factors or a broad set of potentially resilience-promoting mechanisms should also improve PAS. Importantly, if such interventions improved PAS, this improvement should translate into better resilience outcomes (lower SR). If this can be shown, this would be a strong argument for a causal role for PAS in resilience.

A third goal of the present work therefore was to perform a planned secondary analysis of a randomized controlled trial (RCT) testing a psychological stepped-care intervention in stressed healthcare workers in Spain during the COVID-19 pandemic, conducted by the EU Horizon consortium RESPOND (here: 'RESPOND-RCT Spain'; ClinicalTrials.gov Identifier: NCT04980326)[36]. Early analyses had indicated that healthcare workers are among the populations whose mental health was most impacted by the pandemic[37]. In this trial, stressor exposure, internalizing mental health problems, and PASS-content were assessed at four time points (baseline, peri-intervention, post-intervention, follow-up), spaced several weeks apart, both in the intervention and in a control

group who received enhanced care as usual. The first intervention step offers practices based on acceptance and commitment and mindfulness approaches that aim at modifying cognition through experiencing reality in a different way[38]; the second step explicitly targets dysfunctional behaviors and cognitions[39]. Hence, the intervention used a multi-component approach serving to initiate or enhance a broad range of potentially protective processes, making it suitable to test mediation by PAS. The primary analysis of the trial data has shown that the intervention successfully reduces internalizing symptoms[40].

In both MARP and LORA, we find a negative prospective association between the PAS scales and long-term SR scores (goal 1). PAS also mediates the negative association between perceived social support and SR, and its negative association with SR is in turn mediated by perceived good stress recovery in both samples (goal 2). In RESPOND-RCT Spain, we find that the intervention reduces SR and enhances PAS. Baseline PAS shows a negative prospective association with SR at later time points. Most importantly, the increase in PAS from baseline to post-intervention prospectively and strongly mediates the decrease in SR from baseline to follow-up, suggesting a causal contribution of PAS to resilience (goal 3).

## Results

Observational discovery sample: MARP

In the ongoing MARP study, a mixed laboratory and online battery assessing potential resilience factors (such as PAS) and other mental health predictors is administered approximately every 1.75 years (time points B0, B1, B2, … in Figure 1). Every three months, starting at the time of the first battery (time points T0=B0, then T1, T2, T3, …), exposure to both macrostressors (life events) and microstressors (daily hassles) as well as the magnitude of potential internalizing mental health problems (General Health Questionnaire-28, GHQ-28)[41] are monitored via online self-report. Of the 200 participants included at study baseline (B0/T0) between July 2016 and March 2019, N=132 could be used for longitudinal analyses that covered online monitoring until the time of the third battery administration at B2. The average B0-B2 interval was 3.7 years (range 2.8-4.8 years, see Methods). At baseline, these participants had a mean age of 19.2 years (sd=0.8), 83 (62.9%) were female, 92 (69.69%) were university students. Average baseline scores on the mental health instrument were 21.0 (sd=9.0, possible range 0-84). A recommended screening cut-off for the GHQ-28 is 23/24[42], indicating that some mental problem load was present in this sample already at inclusion. This is consistent with the selection criterion of having experienced at least three negative life events and with participants being confronted with the challenges of transiting into adulthood. For further sample characteristics, see Supplementary Table S1.

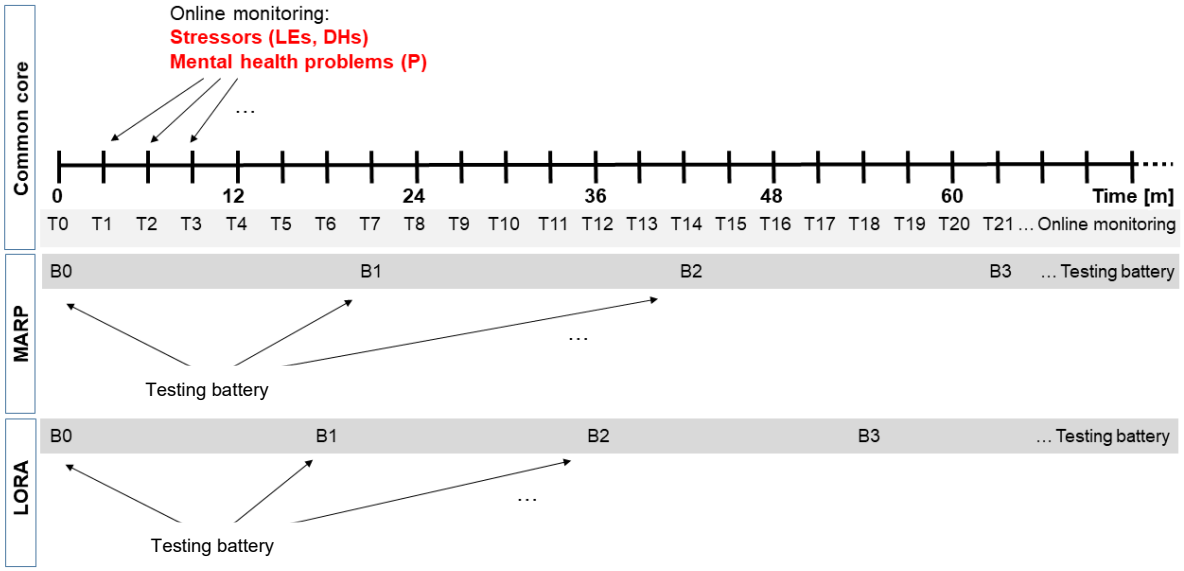


**Figure 1. MARP and LORA study designs.** Both studies implement the frequent stressor and mental health monitoring (FRESHMO) paradigm[23], where stressors (life events, daily hassles) and mental health problems (internalizing symptoms) are repeatedly and frequently assessed, via a three-monthly online monitoring (T0, T1, T2, …), permitting to describe mental health changes associated with stressor exposure. In order to identify resilience factors, such as PAS, a testing battery is repeatedly administered approximately every 1.75 (MARP) and 1.5 (LORA) years.

Over the 3.7 years, the most frequent life events reported by participants at the occasion of the online monitorings (T1, T2, T3, …) were in the categories of 'other impactful event' (such as exams, accidents, natural disasters, or armed conflicts; mean(M)=0.5 (sd=0.5) times per three-monthly

monitoring time window), constant arguments between family members (M=0.3, sd=0.5), and serious illness, accident or diagnosis of oneself or a close family member (M=0.2, sd=0.4). The life events with the highest severity rating (from 1 to 5) were serious arguments with boyfriend/girlfriend or spouse (M=4.0, sd=0.9), break-up from girlfriend/boyfriend/spouse (M=4.0, sd=1.0), and death of a beloved pet (M=3.9, sd=1.0). The most frequently reported daily hassles in the sample were household management (M=4.5 (sd=1.9) days per past week at each three-monthly monitoring), high performance demand or workload at work/school/university (M=4.4, sd=2.0), and commuting (M=3.9, sd=1.8). The daily hassles rated as most severe were bad news (M=3.7, sd=1.2), high performance demand or workload at work/school/university (M=3.7, sd=1.0), and performance situations at work/school/university (e.g., exam) (M=3.6, sd=1.1). See Supplementary Tables S2a,b for further details on stressor exposure.

A stressor exposure score E, aggregating life event and daily hassle counts, explained 32.9% of variance in the mental health problem score P (GHQ-28) in a linear mixed model across all online monitoring time points and participants (see Methods). This allowed us to calculate SR scores to obtain an inverse outcome-based measure of resilience.

Intra-class correlations (ICCs) between battery time points B0 and B1 for PASS-content (0.75) and PASS-process (0.58) indicated long-term stability of the two PAS measures. They were also highly correlated with each other at both battery assessments (B0: R=0.56; B1: R=0.60), congruent with them indexing the same psychological construct.

Controlling for age, sex, childhood trauma as well as smoking, both PASS-content and PASS-process at B0 were prospectively negatively associated with the SR scores from B0 to B2, that is, with average SR calculated using the online monitoring data starting with the first post-baseline time point, placed three months after B0 (T1 in Figure 1), until the time point concordant with B2, approximately 3.7 years after B0. After adjustment, PASS-content explained 18.8% of the variance in SR and PASS-process 12.8%. See Table 1. For PASS-content, significant negative prospective relationships were also found at shorter time scales (predicting SR in the B0-B1 interval or at the first three monitoring time points (nine months) after B0 from scores at B0 and, analogously, SR in the B1-B2 interval or at the first three monitoring time points after B1 from scores at B1). Prediction results were similar when analyzing only the most stressor-exposed participants (top two terciles of mean E between B0 and B2; Supplementary Table S3), as prescribed[23]. These observations indicate that PAS is a resilience factor, as hypothesized.

Next to the two PAS instruments, perceived social support and perceived good stress recovery also showed covariate-controlled negative prospective associations with SR (Supplementary Tables S4 and S5). The prospective associations of social support(B0) with SR(B0-B2) were mediated by PASS-content(B0), but not PASS-process(B0). The associations of both PASS-content(B0) and PASS-process(B0) with SR(B0-B2) were in turn mediated by good stress recovery(B0) (Figure 2). Note, however, that these mediation analyses were underpowered (see Methods) and are only reported for discovery purposes here.

Overall, these findings confirm a link between positive appraisal and resilience, potentially via optimization of stress responses (better stress recovery), and they indicate that positive appraisal style may be a more proximal resilience factor than social support.

**Table 1. MARP: Prediction of stressor reactivity (SR) by PASS-content and PASS-process, controlling for baseline (B0) covariates.**

| *Predictor time point (battery)* | B0 | | B0 | | B0 | | B1 | | B1 | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Outcome interval (SR score)* | B0-B2 (~3.7 yrs) | | B0-B1 (~1.9 yrs) | | 3 monitorings post B0 (~9 m) | | B1-B2 (~1.6 yrs) | | 3 monitorings post B1 (~9 m) | |
| PASS-content | **-0.307**$^{***}$ | | **-0.360**$^{***}$ | | **-0.273**$^{***}$ | | **-0.336**$^{***}$ | | **-0.328**$^{***}$ | |
| | (0.081) | | (0.085) | | (0.085) | | (0.123) | | (0.112) | |
| PASS-process | | **-0.155**$^{*}$ | | **-0.159**$^{*}$ | | **-0.186**$^{**}$ | | **-0.245**$^{**}$ | | **-0.230**$^{**}$ |
| | | (0.087) | | (0.092) | | (0.090) | | (0.123) | | (0.112) |
| Age | -0.136 | -0.131 | -0.141 | -0.127 | -0.077 | -0.062 | -0.081 | -0.019 | -0.044 | -0.009 |
| | (0.098) | (0.101) | (0.102) | (0.109) | (0.108) | (0.111) | (0.140) | (0.146) | (0.128) | (0.133) |
| Sex | **0.429**$^{***}$ | **0.362**$^{**}$ | **0.392**$^{**}$ | **0.333**$^{*}$ | **0.299**$^{*}$ | 0.214 | 0.301 | 0.336 | 0.228 | 0.233 |
| | (0.163) | (0.171) | (0.171) | (0.184) | (0.172) | (0.179) | (0.228) | (0.240) | (0.203) | (0.213) |
| Childhood trauma | 0.227 | **0.421**$^{*}$ | 0.222 | **0.439**$^{*}$ | 0.043 | 0.179 | 0.115 | 0.091 | 0.229 | 0.229 |
| | (0.240) | (0.244) | (0.248) | (0.259) | (0.285) | (0.292) | (0.362) | (0.379) | (0.327) | (0.342) |
| Smoking | 0.048 | 0.051 | 0.045 | 0.052 | 0.040 | 0.048 | 0.031 | 0.053 | 0.029 | 0.051 |
| | (0.041) | (0.043) | (0.042) | (0.045) | (0.044) | (0.045) | (0.052) | (0.053) | (0.048) | (0.049) |
| Number of assessments | **-0.136**$^{**}$ | **-0.184**$^{***}$ | 0.122 | 0.107 | | | -0.063 | -0.078 | | |
| | (0.065) | (0.068) | (0.131) | (0.143) | | | (0.092) | (0.096) | | |
| Constant | 3.298 | 3.687 | 0.914 | 0.565 | 0.892 | 0.549 | 1.291 | 0.164 | 0.143 | -0.573 |
| | (2.141) | (2.230) | (2.197) | (2.336) | (2.163) | (2.224) | (2.910) | (3.038) | (2.545) | (2.652) |
| Observations (n) | 132 | 131 | 128 | 126 | 114 | 113 | 83 | 80 | 85 | 83 |
| $R^2$ | 0.225 | 0.168 | 0.200 | 0.109 | 0.124 | 0.077 | 0.140 | 0.105 | 0.138 | 0.093 |
| Adjusted $R^2$ | 0.188 | 0.128 | 0.161 | 0.064 | 0.084 | 0.034 | 0.072 | 0.031 | 0.083 | 0.035 |
| Residual Std. Error | 0.900 (df = 125) | 0.933 (df = 124) | 0.927 (df = 121) | 0.986 (df = 119) | 0.899 (df = 108) | 0.924 (df = 107) | 0.996 (df = 76) | 1.035 (df = 73) | 0.921 (df = 79) | 0.956 (df = 77) |
| F Statistic | **6.043**$^{***}$ (df = 6; 125) | **4.184**$^{***}$ (df = 6; 124) | **5.053**$^{***}$ (df = 6; 121) | **2.416**$^{**}$ (df = 6; 119) | **3.068**$^{**}$ (df = 5; 108) | 1.781 (df = 5; 107) | **2.056**$^{*}$ (df = 6; 76) | 1.428 (df = 6; 73) | **2.527**$^{**}$ (df = 5; 79) | 1.587 (df = 5; 77) |
| *Note:* | Estimates are standardized betas; standard errors are reported in brackets.***p<0.05; **p<0.01; ***p<0.001** | | | | | | | | | |

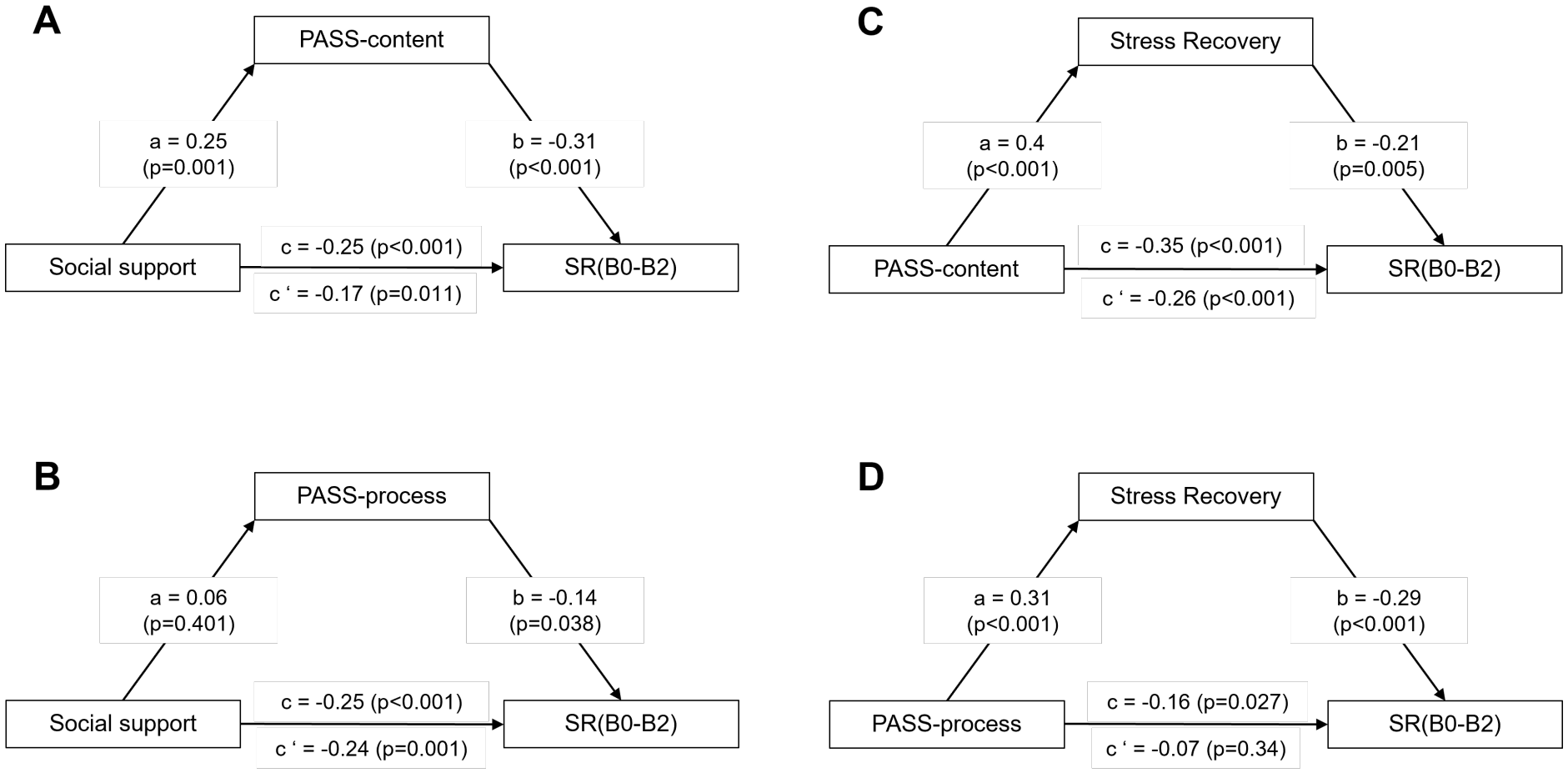


**Figure 1. MARP: Mediation analysis.** The effect of perceived social support(B0) on SR(B0-B2) was mediated by PASS-content(B0) (mean bootstrapped indirect effect ab: 0.07, 95% CI [-0.15, -0.02]) **(A)**, but not PASS-process(B0) (ab: -0.01, CI [-0.04,0.02]) **(B)**. Perceived good stress recovery(B0) mediated the effect of PASS-content(B0) (ab: -0.08, CI [-0.17, -0.01]) **(C)** as well as PASS-process(B0) (ab: -0.09, CI [-0.17, -0.03]) **(D)** on SR(B0-B2). a, effect of predictor on mediator; b, effect of mediator on outcome; c, total effect of predictor on outcome; c’, direct effect of predictor on outcome removing the mediator.

Observational replication sample: LORA

In the ongoing LORA study, a resilience factor battery partly overlapping with the one used in MARP is administered approximately every 1.5 years (B0, B1, B2, …), and online monitoring using the same instruments as MARP also occurs every three months (T0, T1, T2, …) (Figure 1). Of the 1091 participants included at baseline (B0/T0) between October 2016 and July 2019, N=1034 could be used for the longitudinal analyses until B2, that is, approximately three years after baseline. At baseline, these participants had a mean age of 28.8 years (sd=8.0) and were mostly female (n=686, 66.3%). 576 (52.4%) were university students, 466 (45.1%) had a university education, and 463 (44.8%) were in employment. Average baseline scores on the mental health instrument (GHQ-28) were 16.5 (sd=7.7), that is, lower than in MARP, in line with LORA participants not being pre-selected for risk. For further sample characteristics, see Supplementary Table S6.

Over the 3 years, the most frequent life events reported by participants at the online monitoring were 'other impactful event' (M=0.3 (sd=0.4) times per three-monthly monitoring time window), constant arguments between family members (M=0.4, sd=3), and serious arguments with boyfriend/girlfriend/spouse (M=0.2, sd=0.4). The life events rated as most severe were break-up with boyfriend/girlfriend/spouse (M=2.9, sd=1.0), difficult pregnancy or miscarriage of partner or oneself (M=2.8, sd=1.3), and serious argument with boyfriend/girlfriend/spouse (M=2.6, sd=1.0). The most frequently reported daily hassles were household management (M=4.8 days (sd=2.0) per past week at each three-monthly monitoring), commuting (M=4.1 days, sd=1.5), and high performance demand or workload at work/school/university (M=4.0 days, sd=2.0). The daily hassles rated as most severe were conflict or disagreement with close persons (M=1.7, sd=1.2), high performance demand (M=1.6, sd=1.1), and time pressure (M=1.6, sd=1.1). From the severity ratings it becomes apparent that LORA participants perceived their stressors as less burdensome than MARP participants, presumably reflecting that the LORA sample was not enriched for individuals in critical life phases. For further details, see Supplementary Tables S7a,b.

The aggregated stressor exposure score E explained 35.8% of variance in the mental health problem score P in a mixed linear model across all time points and participants.

ICCs between B0 and B1 of the PAS instruments were similar to MARP (PASS-content: 0.71; PASS-process: 0.53), and both instruments were again highly correlated at each battery assessment (B0: R=0.55; B1: R=0.56).

Controlling for age, sex, childhood trauma, and household income at baseline, all tested resilience factors (PASS-content, PASS-process, perceived social support, perceived good stress recovery) were negatively prospectively associated with SR at the different time scales (Table 2, Supplementary Table S8). PASS-content again showed stronger associations than PASS-process. In particular, PASS-content explained 12.5 % of the variance in SR(B0-B2), while PASS-process only explained 6.8%. Prediction results were again similar when analyzing only the most stressor-exposed participants (top two terciles of mean E between B0 and B2; Supplementary Tables S9, S10). Mediation analyses were well powered (Methods) and showed the expected mediation of social support effects on SR via PAS and of PAS effects on SR via good stress recovery (Figure 3).

As an interim conclusion, observations using two different questionnaires (PASS-content, PASS-process) in two independent, demographically different German samples are compatible with the theoretical claims that PAS is a resilience factor, that it mediates the effects of other resilience factors (social support), and that it acts on resilience by shaping stress responses in an optimal way (facilitating stress recovery).

**Table 2. LORA: Prediction of stressor reactivity (SR) by PASS-content and PASS-process, controlling for baseline (B0) covariates.**

| *Predictor time point (battery)* | B0 | | B0 | | B0 | | B1 | | B1 | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Outcome interval (SR score)* | B0-B2 (~3 yrs) | | B0-B1 (~1.5yrs) | | 3 monitorings post B0 (~9 m) | | B1-B2 (~1.5 yrs) | | 3 monitorings post B1 (~9 m) | |
| PASS-content | **-0.209**$^{***}$ | | **-0.221**$^{***}$ | | **-0.191**$^{***}$ | | **-0.223**$^{***}$ | | **-0.241**$^{***}$ | |
| | (0.022) | | (0.024) | | (0.029) | | (0.032) | | (0.033) | |
| PASS-process | | **-0.110**$^{***}$ | | **-0.122**$^{***}$ | | **-0.117**$^{***}$ | | **-0.101**$^{***}$ | | **-0.071**$^{**}$ |
| | | (0.023) | | (0.025) | | (0.029) | | (0.032) | | (0.034) |
| Age | -0.001 | -0.001 | -0.003 | -0.003 | -0.003 | -0.002 | 0.002 | 0.003 | 0.001 | 0.003 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| Sex | **0.307**$^{***}$ | **0.286**$^{***}$ | **0.332**$^{***}$ | **0.309**$^{***}$ | **0.297**$^{***}$ | **0.277**$^{***}$ | **0.244**$^{***}$ | **0.236**$^{***}$ | **0.235**$^{***}$ | **0.242**$^{***}$ |
| | (0.047) | (0.049) | (0.050) | (0.052) | (0.061) | (0.062) | (0.067) | (0.068) | (0.069) | (0.071) |
| Childhood trauma | **0.005**$^{**}$ | **0.007**$^{***}$ | **0.007**$^{***}$ | **0.009**$^{***}$ | **0.009**$^{***}$ | **0.011**$^{***}$ | 0.004 | **0.006**$^{*}$ | 0.005 | **0.008**$^{**}$ |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.004) |
| Income | **-0.032**$^{**}$ | **-0.037**$^{***}$ | **-0.029**$^{**}$ | **-0.034**$^{**}$ | **-0.036**$^{**}$ | **-0.037**$^{**}$ | **-0.049**$^{***}$ | **-0.060**$^{***}$ | **-0.061**$^{***}$ | **-0.072**$^{***}$ |
| | (0.013) | (0.013) | (0.013) | (0.014) | (0.016) | (0.017) | (0.018) | (0.018) | (0.019) | (0.019) |
| Constant | **-0.510**$^{***}$ | **-0.534**$^{***}$ | **-0.569**$^{***}$ | **-0.593**$^{***}$ | **-0.543**$^{***}$ | **-0.588**$^{***}$ | **-0.405**$^{**}$ | **-0.436**$^{**}$ | **-0.343**$^{*}$ | **-0.458**$^{**}$ |
| | (0.137) | (0.142) | (0.146) | (0.152) | (0.176) | (0.180) | (0.195) | (0.199) | (0.206) | (0.212) |
| | | | | | | | 0.002 | 0.003 | 0.001 | 0.003 |
| Observations (n) | 1,034 | 1,033 | 1,034 | 1,033 | 929 | 930 | 749 | 756 | 700 | 704 |
| $R^2$ | 0.130 | 0.073 | 0.132 | 0.077 | 0.089 | 0.060 | 0.089 | 0.039 | 0.101 | 0.038 |
| Adjusted $R^2$ | 0.125 | 0.068 | 0.128 | 0.073 | 0.085 | 0.055 | 0.080 | 0.030 | 0.092 | 0.028 |
| Residual Std. Error | 0.715 (df = 1028) | 0.743 (df = 1027) | 0.762 (df = 1028) | 0.790 (df = 1027) | 0.872 (df = 923) | 0.892 (df = 924) | 0.859 (df = 741) | 0.882 (df = 748) | 0.864 (df = 692) | 0.892 (df = 696) |
| F Statistic | **30.622**$^{***}$ (df = 5; 1028) | **16.063**$^{***}$ (df = 5; 1027) | **31.364**$^{***}$ (df = 5; 1028) | **17.225**$^{***}$ (df = 5; 1027) | **18.132**$^{***}$ (df = 5; 923) | **11.716**$^{***}$ (df = 5; 924) | **10.325**$^{***}$ (df = 7; 741) | **4.337**$^{***}$ (df = 7; 748) | **11.063**$^{***}$ (df = 7; 692) | **3.945**$^{***}$ (df = 7; 696) |
| *Note:* | Estimates are standardized betas; standard errors are reported in brackets.***p<0.05; **p<0.01; ***p<0.001** | | | | | | | | | |

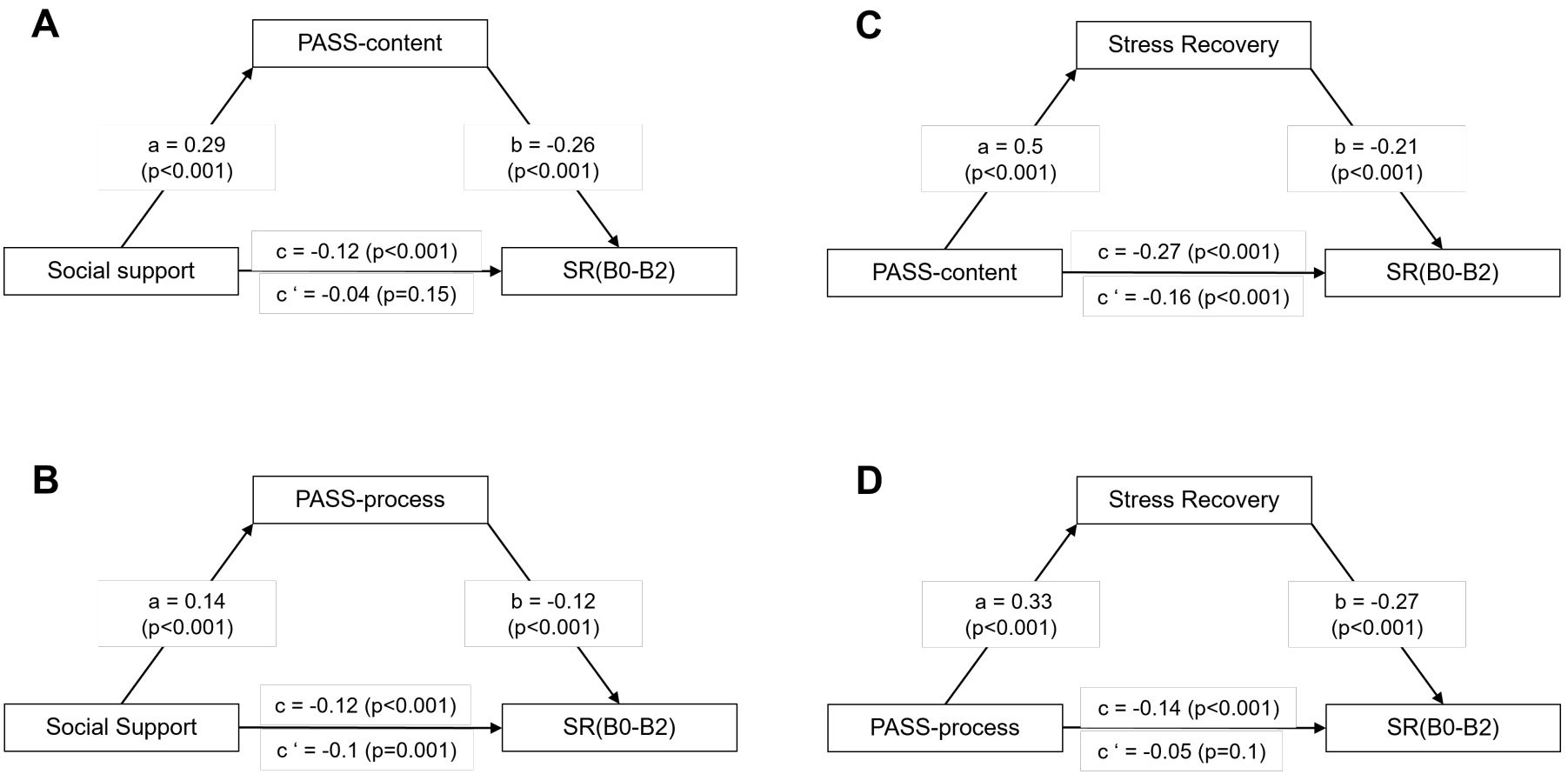


**Figure 3. LORA: Mediation analysis.** The effect of perceived social support(B0) on SR(B0-B2) was mediated by PASS-content(B0) (mean bootstrapped indirect effect ab: -0.07, 95% CI [-0.1,-0.05]) **(A)** as well as PASS-process(B0) (ab: -0.02, CI [-0.03,-0.01]) **(B)**. Perceived good stress recovery(B0) mediated the effect of PASS-content(B0) (ab: -0.1, CI [-0.15,-0.07]) **(C)** as well as PASS-process(B0) (ab: -0.09, CI [-0.12,-0.06]) **(D)** on SR(B0-B2). a, effect of predictor on mediator; b, effect of mediator on outcome; c, total effect of predictor on outcome; c’, direct effect of predictor on outcome removing the mediator.

Interventional sample: RESPOND-RCT Spain

The RESPOND-RCT Spain (Figure 4) was conducted in stressed healthcare workers in hospitals in the Madrid and Barcelona regions, with baseline assessments (T0) lasting from November 2021 to March 2022. During this period, there was a new peak of hospital admissions and patients in intensive care in Spain due to COVID-19[43] and a concomitant substantial disruption of normal working conditions[40]. 93% of participants were or had been directly involved in caring for COVID-19 patients, and 59% had been infected with the Corona virus[40]. Average T0 PHQ-ADS scores were 20.47 (sd=8.4). On this instrument, values above 20 indicate moderate levels of depression/anxiety[44]. 53% of participants scored above the recommended cut-off for depression (9 on the PHQ-9 subscale) and 58% above the cut-off for anxiety (9 on the GAD-7 subscale)[45,46]. This suggests substantial distress in the sample, in line with participants being pre-selected for a K10 value of ≥16. Groups did not differ on these characteristics (Supplementary Table S13). A detailed trial description and further sample characteristics can be found in the study protocol[36] and the publication of the primary analysis[40]. All secondary analyses reported in this paper were performed on the entire sample (intention to treat analyses), as specified in the study protocol[36]. In all analyses, we controlled for age, gender, and education at baseline (see Methods for details).

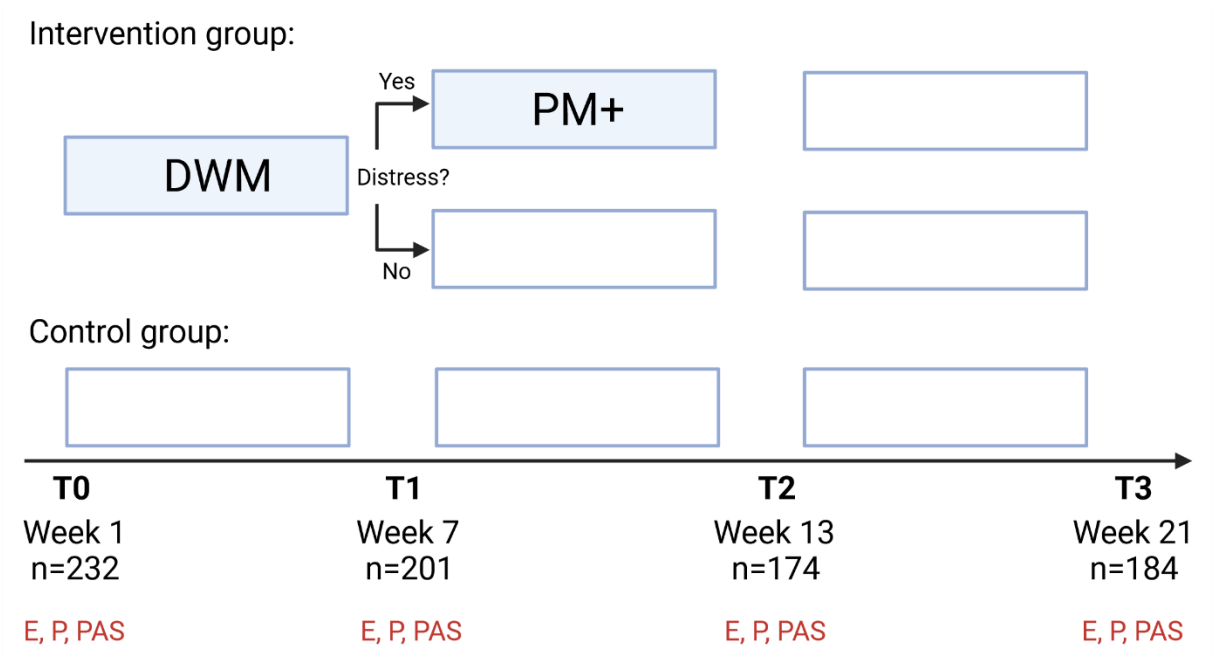


**Figure 4. RESPOND-RCT Spain: Design.** The trial sample (N=232) was predominantly female (n=200, 86%), with an average 37.5 years of age (sd=10.3) at baseline. Most participants had a university degree (n=192, 82%) and were nurses (n=130, 56%), physicians (n=50, 22%), or nursing technicians (n=29, 13%). The intervention group (top panel, N=115) took part in a stepped-care program consisting of Doing What Matters (DWM) and, if distress continued to be present (score ≥16 on the Kessler Psychological Distress Scale (K10)[47] five to seven days after DWM), in Problem Management + (PM+; n=84 or 75% of participants in the intervention group). The control group (N=117) received enhanced care as usual in the form of psychological first aid. Empty boxes illustrate no intervention. Stressor exposure (E), mental health problems (P), and PAS were assessed in all participants at four time points (T0 to T3). Stressor assessment used instruments adapted to the specific population and context in prior qualitative work[36,48], one list featuring three major life events and one list featuring six general, five pandemic-related, and four population-specific stressors (Supplementary Tables S11 and S12). Mental health assessment used the Patient Health Questionnaire-Anxiety and Depression Scale (PHQ-ADS)[44], a composite measure of anxiety (GAD-7) and depression (PHQ-9) symptoms. To limit participant burden, PAS assessment in the RESPOND trial was restricted to the PASS-content instrument, which had shown

stronger SR associations than PASS-process in MARP and LORA and has the advantage that it directly targets the element in appraisal (appraisal contents, or outcomes) that is hypothesized to eventually determine stress responses, rather than antecedent cognitive processes leading to these contents (as in PASS-process)[12]. Also, social support and stress recovery were not assessed. Figure adjusted from[40].

Over the trial, the most frequently reported life event was 'serious illness, accident or diagnosis of disease experienced by me or a close person' (reported by an average of 67.2 (sd=75.3) participants per time point). This life event was also rated as most burdensome (from 0 to 4: M=3.7, sd=0.8). The most frequently reported daily hassles were high demands/high workload/time pressure (reported by an average of 112.2 participants per time point (sd=38.2)), less physical activity than usual (M=79.7, sd=30.2), and difficulty combining social life with work (M=74.0, sd=28.3). Participants were not asked to report hassle severity.

The aggregated stressor exposure score E (see Methods) decreased over time (effect of time: B=-2.02, SE=0.22, p<0.001; Figure 5A, Supplementary Table S14). The interaction between intervention group and time (B=-0.77, SE=31, p=0.015) was significant, such that E decreased more in the intervention group (non-significant effect of group: B=-0.23, SE=1.02, p=0.819). This interaction effect may be explained by effects of the intervention on stressor perception and reporting or on stressor exposure (e.g., decreased risk taking, better problem solving, or better stressor avoidance). The effect highlights the need to control for exposure differences also in randomized trials.

As already described in the primary analysis[40], mental health problems P also decreased over time and more so in the intervention group (Figure 5B).

E explained 64.1% of variance in P across assessment time points and participants. Unlike E and P, SR did not show an effect of time (B=-0.037, SE=0.038, p=0.328; covariate-controlled) (Figure 5C). There was a significant group by time interaction (B=-0.15, SE=0.05, p=0.006), reflecting a reduction specifically in the intervention group (non-significant effect of group: B=0.13, SE=0.16, p=0.414). These findings can be interpreted as the intervention promoting resilience against the exacerbating effects of stressor exposure on internalizing symptomatology. For effect sizes, see Supplementary Table S15.

In congruence with MARP and LORA, baseline PASS-content(T0) scores prospectively and negatively predicted SR across T1 to T3 (B=-0.028, SE=0.010, p<0.001; covariate-controlled). There were no significant time or group effects (time: B=-0.04, SE=0.04, p=0.322; group: B=0.11, SE=0.16, p=0.508).

Importantly, the intervention affected PASS-content (Figure 5D). There was a significant group by time interaction (B=1.02, SE=0.24, p<0.001; covariate-controlled), such that PASS-content scores increased more over time in the intervention group (non-significant effects of group: B=-0.89, SE=0.91, p=0.330; and time: B=0.33, SE=0.17, p=0.054).

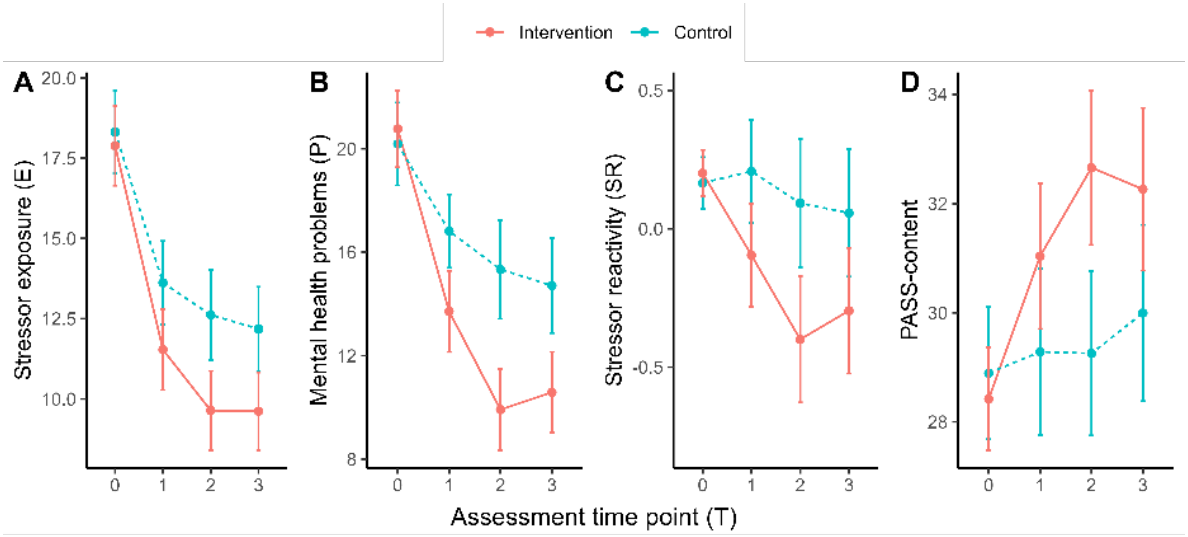


**Figure 5. RESPOND-RCT Spain: Results.** Estimated marginal means and 95% confidence intervals for stressor exposure (E) scores **(A)**, mental health problem (P) scores from the PHQ-ADS scale **(B)**, stressor reactivity (SR) scores **(C)**, and PASS-content scores **(D)** in the intervention and control groups. Changes in P have been reported elsewhere[40].

These results raise the possibility that intervention-induced increases in PAS mediate the beneficial intervention effects on SR. Post-hoc power analysis (Methods) showed a power of >0.9 for a sample larger than 220, indicating that the study was sufficiently powered to detect mediation.

We therefore conducted a planned prospective mediation analysis, estimating the effect that the intervention has on the mediator (PASS-content at post-intervention, T2) and the subsequent outcome (SR at follow-up, T3; cf. Figure 4). Analysis used the VanderWeele approach[49] and controlled for baseline (T0) age, gender, education, PASS-content, and SR. For details, see Methods.

The total effect (te) of the intervention on SR at T3 was -5.37 (95 % CI [-10.18, -0.28], p=0.042), and the total natural direct effect (nde) of the intervention on SR at T3 not mediated through PASS-content at T2 was -3.46 (CI [-8.30, 2.38]). This was not significant (p=0.280). The natural indirect effect (nie) was -2.31 (CI [-5.24, -0.85], p = 0.036), indicating that the effect of the intervention on SR at T3 was mediated through PASS-content at T2. The proportion mediated (pm) by PASS-content was 47% (0.47, CI [-1.35, 2.23]).

When only analyzing the complete cases (n=135; 63 in the intervention group and 72 in the control group), the estimated effects and their confidence intervals were similar (te=-7.49, CI [-12.98, -1.93], p=0.004; nde=-5.07, CI [-10.74,0.66], p=0.096; nie=-2.42, CI [-5.37, -0.038], p=0.046; pm=0.32, CI [0.001, 1.18]).

These results robustly support the hypothesis that PAS is partially responsible for the positive effect of the multi-component intervention on resilience.

**Discussion**

PASTOR relies on the assumption that stress results from the appraisal of a stimulus or situation as threatening one's goals or needs[12]. PASTOR further assumes that individuals exhibit style-like (relatively stable, but not entirely temporally-invariant) individual differences in the way they appraise potential threats. Individuals with a PAS typically avoid overestimating threat magnitude/cost (catastrophizing) and threat probability (pessimism) and underestimating their coping potential (helplessness). At the same time, they avoid very unrealistically positive estimates, which would equate to trivialization, blind optimism, and delusional over-confidence, respectively. Hence, their usual appraisals on key threat appraisal dimensions range from realistic to mildly positive values. As a result, these individuals are still able to produce stress responses as necessary to cope with challenges but also do not normally over-react and, hence, are less likely to unnecessarily consume resources and experience exhaustion, allostatic load effects, and eventually stress-related mental health problems. Their mild tendency to under-react prevents life in a continuous alarm mode and allows them more easily to rebuild resources and to expand their behavioral repertoire and life possibilities by learning from the encounter and exploration of new situations, which negative appraisers would avoid[12].

Testing PASTOR requires valid measurement of PAS. One important consideration in the development of PAS measurement instruments is that appraisals may be generated via a heterogeneous set of cognitive processes, from unconscious, non-verbal, and implicit to conscious, verbal, and explicit[12]. The PASS-process instrument that we first created during the COVID-19 pandemic to serve as a tool for large-scale online surveys aims at indexing conscious positive appraisal and reappraisal processes[15]. By its very nature, it cannot index unconscious processes. By contrast, the more recently validated PASS-content instrument focuses on the generated appraisals, that is, on how individuals typically think of stressful situations[19]. These appraisals may as well originate from unconscious mental operations that eventually surface as appraisal-thoughts. The instrument is therefore broader in scope than the PASS-process instrument, and it also has the advantage that it directly targets the assumed causal determinants of stress responses, i.e., the appraisals. Nevertheless, it also cannot inform about possible unconscious appraisals, which, too, may affect stress responding. This reliance on measures that are restricted to consciously accessible mental contents is a limitation of the present work. This limitation goes along with the known vulnerability of self-report instruments to reporting and memory biases[19]. In particular, healthy humans tend to uphold a stable and positive self-model and also to search for stability in their world-model, and this source of bias is likely to shape the way they think and communicate about internal or external threats to these important goals. This may have the ironic consequence that individuals who are more successful in protecting their self- and world-models by recurring to partly illusionary, positively biased stressor appraisals are probably also mentally healthier[19,50,51]. In this sense, it is also possible that the methodological biases inherent to our PAS instruments may not be a source of error but rather provide some key information on an important source of mental health. This may apply in particular to the PASS-content scale, high scores on which can be interpreted as reflecting a positive self-/world-perception[19].

Our results show that PAS - measured with either instrument, but more so with PASS-content – prospectively predicts low stressor reactivity over long time frames of more than three years. This is an important insight, since the initial studies with PASS-process had either tested association with SR scores derived from a single, concurrent time point (asking participants about their stressor exposure and changes in mental health in the past weeks[15,16]), or from short prospective intervals of five weeks[17] or six months[18]. Another insight from the available data is that PAS is a resilience factor across different populations: European adults[15,17], mental health practitioners from various

countries[16], Dutch Parkinson patients[18], German young adults (MARP), German adults (LORA), and Spanish health care workers (RESPOND-RCT Spain). (We also note that PASS-process was inversely related to internalizing symptoms and to the strength of symptom network connections in Dutch elderly persons during the pandemic[52].) This conclusion is still limited by the absence of data from non-European and from non-adult samples. A final insight is that PAS appears to protect against various types of stressors. Thus, of the five studies focusing on individuals confronted with the pandemic[15–18,36], two (the mental health practitioner study[16] and RESPOND-RCT Spain) used samples where the pandemic-related challenges stemmed at least in part from professional demands. The MARP and LORA assessments, on the other hand, were to a substantial extent performed before the pandemic, and especially the shorter early SR time frames (B0-B1, first 9 months post B0) were not or minimally influenced by this large-scale stressor. Our detailed analyses of the stressor exposure in these samples further substantiate that the participants experienced qualitatively different exposure. What the existing data cannot answer is whether the protective effects of PAS extend to different types of mental health problems, notably to symptoms beyond the internalizing spectrum (mainly anxiety and depression). An analysis of mental health problems specifically observed in mental health practitioners, featuring aspects of burnout and secondary traumatic stress, suggested PAS may be less protective against these impairments[16]. Protection against externalizing or psychotic symptoms has not been tested yet.

Our present data also showed that PAS is a relatively stable individual-differences factor, with ICCs above 0.7 in the case of our now preferred instrument, PASS-content. This raised the question whether PAS can change, as the original conceptualization of PAS as having plasticity and being modifiable by life experiences or interventions suggests[12]. We tried to answer this question intertwined with the question of whether PAS is a proximal resilience factor that integrates the effects of various other factors on resilience. The finding that PAS mediates effects of social support, now consistently observed in the four initial studies[15–18] as well as here in MARP and LORA, aligns with the idea in PASTOR that different kinds of beneficial life circumstances or experiences (as well as protective predispositions, skills, or behavioral styles) all promote resilience because they eventually bias appraisal towards more positive values. This led us to ask whether a broad psychosocial-behavioral intervention, combining various elements from traditional and more recent therapy approaches[36], would enhance PAS and this in turn would mediate the expected beneficial effects of the intervention on resilience. This was confirmed in the RESPOND-RCT, suggesting PAS is a key proximal resilience factor, stable but also malleable.

The randomized controlled design of that study and the clear hypothesis-driven nature of our analysis further allow us to forward the hypothesis that the influence of PAS on resilience was likely causal in the trial. This likely causal effect may well have been exerted by PAS optimizing stress reactions, as is indirectly indicated by the mediation of PAS effects on resilience via good self-perceived recovery from stressors, observed in the initial studies[15–17] as well as now in MARP and LORA.

Overall, our findings allow us to start painting a coherent mechanistic picture of resilience, whereby factors that promote a tendency to appraise stressors in a mildly unrealistically positive fashion lead to optimally regulated (fine-tuned, situation-appropriate) stress responses, and this in turn preserves bodily and cognitive capacities that are crucial for long-term mental functioning. One major challenge for future work will be to complement the existing self-report instruments for PAS with more objective, task-based measures. Another challenge will be to empirically compare and integrate PASTOR with theories emphasizing the role of flexible coping and emotion regulation for resilience (e.g., [53–58]). From the perspective of PASTOR, regulatory flexibility may be one aspect of optimized stress response regulation and depend on PAS[12,14].

Irrespective of further theoretical progress, our results highlight a promising avenue for promoting resilience, via boosting of PAS through more targeted interventions. This may involve positive mindset interventions[59], social-psychological interventions[60], or dedicated positive reappraisal[61,62] or bias modification[63] trainings. Such mechanistically specific resilience trainings may become an important tool in the global fight against stress-related disorders.

## Methods

All analyses were conducted using R (4.2.3)[64] and R studio (Version 2023.090)[65]. The following packages were used: cmaverse (0.1.0)[66], tidyverse (2.0.0)[67], psych (2.3.3)[68], lme4 (1.1-32)[69]. Code is available on: https://osf.io/d4exm/

### Observational discovery sample: MARP

#### Design

MARP is a multi-modal longitudinal observational study being conducted by the University Medical Center of Johannes Gutenberg University and the Leibniz Institute for Resilience Research in Mainz, Germany. At baseline (B0), MARP has included N=200 mentally healthy participants aged between 18 and 21 years. Participants were selected based on previous experience of stressful life events (a minimum of 3 before the age of 18). Exclusion criteria included current psychological or neurological disorder, taking psychoactive medication, and physical illness that affect mental health. Sampling was non-representative. Inclusion for B0 took place between July 2016 and March 2019. Participants gave their written and informed consent. Ethical approval was granted by Medical Board of Rhineland-Palatinate, Mainz, Germany. Participants received a reimbursement for their efforts.

The MARP design involves regular testing batteries (B0, B1, B2., ..) planned approximately 1.75 years apart as well as online assessments planned every three months (T1, T2, T3, …). Cf. Figure 1. The first online monitoring (T0) only serves to acquaint participants with the procedure and is not analyzed. The batteries consist of online questionnaires (in German) covering sociodemographic information, mental health measures, as well as lifestyle, psychosocial and psychological constructs. On-site testing, such as neuroimaging as well as biospecimen collection, is also conducted at each battery but is not the subject of this study. The three-monthly online assessments serve to regularly monitor mental health problems and stressor exposure (see Measures). For an overview and first methodological publications, see[20,70].

#### Data cleaning and preparation

A data freeze was performed November 11th 2022. In this data set, in some cases and particularly during the pandemic, the interval between battery administrations could be more or less than 21 months. If the interval between two battery administrations exceeded 21 months, more online monitorings than planned could take place. Also, the online monitorings planned concordant with the batteries (T7/B1, T14/B2, cf. Figure 1) were conducted separately from the corresponding battery assessments and could therefore take place before or after a battery. Finally, participants were allowed to miss online monitorings. As a result, the number of online monitorings between battery administrations varied between participants. See Table 3. No data was imputed. Of the 200 participants at inclusion, 132 participants could be included in the longitudinal analysis, since they provided the minimally accepted number of four completed online monitorings between B0 and B2. Their demographics did not significantly differ ($p<0.05$) from the full baseline sample on any of the variables given in Supplementary Table S1. For further details, see Supplementary Methods.

**Table 3. MARP: Descriptive statistics of number of online monitorings (starting with T1) and time intervals between battery administrations in the included sample (N=132).**

| | Number of online monitorings | | | | | Number of months | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | sd | Median | Min | Max | Mean | sd | Median | Min | Max |
| **B0 to B1** | 7.2 | 1.4 | 7 | 1 | 9 | 23.45 | 2.03 | 23.54 | 18.87 | 30.61 |
| **B1 to B2** | 6.8 | 1.8 | 7 | 1 | 11 | 20.72 | 2.66 | 20.48 | 15.88 | 29.62 |
| **B0 to B2** | 13.59 | 3.43 | 14 | 2 | 16 | 43.97 | 2.67 | 44.15 | 33.43 | 51.25 |

Measures

*Positive appraisal style (PAS).* PAS is assessed in each battery (B0, B1, …) with two recently developed scales that were validated in the MARP and LORA samples (reported in[19]). Firstly, the 14-item Perceived Positive Appraisal Style Scale, content-focused (PASS-content) (internal reliability: Cronbach's $\alpha$=0.87) measures the self-reported frequency with which someone produces thoughts that amount of positive appraisal, such as "I think that every difficult situation will end eventually", in stressful situations. Answers are scored on a 4-point Likert scale from 1 ("never") to 4 ("almost always"). A higher sum score (range 14 to 56) denotes more frequent positive appraisal thoughts, that is, a more positive appraisal tendency. Secondly, the 10-item Perceived Positive Appraisal Style Scale, process-focused (PASS-process) ($\alpha$=0.78) assesses the self-reported frequency of mental operations (cognitive strategies and tactics) that someone employs in stressful situations and that can generate positive appraisal contents. These cognitive processes include, for instance, acceptance ("I think that I have to accept the situation"), positive reframing ("I think that I can become a stronger person as a result of what has happened"), or distancing ("I try to look at the situation from an objective perspective"). Participants rate their use on a 5-point Likert scale from 1 ("(almost) never") to 5 ("(almost) always"). A higher sum score (range 10 to 50) signifies a more frequent use of such positive appraisal and reappraisal processes[19].

*Perceived social support.* The 14-item version of the perceived social support questionnaire by Fydrich et al.[71] ($\alpha$=0.94) is included in all batteries. Participants rate their agreement on a 5-point Likert scale from 1 to 5. A higher mean score denotes higher perceived social support.

*Perceived good stress recovery.* Perceived good stress recovery is assessed using the 6-item Brief Resilience Scale[72] ($\alpha$=0.8 to 0.91) in each battery. Respondents rate their agreement on a 5-point Likert scale from 1 to 5. A higher mean score denotes a higher self-perceived ability to bounce back.

*Mental health problems (P).* Mental health problems are captured at every assessment (batteries and online monitorings) with the 28-item General Health Questionnaire (GHQ-28)[41] ($\alpha$=0.9 to 0.95)[42], covering general internalizing mental health symptoms, including depressive and anxious symptoms. Participants assess their symptoms over the previous weeks, rating each item on a scale from 0 to 3. All items are then summed into a total score (range 0 to 84). Only the online monitoring data were analyzed here.

*Stressor exposure (E).* Stressors are assessed at every online monitoring (T0, T1, T2, …). This includes a list of 27 life events (macrostressors) adapted from Canli's Life Experience Questionnaire[73]. Participants report which life events occurred over the past three months and, if it occurred, rate its severity (5-point Likert scale, from 1 ("not at all burdensome") to 5 ("very burdensome")). To quantify life event exposure independent from severity, a sum count of the reported life events was calculated at each time point, as previously described[23]. Next to major events, the accumulation of daily hassles (daily stressors, microstressors) can also have a strong negative impact on mental

health[74,75]. Daily hassles are assessed with the Mainz Inventory of Microstressor[76], a comprehensive list of 58 commonly occurring microstressors. Each item is rated in two ways. First respondents indicate on how many days out of the past seven a stressor occurred. Second, participants rate the severity of a reported stressor on a 5-point Likert scale. To quantify daily hassles exposure independent from severity, a sum count of the number of days was calculated across all reported daily hassles at each time point[23]. A total E score aggregating life events and daily hassles exposure was then computed at each time point as the mean of the z-scored life events and daily hassles counts, following a predefined procedure[23].

Stressor reactivity (SR) score

The sample's normative stressor reactivity, that is the E-P relationship, was determined by regressing participants' average P scores of the first nine months (covering the first three online monitorings T1 to T3) onto their average E score of the same period, as predefined for all analyses of the data set while the study is still ongoing[23]. The relationship was linear and was not improved by adding a quadratic term (F=0.025, p=0.876). For each outcome interval of interest (e.g., B0 to B1; cf. Table 1), the average E and P scores in that interval were then used to calculate individual SR scores as the residuals to the normative E-P line. Required minimum numbers of completed online monitorings per outcome interval were four for B0-B2, three for both B0-B1 and B1-B2, and two for the nine months after a battery. A negative SR score indicates that this individual displayed less mental health symptoms than others with similar stressor exposure, whereas a positive SR score indicates a higher reactivity than the sample[23]. To assess the variance of P explained by E across all time points, a separate linear mixed model with random slope and intercept was fitted across all time points and participants. Variance explained ($R^2$) was computed following the method for mixed models outlined by[77,78].

Analyses

*Prediction analyses.* For SR prediction (Table 1 and Supplementary Tables S3-S5), separate multivariate regression analyses were calculated per predictor and outcome interval. Covariate selection followed the procedures used in the initial studies[15–17]: age and sex at baseline (B0) were always included; further baseline covariates were selected based on p values <0.2 in univariate regression models on SR(B0-B2) (see Supplementary Table S16). The only deviation from this decision-making procedure was that we also included the number of online monitorings in the B0-B2 interval for analyses with SR(B0-B2), given participants could deviate strongly in this variable (see Table 3).

*Mediation analyses.* Prospective mediation analyses were based on linear models. The indirect effect was estimated as a mean bootstrapped effect with bootstrapped confidence intervals. Power analyses following Schoemann et al.[79] indicated all mediation analyses were underpowered (see Table 4).

**Table 4. MARP: Power calculations for mediation analyses.** Monte Carlo power analysis for an indirect effect >0 by Schoemann et al.[79] (1000 repetitions, 20000 Monte Carlo draws per repetition).

| X | M | Y | N for power >0.8 | Power at 132 (sample size) |
|---|---|---|---|---|
| Social support | PASS-content | SR(B0-B2) | 190 | 0.79 |
| Social support | PASS-process | SR(B0-B2) | 645 | 0.61 |
| PASS-content | Stress recovery | SR(B0-B2) | 325 | 0.15 |
| PASS-process | Stress recovery | SR(B0-B2) | 190 | 0.85 |

Observational replication sample: LORA

Design

LORA (LOngitudinal Resilience Assessment) is a multi-modal longitudinal observational study being conducted by the University Medical Center of Johannes Gutenberg University Mainz, Germany, and the University Hospital of Goethe University in Frankfurt am Main, Germany, since 2017. At baseline (B0), LORA included mentally healthy participants in the Rhine-Main area in Germany. Inclusion criteria included: being between 18 to 50 years old at study entry, proficiency in German, no lifetime diagnoses of chronic mental disorders such as schizophrenia or bipolar disorder, no organic mental disorders, substance dependence syndromes (other than nicotine), and no other current severe axis I disorder or current severe medical conditions. Inclusion took place between October 2016 and July 2019 via convenience sampling and was not representative. Participants gave written informed consent. Ethical approval was granted by Medical Board of Rhineland-Palatinate, Mainz, and the Ethics Committee of the Department of Medicine at the Goethe University Frankfurt.

The LORA design involves regular testing batteries (B0, B1, B2, ...) planned approximately 1.5 years apart as well as online assessments planned every three months (T1, T2, T3, …). Cf. Figure 1. The first online monitoring (T0) only serves to acquaint participants with the procedure and is not analyzed. The batteries consist of online questionnaires (in German) covering sociodemographic information, mental health measures, as well as lifestyle, psychosocial and psychological constructs. On-site testing, such as behavioral testing as well as biospecimen collection, is also conducted at each battery but is not the subject of this study. The three-monthly online assessments serve to regularly monitor mental health problems and stressor exposure (see Measures). For a study protocol and detailed sample characterization, see[76].

Data cleaning and preparation

Data collected up to April 2022 were included in these analyses. Unlike in MARP, the design of the study did not allow for individual variation in the number of scheduled online monitorings between battery administrations. Therefore, all participants had a possible maximum of five online monitorings between B0 and B1 and between B1 and B2. Only participants providing the minimum number of completed online montorings, defined as in MARP, were analyzed (1034 out of the 1191 included participants). Their demographics did not significantly differ ($p<0.05$) from the full baseline sample on any of the variables given in Supplementary Table S6.

Measures and analyses

All measures were as in MARP, with the exception that the severity of daily hassles and life events were rated from 0 to 4. All analyses were analogous, with the exception that the number of online monitorings was not included as a covariate (see Supplementary Table S17 for covariate selection). For the mediation analyses, we concluded that they were sufficiently powered, based on the power calculations in MARP (Table 4).

Interventional sample: RESPOND-RCT Spain

Design

Recruitment of participants lasted from November 3, 2021, to March 31, 2022. The follow-up period concluded August 21, 2022. The target population of the original study were healthcare workers who reported psychological distress. Inclusion criteria were: being employed by the Department of Health

in Madrid or Catalunya, scoring >= 16 on the Kessler Psychological Distress Scale (K10), and literacy in Spanish or Catalan. Persons who would require immediate hospitalization, had a severe mental disorder, severe cognitive impairment, were at risk of suicide or harm of self or others, and those who initiated or changed pharmacotherapy or psychological treatment in the past eight weeks were excluded from participation.

The stepped-care intervention consisted of Doing What Matters (DWM) and Problem Management Plus (PM+). Each intervention was delivered over 5 to 6 weeks. DWM is a guided self-help intervention. Material was made available online and a helper would provide phone-based or message-based support on a weekly basis. Participants who scored >= 16 on the K10 5 to 7 days after DWM would step up to PM+. PM+ consisted of online group sessions of 60 minutes. The control group received enhanced care as usual (eCAU), which consisted of psychological first aid[36]. Outcomes, covariates, and the mediator were measured at baseline (T0) and three assessment points (T1 to T3). See Figure 4. The full study protocol[36] and the results of the primary analysis (outcome evaluation)[40] are available elsewhere.

Measures

*Positive appraisal style (PAS).* PAS was assessed using a preliminary version of the Perceived Positive Appraisal Scale Style, content-focused (PASS-content)[19]. The published version has 14 items, whereas the version used in this trial has 12 items and a sum score range from 12 to 48. The items "I tend to see things rather optimistically" (Item 6) and "I think life is wonderful after all" (Item 9) are missing in this version. The correlation between the 14-time and the 12-item versions in LORA is 0.99, indicating sufficient overlap.

*Mental health problems (P).* The 16-item Patient Health Questionnaire-Anxiety and Depression Scale (PHQ-ADS)[44] was used to assess mental health. The sum score ranges from 0 to 48.

*Stressor exposure (E).* Stressor exposure was measured by a stressor list that has been adapted for this sample, as described in preparatory qualitative work[48] and the study protocol[36]. Briefly, life events were adapted from the list of life events used in the first study on PAS during the COVID-19 pandemic[15] (see Supplementary Table S11). Daily hassles were based on the Mainz Inventory of Microstressors[76], used in MARP and LORA, and the stressor list used in above COVID-19 study[15]. The most frequently reported items in the LORA sample and the COVID-19 study were considered for inclusion and judged based on their relevance to the sample. Additionally, new items were created based on qualitative interviews with healthcare workers who identified relevant and frequent stressors specific to the sample. The final list included three life events, five COVID-19-related daily hassles, six general daily hassles, and four population-specific daily hassles (see Supplementary Table S12). Life events were rated from 0 to 4, indicating the severity of this event from "This situation did not happen" to "Severe impact". The life events were dichotomized to indicate whether they occurred or not (maximum sum score: 3). The frequency of the 15 daily hassles over the past two weeks was rated on a Likert-scale from 0 to 3 ("did not happen/almost never", "sometimes", "often", "(nearly) every day"), such that a maximum sum score would be 45. A total E score was computed as the sum of dichotomized life events and daily hassles at each time point. This way of scoring stressor exposure explained more variance in P (see below) than averaging the z-scores of life events and daily hassles (E scoring procedure for MARP and LORA). Participants reported a mean stressor load E of 13.50 (sd=7.02) out of a possible 48 over all time points. (See Supplementary Table S14 for details on stressor exposure.)

Stressor reactivity (SR) score

The normative E-P relationship was calculated by fitting a mixed linear regression model of P against E across the entire sample and all time points. Adding a quadratic term did not improve model fit significantly ($\chi$=1.28 (df=1), p=0.259). A random intercept and slope were added to the model. Individual SR scores were then calculated as the residuals at each time point to the E-P line. Variance explained ($R^2$) was calculated following the approach by Nakagawa[78].

Analyses

*Intervention effects*. Analyses of intervention effects on E, P, SR, and PASS-content followed the study protocol[36]. For all effects estimations, we used an intention-to-treat (ITT) approach considering T3 (follow-up) as the primary endpoint. Each effect was tested in a linear mixed model that included participant as random effect and covariates as fixed effects, as well as a time, group, and time by group effects. Covariate selection is not detailed in the study protocol; for consistency with MARP and LORA, we used the same covariate selection procedure as there (see above and Supplementary Table S18). The study protocol specifies that the analysis of the primary outcome (PHQ-ADS, that is, P, as already reported in the primary analysis[40]) and of all secondary outcomes (that is, here, SR) should use baseline (T0) values of the given outcome as covariate (one baseline-adjusted model and one fully adjusted model including also other covariates). For consistency with the analyses of E and PASS-content effects, the P and SR analyses reported in the main text and Figure 5 do not use baseline adjustment, but only adjust for the other covariates. Baseline-adjusted results are given in Supplementary Table S15."

*Prediction analysis (association of baseline PAS with SR).* To test the effect of the baseline (T0) PASS-content score on SR, we computed a linear mixed model with a random effect for time and a nested random intercept for group and participant. This reflects that participants within a group might be more similar to each other and that they can only belong to one randomization group. Covariates (age, gender, education) were included as fixed effects. This analysis was not prespecified.

*Mediation analyses.* Post-hoc power analyses were conducted utilizing the shiny extension by[79]. Results indicated adequate power at sample sizes of >190. See Table 5.

**Table 5. RESPOND-RCT Spain: Power calculation for causal mediation analysis.** Monte Carlo power analysis for an indirect effect >0 by Schoemann et al.[79] (1000 repetitions, 20000 Monte Carlo draws per repetition).

| N for power >0.8 | N for power >0.9 | Power at n=135 (complete cases) |
|---|---|---|
| 170 | 210 | 0.69 |

The study protocol specifies that we should investigate mediation of the intervention effect on SR by PASS-content, but does not prescribe a specific method. Our main analyses used the VanderWeele approach (mediation based on potential outcomes)[49] and were performed with five imputed datasets using direct counterfactual imputation estimation. Results are presented in additive scale. We fit two regression models, the intervention-outcome model and the mediator-outcome model[80,81]. The VanderWeele approach allows for estimating the effect of the intervention mediated through PASS-content(T2) by comparing the potential outcomes: (i) the observed intervention condition and (ii) the potential (and unobservable) outcome of an intervention condition in which the intervention's effect on SR(T3) through PASS-content(T2) is blocked[82]. See Figure 6.

Here, natural effects (nde) are the effects of the intervention on the outcome (SR) if the mediator (PASS-content) is allowed to arise naturally and is not set at a specific value. The nde is the effect the intervention would have if it did not produce changes in PASS-content. nde represents the difference

between the two potential outcomes. The first potential outcome is the risk of higher SR if every participant received the intervention, and their PASS-content score would be as if they had not received it. The second (observed) potential outcome is the risk of higher SR if every participant received the intervention and their PASS-content score would be the value that it would take if they had received the intervention. Therefore, nde indicates how SR changes if the intervention's effect on SR through PASS-content is blocked[83,84]. The natural indirect effect (nie) compares two potential outcomes. The first and observed outcome would be the SR scores if every participant were exposed to the interventions. The second potential outcome would be SR scores if every participant received the DWM and PM+, but PASS-content would remain as if they had not received the interventions.

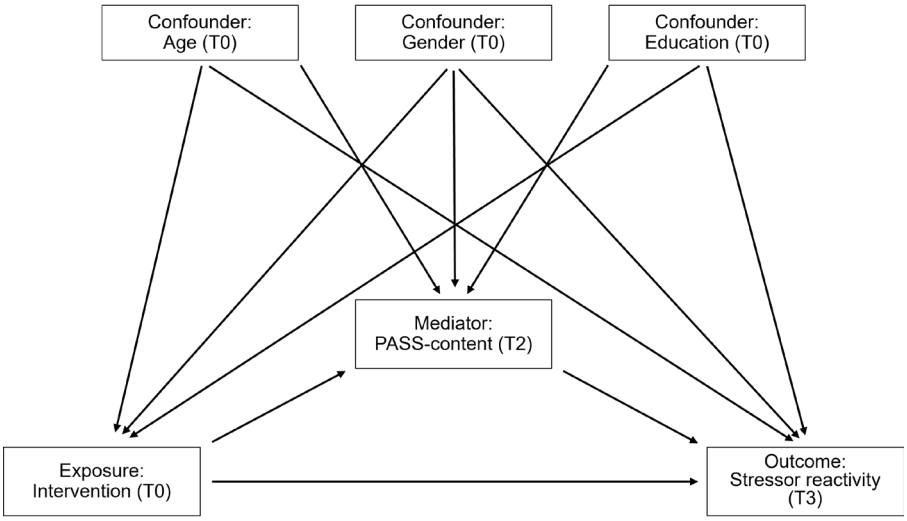


**Figure 6. RESPOND-RCT Spain: Directed acyclic graph showing the hypothetical causal pathways.**

Age, gender, and education level as well as SR and PAS at baseline (T0) were included as covariates. The main results presented include causal effect estimation based on counterfactual imputation of 10 datasets. Further sensitivity analyses were computed, including models allowing for exposure-mediator interaction and using weight-based estimation, rather than regression-based estimation. For the ease of interpretation, these are not reported in the main text, as they all rendered similar confidence intervals. For the comparison of different models, see Supplementary Table S19. The SR scores were scaled prior to the effect estimation to take values from 0 to a 100, so that the difference scale can be interpreted.

We report total effect of the intervention, the natural direct effect (nde), the natural indirect effect (nie) and the proportion mediated (pm). The nde is the effect the intervention would have if it did not produce changes in PAS[83,84]. The nie is the effect of the intervention through PAS. For both nde and nie, a pure and a total effect is estimated, reflecting which of the effects absorbs a potential interaction between the mediator and the group. We report the pure indirect effect and the total direct effect.

**Author contributions**

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**Conflicts of interest**

RK has received advisory honoraria from JoyVentures, Herzlia, Israel. The rest of the authors declare no conflict of interest.

**Data availability**

Anonymized data are available on: https://osf.io/d4exm/. In order to achieve anonymization in accordance with EU GDPR and participant consent, all demographic information has been removed and only sum scores of other variables have been made available.

**Code availability**

The analytic code is available on https://osf.io/d4exm/.

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**References**


1. Kilpatrick, D. G. *et al.* National estimates of exposure to traumatic events and PTSD prevalence using DSM-IV and DSM-5 criteria. *J Trauma Stress* **26**, 537–547 (2013).
2. Mazure, C. M. Life Stressors as Risk Factors in Depression. *Clinical Psychology: Science and Practice* **5**, 291–313 (1998).
3. McLaughlin, K. A., Conron, K. J., Koenen, K. C. & Gilman, S. E. Childhood adversity, adult stressful life events, and risk of past-year psychiatric disorder: a test of the stress sensitization hypothesis in a population-based sample of adults. *Psychol Med* **40**, 1647–1658 (2010).
4. Tracy, M., Morgenstern, H., Zivin, K., Aiello, A. E. & Galea, S. Traumatic event exposure and depression severity over time: results from a prospective cohort study in an urban area. *Soc Psychiatry Psychiatr Epidemiol* **49**, 1769–1782 (2014).
5. Kalisch, R. *et al.* The resilience framework as a strategy to combat stress-related disorders. *Nat Hum Behav* **1**, 784–790 (2017).
6. GBD 2019 Mental Disorders Collaborators. Global, regional, and national burden of 12 mental disorders in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet Psychiatry* **9**, 137–150 (2022).
7. Schäfer, S. K., Kunzler, A. M., Kalisch, R., Tüscher, O. & Lieb, K. Trajectories of resilience and mental distress to global major disruptions. *Trends Cogn Sci* **26**, 1171–1189 (2022).
8. Arnold, M. B. *Human Emotion and Action*. (Academic Press, 1969).
9. Frijda, N. H. The place of appraisal in emotion. *Cognition and Emotion* **7**, 357 (1993).
10. Lazarus, R. S. & Folkman, S. *Stress, Appraisal and Coping*. (Springer, New York, 1984).
11. Scherer, K. R. Appraisal considered as a process of multilevel sequential checking. in *Appraisal processes in emotion: theory, methods, research* (eds. Scherer, K. R., Schorr, A. & Johnstone, T.) 92–120 (Oxford University Press, NY, 2001).
12. Kalisch, R., Müller, M. B. & Tüscher, O. A conceptual framework for the neurobiological study of resilience. *Behav Brain Sci* **38**, e92 (2015).
13. Haehner, P. *et al.* The relationship between the perception of major life events and depression: A systematic scoping review and meta-analysis. *J Affect Disord* **349**, 145–157 (2024).
14. Kalisch, R., Russo, S. J. & Müller, M. B. Neurobiology and systems biology of stress resilience. *Physiological Reviews* (2024) doi:10.1152/physrev.00042.2023.
15. Veer, I. M. *et al.* Psycho-social factors associated with mental resilience in the Corona lockdown. *Transl Psychiatry* **11**, 67 (2021).
16. Zerban, M. *et al.* What helps the helpers? Resilience and risk factors for general and profession-specific mental health problems in psychotherapists during the COVID-19 pandemic. *Front Psychol* **14**, 1272199 (2023).
17. Bögemann, S. A. *et al.* Psychological Resilience Factors and Their Association With Weekly Stressor Reactivity During the COVID-19 Outbreak in Europe: Prospective Longitudinal Study. *JMIR Ment Health* **10**, e46518 (2023).
18. van der Heide, A. *et al.* Predictors of stress resilience in Parkinson's disease and associations with symptom progression. *NPJ Parkinsons Dis* **10**, 81 (2024).
19. Petri-Romão, P. *et al.* Self-report assessment of Positive Appraisal Style (PAS): Development of a process-focused and a content-focused questionnaire for use in mental health and resilience research. *PLoS One* **19**, e0295562 (2024).
20. Kampa, M. *et al.* A Combined Behavioral and Neuroimaging Battery to Test Positive Appraisal Style Theory of Resilience in Longitudinal Studies. *bioRxiv* (2018) doi:doi: https://doi.org/10.1101/470435.
21. Kampa, M. *et al.* Replication of fMRI group activations in the neuroimaging battery for the Mainz Resilience Project (MARP). *Neuroimage* **204**, 116223 (2020).
22. Chmitorz, A. *et al.* Longitudinal determination of resilience in humans to identify mechanisms of resilience to modern-life stressors: the longitudinal resilience assessment (LORA) study. *Eur Arch Psychiatry Clin Neurosci* **271**, 1035–1051 (2021).

23. Kalisch, R. *et al.* The Frequent Stressor and Mental Health Monitoring-Paradigm: A Proposal for the Operationalization and Measurement of Resilience and the Identification of Resilience Processes in Longitudinal Observational Studies. *Frontiers in Psychology* **12**, (2021).
24. Bowes, L., Maughan, B., Caspi, A., Moffitt, T. E. & Arseneault, L. Families promote emotional and behavioural resilience to bullying: evidence of an environmental effect. *J Child Psychol Psychiatry* **51**, 809–817 (2010).
25. Miller-Lewis, L. R., Searle, A. K., Sawyer, M. G., Baghurst, P. A. & Hedley, D. Resource factors for mental health resilience in early childhood: An analysis with multiple methodologies. *Child Adolesc Psychiatry Ment Health* **7**, 6 (2013).
26. Amstadter, A. B., Myers, J. M. & Kendler, K. S. Psychiatric resilience: longitudinal twin study. *Br J Psychiatry* **205**, 275–280 (2014).
27. van Harmelen, A.-L. *et al.* Adolescent friendships predict later resilient functioning across psychosocial domains in a healthy community cohort. *Psychol Med* **47**, 2312–2322 (2017).
28. Cornwell, H. *et al.* Identifying structural brain markers of resilience to adversity in young people using voxel-based morphometry. *Development and Psychopathology* **35**, 2302–2314 (2023).
29. Cahill, S., Hager, R. & Chandola, T. The validity of the residuals approach to measuring resilience to adverse childhood experiences. *Child Adolesc Psychiatry Ment Health* **16**, 18 (2022).
30. Lowe, S. R. *et al.* Are Women Less Psychologically Resilient Than Men? Background Stressors Underlying Gender Differences in Reports of Stress-Related Psychological Sequelae. *J Clin Psychiatry* **83**, 21br14098 (2021).
31. Kalisch, R. & Kampa, M. Stressor appraisal as an explanation for the influence of extra-individual factors on psychological resilience. in *Multisystemic Resilience: Adaptation and Transformation in Contexts of Change* (Oxford University Press, 2021).
32. Fritz, J., de Graaff, A. M., Caisley, H., van Harmelen, A.-L. & Wilkinson, P. O. A Systematic Review of Amenable Resilience Factors That Moderate and/or Mediate the Relationship Between Childhood Adversity and Mental Health in Young People. *Front Psychiatry* **9**, 230 (2018).
33. Bonanno, G. A., Romero, S. A. & Klein, S. I. The Temporal Elements of Psychological Resilience: An Integrative Framework for the Study of Individuals, Families, and Communities. *Psychological Inquiry* **26**, 139–169 (2015).
34. Mancini, A. D. & Bonanno, G. A. Predictors and Parameters of Resilience to Loss: Toward an Individual Differences Model. *Journal of Personality* **77**, 1805–1832 (2009).
35. Sullivan, C. & Infurna, F. J. The multidimensional nature of social support and engagement in contributing to adjustment following spousal loss. *Aging Ment Health* **24**, 857–869 (2020).
36. Mediavilla, R. *et al.* Effectiveness of a stepped-care programme of internet-based psychological interventions for healthcare workers with psychological distress: Study protocol for the RESPOND healthcare workers randomised controlled trial. *DIGITAL HEALTH* **8**, 20552076221129084 (2022).
37. Manchia, M. *et al.* The impact of the prolonged COVID-19 pandemic on stress resilience and mental health: A critical review across waves. *Eur Neuropsychopharmacol* **55**, 22–83 (2022).
38. Epping-Jordan, J. E. *et al.* Self-Help Plus (SH+): a new WHO stress management package. *World Psychiatry* **15**, 295–296 (2016).
39. Dawson, K. S. *et al.* Problem Management Plus (PM+): a WHO transdiagnostic psychological intervention for common mental health problems. *World Psychiatry* **14**, 354–357 (2015).
40. Mediavilla, R. *et al.* Effectiveness of a mental health stepped-care programme for healthcare workers with psychological distress in crisis settings: a multicentre randomised controlled trial. *BMJ Ment Health* **26**, (2023).
41. Goldberg, D. P. & Hillier, V. F. A scaled version of the General Health Questionnaire. *Psychol Med* **9**, 139–145 (1979).
42. Sterling, M. General Health Questionnaire - 28 (GHQ-28). *J Physiother* **57**, 259 (2011).
43. WHO Coronavirus Disease (COVID-19) Dashboard. in *Bangladesh Physiotherapy Journal* vol. 10 (2020).

44. Kroenke, K. *et al.* Patient Health Questionnaire Anxiety and Depression Scale: Initial Validation in Three Clinical Trials. *Psychosomatic Medicine* **78**, 716 (2016).
45. García-Campayo, J. *et al.* Cultural adaptation into Spanish of the generalized anxiety disorder-7 (GAD-7) scale as a screening tool. *Health Qual Life Outcomes* **8**, 8 (2010).
46. Muñoz-Navarro, R. *et al.* Utility of the PHQ-9 to identify major depressive disorder in adult patients in Spanish primary care centres. *BMC Psychiatry* **17**, 291 (2017).
47. Kessler, R. & Mroczek, D. Final Versions of our Non-Specific Psychological Distress Scale. in (1994).
48. Mediavilla, R. *et al.* Mental health problems and needs of frontline healthcare workers during the COVID-19 pandemic in Spain: A qualitative analysis. *Front Public Health* **10**, 956403 (2022).
49. VanderWeele, T. J. Mediation Analysis: A Practitioner's Guide. *Annual Review of Public Health* **37**, 17–32 (2016).
50. Sharot, T. & Garrett, N. Forming Beliefs: Why Valence Matters. *Trends Cogn Sci* **20**, 25–33 (2016).
51. Taylor, S. E. & Brown, J. D. Illusion and well-being: A social psychological perspective on mental health. *Psychological Bulletin* **103**, 193–210 (1988).
52. Resilience Among Older Individuals in the Face of Adversity: How Demographic and Trait Factors Affect Mental-Health Constructs and Their Temporal Dynamics - Lotte P. Brinkhof, Monique Chambon, K. Richard Ridderinkhof, Frenk van Harreveld, Jaap M. J. Murre, Harm J. Krugers, Sanne de Wit, 2023. https://journals.sagepub.com/doi/10.1177/21677026231190294.
53. Sheppes, G., Suri, G. & Gross, J. J. Emotion regulation and psychopathology. *Annu Rev Clin Psychol* **11**, 379–405 (2015).
54. Aldao, A., Sheppes, G. & Gross, J. J. Emotion Regulation Flexibility. *Cogn Ther Res* **39**, 263–278 (2015).
55. Bonanno, G. A., Chen, S., Bagrodia, R. & Galatzer-Levy, I. R. Resilience and Disaster: Flexible Adaptation in the Face of Uncertain Threat. *Annu Rev Psychol* **75**, 573–599 (2024).
56. Cheng, C., Lau, H.-P. B. & Chan, M.-P. S. Coping flexibility and psychological adjustment to stressful life changes: a meta-analytic review. *Psychol Bull* **140**, 1582–1607 (2014).
57. Roelofs, K., Bramson, B. & Toni, I. A neurocognitive theory of flexible emotion control: The role of the lateral frontal pole in emotion regulation. *Annals of the New York Academy of Sciences* **1525**, 28–40 (2023).
58. Troy, A. S. *et al.* Psychological Resilience: An Affect-Regulation Framework. *Annu Rev Psychol* **74**, 547–576 (2023).
59. Yeager, D. S. *et al.* A synergistic mindsets intervention protects adolescents from stress. *Nature* **607**, 512–520 (2022).
60. Brummelman, E. & Walton, G. M. 'If you want to understand something, try to change it': Social-psychological interventions to cultivate resilience. *Behav Brain Sci* **38**, e96 (2015).
61. Marciniak, M. A. *et al.* ReApp – an mHealth app increasing reappraisal: results from two randomized controlled trials. (2023) doi:10.31234/osf.io/u4f5e.
62. Wang, B., Miao, Z., Wan, B. & Xu, X. Prevention for post-traumatic stress disorder after the COVID-19 epidemic: Lessons from the SARS epidemic. *Stress and Brain* **1**, 1–10 (2021).
63. Woud, M. L. *et al.* The Effects of Modifying Dysfunctional Appraisals in Posttraumatic Stress Disorder Using a Form of Cognitive Bias Modification: Results of a Randomized Controlled Trial in an Inpatient Setting. *Psychother Psychosom* **90**, 386–402 (2021).
64. R Core Team. *R: A Language and Environment for Statistical Computing*. (R Foundation for Statistical Computing, Vienna, Austria, 2023).
65. Posit team. *RStudio: Integrated Development Environment for R*. (Posit Software, PBC, Boston, MA, 2023).
66. Shi, B., Choirat, C., Coull, B. A., VanderWeele, T. J. & Valeri, L. CMAverse: A Suite of Functions for Reproducible Causal Mediation Analyses. *Epidemiology* **32**, e20–e22 (2021).
67. Wickham, H. *et al.* Welcome to the Tidyverse. *Journal of Open Source Software* **4**, 1686 (2019).
68. Revelle, W. *Psych: Procedures for Psychological, Psychometric and Personality Research.* (Northwestern University, 2021).

69. Bates, D., Mächler, M., Bolker, B. & Walker, S. Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software* **67**, 1–48 (2015).
70. Kampa, M. *et al.* Replication of fMRI group activations in the neuroimaging battery for the Mainz Resilience Project (MARP). *Neuroimage* **204**, 116223 (2020).
71. Fydrich, T., Sommer, G., Tydecks, S. & Brähler, E. Fragebogen zur sozialen Unterstützung (F-SozU): Normierung der Kurzform (K-14). [Social Support Questionnaire (F-SozU): Standardization of short form (K-14).]. *Zeitschrift für Medizinische Psychologie* **18**, 43–48 (2009).
72. Smith, B. W. *et al.* The brief resilience scale: Assessing the ability to bounce back. *Int. J. Behav. Med.* **15**, 194–200 (2008).
73. Canli, T. *et al.* Neural correlates of epigenesis. *Proceedings of the National Academy of Sciences* **103**, 16033–16038 (2006).
74. Serido, J., Almeida, D. M. & Wethington, E. Chronic stressors and daily hassles: unique and interactive relationships with psychological distress. *J Health Soc Behav* **45**, 17–33 (2004).
75. Infurna, F. J., Staben, O. E., Gardner, M. J., Grimm, K. J. & Luthar, S. S. The accumulation of adversity in midlife: Effects on depressive symptoms, life satisfaction, and character strengths. *Psychol Aging* **38**, 230–246 (2023).
76. Chmitorz, A. *et al.* Assessment of Microstressors in Adults: Questionnaire Development and Ecological Validation of the Mainz Inventory of Microstressors. *JMIR Ment Health* **7**, e14566 (2020).
77. Nakagawa, S., Johnson, P. C. D. & Schielzeth, H. The coefficient of determination R2 and intra-class correlation coefficient from generalized linear mixed-effects models revisited and expanded. *Journal of The Royal Society Interface* **14**, 20170213 (2017).
78. Nakagawa, S. & Schielzeth, H. A general and simple method for obtaining R2 from generalized linear mixed-effects models. *Methods in Ecology and Evolution* **4**, 133–142 (2013).
79. Schoemann, A. M., Boulton, A. J. & Short, S. D. Determining Power and Sample Size for Simple and Complex Mediation Models. *Social Psychological and Personality Science* **8**, 379–386 (2017).
80. Valeri, L. & Vanderweele, T. J. Mediation analysis allowing for exposure-mediator interactions and causal interpretation: theoretical assumptions and implementation with SAS and SPSS macros. *Psychol Methods* **18**, 137–150 (2013).
81. VanderWeele, T. J. & Vansteelandt, S. Mediation Analysis with Multiple Mediators. *Epidemiol Methods* **2**, 95–115 (2014).
82. Nguyen, T. Q., Schmid, I. & Stuart, E. A. Clarifying causal mediation analysis for the applied researcher: Defining effects based on what we want to learn. *Psychological methods* **26**, 255–271 (2021).
83. Hafeman, D. M. & Schwartz, S. Opening the Black Box: a motivation for the assessment of mediation. *Int J Epidemiol* **38**, 838–845 (2009).
84. Vanderweele, T. J. *Explanation in Causal Inference: Methods for Mediation and Interaction*. xvi, 706 (Oxford University Press, New York, NY, US, 2015).