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Pre-pandemic autonomic nervous system activity predicts mood regulation expectancies during COVID-19 in Israel

Ilanit Gordon[1,2] | **Danny Horesh**[1,3] | **Nir Milstein**[1] | **Alon Tomashin**[1,2] | **Oded Mayo**[1] | **Adi Korisky**[2]

[1]Department of Psychology, Bar-Ilan University, Ramat-Gan, Israel

[2]The Gonda Multidisciplinary Brain Research Center, Bar Ilan University, Ramat-Gan, Israel

[3]Department of Psychiatry, Grossman School of Medicine, New York University, New York, NY, USA

Correspondence

Ilanit Gordon, Department of Psychology and The Gonda Brain Research Center, Bar-Ilan University, Ramat-Gan 5290002, Israel.

Email: ilanit.gordon@biu.ac.il

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Abstract

Despite the unfolding impact of the COVID-19 pandemic on psychological well-being, there is a lack of prospective studies that target physiological markers of distress. There is a need to examine physiological predictors from the pre-pandemic period to identify and treat individuals at-risk. In this study, our aim was to use pre-pandemic markers of autonomic nervous system (ANS) parasympathetic and sympathetic regulation to predict individuals' psychological well-being during the crisis. We also assessed the role of mood regulation expectancies as a mediator of the association between pre-pandemic physiological measures and COVID-related well-being. In May to June 2020, 185 Israeli adults completed online questionnaires assessing their mood regulation expectancies since COVID-19 began, and their current well-being. These individuals had participated in lab studies 1.5–3 years prior to this assessment, where their physiological measures were taken, including respiratory sinus arrhythmia (RSA) and skin conductance level (SCL). RSA was positively related to mood regulation expectancies during COVID-19 ($b = 3.46$, 95% CI [0.84, 6.05]). Mood regulation expectancies, in turn, positively predicted well-being during the crisis ($b = 0.021$, 95% CI [0.016, 0.027]). The mediation was significant and moderated by SCL (index = −0.09, 95% CI [−0.02, −0.0001]), such that it was strongest for individuals with low SCL. We point to pre-pandemic physiological mechanisms underlying individuals' mental well-being during the COVID-19 pandemic. These findings have theoretical, diagnostic, and clinical implications that may refine our understanding of the physiological basis of resilience to the COVID-19 pandemic and thus may be implemented to identify and assist individuals in these times.

KEYWORDS

autonomic nervous system, COVID-19, emotion regulation, RSA, SCL, well-being

1 | INTRODUCTION

1.1 | The COVID-19 pandemic and well-being

The spread of the COVID-19 virus poses a major psychological challenge, largely due to its unique characteristics associated with social isolation and restriction on movement (e.g., Brooks et al., 2020). This unprecedented pandemic has already been linked to worldwide reported elevations in psychological distress, including depression, anxiety, posttraumatic stress disorder, and loneliness (Roy et al., 2020; Tang et al., 2020). However, while numerous studies are currently being conducted, most of the findings published so far have

[Corrections added on August 7, 2021 after first online publication: Figures one and two have been reordered.]

focused on social and environmental predictors of distress, including sociodemographic characteristics (e.g., Horesh et al., 2020) and quarantine circumstances (e.g., Orgilés et al., 2020). Notably, studies examining physiological predictors of COVID-19-related distress, as well as their interaction with psychological factors, are almost entirely missing from the literature. Finally, only a handful of studies have shown the role of factors measured pre-COVID on emotional responses to the crisis. The present study aims to bridge these large gaps in research by examining the role of autonomic nervous system (ANS) markers in psychological well-being during the COVID-19 crisis and their interaction with emotion regulation. We present findings collected during May to June 2020 in Israel, where the Ministry of Health has led a highly conservative policy in managing the pandemic, including restricting movement to 100 meters around one's house, closing all shops and malls, and moving to remote work/learning for months. Restrictions were announced very early, as soon as the first cases were identified in Israel in late February 2020.

1.2 | The autonomic nervous system (ANS) and emotion regulation during COVID-19

In this investigation, we used pre-pandemic markers of the ANS, collected 1.5–3 years prior to the COVID pandemic in the lab, to predict individuals' psychological well-being during the crisis and individuals' expectancies regarding their ability to regulate negative emotions in these times.

Emotion regulation, which is the ability to control the nature, intensity, and timing of one's emotional reactions, has been shown to be one of the most prominent underlying mechanisms of psychological distress, in a variety of disorders and life circumstances (Werner & Gross, 2010). Emotion regulation is a multifaceted construct, which has been conceptualized in many ways. While some emphasize the distinction between reappraisal and suppression of emotion (Gross & John, 2002), others highlight concepts such as acceptance and non-reactivity to negative emotion (Chambers et al., 2009). In this study, we specifically explored negative mood regulation expectancies, which are people's beliefs that they can use behaviors and cognitions to alleviate unpleasant emotional states. Although emotion regulation has not yet been extensively studied in relation to COVID-19, some studies have shown an association between adaptive regulation strategies and well-being during the pandemic (Panayiotou et al., 2021). Studies of this kind highlight the importance of finding a biological mechanism underlying the ability to regulate negative emotions to better identify individual differences in resilience. One potential group of physiological mechanisms are markers of ANS activity, which play an established role in regulating emotions, especially in the face of stressful situations (Carnevali et al., 2018). The ANS has two branches—the parasympathetic (PNS) and the sympathetic nervous system (SNS). Both branches play a crucial and dynamical role in the maintenance of homeostasis during stressful situations. According to the polyvagal theory, in order to best understand responses to potentially threatening changes in the environment, like COVID-19, one must consider the dynamic interplay between the PNS and the SNS influences on RSA function (Porges, 1995). According to the "autonomic space" model (Berntson et al., 1994), these branches do not form a continuum but rather two dimensions in the autonomic space. To fully understand and characterize psychophysiological phenomena, one must include measures of both dimensions of ANS activity—SNS and PNS, as we propose to do in the current study.

1.3 | Parasympathetic nervous system (PNS) and emotional regulation

In the current study, we focus on resting respiratory sinus arrhythmia (RSA), a marker of PNS activity denoting heart rate variability attributed to respiration (Berntson et al., 1993). Two main theoretical models regarding PNS activity provide a conceptual framework for the current investigation. First, the polyvagal theory (Porges, 1995, 2001), and second, the model of neurovisceral integration (Thayer & Lane, 2000). Both theories suggest that there are bidirectional interactions between the heart and the tenth cranial nerve—the vagus. The evolution of these interconnections enabled flexible mammalian behavior required to respond well to environmental changes. RSA is one measure of heart rate variability which relates specifically to cardiac vagal control (Porges, 2001). These theories propose that higher levels of RSA reflect an optimal level of vagal tone flexibility, which, in turn, is reflected in a positive association between RSA and adaptive emotional regulation. Thus, RSA measures may quantify the ability to self-regulate, via the organization of physiological resources, which promotes goal-directed behavior (Nyklíček et al., 1997; Porges, 1992; Thayer et al., 2000; Thayer & Lane, 2000). According to the polyvagal model, during routine and in situations that are considered safe, the vagus implements a "vagal brake" that increases the PNS' influences to the heart, resulting in increased RSA and facilitating engagement with the social surrounding—Also known as the "social engagement" state (Porges, 2001) or the "rest and digest" state (Jänig, 2006).

Conversely, during "unsafe" situations, which are perceived as threatening, there is a withdrawal of the "vagal brake" that results in a shift to the SNS's control of the heart, supporting an essential increased metabolic output. This shift results in decreases in RSA—and allows individuals to quickly respond to the situation ("fight-or-flight"; Porges, 2001). The neurovisceral integration model (Friedman & Thayer, 1998; Thayer & Lane, 2000) considers resting RSA as a marker for neural feedback mechanisms needed for the integration between the ANS and the central nervous system, termed as "autonomic nervous system integration." This central-peripheral feedback loop, or integration, is essential for vital aspects of self-regulation (Friedman & Thayer, 1998). Specifically, high RSA (or vagal tone) is associated with the ability to self-regulate and thus to have greater behavioral efficiency, flexibility, and adaptability in a changing environment. As such, these models are quite constant in perceiving high levels of resting RSA as an index of more optimal self-regulation and emotional flexibility in healthy adults (Porges, 1995, 2001; Thayer & Lane, 2000).

RSA is an established marker of emotional regulation, which has been linked to capacities such as effortful control, persistence during frustration, more active coping strategies, and decreased defensiveness (for review see: Balzarotti et al., 2017). There is consistent and extensive research connecting low resting RSA to emotion dysregulation and psychopathology (see e.g., Beauchaine, 2001; Beauchaine et al., 2007; Porges, 2007). Importantly, an increase in RSA in response to stress is considered adaptive, as it is a marker of regulatory effort (Butler et al., 2006), and higher RSA at rest was shown to be related to well-being in the past (Balzarotti et al., 2017). In light of the above, we hypothesized that pre-pandemic measures of higher baseline RSA would predict improved emotion regulation and well-being during the COVID-19 pandemic.

1.4 | Sympathetic nervous system (SNS) modulation of PNS activity

As mentioned above, the polyvagal theory (Porges, 2001) posits that PNS activation by the myelinated vagus nerve is reflected in higher resting RSA, a marker of social engagement associated with emotional regulation. Conversely, when we experience increased stress and a reduced sense of security, there is a withdrawal of the "vagal break", the phylogenetically more ancient SNS is activated and we witness increases in SNS measures of electrodermal activity, like skin conductance levels (SCL). Electrodermal activity can occur spontaneously during resting-state even in the absence of any external events. These resting skin conductance responses are considered non-specific, as they are not event-related, and they appear during baseline or rest measurements (Gertler et al., 2020; Zimmer, 2000). Individual differences in spontaneous electrodermal activity are considered trait-like (Crider, 2008) and have been related to a widespread cortical neural activation pattern (Gertler et al., 2020). This trait of increased non-specific electrodermal activity has been termed "lability" versus "stability" (for a review, see: Crider, 2008; Dawson et al., 2017). Electrodermal lability refers to individuals who have a high rate of skin conductance responses that are not necessarily accounted for by an external event and take longer to habituate compared to "electrodermal stabile" individuals.

Differences in EDA during baseline have been recorded beginning at childhood (Gatzke-Kopp & Ram, 2018). In the healthy population, several studies have suggested that electrodermal lability is related to increased vigilance, the allocation of attention, emotional reactivity, and effortful self-control of emotional expressions (Boucsein, 2012; Crider, 2008; Dawson et al., 2017)—all highly relevant for emotional reactivity and the effeorts made to regulate said reactivity. In psychopathology research, Van Zuiden et al. (2012) have shown the role of pre-deployment glucocorticoid sensitivity in post-deployment PTSD among soldiers. i.e., those with higher baseline physiological sensitivity went on to show higher PTSD levels. Finally, it has been shown that heightened SNS activity at rest might reduce the benefits of PNS regulation of cognitive coping (Giuliano et al., 2017). For these reasons, we expected that baseline SCL, prior to the pandemic, would moderate the effect of RSA on emotion regulation during COVID-19. Specifically, we hypothesized that RSA would be more reflective of emotion regulation and well-being under conditions of lower skin conductance activity.

In sum, in the present study we had two major aims: 1. To assess the roles of the PNS, SNS and their interplay in well-being during the COVID-19 pandemic. 2. To examine the potential mediating role of emotion regulation in the association between ANS activity and well-being in the face of the the COVID-19 pandemic.

2 | METHOD

2.1 | Participants

The Bar-Ilan University Department of Psychology Ethics Committee approved this study. Written informed consent was obtained from all participants. All methods were conducted in accordance with the approved ethical guidelines. The online survey, powered by Qualtrics, was taken during the COVID-19 outbreak in Israel (May 21st to June 5th, 2020). Each participant provided informed consent, demographic information, and self-reports regarding COVID-19, emotion regulation, and well-being. Three hundred potential participants, who participated in one of two former studies that took place in the lab (72.6% female, mean age = 23.32 years, *SD* = 3.27, minimum = 18; maximum = 36), received an invitation to the survey via email, which also detailed their chance to win a monetary prize (500 NIS, ~145 USD) if they participate in the current study. Hundred and eighty five participants agreed to participate in the study (71% female, mean age at time 1 = 23.16 years, SD = 3.05, mean age during the current study = 25.30, SD = 3.37). Hundred and nine participants were involved in study 'A' during 2018 (17–27 months prior to the COVID survey), and 76 participated in study 'B' in 2017 (30–36 months prior to the COVID survey). We ran a power analysis by using the G*Power desktop app (Faul et al., 2009). We expected small-medium effect sizes ($f^2 = 0.08$), a power of 0.80 and 0.05 alpha. We defined six predictors (two controls, an IV, mediator, moderator, and an interaction effect). This yielded a desired sample size of 170 participants. We also note that resampling techniques, like those taken in the current study to explore mediation and moderated mediation, may somewhat overcome power issues in these sorts of models (Mackinnon et al., 2010; Preacher et al., 2007).

All participants were undergraduate students in the Department of Psychology at time 1 of the study. Most of the participants received course credit in exchange for their participation, and the minority received monetary compensation for their time. There were no differences between participants who participated in the current study and those who decided not to participate in the COVID-related portion, in terms of age, $t(297) = 1.68$, $p = .09$, nor in terms of gender, $\chi^2(1) = 0.63$, $p = .43$. There were also no differences in their baseline physiological measures during the lab studies: baseline RSA, $t(278) = 0.90$, $p = .37$ and baseline SCL, $t(284) = 0.36$, $p = .72$. Overall, we had full demographic, self-report, and physiological data from 164 participants.

Both 'A' and 'B' studies were aimed at addressing interpersonal synchrony from a physiological perspective during group interactions. In each of these studies, participants arrived at the lab for a triadic group task. The first stage of these studies consisted of a 5-min "physiological baseline" assessment, in which we asked the three group members to sit in a room together, without interacting or talking, and simply rest. We recorded their electrocardiogram and electrodermal activity via specialized electrodes. Full details about study A are reported elsewhere (Gordon et al., 2020). A more detailed description of studies 'A' and 'B' can be found in supplemental digital content 1. Details of physiological measures collection and analysis appear in the measures section below.

According to their self-reports, none of our participants were tested positive for COVID-19, and 10% reported that they had symptoms that might be related to the virus. In addition, 34% of our sample were acquainted with someone who was tested positive, 6% reported knowing someone who died from the virus, and 61% reported a decrease due to COVID-19 in income to some degree.

2.2 | Measures

The survey included two widely used psychological scales, as well as several background questions.

2.2.1 | Days since baseline

In order to account for the variability in the time that elapsed since we collected physiological data for different participants, we calculated the time that elapsed (in days) from physiological measurement to the measurement of COVID-related data. We used this variable as a control variable in all regression models.

Background questionnaires

We asked participants for their age, gender, pre- COVID-19 occupation, and the number of people living in their house during the lockdown. We also asked them if they were tested for COVID-19 or found positive for the virus. Additionally, we asked if they had any common COVID-19 symptoms, whether they knew someone positive for the virus or died because of it. Lastly, we asked participants if they have suffered from an income decrease due to the pandemic.

Negative mood regulation expectancies

We used the Hebrew version (Gilboa-Schechtman et al., 2006) of the generalized expectancy for negative mood regulation scale (NMR; Catarizaro & Mearns, 1990). The NMR assesses a specific aspect of emotion regulation—one's perception of his or her ability to regulate negative mood. In the current study, we instructed participants to refer to their regulation of negative moods "since the beginning of the COVID-19 pandemic." A higher score stands for a stronger belief in the self-ability to regulate negative mood. This NMR scale consists of 30 statements about negative mood regulation, each rated on a 5- point Likert scale (1 = "strongly disagree" to 5 = "strongly agree"). Individuals' scores range from 30 to 150. The final score is the sum of its three subscales, each comprising 10 items reflecting different strategies to alleviate negative mood—behavioral, cognitive, and general. Cronbach's alpha was 0.90.

Well-being

A Hebrew translation of the Warwick–Edinburgh mental well-being scale (WEMWBS; Tennant et al., 2007) is a 14-item self-report scale that measures positive aspects of well-being, including optimistic and vivid thinking, positive functioning, and satisfaction (e.g., "I am feeling optimistic about the future"). Participants were asked to note the degree to which each statement applied to them during the last two weeks on a 5-point Likert scale (1 = "none of the time" to 5 = "all of the time"). Individuals' scores were calculated as the mean of all ratings, with a higher score representing a higher level of psychological well-being. Here we used the Hebrew version of this scale. Cronbach's alpha was 0.91.

2.2.2 | Physiological measures: RSA and SCL

RSA is a frequency-domain index of PNS activity derived from participants' electrocardiograms (ECGs). Higher RSA levels indicated increased parasympathetic tone, hence enhanced regulatory capacities. Each participant was connected to a mobile impedance cardiograph device (MindWare technologies, Gahanna, OH) using three electrodes placed on the torso according to the modified lead II configuration. Respiration was derived from four additional electrodes that measured cardiac impedance (see: Sherwood et al., 1990 for the procedure). The MindWare device collected participant's ECG and respiration at a 500 HZ sampling rate. Each participant's ECG was later analyzed in MindWare Technology's HRV application, version 3.1.4. Visual inspection and manual editing of the data were completed by trained graduate and undergraduate students to ensure the proper removal of artifacts and ectopic beats. The signal was amplified by a gain of 1,000 and filtered with a hamming windowing function. After correcting the data, we extracted RSA by using MindWare's HRV application.

SCL indexed electrodermal activity, which denoted the input of the SNS. A higher SCL indicated higher arousal of the SNS. We used the same MindWare Technology's device to simultaneously collect ECG with mean SCL at 500 HZ, by using two Ag/AgCl MindWare electrodes placed on the nondominant palm. Later, we analyzed the data with MindWare Technology's EDA application software, version 3.1.5. The signal was smoothed with a rolling filter of 500 data points per block. Visual inspection and manual editing of the data were completed by trained students to ensure proper removal of artifacts such as disconnections of electrodes. According to the provider's guidelines, artifacts were corrected by the spline function included in the application.

3 | RESULTS

Descriptive statistics and zero-order correlations for the main measures in the study are presented in Table 1.

As presented in Table 1, we found a positive and significant correlation between RSA at rest (taken during 2017 or 2018) and negative mood regulation expectancies during the COVID-19 crisis. Additionally, a strong positive correlation between negative mood regulation expectancies and well-being during the COVID-19 pandemic. We did not find associations between SCL at rest (taken during 2017 or 2018) and the outcome variables measured during the COVID-19 crisis. We next present the results of a mediated moderation model.

To evaluate our model (see Figure 1), we performed hierarchical regressions and used the SPSS Process macro (Hayes, 2017). We assessed the moderation-mediation model with the macro (model 8), which generated 95% bias-corrected confidence intervals (CIs) with a bootstrap approach developed by Preacher and Hayes (Preacher & Hayes, 2004, 2008) with 5,000 resamples. Since gender is related to sympathetic and parasympathetic activation, especially during fertility years (Jönsson & Sonnby-Borgström, 2003; Kring & Gordon, 1998; Kuo et al., 1999), we took a conservative approach and held gender as a covariate in the model. Since our sample varied with respect to the date of baseline measurement but was homogeneous with respect to the date of measurement during the crisis, we also held time elapsed since baseline measurement as a covariate in the model.

As Model 1 in Table 2 demonstrates, RSA was positively related to negative mood regulation expectancies ($\beta = 0.24$, $p = .002$). Further, as shown in Model 2 of Table 2, results revealed a significant interaction between RSA and SCL on negative mood regulation expectancies ($\beta = -0.22$, $p = .003$). Following Aiken and West (Aiken et al., 1991), we plotted the interaction at one standard deviation above and below the moderator's mean (see Figure 2). A simple slopes analysis revealed that there is a positive and significant association between RSA and negative mood regulation expectancies for those who had low sympathetic activation ($t = 3.26$, $p = .001$) and average sympathetic activation ($t = 2.22$, $p = .028$) at baseline, as depicted by SCL, whereas this relationship was not significant for those who had high sympathetic activation at baseline, as depicted by SCL ($t = -0.02$, $p = .98$). In its turn, as shown in Model 3 of

TABLE 1 Means, SDs, and pearson correlations between the study variables

Variable	M	*SD*	1	2	3	4	5	6
1. Gender[a]			—	—	—	—	—	—
2. Days since baseline	772.45	223.93	−0.19**	—	—	—	—	—
3. RSA at baseline	6.40	1.00	−0.08	−0.20**	—	—	—	—
4. SCL at baseline	10.74	6.10	−0.03	−0.13	−0.01	—	—	—
5. Mood Regulation Expectancies	110.09	14.58	−0.11	0.01	0.23**	0.12	—	—
6. Well-being	3.61	0.52	−0.17**	0.10	0.13	−0.01	0.61***	—

Note: $N = 166–185$.

[a](1 = men, 2 = women); RSA, respiratory sinus arrhythmia; SCL, skin conductance level.

$^{**}p < .01$, $^{***}p < .001$.

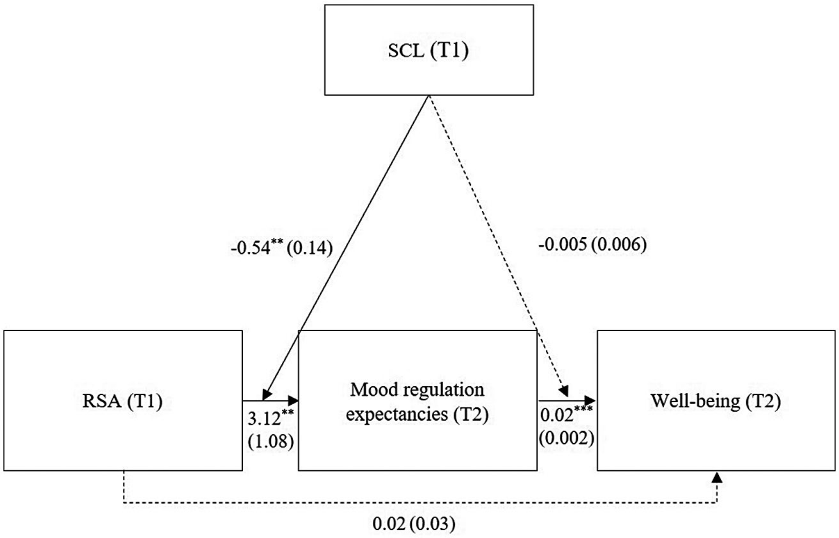

FIGURE 1 Research model. $N = 164$. Unstandardized regression coefficients are reported with standard errors in parentheses; Gender and days since baseline measurement (T1) are covariates in the model; RSA, respiratory sinus arrhythmia; SCL, skin conductance level; $^{**}p < .01$, $^{***}p < .001$; RSA and SCL were mean-centered

TABLE 2 Hierarchical regression results[a]

	Mood regulation		Well-being
Variable	Model 1 *b* (SE)	Model 2 *b* (SE)	Model 3 *b* (SE)
Gender[b]	−3.72 (2.43)	−4.13† (2.37)	−0.13† (0.07)
Days since baseline	0.004 (0.005)	0.004 (0.005)	0.00 (0.00)
RSA in baseline	3.46** (1.10)	3.12** (1.08)	0.02 (0.03)
SCL in baseline	0.28 (0.18)	0.31† (0.17)	−0.004 (0.005)
Mood regulation expectancies			0.02*** (0.002)
RSA X SCL		−0.54** (0.18)	−0.005 (0.006)
R^2	0.09**	0.14**	0.38***

[a] $N = 164$. Unstandardized regression coefficients are reported with standard errors in parentheses.
[b] (1 = men, 2 = women); RSA, respiratory sinus arrhythmia; SCL, skin conductance level.
† $p < .10$; $^{**}p < .01$, $^{***}p < .001$; RSA and SCL were mean-centered.

Table 2, negative mood regulation expectancies significantly predicted well-being ($\beta = 0.58, p < .001$). However, as shown in Model 3 of Table 2, we did not find an interaction effect between RSA and SCL in predicting well-being. Note that in Table 2, we present unstandardized regression coefficients with standard errors in parentheses and that RSA and SCL were mean-centered.

Supporting our hypothesis, we found a significant conditional indirect effect of RSA on well-being through negative mood regulation expectancies. The index for moderated-mediation was significant (*index* = −0.008, 95% CI [−0.02, −0.0001]). The indirect effect was significant for participants with low sympathetic activation (*indirect effect* = 0.10, 95% CI [0.04, 0.18]), and for participants with average sympathetic activation (*indirect effect* = 0.05, 95% CI [0.006, 0.10]). As expected, we found no effect for participants with high sympathetic activation (*indirect effect* = −0.007, 95% CI [−0.08, 0.07]). In the model presented, we controlled for differences between studies "A" and "B" by holding the "days since baseline" variable as a covariate in the analysis. We further tested the data with a multilevel structural equation model to make sure there were no major differences between the various studies included in our sample. The model was conducted using the lavaan package in R (Rosseel, 2012), and yielded similar results (see full details in the supplemental digital file).

4 | DISCUSSION

In the current paper, we suggest pre-pandemic physiological mechanisms as the basis of the relationship between negative mood regulation expectancies and well-being during COVID-19. More specifically, we revealed that RSA at rest, measured—on average—more than two years before the global pandemic emerged, indirectly predicted via negative

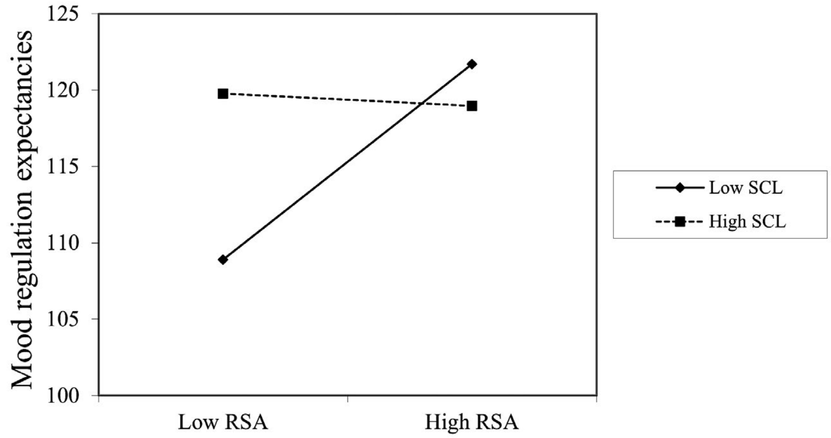

FIGURE 2 RSA predicts mood regulation expectancies in high and low sympathetic activation

mood regulation expectancies, participants' well-being during the COVID-19 crisis. Moreover, we found that this mechanism only existed for individuals with low and average SNS arousal at rest.

In line with our hypothesis, baseline RSA predicted negative mood regulation expectancies during COVID-19. The association between ANS activity and emotion regulation was found among both non-clinical (Nasso et al., 2019) and clinical (Musser et al., 2011) populations. More specifically, our finding is in line with the literature showing a well-established link between emotional regulation and RSA (Balzarotti et al., 2017). Since COVID-19 may be considered a mass global crisis (Horesh & Brown, 2020), it may be useful to turn to the trauma literature to examine the associations between ANS measures and mental health. RSA was found to be associated with individuals' psychological reactions to traumatic events and stressful circumstances. For example, previous studies have linked decreased RSA to PTSD (Campbell et al., 2019; Gillie et al., 2014). A large study that examined a marker of PNS activity, highly related to RSA, in pre-deployment soldiers, found it was related to subsequent symptoms of PTSD (Pyne et al., 2016). While these studies do not refer to pandemic circumstances, they nonetheless show the potential link between ANS activity and distress under chronic severe stress. We note here that there is also some prospective evidence that has linked interactions between RSA & SNS measures (specifically, epinephrine and norepinephrine) to future outcomes in adults (in this case, the study assessed changes in executive functioning; Knight et al., 2020). Nonetheless, to the best of our knowledge, this is the first COVID-related study providing prospective evidence on pre-pandemic physiological markers that have a role in predicting coping during the pandemic.

As we further expected, when we included the workings of the SNS as a moderator into the mediation model, the mediation of negative mood regulation expectancies on the link between RSA and well-being was significant only for individuals who had low and average baseline SCL pre-pandemic. This result provides insight regarding the co-action of the PNS and SNS in psychological coping. One possible explanation is that heightened SNS activity is a marker of chronic psychosocial stress (Cacioppo et al., 2000), which may impact prefrontal functioning (McEwen & Gianaros, 2011), thereby affecting the ability of the PNS to regulate emotion (Porges, 2001). Another explanation, which is in line with the literature regarding EDA lability, is that heightened resting SCL is related to increased vigilance, attention, and effortful self-control (Boucsein, 2012; Crider, 2008; Dawson et al., 2017). By both explanations, individuals with heightened SNS activity might not engage the PNS to meet moment-to-moment demands of psychological coping, especially during stressful times. The fact that higher resting SCL was related to higher ratings of well-being compared to low SCL (albeit, not via the mediation of emotion regulation), supports the latter explanation, indicating that the control of the SNS over mood regulation may be beneficial during times of stress and "protect" against the disengagement of the PNS. This notion needs to be further assessed in future research. It is important to note here that SCL and RSA were not directly related to each other. This is probably due to the dynamic interaction between PNS and SNS, which are not always reciprocally controlled. This is especially true in complex psychological processes that involve either the independent activation or the coactivation of the two ANS branches depending on the context (Berntson et al., 2008). The autonomic space model similarly calls to examine distinct SNS and PNS functions together in order to reach a full understanding of the relationship of ANS to mental or health outcomes (Berntson et al., 1994). Future studies are required to substantiate our findings and fully elucidate the complex and dynamic interactions between SNS and PNS activity that may support enhanced resilience during these times.

This study has several limitations. First, participants' physiological measures were collected over a relatively long period. Second, psychological variables were assessed via self-report measures, which may be prone to memory and reporting bias. Another limitation is the over-representation of women in our study. We addressed this issue by controlling for gender in all analyses. Furthermore, it should be noted that in this study, we have assessed a specific facet of emotion regulation, i.e., expectancies for negative mood regulation. Future studies are encouraged to assess psychophysiological markers of other emotion regulation facets during COVID-19. Finally, we did not collect in-depth measures of depression, PTSD, or anxiety, which could have deepened our understanding of mental well-being reported here. These issues should be addressed in future research. Nonetheless, the study is unique in several ways and may carry important theoretical and clinical implications.

To the best of our knowledge, this is the first study to include pre-pandemic physiological measures, and the first to combine such measures with psychological factors to predict well-being during the COVID-19 pandemic. In difficult days of global crisis, it is crucial to understand the heterogeneity of psychological response in terms of both physiology and psychology. Our findings shed initial light on the complexity of individuals' reactions to mass crises, in line with what has been shown in other major traumatic events (e.g., Busso et al., 2014). In this era of bio-psycho-social models of distress and psychopathology, more COVID-19 studies combining different types of data (biological, cognitive, behavioral) are needed. Our findings should also be looked upon from the specific perspective of Israel, a war-ridden country exposed to ongoing political violence for the past few decades (Bleich et al., 2003). It is quite possible that pre-pandemic physiological data collected in Israel represents a unique reality, where stress is abundant in daily life, and thus may be more strongly connected to stressful episodes like that of COVID-19. To expand the generalizability of our findings, more studies such as the current one should be conducted in other regions of the world. From a clinical perspective, the unique combination of physiological and psychological measures presented here has the potential to inform novel ways of identifying populations vulnerable to COVID-related distress, and subsequently offer them early mental health interventions. This is particularly true in the case of a health pandemic, as numerous people worldwide are unfortunately forced to attend emergency rooms and health clinics (Morris et al., 2016), where basic physiological data is routinely being collected. Finally, our findings further support the important role of emotion regulation and, more specifically, one's belief about one's ability to regulate emotion as a potent predictor of psychological well-being and distress. Emotion regulation is considered a highly malleable factor, targeted by numerous psychotherapeutic interventions (Berking et al., 2008). Its role in a chronic, long-lasting crisis, may be particularly important, as individuals are forced to find new and flexible ways of managing their emotional resources to avoid burnout and depletion over time. Our emphasis on the perceived ability to regulate negative emotion also stands to show the importance of one's subjective perception of emotion regulation, which may also be a malleable target for psychotherapy.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Ilanit Gordon: Conceptualization; Formal analysis; Funding acquisition; Writing-original draft; Writing-review & editing. **Danny Horesh:** Formal analysis; Writing-original draft; Writing-review & editing. **Nir Milstein:** Formal analysis; Writing-original draft; Writing-review & editing. **Alon Tomashin:** Data curation; Formal analysis; Writing-review & editing. **Oded Mayo:** Formal analysis; Writing-original draft; Writing-review & editing. **Adi Korisky:** Writing-original draft; Writing-review & editing.

ORCID

Ilanit Gordon https://orcid.org/0000-0002-4888-1308

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