Contextualized Mental Health: Predicting Mood Fluctuations by Social Contact, Emotion
Coping, Physical Activity, Sleep, and Negative Events in Concert

Vera E. Heininga¹, Nienke C. Jonker², Bertus F. Jeronimus¹, & Peter de Jonge¹

¹ University of Groningen, Department of Developmental Psychology, The Netherlands

² University of Groningen, Department of Clinical Psychology and Experimental
Psychopathology, The Netherlands

Abstract

Background: The unique and synergistic effects of daily risk and protective factors that shape our moods remain largely unknown because each is typically studied in isolation. Using experience sampling techniques 1396 Dutch adults reported on their positive and negative affect (PA/NA), social contact, emotion coping, physical activity, sleep quality, and negative events; thrice daily for 30 days (90 assessments). These five risk/protective factors combined explained approximately 15% of the variation in PA and 23% in NA, with emotion coping and sleep quality as the strongest predictors. All risk and protective factors influenced subsequent mental health, but examined collectively, only coping ability and sleep quality significantly affected individuals' mental health. These results identify coping and sleep as the most interesting targets for depression interventions and psychotherapy to enhance positive mood and decrease negative mood.

Keywords: Depression; Negative Affect; Positive Affect; individual differences; Ecological Momentary Assessment (EMA)

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Background

Mental health includes the combined and synergistic effects of positive affect (PA) such as feeling happy, cheerful, or relaxed, and negative affect (NA) such as being angry, anxious, or sad, each in response to our internal and external daily contexts. PA emerges when our primary needs and goals are fulfilled, and serve to broaden our cognitive scope, to propel goal directed actions, and to buffer us against future adversity (Carver & Scheier, 1998; Fredrickson et al. 2000; Frijda, 1988; Gable & Harmon-Jones, 2008; Harmon-Jones, Harmon-Jones, & Price, 2013). Negative affect (NA), in turn, emerges in response to adverse experiences and stress, and play a key role in the development and maintenance of negative moods and mental health problems (Frijda & Mesquita, 1994).

Mental health is a process that unfolds in the flow of our everyday lives, and Ecological Momentary Assessment (EMA) studies that sample mood and contexts in everyday life suggest that there are several risk and protective factors that play a key role in PA and NA experiences in daily life: physical activity; social interactions; negative events, sleep quality; and coping ability (for a review, see: Pemberton & Fuller-Tyszkiewicz, 2016). Physical activity and social interaction are considered protective factors for mood in daily life. Indeed, more frequent and longer lasting physical activity are related to higher levels of PA (Cushing et al., 2017; Schöndube et al., 2016; Wen et al., 2020), lower levels of NA (Aggio et al., 2017; Cushing et al., 2018; Kerrigan et al., 2020; for a review, see: Buecker et al., 2021), or both (Schultchen et al., 2019; Smith et al., 2020). In some cases the effect of physical activity varies considerably (e.g., Stavrakakis et al, 2015), or more physical activity than usual was linked to PA but not to NA (Heininga et al., 2017). In a similar vein, being in the social company of others, as well as the positive appraisal of a social interaction, are strong predictors of increased PA and decreased NA (see for a systematic review and meta-analysis

Liu et al., 2019; Rivera et al., 2020).

Negative events and poor sleep quality are considered risk factors for changes in daily mood (Pemberton & Fuller-Tyszkiewicz, 2016). Most people experience about 20 negative events per week (Kanner et al., 1981), and, after such events, people typically report more NA and less PA (e.g., Mey et al., 2020). The effect of negative events on mood are likely dependent on social contexts, as some studies show that social company has the power to undo the effect of stressful events on subsequent NA (Sicorello et al., 2020; Bayer et al., 2016; Kafetsios et al., 2017). Next to negative events also poor sleep quality is typically linked to lower PA (Lydon-Staley et al., 2017) and higher NA (O’Leary et al., 2017), in which the subjective experience of sleep (e.g., satisfaction, sleep quality, and sleep latency) was more predictive than objectively measured hours of sleep (Das-Friebel et al., 2020; Scott et al., 2017).

Coping ability is a complex and interactive process that refers to the ability to restore emotional balance by modulating the frequency, intensity, and duration of affective experiences (Gross, 2014, 2015), and specific coping strategies improve or worsen emotional outcomes. Strategies such as reappraisal and self-distraction enable people to upregulate PA and downregulate NA, for example, while maladaptive strategies such as repetitive thinking prolong NA (e.g., rumination/worry). Adaptive strategies upregulate PA and downregulate NA, while strategies such as repetitive thinking prolong NA (e.g., rumination/worry; Colombo et al., 2020; Ma et al., 2020). Indeed, a variety of studies showed that poor coping plays a key role in persistent high NA and depression (Joormann & Stanton, 2016; Liu & Thompson, 2017) and low PA (Vanderlind et al., 2020).

Although physical activity, sleep quality, social interactions, negative events, and coping ability occur in the same daily contexts, their synergistic effects on mental health remain largely unclear. One study that examined the collective effect of the five risk and protective factors on mood in daily life showed that, collectively, they may account for

15-40% of the changes in NA up to five hours later (Fuller-Tyszkiewicz et al., 2017), with stress and poor coping as the strongest predictors. The collective explained variance for PA has never been studied, but EMA studies on isolated factors suggest that changes in PA are primarily linked to social interaction and physical activity (for an overview up until 2015, see Liao et al., 2015). That the collective effects of the risk and protective factors on PA have not yet been examined is remarkable, as PA has notable relevance for the diagnosis, treatment, and recovery from depression (Barge-Schaapveld, 1995; Borsini et al., 2020; Heininga et al., 2017). Indeed, depressed individuals suffer from either too much NA (i.e., depressed mood), the loss of PA (i.e., anhedonia), or both. Given that PA and NA are increasingly understood as independent dimensions (Feldman Barrett & Russell, 1998; Gross & John, 2003; Kim & Hamann, 2007; Posner et al., 2005), a reduction in NA does not necessarily lead to improvements in PA (Keyes, 2014; Watson et al., 1988).

The present study

In the present study, we address this gap and investigate the relative and synergistic impact of the five risk and protective factors for both NA and PA in a large general population sample, to better understand optimal mental health (cq. Westerhof & Keyes, 2010). Based on previous ESM research outlined above, we expect (pre-registration of these hypotheses: <https://doi.org/10.17605/OSF.IO/8N54H>):

1. Outcomes similar to those of Fuller-Tyszkiewicz and colleagues (2017) with regard NA, namely a positive association between negative events experienced in the past six hours and subsequent changes in NA, and a negative association between coping ability in the past six hours and subsequent changes in NA.
2. A positive association between appraisal of social company in the past six hours and subsequent changes in PA, and a positive association between physical activity in the past six hours and subsequent changes in PA.

In addition, because mood is disturbed in depression, and knowledge on whether the combined and relative effects of risk and protective factors on mood differ may inform prevention and treatment strategies, we also explore combined and relative effects in the sub sample of participants with at least mild depressive symptoms.

Methods

Participants

The sample used is a $N = 1396$ sub sample of the HowNutsAreTheDutch (HND, in Dutch: HoeGekIsNL, see van der Krieke et al., 2015; 2016). HND is a national crowdsourcing study designed to investigate multiple continuous mental health dimensions in a sample from the general population ($n > 16.000$). Participants can enroll themselves on an internet platform that allows participants to (a) compare themselves to other participants via cross-sectional questionnaires and (b) to monitor themselves three times a day for 30 days by an Ecological Momentary Assessments (EMA) study via their smartphone. In total, the sample consisted of 1396 participants with 90 assessments each (three times a day).

HND launched an open call to inhabitants of the Netherlands to join the research in December of 2013, and invited them to visit the Dutch website www.HoeGekIs.nl (also www.HowNutsAreTheDutch.com). The open call was announced on local and national radio broadcasts, television, during local podium discussions, in newspapers, and in magazines. The news about the HND research project was further disseminated via personal outlets of those interested (e.g., online blogs, twitter). To participate, people had to register, create, and confirm their account on www.HoeGekIs.nl. In a general start questionnaire, participants were asked to provide information such as gender, birth year, and country of residence (the Netherlands/Belgium/Other). Although HND was initially targeted on Dutch citizens located in The Netherlands, a question on country of residence was included after news about the study spread to Belgium and other Dutch speaking regions.

Procedure

Design of ESM-part of the study. After enrollment, before the diary part started, participants had to complete a baseline assessment consisting of the items of the positive and negative affect schedule (PANAS; Peeters et al., 1996; Raes et al., 2009), the Quick Inventory of Depressive Symptoms (QIDS; Rush et al., 2003, 2006), and two extra items retrieved from the Inventory of Depressive Symptomatology (IDS; Rush et al., 1996) to assess anxiety/panic symptoms.

From the start of the diary study, for 30 days, participants filled out a short questionnaire of 43 diary questions on a variety of topics (e.g., subjective well-being, sleep, mood, mindfulness, and being outdoors) on their smartphone device three times a day with a fixed 6 hour interval Experience Sampling Method (ESM) design. To lower the burden of the diary study, the starting time of the assessment schedule was chosen in consultation with the participant. For example, people getting up at 8:00 could request their first diary at 8:30. The next would follow respectively six and 12 hours thereafter. Participants received a text message on their mobile phone with a link to a questionnaire, and were asked to fill out the questionnaire as soon as possible within one hour. After one hour, the questionnaire was no longer be accessible.

Participant Inclusion and Monitoring Protocol.

Inclusion criteria.

The study requirements for the larger HND study were age 18 or above; having a mobile phone with internet connection; not engaged in shift work; and not anticipating a major disruption of daily routines (e.g. a planned trip abroad, an anticipated surgical operation). In addition, participants were also asked to indicate whether they were aware that participation would be useless in case too many assessments would be missed, and whether they approved that their anonymised data would be used for scientific research. Participants had to check a box for each of these requirements before they could proceed.

Exclusion Criteria.

Although not described in the preregistration (<https://doi.org/10.17605/OSF.IO/8N54H>), we decided to only use the first 90 measurements of the first study period according to HND protocols for EMA studies.

Measures

Negative Affect (NA). The NA variable reflects the mean of feeling gloomy/ anxious/ nervous/ irritable/ dull/ tired per assessment on a slider scale ranging from “Not at all” (0) to “Very much” (100). The momentary item selection is based on the circumplex model of affect, which describes valence and activation dimensions of affect (Barrett and Russell, 1998; Yik et al., 1999).

Positive Affect (PA). In a similar vein, the PA variable reflects the mean of feeling relaxed/ energetic/ enthusiastic/ content/ calm/ cheerful per assessment on a slider scale ranging from “Not at all” (0) to “Very much” (100).

Sleep quality. Participants were asked “Did you sleep well?” with an answer-slider ranging from “Not at all” to “Very well” (0-100).

Negative event. Participants were asked “Did something special happen since the last measurement?” with answer categories being (1) No, nothing; (2) Yes, something positive; (3) Yes, something neutral; (4) Yes, something negative. The answers were recoded reflecting 0 when nothing special happened since the last measurement or something positive or something neutral (i.e., $0 = 1/2/3$), and 1 when a negative event took place (i.e., $1 = 4$).

Coping ability. Poor coping ability was operationalized as feeling unbalanced. Participants were asked “I am unbalanced,” with an answer-slider ranging from “Not at all” to “Very much” (0–100). Although unintentionally not mentioned in the preregistration, the item was recoded, so that higher scores reflected better coping ability.

Physical activity. Since the last measurement I was physically active, answered on a slider ranging from “Not at all” to “Very much” (0–100)

Appraisal of social company. Participants were asked “I found my company predominantly,” with an answer-slider ranging from “Very unpleasant,” via “Neutral,” to “Very pleasant” (0-50-100).

Statistical procedures

We use R 4.1.2 (R Core Team., 2016), Rmarkdown (Allaire et al., 2016), and papaja (Aust & Barth, 2017) to create a reproducible manuscript. The hypotheses and analyses were preregistered (<https://doi.org/10.17605/OSF.IO/8N54H>).

To test our hypotheses, we use random slopes Linear Mixed-Effects Model with assessments nested within subjects, with the change score of affect for that person’s the dependent variable (i.e., the level of affect on time point t minus the level of affect on t-1), defined as:

Level 1:

$$\begin{aligned} \text{Change in affect}_{(i-(i-1))} = & \beta_0 + \beta_1(\text{Sleep quality}_i) + \beta_2(\text{Negative event}_i) + \\ & \beta_3(\text{Coping ability}_i) + \beta_4(\text{Physical activity}_i) + \beta_5(\text{Appraisal of social company}_i) \end{aligned}$$

Level 2:

$$\begin{aligned} \beta_0 = & \gamma_{00} + \gamma_{01} + u_0 \\ \beta_3 = & \gamma_{30} + \gamma_{31} + u_3 \end{aligned}$$

In this multilevel model, all predictors were person-mean centered except those of which the zero-point is already meaningful on its own and present in the data (i.e., negative events). It should be noted that, due to overfitting, we were unable to take into account all random slopes that were defined in the preregistration (see: <https://osf.io/hk4pm/>). Based on the REML criterion at convergence, we decided to only include the random effects that improved model fit which was individuals’ coping ability. As a robustness check, we repeated these

analyses among the sub sample of people who completed $> 70\%$ of the ESM assessments (N=552).

Finally, to explore if the relative contribution patterns are different in people who experience mood problems, we re-ran the analyses described above in the sub-sample of people who meet the criteria for Major Depressive Disorder as indicated by a score of 6 or higher on the Quick Inventory for Depressive Symptomatology (QIDS-SR; Rush et al., 2003; i.e., experiencing at least mildly depressive symptoms).

Results

Descriptive statistics

The sample consisted of 1396 participants who completed 74.71 ($SD=28.19$) assessments on average, with a minimum of 1 and maximum of 89.

Table 1 shows the distributions of main variables, as well as the group-level correlations between variables. On average, participants experienced more PA than NA. With regard to the five risk and protective factors to mood and mood disorders, participants reported on average moderate sleep quality; moderate coping ability; found their company predominantly pleasant, were remotely physically active, and experienced between zero and 89 negative events during the study period with six to seven negative events on average. The correlation between PA and NA was strong on both the on the between-participants level ($r=-.69$; $p<.01$; see Table 1, and within-participants level ($r=-.74$; $p<.01$).

The Intraclass Correlation Coefficient (ICC) of affect, that shows how much variation is present on the within level (individual) and between level (group), showed that most of the variance comes from within-person differences, both NA (41%; $ICC=0.59$) and PA (54%; $ICC=0.46$).

Combined and relative contributions to Negative Affect (NA)

Collectively, the R square was 23, meaning that the five risk/protective factors account for approximately 23% of the variations in participants' NA.

Table 2 and Figure 1 show that change in NA is most strongly associated with deviations from participants' own coping ability, sleep quality, and appraisal of social company. That is, when participants reported being more balanced (i.e., better coping ability) compared to their own mean, NA decreased with 3.99 per SD ($p<.001$). When participants reported better sleep quality compared to their own mean, NA decreased with 2.33 per SD ($p<.001$). The combined and relative effect of social company on NA was not robust, as the significance of this effect was not present in those participants who filled out >70% of all measurements ($p<.06$; for details, see supplementary materials).

Exploratory analyses for all risk/protective factors separately showed the same order in magnitude of effects (i.e., relative influence on PA/NA), but flagged all factors as significant.

Combined and relative contributions to Positive Affect (PA)

The R square indicated that approximately 15% of the change in PA is explained by the five risk/protective factors collectively.

Table 2 and Figure 1 show that change in PA is most strongly associated with participants' coping abilities ($b=3.09$; $p<.001$), followed by their quality of sleep ($b=3.03$; $p<.001$) and the experience of a negative event (compared a neutral or positive event; $b=-1.12$; $p<.001$). Robustness checks using the sub sample of participants that filled out >70% of all assessments showed no combined and relative effect of negative events on changes in PA ($p=.05$; for details, see supplementary materials).

Exploratory analyses for all risk/protective factors separately showed the same order in magnitude of effects, again, all statistically significant.

Depression

With regard to NA, the five risk/protective factors in participants with at least mild depressive symptoms collectively accounted for approximately 24% of the variation in participants' changes in NA. When participants reported being more balanced (i.e., experiencing better coping ability) than normal (i.e., compared to their own mean), NA decreased with 0.22 units per SD. When participants reported better sleep quality than normal (i.e., compared to their own mean), NA decreased with 0.15 units per SD (for details, see supplementary materials).

With regard to PA, the five risk/protective factors in participants with at least mild depressive symptoms collectively accounted for approximately 19% of the variation in participants' changes in PA. When participants reported to be more balanced (i.e., experiencing better coping ability) than normal (i.e., compared to their own mean), PA increased with 0.18 units per SD. When participants reported better sleep quality than normal (i.e., compared to their own mean), PA increased with 0.16 units per SD.

Discussion

Positive and negative affect are crucial to good mental health, and vary as a function of context. Physical activity, sleep quality, social interactions, negative events, and coping ability were recently identified as the five major risk and protective factors for mental health (Pemberton & Fuller Tyszkiewicz, 2016). Although all five major risk and protective factors can occur simultaneously and in the same context, their effects on mental health are typically studied in isolation, leaving their combined and relative contributions to mental health largely unknown. Furthermore, research on mental health is predominantly focused on Negative Affective (NA), although Positive Affective (PA) is an equally important component of mental health. In the current study we addressed this gap. Using a Ecological Momentary Assessments (EMA) data of 1396 individuals, we examined the collective and relative contributions of the five risk/protective factors for both NA and PA experiences in daily life.

Collectively, the within-subject changes (relative to participants' own average) in the five risk and protective factors accounted for approximately 23% of the within-subject changes in NA within the next six hours, and for 18% of the changes in PA within the next six hours. The explained variance of 23% for NA was large, compared to the 13% of explained variance reported by the only other study that examined the collective effects of the five risk and protective factors on NA with respect to a 2-5 hour interval (Fuller-Tyszkiewicz and colleagues, 2017). Nevertheless, the authors also reported 39% explained variance in NA for assessments that occurred less than two hours apart. Combined, these findings suggest that the effects of the five factors on NA wane over time but are still observable across a 6 hour time interval. Most importantly, the five risk/protective factors consistently explain a considerable amount of variance in NA across different studies, different time intervals, and study designs, which suggests a robust combined effect.

With regard to the relative contributions of the five risk/protective factors to NA, the largest contributor to changes in NA was coping ability. These results underscore the importance of coping for prevention and intervention strategies, as similarly large effect sizes for coping abilities on NA were previously reported (Fuller-Tyszkiewicz et al., 2017). That coping is a relative strong predictor suggests that, when clinicians who aim to reduce NA and/or increase PA (e.g., in psychotherapy sessions for depression) are faced with the choice to intervene on physical activity, sleep quality, social interactions, negative events, or coping, that the latter, on average, could yield the greatest benefits in terms of improvement.

Coping ability as the largest contributor to changes in NA was followed by sleep quality, and appraisal of social company (note that the effect of social company disappeared in our robustness checks). Sleep quality as one of the strongest predictors of change in NA is unsurprising, as both sleep duration and sleep quality are consistently linked to NA (Das-Friebel et al., 2020; Fuller-Tyszkiewicz et al., 2017; Kaufmann et al., 2016; Pemberton et al., 2016; O'Leary et al., 2017; Scott et al., 2017). The fact that we found a moderate

effect of sleep quality on NA, whereas Fuller-Tyszkiewicz and colleagues (2017) found no effect, fuels the speculations by Fuller-Tyszkiewicz and colleagues (2017) that tiredness might not be a good proxy for sleep quality. Future studies into sleep and mood/mental health in daily life may thus want to ask sleep quality directly rather than tiredness.

Opposing our expectations, negative events were unrelated to participants' subsequent changes in NA. Such lack of effect can sometimes result from a lack of power to observe an effect. Although we had a very large sample size ($N=1396$), and in line with other EMA studies, participants on average experienced six to seven negative events during the 30 day study duration. Perhaps, the low amount of negative events experienced by participants resulted in lower predictive power compared to the other risk/protective factors. Another possibility is that 1) the time lag of 0-6 hours was too large to capture the effects of negative events on NA, or 2) our binary measure of negative events either is too generic to be of unique predictive value in collectively predicting NA. Johnson et al. (2008) showed that the effects of daily stressors on NA linger around 6–9 h after onset, and Fuller-Tyszkiewicz and colleagues (2017) also found effects of stressful experiences on mood 2-5 hours later. However, Fuller-Tyszkiewicz and colleagues measured the level of stress caused by negative events on a continuous scale, which points to the direction that our binary measure of negative events was maybe too generic in terms of the stress caused by the event. Table 1 shows a small to moderate negative correlation (-0.30) between negative events and coping, suggesting that negative events captured generated stress only for a small part.

Turning to PA and the five risk and protective factors, we expected a protective effect of appraisal of social company and physical activity (i.e., a positive association between appraisal of social company and physical activity in the past six hours and subsequent changes in PA). Different for our expectations, however, the results show no association between physical activity or social activity and subsequent change in PA. Instead, the pattern of estimates almost inversely mirrored the pattern for NA, with the largest

contributors to changes in PA being respectively coping ability, and sleep quality. Although the mirroring can be partly explained by the moderately to strong PA-NA correlation both on the within- and between-subject level that we found (in line with Gill et al., 2017) such inverse patterns remain remarkable, given that previous findings seem to suggest that NA and PA are affected differently by the five major risk and protective factors. Our exploratory post hoc analyses showed that, when the risk and protective factors were studied in isolation, negative events were risk factors and physical and social activities were protective factors for mental health. However, when studied collectively in one model, physical and social activities appeared to have no unique predictive value for changes in PA up to six hours later above and beyond coping, sleep, and negative events. These results underscore the importance of context when targeting lifestyle factors in prevention and intervention strategies aimed at improving PA, and that, instead of in isolation, the predictive value of risk/protective factors should be targeted after studying their combined and collective effect relative to the other important risk/protective factors.

Other explanations for the inverse patterns of PA and NA are also possible. For example, it is possible that physical activity has a unique predictive value for subsequent changes in PA in a collective model but we were unable to capture this effect across a time window of 0-6 hours. Support for this alternative explanation comes from research that shows that physical activity likely takes about 30 min to influence mood (Wen et al., 2018), and its mood-changing effects linger up to 180 minutes (Wichers et al., 2012). In line with these findings, Fuller-Tyszkiewicz and colleagues (2017) compared the effect of physical activity on NA across different time lags, and found a small negative association between physical activity and NA when assessed up to two hours apart which disappeared when physical activity and NA were assessed 2-5 hours apart. Together, these findings suggest that the effect of physical activity may have already waned before we tried to assess it zero to six hours later. Purely speculative, similar processes might be at play for appraisal of social company, at least for PA. For NA the latter is less likely, given that for social

interaction Fuller-Tyszkiewicz and colleagues (2017) found no significant associations with NA (not across less than two hours, 2-5 hours, nor after five hours).

In the present study we assumed NA and PA were two independently functioning dimensions, and examined the effects of the risk/protective factors on PA and NA separately. Indeed, a reduction in NA does not necessarily lead to improvements in PA (Keyes, 2014; Kim and Hamann 2007; Gross and John 2003; Posner et al. 2005; Watson et al., 1988), and that risk/protective factors could have different effects on NA compared to PA. For both NA and PA, sleep and coping relatively provided the largest contribution to subsequent changes in PA, followed by social activity (NA) and negative events (PA). That we found a nearly inverse pattern of the risk-/protective factors for PA compared to NA indicates that general affect could be less independent than we assumed a priori. Support for such dependence between NA and PA comes from the moderate to strong PA-NA correlation we found on both inter and intra-subject levels. Such strong correlation are also found in previous studies (Gill et al., 2017). If both dimensions of affect are so closely related, in an ideal world, the effect of the major risk and protective factors on NA and PA should also be modelled simultaneously. In reality, however, this not always seems statistically possible, as also evidenced by the risk of overfit we encountered in the present study.

Finally, because the combined and relative effects on mood might be different in individuals with clinically relevant levels of depressive symptoms, we also explored patterns in participants with at least mild depressive symptoms. When eyeballing the explained variance across models (i.e., without formal testing), there seems little difference in depressed participants: the collective models explain approximately 24% (versus 23% in the whole sample) of participants' changes in NA and approximately 19% (versus 15% in the whole sample) of participants' changes in PA. Also the regression coefficients seem fairly similar, suggesting that coping and sleep may prove interesting targets for both prevention and treatment strategies.

Study limitations

This study has several limitations. First, some of the risk/protective factors correlate, which may have caused some level of multicollinearity although we standardized all predictors. Although the correlations in Table 1 are not indicative of exact or perfect multicollinearity, the coefficients show a considerably range, suggesting that the correlation among the factors creates at least some redundant information that blows up the explained variance.

Second, we studied unidirectional effects of the risk/protective factors on mood states in daily life, but there may actually be bi-directional effects present for some – or all – of the risk/protective effects. For example, subjective sleep variables show a reciprocal relationship, as affective states also predict subjective sleep as reported on the next day (Konjarski et al., 2018; Könen et al., 2016; but see: Koch et al., 2020).

Third, we focused on direct effects of the five major risk and protective factors for mental health, but cannot exclude any indirect effects. For example, physical activity shows no direct effects in our collective model, but could potentially indirectly influence mood via sleep. That is, more physical activity could lead to better sleep which, in turn, increases PA and decreases NA experiences in the six hours thereafter.

Conclusions

Physical activity, sleep quality, social contexts, negative events, and coping are major risk and protective factors for mental health. Collectively, these factors explain a considerable amount of variance in the subsequent changes in negative mood (23%), and positive mood (15%), up to six hours later. Although all five factors seem related to mental health when studied in isolation, studying the risk and protective factors collectively shows that only primarily coping ability and sleep quality affect individuals' mental health, making them potentially interesting targets for interventions and psychotherapy that aim to enhance

positive mood and decrease negative mood.

Declarations

Author's contribution

V.E.H. and N.C.J. developed the study concept. Data collection was performed by B.F.J and P.d.J., and V.E.H. performed the data analysis. V.E.H. drafted earlier versions of the manuscript, and N.C.J., B.F.J. and P.d.J. provided critical comments and suggestions for revisions. All authors approved the final version of the paper for submission.

Ethics approval and consent to participate

The HND study protocol was assessed by the Medical Ethical Committee of the University Medical Centre Groningen. The committee judged the protocol to be exempted from review by the Medical Research Involving Human Subjects Act (in Dutch: WMO) because it concerned a non-randomized open study targeted at anonymous volunteers in the general public (registration number M13.147422 and M14.160855).

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Table 1

Means, standard deviations, and correlations with confidence intervals

Variable	M	SD	1	2	3	4	5	6
1. PosAffect	54.77	12.18						
2. NegAffect	29.75	14.09	-.69** [.72, -.66]					
3. Sleep	62.48	13.51	.54** [.50, .58]	-.47** [.51, -.42]				
4. Coping	76.57	16.93	.53** [.49, .57]	-.79** [.81, -.77]	.37** [.32, .42]			
5. NegEvent	6.42	10.00	-.18** [.23, -.13]	.20** [.15, .25]	-.16** [.21, -.10]	-.30** [.35, -.25]		
6. Social	72.11	11.00	.53** [.49, .57]	-.43** [.47, -.38]	.40** [.35, .45]	.36** [.32, .41]	-.16** [.22, -.11]	
7. Physical	35.66	13.81	.28** [.23, .33]	-.07* [.12, -.02]	.07* [.01, .12]	.01 [.04, .07]	-.08** [.14, -.03]	.15** [.10, .21]

Note. M and SD are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval (Cumming, 2014). The correlations are on between-subjects level. Please note that correlation might be different on the within- and between-subjects level (c.f., Gill et al., 2017). * indicates $p < .05$. ** indicates $p < .01$.

Table 2

Association between the five major risk/protective factors and Negative Affect (left)/ Positive Affect (right)

	Negative Affect (NA)				Positive Affect (PA)					
	Estimate	Std. Error	df	t value	Pr(> t)	Estimate	Std. Error	df	t value	Pr(> t)
(Intercept)	-1.31	0.37	300.50	-3.53	0.00	0.53	0.38	292.60	1.38	0.17
scale(coping_c)	-3.99	0.43	193.50	-9.28	0.00	3.09	0.41	1,310.60	7.56	0.00
scale(sleep_c)	-2.33	0.36	1,225.04	-6.47	0.00	3.03	0.39	1,291.08	7.72	0.00
scale(social_c)	-0.75	0.37	1,277.15	-2.04	0.04	0.73	0.40	1,310.32	1.84	0.07
scale(NegEvent)	0.64	0.38	1,079.40	1.69	0.09	-1.12	0.40	1,304.77	-2.83	0.00
scale(physical_c)	-0.25	0.36	1,253.43	-0.70	0.49	0.65	0.40	1,290.01	1.62	0.11

Note. Std. Error and df refer to standard error and degrees of freedom. Significant effects are in bold.

Figure 1. Forest-plot of standardized beta values for the association between risk/protective factors and changes in Positive Affect (PA) in daily life. To make the coefficients are then directly comparable for untransformed binary predictors, following Gelman (2008), standardization is done by dividing by two sd. Coefficients are sorted on effect size.