



## Ecological momentary assessment of self-rated health, daily strategies and self-management app use among trauma-exposed adults

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### ABSTRACT

**Background:** The process whereby trauma-exposed people benefit from self-management apps to increase health is poorly understood.

**Objective:** We investigated whether access to a self-management smartphone app for post-traumatic stress (PTSD Coach) improved momentary self-rated health (SRH) and if use of a self-management app or specific strategies related to SRH.

**Method:** Participants were 179 adults in Sweden with trauma exposure in the past 2 years who were enrolled in a randomized trial of PTSD Coach versus waitlist. Ecological momentary assessments (EMA) were collected twice daily during 21 consecutive days from participants in both groups, with questions about momentary SRH as well as self-management app use and use of strategies (social support, distress management, monitoring of discomfort and seeking information) in the preceding 12 hours.

**Results:** Overall, neither access to PTSD Coach nor reported use of an app in the preceding hours was related to SRH. Even so, people with access to PTSD Coach reported using more social support over time. Socializing and use of social support predicted greater SRH. Use of other strategies was associated with worse short-term SRH.

**Conclusions:** Momentarily improved health relates to utilization of social support. However, the directionality of the day-to-day associations is unclear; uncertainty remains around the timing for assessing these relationships.

### Evaluación ecológica momentánea de la salud autoevaluada, las estrategias diarias y el uso de aplicaciones de autogestión entre adultos expuestos a trauma

**Antecedentes:** El proceso por el cual las personas expuestas al trauma se benefician de las aplicaciones de autogestión para mejorar la salud es poco conocido.

**Objetivo:** Investigamos si el acceso a una aplicación de autogestión para teléfonos inteligentes, para el estrés postraumático (PTSD Coach) mejora la salud autoevaluada del momento (SRH en su sigla en inglés) y si el uso de una aplicación de autogestión o estrategias específicas se relacionan con la SRH.

**Método:** Los participantes fueron 179 adultos en Suecia con exposición a trauma en los últimos dos años que se inscribieron en un ensayo aleatorio de PTSD Coach versus lista de espera. Las evaluaciones ecológicas momentáneas (EMA en su sigla en inglés) se recopilaron dos veces al día durante 21 días consecutivos en los participantes de ambos grupos, con preguntas sobre SRH del momento, así como el uso de aplicaciones de autogestión y el uso de estrategias (apoyo social, manejo del estrés, monitoreo del malestar y búsqueda de información) en las 12 horas anteriores.

**Resultados:** En general, ni el acceso a PTSD Coach ni el uso informado de una aplicación en las horas anteriores se relacionaron con la SRH. Aun así, las personas con acceso a PTSD Coach informaron que usaron más apoyo social a lo largo del tiempo. La socialización y el uso del apoyo social predijeron una mayor SRH. El uso de otras estrategias se asoció con peor SRH a corto plazo.

**Conclusiones:** La mejora en salud del momento se relaciona con la utilización del apoyo social. Sin embargo, la direccionalidad de las asociaciones del día a día no está clara y persiste la incertidumbre sobre el momento para evaluar estas relaciones.

### 成年创伤暴露者自评健康状况、日常策略和自我管理应用程序使用的生态瞬时评估

**背景:** 对于创伤暴露者从用以提高健康水平的自我管理应用程序中受益的过程了解很少。

**目的:** 我们考查了使用针对创伤后应激的自我管理智能手机应用程序 (PTSD Coach) 是否改善了瞬时自我评估的健康状况 (SRH), 以及是否使用自我管理应用程序或特定策略与SRH相关。

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### PALABRAS CLAVE

TEPT; salud autoevaluada; aplicación; salud mental a distancia; RCT; EMA

### 关键词

PTSD; 自评健康状况; 应用程序; 电子心理健康; RCT; EMA

### HIGHLIGHTS

- Access to the self-management app PTSD Coach increased use of social support, but not momentary self-rated general health, compared to waitlist.
- Use of social support was related to greater short-term health.

**方法:** 参与者为179名在过去两年中有创伤暴露的成年瑞典人,他们参与了PTSD Coach组与候补名单组的随机试验。两组参与者连续21天每天两次进行生态瞬时评估(EMA),回答了之前12小时内有关瞬时SRH以及自我管理应用程序使用和策略使用(社会支持,困扰管理,不适感监测和寻求信息)的问题。

**结果:** 总体上,在前几个小时中使用PTSD Coach组或未报告使用应用程序组均与SRH无相关。即便如此,可以使用PTSD Coach者报告了随时间推移会使用更多的社会支持。社会化和社会支持的使用预测了更高的SRH水平。使用其他策略与短期SRH恶化有关。

**结论:** 瞬时改善的健康状况与社会支持的使用有关。日常关联的方向性尚不清楚,但是关于评估这些关系的时间选择仍存在不确定性。

## 1. Introduction

Trauma-focused psychological interventions are designed to promote health, but it is unclear whether the intervention components and strategies contribute to well-being. Repeated measurements of intervention or strategy utilization and health during the everyday life of trauma-exposed adults can identify helpful components for improving well-being, and illustrate how factors fluctuate within and between individuals over time.

### 1.1. Health status and posttraumatic stress disorder

Self-rated health (SRH; Idler & Benyamini, 2007) is a single question regarding the perception of overall health (momentarily or in general) which comprises the objective, subjective and social information the respondent has about their health within their cultural context (Jylhä, 2009). SRH is an encompassing and accurate statement of physical and mental health status (Idler & Benyamini, 2007; McDowell, 2006) which relates to other measures of physical and mental health (DeSalvo et al., 2006) and to the trajectory of long-term health-related outcomes such as mortality (Idler & Benyamini, 2007).

Posttraumatic stress disorder (PTSD) is a diagnostic construct of symptoms and disability after exposure to potentially traumatic events (American Psychiatric Association, 2013). PTSD and depression are linked to poor SRH among victims of rape (Amstadter, McCauley, Ruggiero, Resnick, & Kilpatrick, 2011). Survivors of intimate partner violence with comorbidity such as depression or PTSD report poor or fair self-rated mental health more often than other survivors (Kastello et al., 2015). Veterans with PTSD report impaired global well-being compared to veterans without PTSD (Kashdan, Julian, Merritt, & Uswatte, 2006).

### 1.2. Technological interventions and health

New technology facilitates remote administration of trauma-related interventions. People with severe psychiatric illness report using mobile phones and apps to improve their health, to find health-related information or connect with significant others (Naslund, Aschbrenner, & Bartels, 2016). The self-management

app PTSD Coach (Kuhn et al., 2018) is an unguided, low-intensity, trauma-focused intervention with four modules: *Learn* (psychoeducation about trauma-related topics), *Track* (symptom self-evaluation with automatic feedback), *Manage symptoms* (advice and exercises) and *Get support* (contact information for helplines, further treatment and advice on how to increase one's social support).

The app has promising effects for symptom reduction (Cernvall, Sveen, Johannesson, & Arnberg, 2018; Kuhn et al., 2014; Miner et al., 2016; Possemato et al., 2016; Tiet et al., 2019). While existing studies on PTSD Coach have investigated the outcome of app access during 1 to 4 months, we know little about the influence of the specific modules in PTSD Coach, or their corresponding strategies, on health. Mobile analytics data and online reviews of a previous version of PTSD Coach indicated that use of the app declined over time (Owen et al., 2015). Most returning users visited the modules for symptom self-evaluation or symptom management; the social support module was the least visited module (Owen et al., 2015). Indeed, use of a stress management tool in PTSD Coach was linked to decreased momentary distress (Owen et al., 2015).

Changes in health over time are equally relevant to investigate as the presence of symptoms (Kashdan et al., 2006). Therefore, we wanted to explore how the use of self-management apps and specific strategies contributed to variability in health among trauma-exposed adults in their everyday life within the context of our randomized controlled trial (RCT) of the Swedish adaptation of PTSD Coach (Clinical Trials, 2019).

### 1.3. Ecological momentary assessment

People with posttraumatic stress experience fluctuating symptoms and health in their everyday life (Biggs et al., 2019; Chun, 2016; Pfaltz, Michael, Grossman, Margraf, & Wilhelm, 2010). However, research often relies on participants' retrospective recall of their experiences over a period of several weeks or months. Thus, responses may suffer from retrospective bias (Chun, 2016), inaccurate masking of variation, and typical presentation of states, which impairs the quality of data (Schwartz & Stone, 1998). Ecological

momentary assessment (EMA) entails repeatedly collecting data in a person's natural context as the phenomenon of interest (e.g. states, behaviours, experiences) occurs over time (Shiffman, Stone, & Hufford, 2008) in order to explore individual fluctuations in the phenomenon (Bolger & Laurenceau, 2013) and interactions with other factors over time (Shiffman et al., 2008). EMA surveys are often very brief in order to enable a high frequency of assessments over time without unnecessary burden or obstacles for respondents (Chun, 2016). The method is a powerful tool for evaluating the intra- and interpersonal effects of interventions in real life, as it enables investigation of long- and short-term associations among variables and can disentangle within- and between-person deviations from the typical response.

#### 1.4. EMA-research with trauma-exposed people

EMA-research with daily assessments of consequences related to trauma-exposure, posttraumatic stress or PTSD have investigated numerous topics, for example, specific peri- or posttraumatic stress symptoms (e.g. Biggs et al., 2019; Black et al., 2016; Gelkopf, Lapid Pickman, Carlson, & Greene, 2019), other symptoms like anxiety, worry, pain (e.g. Koch, Liedl, Takano, & Ehring, 2020; Pacella, Girard, Wright, Suffoletto, & Callaway, 2018; Pfaltz et al., 2010) and positive and negative emotions (e.g. Dornbach-Bender et al., 2020; Van Voorhees et al., 2018). Few studies have investigated health, rather than symptoms, but related topics such as self-esteem and well-being have been explored (Kashdan, Breen, & Julian, 2010; Kashdan et al., 2006). To the best of our knowledge, previous EMA studies have not explored how trauma-exposed adults cope or utilize strategies in relation to SRH.

Repeated assessments may induce a reactive change in the measured phenomena. Daily EMA-monitoring has been related to decreased symptoms (Dewey et al., 2015; Possemato et al., 2012; TARRIER, Sommerfield, Reynolds, & Pilgrim, 1999), increased symptoms (Pedersen, Kaysen, Lindgren, Blayney, & Simpson, 2013) or unchanged

symptoms of posttraumatic stress (Simpson, Kivlahan, Bush, & McFall, 2005). Daily assessments are generally well tolerated and feasible (e.g. Chun, 2016; Pacella et al., 2018; Pedersen et al., 2013; Possemato et al., 2012).

#### 1.5. Aim of the study

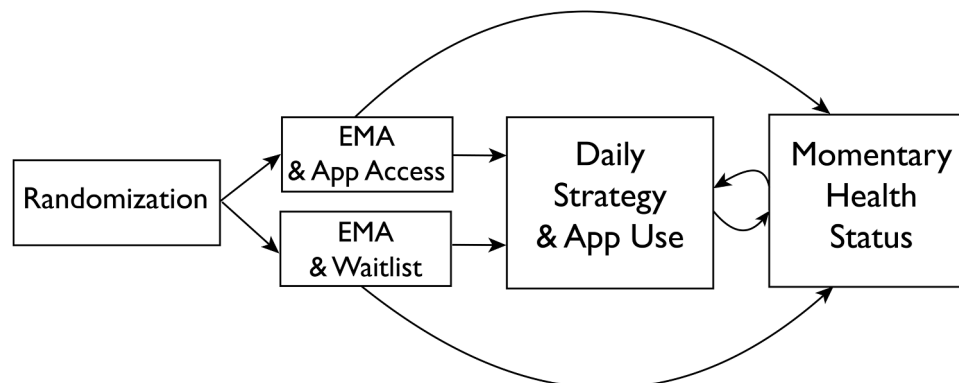
The aim of this study was to investigate whether the use of a self-management app and use of specific strategies, which reflect the content of PTSD Coach, improve SRH among trauma-exposed adults. We posed a number of specific research questions: 1. Is access to PTSD Coach related to momentary health during 21 days? 2. Is individual and between-person variation in use of specific strategies or use of a self-management app associated with momentary health? 3. Do people experience better momentary health during days when they both use an app and use specific strategies? In addition, we explored trends in strategy and app use over time, with and without access to PTSD Coach, and if self-rated posttraumatic stress at baseline correlated with SRH.

## 2. Method

### 2.1. Procedure

We designed the study (Figure 1) as an EMA of SRH within a larger RCT. The RCT investigated whether 3 months of access to PTSD Coach was superior to waitlist in reducing posttraumatic stress, depressive and somatic symptoms. The participants in the intervention condition (EMA<sub>App</sub>) had access to the app PTSD Coach and responded to the EMA-surveys. The participants in the waitlist condition (EMA<sub>Wait</sub>) responded to the EMA-surveys but did not have access to PTSD Coach (Figure 2).

We performed the study at the National Centre for Disaster Psychiatry in Uppsala, Sweden. Participants were recruited through social media advertisements. Enrolment began on 9 May 2019, and ended 25 June 2020. Data collection ended on 2 September 2020. The participants



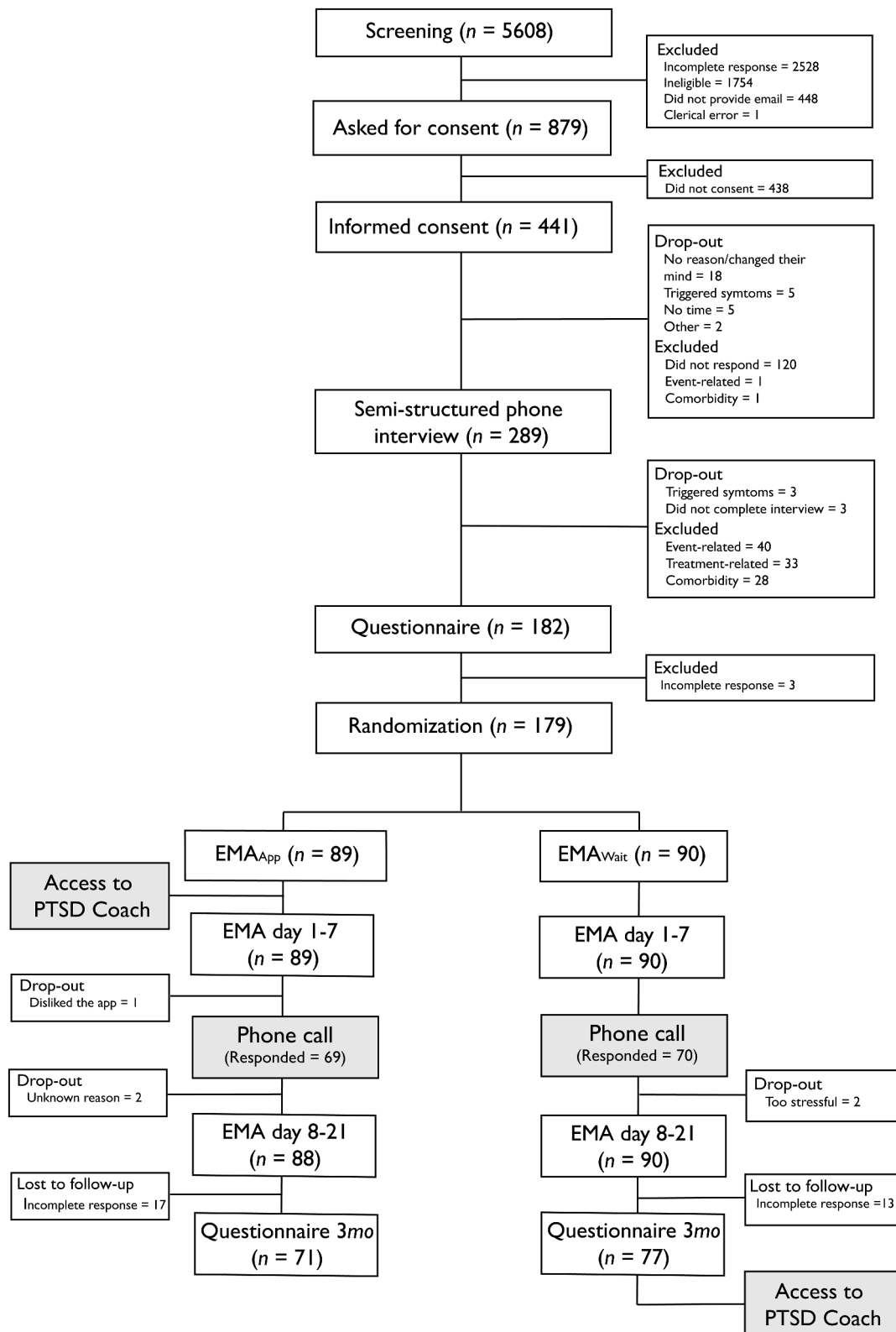
**Figure 1.** Study design and analytic model.

Note. The statistical analysis included time as a predictor of strategies, app use and momentary health. EMA = ecological momentary assessment.

partook remotely from any location with internet access and cellular service. All work pertaining to the study was conducted with the formal approval by the Regional Ethical Review Board in Uppsala, Sweden (Dnr 2018/319).

Potential participants received written information about study participation, confidentiality and provided written, informed consent online. They were

interviewed by a member of the research team over the phone, completed a baseline questionnaire online and randomized on a 1:1 basis. We informed the participants that they could use the app as needed. The EMA-procedure began the day after randomization to waitlist or access to PTSD Coach. Participants filled out the EMA-questionnaire twice daily (at 09:00



**Figure 2.** Study procedure and participant flow.

Note. Shaded boxes indicate scheduled support and intervention administration. EMA = Ecological Momentary Assessment.

and 21:00) at 42 occasions during 21 consecutive days. A link to the assessment was sent by text message to the participant's phone. Incomplete responses triggered at most two reminders after 2 and 4 hours, respectively. The response time was not limited. We asked participants in both groups the same questions about use of strategies, use of self-management apps, and SRH to enable a controlled comparison and exclude confounding reactive change to the assessments. We called participants 1 week after randomization and offered the opportunity to ask questions. Participants filled out a follow-up questionnaire after 3 months. The results of the follow-up will be reported elsewhere. Participation was compensated with two vouchers for movie tickets.

## 2.2. Participants

Inclusion criteria were Swedish verbal and written comprehension, age  $\geq 18$  years, access to a smartphone, experience of a potentially traumatic event according to DSM-5 criteria during the past 2 years, and reporting at least mild symptoms of current posttraumatic stress (i.e. total score  $\geq 10$  on the PTSD Checklist for DSM-5). The inclusion cut-off score of  $\geq 10$  was determined based on the definition of clinically significant change used in prior evaluations of PTSD Coach (Kuhn et al., 2017; Miner et al., 2016; Possemato et al., 2016) to enable detection of reliable symptom change among people with mild posttraumatic stress. Exclusion criteria were screening positive for lifetime manic/hypomanic or psychotic episode, current severe suicidal plans/ideation or alcohol/substance abuse, current exposure to traumatic events, ongoing psychotherapy, medication counter-indicative for psychological interventions (such as benzodiazepines) or medication changes within 3 months.

The final sample included 179 adults (164 women, 15 other/men) with a mean age of 42.78 years ( $SD = 10.90$ ), see Table 1 for sociodemographic characteristics. The participants provided 37 722 observations (Waitlist = 19 627; App = 18 095) during the 42 consecutive 12-hour timeslots (16.37% missing observations). The most common potentially traumatic events were exposure to physical assault, sudden violent death (e.g. murder/suicide), sexual violence and life-threatening illness or injury, and most participants had experienced (55.31%) or witnessed (27.37%) the event first-hand (Table 2). Baseline post-traumatic stress ratings were high ( $M = 37.31$ ,  $SD = 15.94$ ) and 55.31% of participants screened positive for PTSD at inclusion.

## 2.3. Intervention

The smartphone app PTSD Coach is a tool for managing and alleviating posttraumatic stress and other trauma-related problems. It was developed by the U.S. Department of Veterans Affairs' National Center for

**Table 1.** Sociodemographic characteristics and smartphone use at baseline ( $n = 179$ ).

Characteristic	Description	<i>n</i>	%
Gender	Woman	164	91.62
	Man, other/prefer not to answer	15	8.38
Civil status	In relationship	94	52.51
	Single	74	41.34
	Other	14	7.82
Education	University	100	55.86
	Senior high school	37	20.67
	Incomplete university	22	12.29
	Incomplete primary school, junior or senior high school	14	7.82
Occupation	Vocational school	6	3.34
	Employed full-/part-time	115	64.25
	Sick-leave	23	12.85
	Student	18	10.06
	Retired, other	14	7.82
Smartphone use	Unemployed	9	5.03
	Daily, > 2 hours	146	81.56
	Daily, < 2 hours	33	18.44
	Less than daily	0	0.00

**Table 2.** Exposure to potentially traumatic events in the past 2 years.

LEC-5 item	Event description	<i>n</i>	%
1, 2, 5	Natural disaster, fire, explosion, exposure to toxic substance	9	5.03
3, 4	Transportation or other serious accident	20	11.17
6, 7	Physical or weapon's assault	35	19.55
8, 9	Sexual assault, other unwanted or uncomfortable sexual experience	32	17.88
10, 11	Combat or exposure to war-zone, captivity	7	3.91
12	Life-threatening illness or injury	26	14.53
14	Sudden, violent death	32	17.88
15	Sudden, accidental death	12	6.70
17	Other stressful event or experience	6	3.35

Note.  $N = 179$ . LEC-5 = Life Event Checklist for DSM-5.

PTSD and the Department of Defence's DHA Connected Health (Kuhn et al., 2014). The app has four modules. One contains psychoeducation about PTSD and trauma-related problems. A second module provides the user the opportunity to rate their posttraumatic stress and monitor their progress over time. Another module provides self-management exercises inspired by cognitive behavioural therapy to manage and alleviate symptoms, such as mindfulness, visualization, positive psychology, cognitive restructuring and stress inoculation. The last module provides contact information to support and crisis resources via telephone helplines, email, chat forums and websites, and suggestions for using and increasing social support. The Swedish version was adapted from the American version (Kuhn et al., 2014, 2017). Download of the Swedish version of PTSD Coach was restricted to participants in the intervention group during the study.

## 2.4. Measures

### 2.4.1. Momentary health

The primary outcome was momentary SRH. We defined momentary health as the response to the one-

item question ‘How would you rate your general health right now?’ with responses ranging from ‘extremely bad’ (0) to ‘extremely good’ (6) on a 7-point Likert scale. Single-item SRH has been assessed in studies of trauma-exposed people (e.g. Amstadter et al., 2011; Kastello et al., 2015).

#### 2.4.2. Daily app use

We did not have the possibility to retrieve objective usage data from PTSD Coach. Therefore, daily use of self-management apps was assessed with a one-item question phrased as ‘Have you used a self-management app during the past 12 hours?’ with a binary response option (yes or no).

#### 2.4.3. Daily strategy use

Participants were asked to rate to what extent they had used any of the four strategies in the past 12 hours. Specifically, they were asked to what extent they had ‘... evaluated your level of discomfort (for instance taken a quiz)?’ (Symptom monitoring); ‘... socialized or sought support among others?’ (Social support); ‘... used a technique or strategy to handle discomfort?’ (Distress management); or ‘... sought or taken part of information about mental illness?’ (Seeking information). These four strategies correspond to the content of the PTSD Coach modules; however, the questions were worded such that they could be responded to regardless of RCT condition. The participants answered on a 7-point Likert scale from ‘not at all’ (0) to ‘an extreme extent’ (6).

#### 2.4.4. Potentially traumatic events, posttraumatic stress and PTSD

Information about the recent potentially traumatic event was collected during the baseline phone interview. The responses to open-ended questions were categorized by research personnel according to the event categories from the Life Events Checklist for DSM-5 (Gray, Litz, Hsu, & Lombardo, 2004). Symptoms of posttraumatic stress were assessed at baseline with the Swedish version of the PTSD Checklist for DSM-5 (PCL-5; Blevins, Weathers, Davis, Witte, & Domino, 2015; Bondjers, 2020). PCL-5 includes 20 items which reflect DSM-5 PTSD criteria and give a total score of posttraumatic stress symptom burden in the past month (range 0–80). Probable current PTSD according to DSM-5 was assessed with the MINI International Neuropsychiatric Interview (Lecrubier et al., 1997), Swedish version 7.0.0, a semi-structured clinical screening interview for common psychiatric disorders.

### 2.5. Data analysis

We analysed the data in R version 3.5.1 (The R Foundation, 2018) with linear mixed-effects modelling

(Nlme package v3.1-141). The people who dropped out of the study after randomization were retained in the analyses. Missing assessments ( $n = 1194$ ;  $EMA_{Wait} = 498$ ;  $EMA_{App} = 696$ ) and missing data within assessments ( $n = 222$ ;  $EMA_{Wait} = 65$ ;  $EMA_{App} = 157$ ) were not substituted. Mixed-effects models with maximum likelihood estimation were used to evaluate (a) if access to PTSD Coach was related to strategy and app use over time, (b) if access to PTSD Coach was related to health over time and (c) if the interaction between app use and strategy use was related to health over time. Random intercepts and slopes were estimated. For the main analyses of strategy use, app use, and health, the time-varying predictors were centred in two ways to separate between-subject and within-subject relationships (Bolger & Laurenceau, 2013). The process generated two variables for each predictor: Predictors were centred within cluster (*cwc*) by subtracting the individual mean score across time points from the individual’s observation at each time point, as well as central mean centred (*cmc*) by subtracting the group mean across subjects and time points from the individual mean across time points (Bolger & Laurenceau, 2013). We did not include both condition and self-management app use in the models, as more frequent use was expected among participants with access to PTSD Coach. The covariance matrix was specified to have an AR(1) structure. All models did not converge with the standard optimization method, and therefore the optim method was used. The study was sufficiently powered according to the a priori analysis for the RCT; no a priori power analysis was done specifically for the EMA analyses.

### 3. Results

Descriptive data for the average health, use of a self-management app and strategy use across all occasions are reported in Table 3. In total, all  $EMA_{Wait}$  participants used a self-management app at 33 occasions ( $m < 1$  occasion/person) and all  $EMA_{App}$  participants used a self-management app at 537 occasions ( $m \geq 6$  occasions/person) during the 42 occasions (21 days). The  $EMA_{App}$  participants seemed to report more frequent use of a self-management app and greater use of daily strategies compared to the  $EMA_{Wait}$  participants (Table 3). Therefore, we explored the trends in daily strategy and self-management app use across conditions and time in separate regression models with random intercepts and slopes (Table 4). Greater use of symptom monitoring, information seeking and more frequent use of an app were reported at the outset among  $EMA_{App}$  compared to  $EMA_{Wait}$  participants.  $EMA_{Wait}$  participants tended to report less or unchanged use of strategies and self-management apps over time. There were interaction effects between time and condition regarding app use and social support; even though the  $EMA_{App}$  participants used self-

**Table 3.** Averages of self-management app use and daily strategy use related to access to PTSD Coach across 21 days.

	All		EMA <sub>App</sub>		EMA <sub>Wait</sub>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Health <sup>a</sup>	3.22	1.36	3.32	1.25	3.13	1.45
App use <sup>b</sup>	0.09	0.29	0.18	0.38	0.01	0.10
Social support <sup>c</sup>	1.69	1.78	1.85	1.83	1.54	1.73
Distress management <sup>c</sup>	1.17	1.63	1.41	1.73	0.94	1.51
Symptom monitoring <sup>c</sup>	0.55	1.20	0.80	1.41	0.33	0.93
Information seeking <sup>c</sup>	0.41	1.09	0.59	1.28	0.24	0.84

Note. *N* participants = 179 and *n* observations = 37,722 across 42 occasions (12-hour intervals). EMA<sub>App</sub> = participants with access to PTSD Coach; EMA<sub>Wait</sub> = participants on waitlist without access to PTSD Coach.

<sup>a</sup>Rated on an ordinal scale (0 = Extremely bad to 6 = Extremely good). <sup>b</sup>Rated on a binary scale (0 = No, 1 = Yes). <sup>c</sup>Rated on an ordinal scale (0 = Not at all to 6 = To an extreme extent).

**Table 4.** Mixed-effects models of time and access to PTSD Coach on strategy use and app use.

Predictors	App Use		Social Support		Distress Management		Symptom Monitoring		Information Seeking	
	<i>B</i>	<i>SE</i>	<i>B</i>	<i>SE</i>	<i>B</i>	<i>SE</i>	<i>B</i>	<i>SE</i>	<i>B</i>	<i>SE</i>
Intercept	0.02	0.02	1.77***	0.12	1.16***	0.13	0.39***	0.09	0.42***	0.08
Time <sup>a</sup>	-0.003	0.01	-0.11*	0.05	-0.14**	0.05	-0.02	0.04	-0.10*	0.04
App access <sup>b</sup>	0.21***	0.02	0.01	0.18	0.36	0.19	0.41**	0.12	0.37***	0.12
Time × App Access	-0.03*	0.01	0.17*	0.08	0.08	0.07	0.02	0.06	-0.03	0.06
<i>AIC</i>	583.8		22834.4		20186.6		17228.6		16841.3	
<i>BIC</i>	644.4		22895.1		20247.3		17289.3		16902.0	
<i>LL</i>	-282.9		-11408.2		-10084.3		-8605.3		-8411.7	
<i>N</i> observations	6233		6288		6294		6296		6289	

Note. *N* participants = 179 for all models. Access to PTSD Coach was administered the day before the first Ecological Momentary Assessment. App use and strategy use were assessed at 42 occasions (12-hour intervals) during 21 days. *AIC* = Akaike information criterion; *BIC* = Bayesian information criterion; *LL* = log-likelihood.

<sup>a</sup>One unit represents one week for readability. <sup>b</sup>0 = waitlist, 1 = access to PTSD Coach.

\*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$ .

management apps more frequently, app use decreased over time. In addition, access to PTSD Coach was related to greater use of social support over time (Table 4).

### 3.1. Strategies and health

Access to PTSD Coach did not affect health over time (Table 5). We analysed whether within-subjects (*cwc*) or between-subjects (*cmc*) variation in degree of strategy use and frequency of self-management app use predicted health (Table 6) independently over time (Model 1), and if daily strategies in interaction with app use (*cwc*) predicted health over time (Model 2). The participants rated their health as greater over time. Participants who used more social support than usual (*cwc*) during the past 12 hours reported their momentary health as better. Likewise, people who, on average, were more sociable and sought more social support than others (*cmc*) rated their momentary health as better during 21 days. In contrast, people who used the strategies distress management, symptom monitoring (Model 1 and 2) and sought information about mental illness (Model 2) more than usual (*cwc*) during the past 12 hours reported their momentary health as worse (Table 6). Self-management app use (*cwc* and *cmc*) was unrelated to momentary health, and no interaction effects were detected between using a self-management app and daily strategy use (*cwc*).

**Table 5.** Mixed-effects model of access to PTSD Coach on momentary health.

Predictors	<i>B</i>	<i>SE</i>	95% <i>CI</i>	
			Lower	Upper
Intercept	3.05***	0.11	2.83	3.27
Time <sup>a</sup>	0.07	0.04	-0.01	0.14
App Access <sup>b</sup>	0.16	0.16	-0.15	0.47
Time × App Access	0.01	0.06	-0.10	0.12

Note. *N* participants = 179, *n* observations = 6322. Momentary health was assessed at 42 occasions (12-hour intervals) during 21 days. *CI* = confidence interval.

<sup>a</sup>One unit represents one week for readability. <sup>b</sup>0 = waitlist, 1 = access to PTSD Coach.

\*\*\*  $p < 0.001$ .

### 3.2. Posttraumatic stress

We explored the validity of our measurement by correlating baseline posttraumatic stress with the participants' first rating of health. Posttraumatic stress at baseline ( $M = 37.31$ ,  $SD = 15.94$ ) was weakly correlated with the initial rating of health ( $r = -0.37$ ,  $p < .001$ , 95%  $CI = -0.49, -0.24$ ).

## 4. Discussion

In summary, neither access to PTSD Coach nor reported use of a self-management app in the past 12 hours, or greater use of a self-management app than others during 21 days, improved momentary health. Greater use of distress management techniques, symptom monitoring and seeking information

**Table 6.** Mixed-effects models of within-person and between-person effects of daily strategy use and self-management app use on momentary health.

Predictors	Model 1				Model 2			
	<i>B</i>	<i>SE</i>	95% <i>CI</i>		<i>B</i>	<i>SE</i>	95% <i>CI</i>	
			Lower	Upper			Lower	Upper
Intercept	3.15***	0.08	3.00	3.30	3.14***	0.08	2.99	3.29
Time <sup>a</sup>	0.06**	0.02	0.02	0.09	0.06**	0.02	0.02	0.09
<u>Within-person (<i>cwc</i>)</u>								
Social support	0.07***	0.01	0.04	0.10	0.07***	0.01	0.04	0.10
Distress management	-0.07***	0.02	-0.11	-0.04	-0.07***	0.02	-0.10	-0.04
Symptom monitoring	-0.06**	0.02	-0.09	-0.02	-0.07***	0.02	-0.10	-0.03
Information seeking	-0.03	0.02	-0.06	0.00	-0.03*	0.02	-0.07	-0.00
App use	-0.07	0.06	-0.18	0.04	-0.10	0.06	-0.22	0.02
<u>Between-person (<i>cmc</i>)</u>								
Social support	0.20**	0.08	0.05	0.35				
Distress management	-0.02	0.08	-0.18	0.14				
Symptom monitoring	0.03	0.11	-0.19	0.25				
Information seeking	-0.13	0.13	-0.38	0.13				
App use	0.22	0.50	-0.77	1.21				
<u>Within-person interactions (<i>cwc</i>)</u>								
Social support × App use					0.04	0.03	-0.02	0.11
Distress management × App use					-0.04	0.04	-0.12	0.03
Symptom monitoring × App use					0.07	0.04	-0.00	0.15
Information seeking × App use					0.03	0.04	-0.04	0.11
<i>AIC</i>	16689.16				16695.95			
<i>BIC</i>	16924.49				16924.56			
<i>LL</i>	-8309.58				-8313.97			

Note. *N* participants = 179 and *n* observations = 6159 for both models. App use, strategy use and momentary health were assessed at 42 occasions (12-hour intervals) during 21 days. *AIC* = Akaike information criterion; *BIC* = Bayesian information criterion; *CI* = confidence interval; *cwc* = centred within cluster; *cmc* = central mean centred; *LL* = log-likelihood.

<sup>a</sup>One unit represents one week for readability.

\*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$ .

about mental illness more than usual in the past 12 hours was negatively related to momentary health. In contrast, being more sociable and seeking social support (in the past 12 hours or compared to others during 21 days) was positively related to momentary health. Moreover, access to PTSD Coach predicted greater utilization of social support over time compared to people without access to PTSD Coach.

An average EMA<sub>App</sub> participant accessed a self-management app at 14.37% of the 42 consecutive 12-hour intervals of the current study. The relation between frequency of PTSD Coach utilization and posttraumatic stress is unclear (Kuhn et al., 2017; Miner et al., 2016). The adequate dose of PTSD Coach to achieve clinically meaningful change has not been established. In addition, dose, measured as frequency of use, may omit to which extent the user adopts the content of a self-management app. We speculate that users may utilize strategies and information learnt from an app without accessing it simultaneously, or reversely, struggle with integrating the content, and therefore frequently use an app.

Trauma-exposed adults use strategies to manage distress regardless of whether they use an app to that end. In this study, we investigated the everyday use of a select set of strategies, which reflect the modules in PTSD Coach, among participants with and without access to the app. We sought to discern whether these strategies were helpful and if access to PTSD Coach promoted coping and well-being through increased use of these strategies.

Social support emerged as particularly interesting. Social support is an important factor with regard to posttraumatic stress both momentarily (Dworkin, Ullman, Stappenbeck, Brill, & Kaysen, 2018) and in the long term (Ozer, Best, Lipsey, & Weiss, 2003). Our findings show that both between-person differences in social support during 21 days and within-person variation in use of social support during the past 12 hours are related to health. The causality of social support and health is unclear. Receiving social support and interacting with other could improve health, while withdrawal from social support and loneliness could deteriorate health. It is equally plausible that trauma-exposed adults engage socially when their health is better, or reversely, withdraw from social support and company at times of worse mental or physical health.

In contrast, greater use of distress management techniques, symptom monitoring and information seeking than usual during the past 12 hours predicted worse health. Similarly to the results of Pedersen et al. (2013), greater use of the monitoring strategy than usual in the preceding hours was negatively associated with momentary health. The symptom burden may influence whether or not regular assessment of posttraumatic stress is beneficial (Tarrier et al., 1999). Some of our participants reported that they felt discomfort during the interview as they recognized the PTSD-related symptoms. Simply hearing or reading about symptoms may trigger discomfort. If so, self-



rating symptoms or reading psychoeducational material about posttraumatic stress and mental illness could potentially be distressing.

Furthermore, the results contradict that distress management techniques assist people to cope with discomfort (Oflaz, Hatipoğlu, & Aydin, 2008), and specifically, that use of distress management in PTSD Coach relates to decreased momentary distress (Owen et al., 2015). Our procedure does not elucidate whether the characteristics and quality of the distress management techniques reflect recommended cognitive and stress inoculating techniques (Foa, Rothbaum, Riggs, & Murdock, 1991; Harvey, Bryant, & Tarrrier, 2003), the exercises in PTSD Coach, or in contrast, maladaptive strategies. Likewise, the information that participants found when seeking information could come from several sources (but not necessarily PTSD Coach) of variable helpfulness. While utilization of social support was the most reported strategy in our study, the clinical and social support module in a previous version of PTSD Coach was the least visited during active use (Owen et al., 2015).

Nonetheless, one interpretation of the associations between strategy use and momentary health would be that trauma-exposed adults attempt to cope during days of worse health. Indeed, previous research indicates that some users engage with PTSD Coach at times of distress (Owen et al., 2015). The attempts to manage discomfort and cope may not sufficiently improve health at the moment. More detailed information about what techniques the participants use, and how they use them, could help identify more and less successful strategies for coping and elucidate the direction of these associations.

The associations between different strategies and health may also follow temporal patterns that we failed to detect. The associations could differ between long-term assessments and more frequent, momentary assessments (Chun, 2016). Positive emotions among trauma-exposed people show daily variations (Dornbach-Bender et al., 2020) and weekly patterns in levels of posttraumatic stress have been reported (Biggs et al., 2019). The use of strategies may lead to lagged, later improvement in health than the subsequent 12 hours, or to more transient improvements than we could detect. We hope future studies can provide greater certainty regarding the time frame and causality between coping attempts and health.

#### 4.1. Strengths and limitations

Positive outcomes such as health among trauma-exposed adults have not yet been fully explored with EMA. The current study contributes to the knowledge of the variability of coping and well-being among people with experience of psychological trauma. We

considered the effect of time, the order and reactivity to assessments in our study design and analyses. The compliance rate based on all the assessments was good and the attrition was low.

Notably, our sample comprised mostly women, which limits the generalizability of our results to people with other genders. We relied on self-rating scales and did not objectively measure health and behaviours connected to strategy and app use. Furthermore, we did not specifically assess the use of PTSD Coach during the first 21 days, or whether the EMA<sub>wait</sub> participants accessed the American version of the app. Neither did we limit the response time to assessments, which means that if the participants responded to an assessment late and the subsequent assessment early, they were potentially asked to recollect an intersecting 12-hour period.

Although EMA reduces the risk of retrospective bias significantly, the daily assessments are still at risk of retrospective bias. Precise recollection of app and strategy utilization in the past 12 hours may be challenging. We also note that although we framed the questions about strategies to be retrospective, these questions were asked concurrently with the question regarding their momentary health. Thus, the participants' current health state could affect the recollection of the previous behaviour and influence the ratings. Moreover, as post-traumatic stress may fluctuate day to day (Biggs et al., 2019; Black et al., 2016), controlling for momentary distress could shed light on the variability of health and possible moderation of distress.

Consequently, the design of the assessments could be improved. Assessments of coping through strategy use can be further improved by separating the outcome assessment from assessments of momentary coping on a variable schedule, or asking about more specific, categorical behaviours or phenomena. In contrast to the item of social support, the phrasing of some strategies had a slightly negative valence ('discomfort', 'mental illness'). A phrasing with a more positive valence ('health', 'well-being') could have captured strategies that converge with effective or helpful information and coping.

#### 4.2. Future research

EMA is capable of bringing research closer to the daily lives of trauma-exposed people. However, uncertainty about the particulars of the associations between coping and health outcomes among trauma-exposed adults represents a challenge for EMA designs. For example, the optimal time frame for investigating the impact of strategy use on health is unknown. Greater knowledge of the timing, potential lag and directionality of the relationship between coping and health by, for example, assessing coping and health on different schedules, could advance the field significantly. EMA studies related to smartphone apps could also reduce uncertainty in

measurement by using mobile technology to collect objective measures of health indicators and coping behaviour. Finally, the patterns of associations found in our study suggest that one path forward could be to investigate how participants utilize distress management, symptom monitoring and psychoeducation in greater detail, to design effective momentary symptom reduction techniques that promote health.

## 5. Conclusions

We investigated if access to PTSD Coach, use of a self-management app and use of specific strategies were related to momentary SRH within a few hours and during 21 days. Access to PTSD Coach or using a self-management app in the preceding 12 hours did not affect health. Our findings highlight the use of social support as highly relevant for health although the causality is unclear. The causal direction is important to consider, particularly as there were indications that using some strategies could be related to worse short-term health. Although much is left to learn about the relationship between app utilization, coping and health in this population, taken together, social support appears beneficial for health, and access to PTSD Coach may increase the appraised use of social support.

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## Data availability statement

Data are available upon request at <https://doi.org/10.17605/OSF.IO/F6P3R>.

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