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MOOD DISORDERS (E BACA-GARCIA, SECTION EDITOR)

Use of Ecological Momentary Assessment to Study Suicidal Thoughts and Behavior: a Systematic Review

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Abstract

Purpose of Review Ecological momentary assessment (EMA) is a recently introduced approach to patient evaluation that consists of asking patients questions in real time and in their usual habitat. This method seeks to contribute to suicide prevention by providing psychiatrists with detailed information about suicidal thoughts and behavior, how these fluctuate over short periods of time, and the short-term risk factors presented by patients. We conducted a systematic review of published research using EMA to study suicidal thoughts and behavior.

Recent Findings Several systematic reviews of EMA in mental health have been conducted to date, and the literature contains numerous theoretical papers and compilations on EMA and suicide phenomena. To date, however, no systematic reviews have explored the use of this tool to study suicidal thoughts and behavior.

Summary We performed a systematic review of five databases (i.e., PubMed, Embase, Scopus, Web of Science, and PsycINFO) to identify studies on EMA and suicidal thoughts and behavior. An initial search revealed 544 articles. Following the study selection process, 35 studies were included in the review. Almost three-quarters of the studies were published in the last 4 years. The studies reviewed concluded that EMA was generally feasible and well accepted. EMA findings correlated well with the results of a retrospective assessment, though tended to over-represent symptom severity. Our review points to important aspects of suicidal thoughts and behavior, such as its wide fluctuation over short periods of time. Negative affect and disturbed sleep, among others, emerged as short-term predictors of suicidal thoughts and behavior. Therefore, EMA is a potentially useful tool in clinical practice, although not without drawbacks, such as participant fatigue with questionnaires and ethical concerns.

Keywords Suicide · Suicide attempt · Suicidal ideation · Ecological momentary assessment · Mobile health

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Introduction

Suicide is the second leading cause of death worldwide among people between the ages of 15 and 29 years and therefore a major public health concern. While the global prevalence of suicide is over 800,000 cases a year, the number of suicide attempts (SA) is estimated to be at least 20 times this figure [1]. Suicidal ideation (SI) is even more common: data from World Mental Health Surveys shows that each year, roughly 2% of people actively think about killing themselves (active SI) [2]. Moreover, a recent meta-analysis found that passive SI (i.e., desire to be dead) ranges in prevalence from 5.8% in a single year to 10.6% over a lifetime [3]. SA and SI (both active and passive), collectively termed suicidal thoughts and behavior (STB), are associated with death by suicide [3–5] and they alone pose a significant burden of disease [6]. The direct and indirect costs of STB amount to billions of dollars every year [7, 8]. In 2013, the World Health Organization developed a mental health action plan, which set a goal of decreasing the incidence of death by suicide by 10% by the year 2020 [9]. We are still far from reaching this goal.

The search for reliable risk factors for STB is considered a crucial step in suicide prevention. However, research in this area has yielded disappointing results. The meta-analysis by Franklin et al. showed that our ability to predict suicidal behavior has not improved appreciably over the past 50 years, as none of the numerous risk factors described in the study is more accurate in predicting suicidal behavior than flipping a coin [10].

Another reported weakness of suicide research is the scarcity of short-term risk factors [11]. Most studies focus on long-term factors, which may not be as effective in preventing suicidal behavior, sometimes fluctuate over time, and require intensive monitoring in the short term. Also, traditional research methods have some limitations, such as the risk of recall bias, as participants' recollection of past events varies in accuracy [12].

Ecological momentary assessment (EMA) may help overcome these shortcomings. EMA consists of asking participants questions on a daily basis to be answered at the moment, that is, with no interruption to their day-to-day routine. This provides real-time, continuous assessment that respects the ecological context of participants [13]. EMA is especially useful in exploring short-term risk factors, as it can detect the immediate antecedents of a given behavior [14]. Additionally, studying populations in their usual surroundings makes it possible to measure the role of contextual factors (or triggers) and the extent to which these may vary [15]. Initially, EMA was performed using pencil and paper, requiring participants to carry booklets around with them. With the advent of new technologies, however, it became possible to perform EMA using personal digital assistants (PDAs) or smartphones.

EMA has been used in different areas of mental health for a variety of purposes. There are several studies and subsequent systematic reviews on the use of EMA in depression [16, 17], anxiety [18], psychotic disorders [19, 20], child psychiatry [21], and substance use [22, 23]. However, until quite recently, EMA was an underutilized tool in suicide research [24]; this is despite its suitability for this purpose due to the peculiarities of SI, such as fluctuation over time, the need to identify short-term risk factors, and the benefits of close monitoring. Nowadays, there is increasing interest in EMA within suicide research, as shown by the publication of six papers on the topic so far this year [25, 26•, 27, 28•, 29, 30•]. This is a rapidly advancing area in which constant updating and synthesis of the literature are needed.

One previous systematic review of EMA as a research method explored non-suicidal self-injury (NSSI) [31], an independent but related area to STB. Five narrative reviews have been published on the use of EMA in suicide research: three addressed STB in general [24, 32, 33], one reviewed smartphone-based EMA [34], and another focused on a particular aspect of STB, that is, the presence of sleep disturbances during suicidal crises [35]. To our knowledge, no systematic reviews have been carried out on the use of EMA in STB.

The aim of this study is to systematically review the evidence on the use of EMA in suicide research. Primary outcomes of interest were the characteristics and correlates of STB as explored through EMA. Secondary outcomes of interest were the feasibility and validity of EMA compared to other assessment methods.

Methods

This review followed the Preferred Reporting Items for Systematic reviews and Meta-analysis (PRISMA) guidelines [36].

Inclusion/Exclusion Criteria

The inclusion criteria were as follows:

i) Original studies published in peer-reviewed journals;
ii) Studies with a sample size of five participants or more; and
iii) Studies that employed EMA (also known as the experience sampling method, ESM) to explore the dynamics of STB, phenotypes of STB, correlates of STB, validity of EMA for STB assessment, and/or the feasibility of EMA for STB assessment.

The following exclusion criteria were applied:

i) Proofs of concept, protocols for randomized clinical trials, and other studies that did not provide measurable outcomes;

ii) Case reports, case series, and systematic and non-systematic reviews; and
iii) Studies that explored non-suicidal self-injury (NSSI) instead of STB.

There were no restrictions regarding sociodemographic characteristics, diagnosis, or the clinical setting of the participants. No restrictions were placed as regards publication date. Publication language was limited to English or Spanish.

Search Strategy

We performed a systematic search of databases PubMed, Embase, Scopus, Web of Science, and PsycINFO. The last search date was July 2020. The search terms used were as follows: "(Experience Sampling Method OR Ecological Momentary Assessment) AND suicide", adapted to the syntax requirement of each database. The reference lists of eligible articles were manually reviewed to identify additional relevant publications.

Study Selection and Data Extraction

Articles were stored and screened using the online tool Rayyan QCRI [37]. To determine study eligibility, two researchers (MLB and ASC) reviewed the papers independently. The full-text version of potentially eligible studies was independently assessed by the two reviewers. Discrepancies between the reviewers were discussed and resolved by consensus.

Using pre-made tables, the following information was extracted: author and year of publication; country; study design; follow-up period and sample size and characteristics; aims of the study; measures collected through EMA; modality of EMA (paper and pencil; PDA; smartphone; other); app name in the case of smartphone-based EMA; participation rate (i.e., response to recruitment); retention rate; compliance with EMA questions; incentives; outcomes explored; EMA measures; frequency of EMA assessment; and main findings. Extraction was performed independently by the two above-mentioned researchers. Discrepancies were discussed and resolved by consensus.

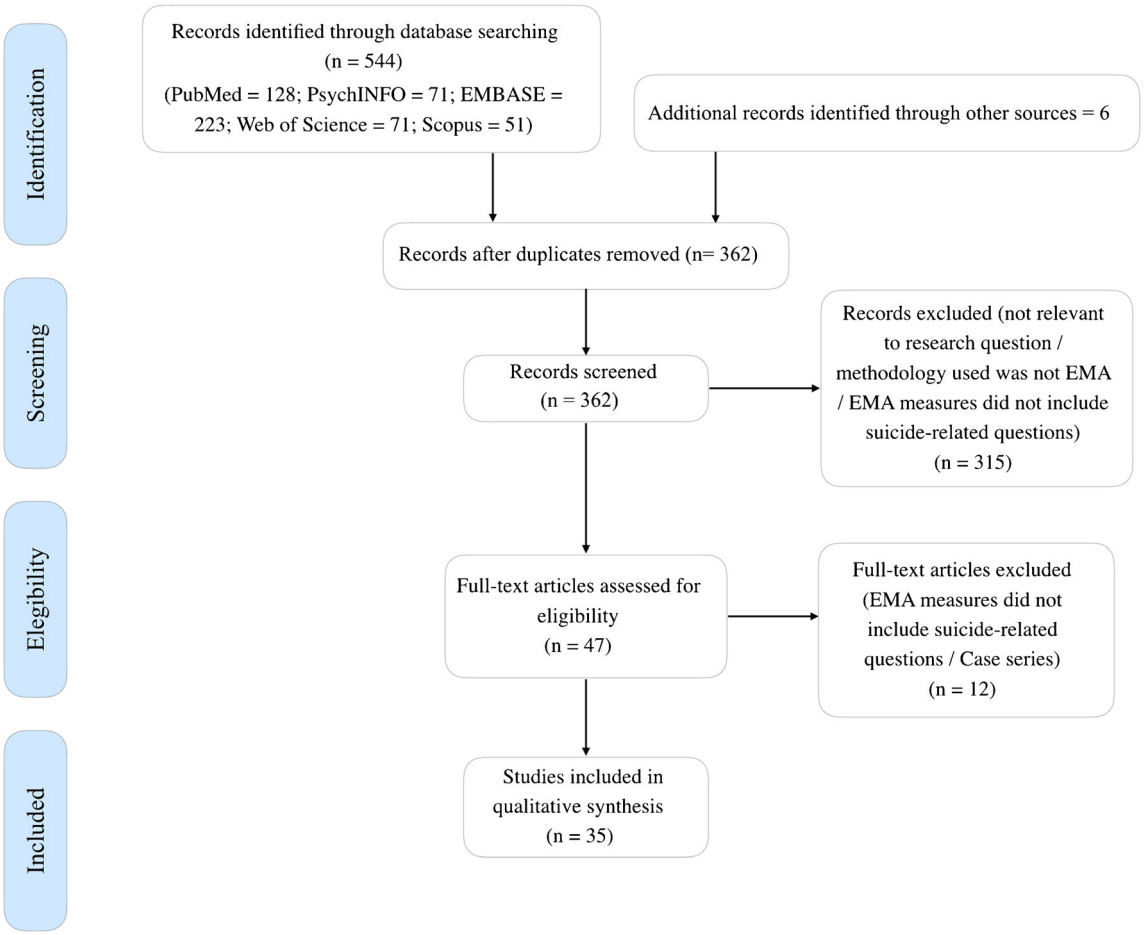


Fig. 1 Flow chart of the bibliographical search

Results

The initial search yielded a total of 544 articles. Following screening and full-text review, 35 publications were finally included in the review, representing 21 unique samples. Figure 1 shows the bibliographic search protocol.

There was an increase in the number of publications over time. For the period spanning 2007 to 2016, we found nine publications, whereas from 2017 to 2020, we found 26 publications. Figure 2 illustrates the number of EMA publications by year of publication.

Characteristics of the Reviewed Studies

Tables 1 and 2 summarize the characteristics and main findings of the reviewed studies.

Regarding the samples of the reviewed studies, six studies (four samples) were conducted in adolescent populations [25, 29, 38–41], while the rest were carried out in adults. Two studies were based on samples solely composed of women [42, 43], while another used only men and was carried out among prison inmates [44].

EMA assessment periods varied widely, ranging from 4 days [29] to 60 days [28•]. Oquendo et al. assessed participants for a total of 42 non-consecutive days, repeating weekly assessments at six timepoints over 2 years [26•].

EMA was applied using four main formats. Seven studies, representing five unique samples, employed paper-based EMA along with an electronic device (such as a wristwatch) to notify participants as to when they should complete the assessments [44, 45, 46, 47•, 48, 49, 50]. Five studies (four unique samples) employed PDA-based EMA [38, 42, 51–53]. Four studies (two samples) used web-based EMA, prompting participants via text message to complete the assessments [39–41, 43]. The remaining 19 studies (ten unique samples) employed smartphone-based EMA through a mobile application [25, 26•, 27, 28•, 29, 30•, 32, 54, 55•, 56–65]. One study that did not meet the inclusion criteria because it was a case series conducted EMA through daily phone calls [66].

The frequency of EMA prompts varied across studies, ranging from one [39–41] to ten assessments per day [32, 61–65]. All studies scheduled the EMA prompts so as not to interfere with sleep.

Four studies included some kind of passive collection of information in addition to active EMA: Littlewood et al. and Glenn et al. used wrist actigraphy to assess sleep [25, 49] while Ben-Zeev et al. and Porras-Segovia et al. used native smartphone sensors to collect data on aspects such as mobility [28, 56].

Studies included in the review assessed different suicidal phenomena: 19 assessed passive SI [26, 28, 30, 32, 42, 44, 47, 48, 50, 54, 55, 57–59, 61–65], thirty-one assessed active SI [25–27, 29, 30, 32, 39–43, 45–49, 51–65], six assessed SA [25, 38–41, 53], and only three assessed suicide plans [38, 47, 48]. No study included death by suicide as an outcome.

Feasibility of EMA

Six studies specifically investigated the feasibility and acceptability of EMA [25, 28•, 39, 51, 53, 55•], while others provided information on feasibility as a secondary outcome.

Across all studies, retention rates ranged from 64.1% [26, 27, 29, 38, 41, 42, 44, 46–49, 52, 54, 56, 57, 59–61, 63, 65] to 100% [38, 44, 51, 52]. Compliance with EMA (i.e., percentage of EMA questions answered out of the total questions) ranged from 52% [56] to 89.7% [32, 61–65]. Most studies offered participants financial incentives that were proportional to their degree of compliance or were given to all who reached a minimum level of compliance [25, 29, 32, 38–41, 43, 54, 55, 57–65].

Glenn et al. explored the feasibility of EMA in adolescents and developed a safety protocol to monitor suicide risk during the study [25]. In the satisfaction survey, performed at the end of the study, adolescents valued the overall experience with

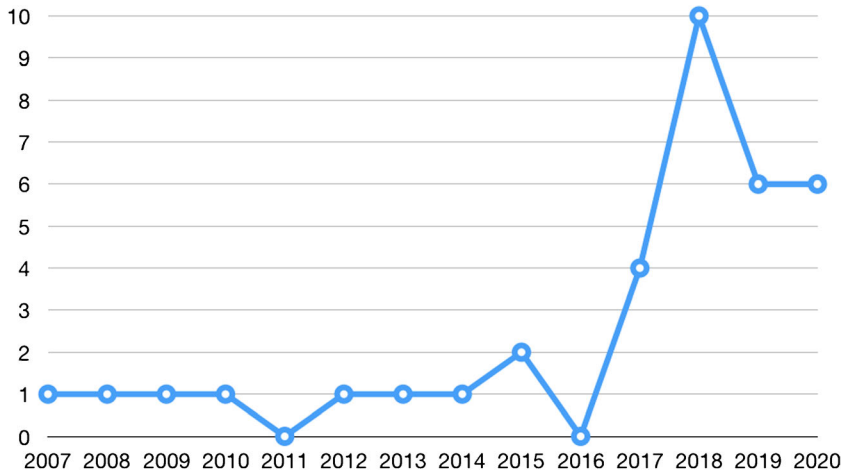


Fig. 2 Number of publications on ecological momentary assessment in suicide research per year

Table 1 Characteristics and main findings of paper-based, PDA-based, and SMS-based EMA studies

Study	Outcomes	Sample	Incentives	Duration	EMA measures	Main findings*
Paper-based						
Links et al., 2007** Canada	Association between affective instability and SI and SB	*N*=82 adult outpatients with BPD and a history of SB	50 dollars	21 days	STB-related: VAS assessing suicidality (active SI, passive SI, suicide plans) Other: VASs of 26 discrete mood states (including dysphoria, hostility, anxiety, shame, positive affect, and guilt); presence of environmental stressors Frequency of assessment: 6 assessments/day prompted by a handheld electronic organizer	Negative mood intensity was associated with SI (intercorrelation=0.62, $p<0.01$) and severity of past SB (intercorrelation=0.44, $p<0.01$)
Links et al., 2008** Canada	Association between affective instability and impulsivity and between affective instability and SB					Subgroup of patients characterized by high mood amplitude and high negative mood intensity had significantly more severe SB in the past year than the other 3 subgroups (12.00 vs 2.00, 2.50 and 7.00; $p=0.001$)
Humber et al., 2013 UK	Association between anger, psychological distress, and self-harm/suicidal ideation	*N*=21 adult male inmates	NR	6 days	STB-related: 10-point scale for questions assessing passive SI ("Life is worth living", "I want to live") Other: 10-point scale for questions assessing anger, psychological distress, and self-harm. Frequency of assessment: 9 assessments/day signaled by routine events at the penitentiary	Anger was associated with concurrent self-harm ideation, but not with SI ($p>0.05$)
Littlewood et al., 2019 UK	Association between SI and sleep quantity and quality. Mediating role of sleep in the association between entrapment and SI.	*N*=51 adult outpatients with MDD	30 pounds	7 days	STB-related: A 7-point Likert question assessing active SI ("Right now I am feeling suicidal") Other: morning section of the Consensus Sleep Diary, a 5-point scale question assessing subjective sleep quality, and two 7-point scale questions assessing entrapment Passive measures: sleep (through wrist-worn actigraphy) Frequency of assessment: 6 assessments /day at quasi-random time points, prompted by a wristwatch + sleep diary every morning	Objective ($\beta=-0.088$, $p=0.018$) and subjective ($\beta=-0.0801$, $p=0.024$) short sleep duration and subjective poor sleep quality ($\beta=-0.109$, $p=0.003$) predicted severity of next-day SI. Poor sleep played a mediating role in the association between entrapment and next-day suicidal ideation ($\beta=-0.091$, $p=0.045$)
Crowe et al., 2019 Ireland	Dynamics of negative and positive affect, self-esteem, suicidality, and tiredness	*N*=64 (31 adult outpatients with MDD and 33 healthy controls)	None	6 days	STB-related: A 7-point scale question assessing passive SI ("I feel that life is worth living right now" and "I am having thoughts about death right now") Other: 7-point scale questions assessing positive and negative affect, self-esteem, and tiredness Frequency of assessment: 10 assessments /day prompted by a wristwatch	Depressed patients exhibited greater variability and instability than controls in PA, NA, self-esteem, and suicidality. Difference between groups in within-person variance of suicidality=0.16 (95% CI 0.13–0.19).
Ben-Zeev et al., 2010† USA	Comparison of EMA with retrospective assessment	*N*=51 (26 adult inpatients with MDD and 25 healthy controls)	Monetary incentives; amount NR	7 days	STB-related: A question assessing active SI ("Since you were last beeped have you had any thoughts about killing yourself?") Other: Twelve questions assessing MDD symptoms Frequency of assessment: Average of one assessment every two hours, prompted by a pager	In depressed patients, retrospective reports were significantly more severe than EMA reports in three areas: anhedonia (5.34 vs. 6.04), confusion (3.80 vs. 4.23), and suicidality (1.56 vs. 2.38).
Ben-Zeev et al., 2012†	Predictors of SI	*N*=31 adult inpatients with MDD				74.2% of participants reported SI through EMA

Table 1 (continued)

Study	Outcomes	Sample	Incentives	Duration	EMA measures	Main findings*
USA						Momentary ratings of sadness ($p=0.032$), tension (0.015), and boredom ($p=0.001$) were associated with greater subsequent SI.
PDA-based						
Nock et al. 2009 USA	Association between SI and NSSI. Context of SI.	$N=30$ adolescents and young adult outpatients with NSSI	100 dollars/ PDA (if >80% entries)	14 days	STB-related: Y/N questions on self-harm thoughts, thoughts about attempting suicide, and reports of attempted suicide. Duration, context, and intensity of STB Other: NSSI Frequency of assessment: 2/day (at mid-day and end of the day)	NSSI thoughts and SI coincided in 1.0%–4.2% Adolescents with SI (33.3%) reported an average of 1.1±0.6 SI/week When SI began, adolescents were socializing (34.6%), listening to music (30.8%), or resting (19.2%). In 42.3% of cases, SI appeared while the patient was alone.
Husky et al., 2014¶ France	EMA feasibility to assess suicide risk	$N=96$ (41 RSA, 20 PSA, 21 AC, and 13 HC)	NR	7 days	STB-related: If negative thoughts were reported in a gate question, participants were asked about active SI or self-harm thoughts Other: Activity, environment, social context, mood state (7-point Likert scale to answer questions assessing happiness, depression, hopelessness, and anxiety), and 7-point Likert scale for stress-related questions with the most salient event of Inventory of Small Life Events Frequency of assessment: 5 assessments/day	73.8% RSA completed all assessments vs. 85.7% HC; observations differed across groups ($F(3,91)=2.95$, $p<0.05$) Frequency of SI in RSA was not reactive to assessment ($\beta=0.016$, T ratio=1.087) 7.8% of RSA reported SI, with 62 daily life SI events. HC and AC reported one and four SI, respectively.
Husky et al., 2017¶ France	Predictive role of mood fluctuations, social contexts, and behavior on subsequent SI	$N=42$ adult outpatients				SI was associated with being at home ($\beta=0.435$; $p=0.018$), working ($\beta=0.245$; $p<0.0001$), passive leisure ($\beta=0.350$; $p=0.003$), inactivity ($\beta=0.823$; $p<0.0001$), being alone ($\beta=0.468$; $p=0.004$), feeling sad ($\beta=0.162$; $p<0.0001$), anxious ($\beta=0.266$; $p<0.0001$), and family events ($\beta=0.448$; $p=0.032$)
Law et al., 2015 USA	Negative effect of repeated assessment of STB	$N=248$ adult outpatients with BPD (129 in an intensive suicide assessment group and 119 in a control group)	20 dollars +125 dollars (screening and participa-tion)	14 days	STB-related: Two Y/N questions inquiring about active SI ("I tried to kill myself", "I thought about committing suicide") Other: 7-point scale questions assessing BPD non-suicide symptoms (17 questions) and BPD-relevant emotions (6 questions) Frequency of assessment: 5/day at fixed times	Of 165 one-tailed contrasts, only 11 (6.7%) significantly ($p<0.05$) triggered a negative outcome, and 18 (11%) marginally did ($p<0.10$)
Rizk et al., 2019 USA	Association of SI variability and affectivity instability	$N=38$ women outpatients with BPD, lifetime SA and current SI	NR	7 days	STB-related: Nine questions answered using a 5-point Likert scale (wish to live/die/escape, thoughts about dying /suicide, urge to die by suicide, thoughts about hurting oneself, urges to hurt oneself, and having reasons for a living) Frequency of assessment: 6 assessments/day at random times	Affectivity instability was associated with SI variability ($\beta=0.046$, $p=0.044$), but not with SI severity ($\beta=0.014$, $p=0.659$), after controlling for depression severity
Web-based (survey link sent by SMS)						
Czyz et al., 2018a‡	Feasibility and acceptability of EMA			28 days	STB-related: Two questions assessing active SI ("At any point in the last 24 h did you have any	Participants regarded the experience as generally positive. Participants with a history of SA were

Table 1 (continued)

Study	Outcomes	Sample	Incentives	Duration	EMA measures	Main findings*
USA		*N*=34 adolescent (13–17 years old) outpatients	20 dollars +4 dollars/-survey		thoughts of killing yourself?" and "At any point in the last 24 h, did you try to kill yourself or make yourself not alive anymore?"), which, if affirmative, prompted 4-point scale questions assessing frequency and duration of episodes Other: 7-point scale questions assessing connectedness, burdensomeness, and hopelessness. Y/N questions (with further questions if affirmative) assessing NSSI and coping behavior Frequency of assessment: One assessment every evening	more compliant than those without a history of SA. SI was more frequently reported through real-time EMA than at the end-of-study traditional assessment (70.6% vs. 45.2%, chi-square=4.24, p=0.039)
Czyz et al., 2018b‡ USA	Dynamics of SI. Association between SI and connectedness, burdensomeness, and hopelessness					Wide variability in day-to-day SI (half of SI ratings changed at least one within-person standard deviation from 1 day to the next). There was a concurrent, but not prospective, association between SI and connectedness, burdensomeness, and hopelessness.
Czyz et al., 2019‡ USA	Association between SI and NSSI					SI duration (OR=1.64, p=0.001) and SI frequency (OR=1.91, p=00.1) predicted within-person daily NSSI
Victor et al., 2019 USA	Association between suicide urges and externalizing NA and internalizing NA, and feelings of rejection	*N*=62 adult female outpatients	Monetary incentives if ≥85% EMA compliance; amount NR	21 days	STB-related: 5-point scale questions assessing active SI ("Since the last prompt, have you...:" "...felt an urge or wanted to harm or injure yourself on purpose, without wanting to die", "...felt the urge or wanted to make a SA") Other: 5-point scale questions assessing about externalizing NA and internalizing NA, and feelings of rejection Frequency of assessment: 6 assessments/day at random times	Suicide urges were associated with internalizing NA (B=0.23, p<0.05) and externalizing NA (B=0.19, p<0.05)

*In line with the purpose of our review, only findings related to STB are reported in detail

**These papers used the same sample

†These papers used the same sample at different points of recruitment

¶Part of the sample was the same in these papers

‡These papers used the same sample

AC, affective control; *BPD*, borderline personality disorder; *EMA*, ecological momentary assessment; *HC*, healthy control; *MDD*, major depressive disorder; *NA*, negative affect; *NR*, not reported; *NSSI*, non-suicidal self-injury; *PA*, positive affect; *PSA*, past suicide attempter; *RSA*, recent suicide attempter; *SA*, suicide attempt; *SB*, suicidal behavior; *SI*, suicide ideation; *STB*, suicidal thoughts and behavior; *VAS*, visual analog scale; *Y/N*, yes/no

Table 2 Characteristics and main findings of smartphone-based EMA studies

Study	Outcomes	Sample	Incentives	Duration	EMA measures	Main findings*
Torous et al., 2015 USA	Feasibility of EMA. Comparison of EMA-delivered PHQ-9 with traditionally administered PHQ-9.	*N*=13 adult outpatients with MDD	50 dollars if ≥70% EMA compliance	30 days	App name: mindful moods STB-related: One 4-point question from the PHQ-9 assessing passive and active SI ("Thoughts that you would be better off dead or of hurting yourself in some way") Other: The remaining eight questions from the PHQ-9 questionnaire Frequency of assessment: 3 assessments/day, each presenting 3 random items from the PHQ-9	Overall compliance of 77.8%. Compliance was higher in the afternoon (84.2%). EMA scores were on average 3.02 (SD= 2.25) points higher than paper scores.
Kleiman et al., 2017 – Study 1** USA	Fluctuations in SI and NA Association between SI and NA	*N*=54 adult outpatients with recent history of SA	40 dollars +10 dollars if ≥75% EMA compliance	28 days	App name: mEMA STB-related: 4-point scale questions assessing active SI, wish to die by suicide ("How intense is your desire to kill yourself right now?"), intention to die by suicide ("How strong is your intention to kill yourself right now?"), and ability to resist the urge to die by suicide ("How strong is your ability to resist the urge to kill yourself right now?"). 3-point scale questions from the BSS assessing wish to live, wish to die, and wish to die by suicide. Other: Social support, NA (8 subdomains, including hopeless, sad, burdensome, and lonely), and PA (3 subdomains, including active, happy, and optimistic) Frequency of assessment: 1 entry/day at 9 pm+4 prompts to report SI at random times + option to self-initiate a SI report at any time	Substantial variation of SI over a few hours (29% of ratings differed by at least one SD from previous assessment). H (B= 0.70, p<0.001), PB (B=0.33, p<0.001), and L (B=0.26, p<0.001) were associated with concurrent but not subsequent SI.
Kleiman et al., 2018a – Study 1** USA	Digital phenotypes of SI	*N*=51 adult outpatients with recent history of SA				Latent profile analysis revealed 5 distinct phenotypes of SI. Phenotype 4, characterized by severe and persistent SI, was associated with recent SAs (past week SA: 25%, p=0.024; past month SA: 75%, p=0.021)
Kleiman et al., 2018b** USA	Association between SI and NA and PA	*N*=43 adult outpatients with recent history of SA				When SI ceased, NA decreased and PA increased (NA: B=−0.55, p<0.001; PA: B=0.40, p<0.001).
Coppersmith et al., 2018** USA	Dynamics of SS. Association between SS and SI	*N*=53 adult outpatients with recent history of SA				SS was associated with concurrent SI (B= −0.41, p<0.001) and next-day SI (B= −0.35, p<0.001).
Kleiman et al., 2017 –Study 2† USA	Fluctuations in SI and NA Association between SI and NA	*N*=36 adult inpatients with STB	10 dollars/day	Hospitalization time (median: 7 days)	App name: MovisensXS STB-related: 9-point scale questions assessing active SI, wish to die by suicide ("How intense is your desire to kill yourself right now?"), intention to die by suicide ("How strong is your intention to kill yourself right now?"), and ability to resist the urge to die by suicide ("How strong is your ability to resist the urge to kill yourself right now?") Other: 10-point scale questions assessing mood states (abandonment, anxiety,	Substantial variation of SI (28% of ratings differed by at least one SD from previous assessment). H (B=0.92, p< 0.001), and L (B=0.16, p=0.041), were associated with concurrent SI, but not with subsequent SI.
Kleiman et al., 2018a – Study 2† USA	Digital phenotypes of SI	32 adult inpatients with STB				Latent profile analysis revealed 5 distinct phenotypes of SI. There were no differences between profiles regarding suicide history.
Mou et al., 2018†	Mediating role of BPD in the association between NA and SI	35 adult inpatients with STB				Diagnosis of BPD mitigated the association between SI and 8 of the 10 explored mood states.

Table 2 (continued)

Study	Outcomes	Sample	Incentives	Duration	EMA measures	Main findings*
					desperation, guilt, hopelessness, humiliation, loneliness, rage, self-hatred, upset) Frequency of assessment: 4 prompts/day at random times	
Ben-Zeev et al., 2017 USA	Correlates of violent ideation and behavior.	*N*=28 adult inpatients	50 dollars	Hospitalization time (mean= 6.3 days)	App name: NR STB-related: One 5-point scale question assessing active SI ("Are you thinking of ending your life?") Other: 5-point scale questions assessing affect, environmental conditions, delusions, substance cravings, withdrawal symptoms, and violent ideation and behavior Passive EMA: speech duration, movement, and location Frequency of assessment: 6 assessments/ day	SI was associated with thinking of harming (OR=6.84, $p<0.01$), report of damaging property (OR=3.43, $p<0.05$), and being physically aggressive (OR=11.59, $p<0.001$).
Halzensleben et al., 2018‡ Germany	Association between fluctuation of SI and depression and history of STB	*N*=20 adult inpatients with MDD	10 dollars +40 dollar if ≥80% EMA compliance	6 days	App name: MovisensXS STB-related: Seven 5-point scale questions assessing passive SI ("...life is not worth living", "...there are more reasons to die than to live for me"), active SI ("...I think about taking my life", "...I want to die"), and CS (pain tolerance, fearlessness about death, and perceived CS). Other: Twenty-four 5-point scale questions assessing PB, TB, H, D, A, PA, mood, activities, situation, company at the moment, medication Frequency of assessment: 10 assessments/day	SI fluctuates over short periods of time (mean MSSD=5.1, SD=6.1). No significant correlation between fluctuation of SI and covariables.
Forkman et al., 2018‡	Fluctuation of SI. Validity of EMA to measure STB.	*N*=74 adult inpatients with MDD				Wide variability of SI (Mean MSSD=4.79, SD=5.57). Correlation of EMA-measured SI and BSS-measured SI (for active SI, $r=0.727$, $p<0.01$; for passive SI, $r=0.756$, $p<0.01$)
Hallensleben et al., 2019‡ Germany	Fluctuation of SI. Association between SI and PB, TB, H, and D.					Concurrent associations with all explored covariates. Prospective association with H and PB.
Rath et al., 2019‡ Germany	Association between SI and PB, TB, H, D, A, and PA					SI was associated with all the explored covariates, most strongly with H.
Spangenberg et al., 2019‡ Germany	Fluctuation of CS					Wide variability of CS (mean MSSD for pain tolerance=1.21, SD=1.38; fearlessness about death=1.99, SD= 2.61; perceived CS=1.37, SD=2.11).
Hadzic et al., 2020‡ Germany	Association between SI and trait impulsivity	*N*=84 adult inpatients with MDD (74 underwent EMA)				No associations between SI and trait impulsivity.
Gratch et al., 2020 USA	Comparison of EMA with retrospective reports	*N*=51 community-dwelling adults with a diagnosis of MDD	125 dollars	7 days	App name: iSURVEY STB-related: Nine 5-point scale questions assessing active and passive SI	Significantly more participants reported SI through EMA than through retrospective assessment (98.0% vs. 39.2%).

Table 2 (continued)

Study	Outcomes	Sample	Incentives	Duration	EMA measures	Main findings*
Oquendo et al., 2020 USA	Association between SI and stressful events Association between SI variability and childhood trauma, affective lability, and aggressive and impulsive traits			6 non--consecutive weeks over 2 years	("Thoughts about dying", "A wish to live", "A wish to die", "A wish to sleep and not wake up", "A wish to escape", "Like there were reasons for living", "Thoughts about hurting yourself", "An urge to hurt yourself", "Thoughts about killing yourself (suicidal thoughts)"). Other: Eight yes/no questions about stressful events Frequency of assessment: 6 assessments/day at random times	Participants with high SI variability experienced greater increases in SI in response to stressful events.
Glenn et al., 2020 USA	Feasibility and acceptability of EMA	*N*=53 adolescent (12–17 years old) outpatients and their parents	Baseline assessment: 25 dollars/h Follow-up: 25 dollars if ≥75% EMA compliance	28 days	App name: mEMA and Metricwire STB-related: Yes/no questions assessing active SI ("Are you thinking about attempting suicide?", "Did you do anything to hurt yourself today?", "Are you thinking of doing any of the following?: hurting myself, but not to die; attempting suicide"?), + 6-point scale questions assessing suicide desire ("How intense is your desire to kill yourself right now?"), suicide intent ("How strong is your intent to kill yourself right now?"), and ability to keep self safe ("How able are you to keep yourself safe right now?") Other: 14 questions assessing sleep, 26 questions assessing affective and cognitive risk factors of STB, 13 questions assessing interpersonal negative life events, naps, and substance use. Passive measures: sleep (actigraphy) Frequency of assessment: One assessment in the morning +3 at random times + one at bedtime + optional event-contingent surveys	Response to recruitment (those who accepted to participate out of those eligible) was 64.6% In the satisfaction survey, mean ratings for overall experience with EMA were 3/4.
Peters et al., 2020 Canada	Correlates of SI intensity and instability	*N*=39 adult inpatients with depression	NR	Hospitalization time (average: 12 days)	App name: Ethica STB-related: visual analog scales scored 0–100 assessing active SIpas ("How suicidal are you right now?") Other: Three visual analog scales scored 0–100 assessing depressed mood, anger, and social connectedness	SI intensity correlated with SI instability (r= 0.52, p<0.001), depression intensity (r= 0.61, p<0.001), and anger intensity (r= 0.52, p<0.001). Baseline SI measured with BSS correlated with EMA-measured SI intensity (r= 0.71, p<0.001), but not with SI instability.

Table 2 (continued)

Study	Outcomes	Sample	Incentives	Duration	EMA measures	Main findings*
					Frequency of assessment: 3 assessments/day at fixed times	
Porras-Segovia et al., 2020 Spain	Feasibility of active and passive EMA	Active EMA: *N*=457 (120 adult outpatients with history of STB, and 337 university student controls). Passive EMA: *N*=1708 (139 adult outpatients with history of STB, 1224 outpatients without a history of STB, and 346 student controls)	Patients: none Controls: academic credits	60 days	Apps name: MEmind (active EMA) and eB2 (passive EMA) STB-related: Two 7-point scale questions assessing passive SI (wish to live and wish to die), based on the Salzburg Suicide Questionnaire Other: 31 questions assessing appetite, sleep quality, and NA Passive EMA: sleep, movement, location, and smartphone use. Frequency of assessment: 2–4 questions per day selected randomly from the pool of 33 questions.	Response to recruitment (those who accepted to participate out of those eligible) was 83.2%. For passive EMA, retention rate was significantly higher in patients with a history of STB than in the total sample (80.3% vs. 69.8%). For active EMA, there were no significant differences among groups. Compliance with active EMA was significantly higher in student controls than in suicidal patients (75.2% vs. 65.0%).
Vine et al., 2020 USA	Association between suicide risk and dissociation experiences	*N*=162 adolescent (11–13 years old) outpatients and their caregivers	10 dollars/-completed EMA timepoint	4 days	App name: NR STB-related: Two yes/no questions assessing active SI ("Had thoughts about killing yourself or hurting yourself?" and "Had told someone you were going to kill yourself or hurt yourself?") Other: Five indicators of dissociation, NA and PA Frequency of assessment: 10 assessments/day at random times	Suicide risk predicted higher dissociation (β =0.24, p<0.05), higher NA (β=0.23, p< 0.001), and lower PA (β=−0.17, p< 0.05).

*In line with the purpose of our review, only findings related to STB are reported in detail

**These publications use the same sample; sample size included in the analysis varied across publications; EMA measures analyzed varied across publications

†These publications use the same sample; sample size included in the analysis varied across publications

‡These publications use the same sample at different points of recruitment; EMA measures analyzed varied across publications

¶These publications use roughly the same sample; analyses were performed at different times throughout follow-up

A, anxiety; *BPD*, borderline personality disorder; *BSS*, Beck Suicide Scale; *CS*, capability for suicide; *D*, depression; *EMA*, ecological momentary assessment; *H*, hopelessness; *L*, loneliness; *MDD*, major depressive disorder; *MSSD*, mean squared successive difference; *NA*, negative affect; *NR*, not reported; *NSSI*, non-suicidal self-injury; *PA*, positive affect; *PB*, perceived burdensomeness; *PHQ-9*, Patient Health Questionnaire-9; *SA*, suicide attempt; *SB*, suicidal behavior; *SD*, standard deviation; *SI*, suicidal ideation; *SS*, social support; *STB*, suicidal thoughts and behavior; *TB*, thwarted belongingness; *VAS*, visual analog scale

EMA (mean rating: 3/4). Thus, if EMA scores rated above a pre-established threshold, participants were contacted. EMA was scheduled outside school hours as not to interfere with participants' daily activities. Risk was also monitored similarly to the study by Czyz et al., which also employed an adolescent sample and also found good acceptability rates among participants [39–41].

Porras-Segovia et al. explored the feasibility of two EMA smartphone applications over a 2-month follow-up period: the MEmind, which administered an EMA questionnaire, and eB2, which gathered participants' data through the smartphone's native sensors, a concept also known as passive EMA. The study compared the use of these two applications in three populations: patients with a history of STB, patients without a history of STB, and student controls. Patients received no incentives, while student controls received academic credits. For passive EMA, the retention rate was significantly higher in patients with a history of STB. For active EMA, there were no significant differences between groups. Compliance with active EMA was significantly higher among student controls [28•].

One study explored whether asking about suicide through EMA had a harmful effect on patients with borderline personality disorder (BPD). The study authors compared a group of patients who underwent a 2-week EMA assessment with another group that was not assessed. The group assessed through EMA did not experience an increase in STB, although they reported a slight negative impact on other BPD-related symptoms [53].

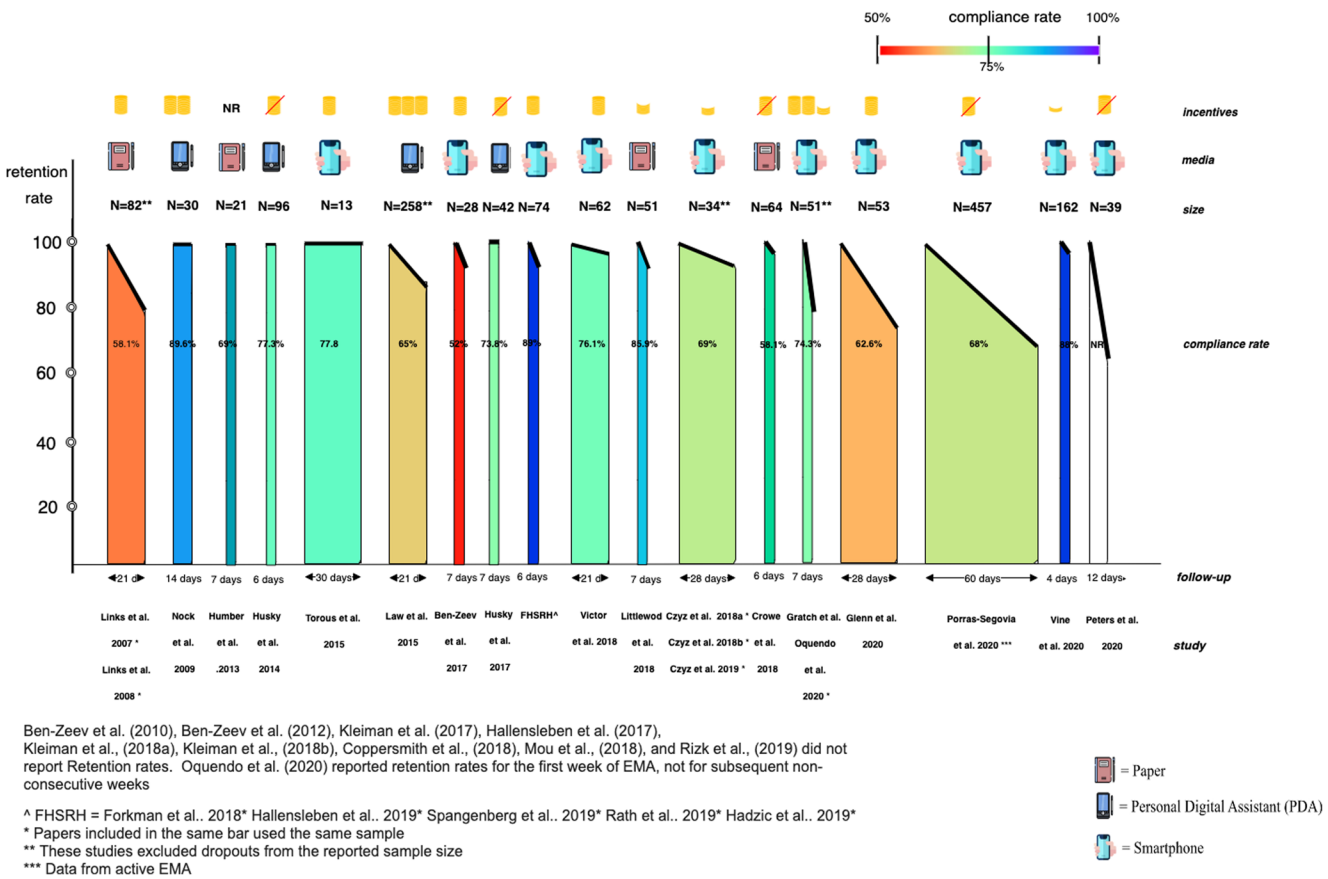
Figure 3 shows a comparison of follow-up periods, retention rates, use of incentives, and EMA compliance across studies.

Validity of EMA

Four studies compared EMA to traditional assessments of STB [30•, 45, 55•, 62].

Ben-Zeev et al. compared EMA against retrospective recall of depressive symptoms in depressed inpatients and healthy controls. Discrepancies were found between EMA and retrospective recalls in both groups. In depressed patients, discrepancies consisted of an exaggerated number of symptoms—including suicidality—in the retrospective recall, while in controls, discrepancies occurred in both directions [45].

In the study by Gratch et al., 51 people with major depressive disorder were prospectively followed using EMA for 1



Ben-Zeev et al. (2010), Ben-Zeev et al. (2012), Kleiman et al. (2017), Hallensleben et al. (2017), Kleiman et al., (2018a), Kleiman et al., (2018b), Coppersmith et al., (2018), Mou et al., (2018), and Rizk et al., (2019) did not report Retention rates. Oquendo et al. (2020) reported retention rates for the first week of EMA, not for subsequent non-consecutive weeks

^ FHSRH = Forkman et al.. 2018* Hallensleben et al.. 2019* Spangenberg et al.. 2019* Rath et al.. 2019* Hadzic et al.. 2019*
* Papers included in the same bar used the same sample
** These studies excluded dropouts from the reported sample size
*** Data from active EMA

= Paper
= Personal Digital Assistant (PDA)
= Smartphone

Fig. 3 Follow-up, retention rates, use of incentives, and EMA compliance across studies

week and were later retrospectively assessed. Sixty percent of the participants who reported SI during the 1-week EMA later denied having experienced any SI that week [30•]. Similarly, Torous et al. found that EMA-based PHQ-9 scores were significantly higher than paper-based scores [55•].

Characterization of STB

Six studies focused on the dynamics of STB over time [32, 40, 50, 57, 58, 64].

Hallensleben et al. explored fluctuation and correlates of active and passive SI in 74 inpatients with MDD through a 1-week EMA protocol. SI showed a wide within-person variability over time [64]. STB-related constructs, such as suicide capability, also exhibited substantial fluctuation over short periods of time [32].

Using paper-based EMA, Crowe et al. explored the within-day dynamics of passive SI, along with other symptoms, in depressed patients vs. controls. They found that depressed patients exhibited a higher variability in most symptoms, including SI [50].

Kleiman et al. explored active SI in two samples—outpatients and inpatients—using a 28-day, smartphone-based EMA program [57]. They examined real-time fluctuations in SI and its risk factors and found that SI could vary widely over a few hours. Using these two samples, Kleiman et al. employed latent profile analysis to reveal distinct phenotypes of suicidal thoughts depending on their intensity and variability. There were five distinct phenotypes of SI. Phenotype number 4, characterized by severe and persistent SI, was associated with a higher probability of recent SA in outpatients, but not in inpatients [58].

Correlates of STB

Twenty of the reviewed studies explored different potential risk factors of STB [26•, 27, 29, 38•, 41, 42, 44, 46, 47•, 48, 49, 52, 54, 56, 57, 59–61, 63, 65].

A good number of studies focused on the association between STB and different subdomains of affect [42–44, 47•, 48, 52]. For instance, in the study by Victor et al., suicide urges were associated with both internalizing and externalizing negative affect [43], while in the study by Kleiman et al., hopelessness and loneliness were associated with concurrent, but not subsequent, active SI [57].

The only study exploring the association between sleep and active SI was the one by Littlewood et al., who found a unidirectional association by which poor sleep quality and short sleep duration predicted more severe SI the next day [49].

Some studies used EMA to investigate the environmental triggers of SI [38, 52]. Husky et al. found that participants were more likely to experience active SI in contexts such as solitude and feelings of sadness or anxiousness, or during family events [52]. Nock et al. found that in over 40% of cases, active SI appeared while the patient was alone [38].

Discussion

In this systematic review, we found a considerable number of studies that used EMA to explore STB, especially among those published in recent years. In fact, almost three-quarters of the studies included in our review were published over the last 4 years.

Comparison With Previous Reviews

This review supports the findings of other systematic reviews in related areas, which show that EMA is a promising methodology in suicidology. In their 2018 review, Rodriguez-Blanco et al. found 23 studies exploring the use of EMA in NSSI research. As in our review, most studies had a short follow-up period, in most cases no longer than 2 weeks. Rodriguez-Blanco et al. argued that studies should aim for longer follow-up periods [31]. Kleiman and Nock's 2018 narrative review highlighted the usefulness of EMA for studying STB in real time, stressing the potential of EMA to improve short-term prediction. The authors also highlighted the need for studies with longer follow-up times and larger sample sizes [33]. As for Chaïb et al.'s narrative review, which focused on the presence of sleep disturbances during suicidal crises, they only found two publications assessing the topic (only one met our inclusion criteria) and stressed the scarcity of studies exploring this topic, despite the potential of sleep as a clinical marker for STB [35].

Evolution of EMA

Study designs using EMA for data collection have changed over time. In the early days of EMA development, assessments were conducted using pencil and paper. This is an accessible and easy-to-use option that involves little expense. However, this method has several limitations: there is a risk of data collection errors, there is no reliable way of knowing if the participant has filled in the data at the right time, and it is inconvenient for patients to carry evaluation materials around with them [67].

With the arrival of PDAs, some of the drawbacks of pen and paper were solved, but soon smartphones took over. In 2019, over 5 billion people owned a mobile device, and over half of these connections were smartphones [68]. The increasing ownership and sophistication of smartphones is leading to increased use of these devices in studies, particularly as these devices are small in size and users tend to have them on their person at all times, and smartphones allow real-time

uploading of data and can be used for purposes such as these at no additional expense, etc.

The Potential of EMA to Study STB

The articles reviewed have employed EMA in different ways to study the particularities of STB. Each of these approaches may in turn have important implications for clinical practice. Thus, studies that examined the dynamics of SI show us the great variability of SI over short periods of time, with changes occurring in a matter of a few hours. EMA offers us the possibility to record these changes and opens the door to real-time clinical monitoring of suicidal risk.

EMA also offers new perspectives on suicide risk assessment. Most studies that explored the validity of EMA found important differences between EMA and the comparison test. Ben-Zeev et al. found that depressed patients tended to exaggerate symptoms on retrospective assessment [45]. In contrast, the study by Torous et al. recorded more instances of SI by measuring it with real-time EMA as compared to subsequent retrospective assessment of the same periods[55•]. This was also the case in the studies by Czyz et al. and Gratch et al. Are these non-specific issues of imprecision motivated by recall bias, or is there difficulty in reporting SI in face-to-face assessments?

Some research shows that patients may feel uncomfortable talking about their SI [69], or may have difficulties articulating their thoughts on this issue [70, 71]. This is part of the rationale behind the D/S Implicit Association Test (IAT), developed by Nock et al., which relies on patients' unconscious feelings about death and is showing promising results in suicide prediction [72, 73]. Though not a substitute for traditional assessments, non-face-to-face assessments and other novel methods of suicide risk assessment could represent a useful complementary tool.

Feasibility of EMA

As shown by the articles reviewed, EMA is generally well accepted by patients, with relatively high rates of retention and compliance. Although EMA appears to be a feasible method for the study of STB, it also has some drawbacks. Repeatedly assessing participants can lead to fatigue, which may influence compliance and retention. The meta-analysis by Vachon et al. found that average compliance in EMA studies was 78.7% and that this rate was affected by several factors. For instance, compliance was higher when assessments were more sparse, when there were fewer assessments per day, and when the incentives given to patients were greater [74].

In our review, we have observed different strategies for decreasing the repetitiveness of EMA. For instance, studies tend to have short follow-up periods, many lasting no more than 1 week [29, 30•, 32, 42, 44–46, 49–51, 61–65]. Also, assessments were scheduled so that they did not interfere with patients' rest or daily activities. Another strategy is to introduce variation by rotating the questions, asking a few each day from a pool of several questions [28•, 55•]. Other researchers chose to send reminders to participants when their compliance started to decline [25] or to give users compliance-related feedback [62].

Another strategy that complicates efforts to empirically determine the feasibility of EMA is the use of incentives, which were employed by a good number of the articles reviewed. Incentives make it difficult to draw conclusions about feasibility and for some authors they pose ethical conflicts [75–77]. Moreover, some studies have been conducted in inpatient settings [27, 32, 45, 46, 56–58, 60–65], whereas the interest of EMA lies in being used in real environment.

Future Lines of Research

One of the most promising lines of future research in EMA is passive monitoring of information, that is, without active collaboration of the user. Smartphones open up this possibility thanks to the native sensors included in the device. This concept, known as passive EMA, is beginning to be explored in a small number of studies in suicide research [28•, 56] and has been explored more widely in other areas of mental healthcare [78–80]. Passive EMA does not allow direct assessment of STB, but it does make it possible to collect variables that could serve as clinical proxies of suicide risk factors, such as mobility, sleep, or smartphone use. Additionally, it may be useful for studying the context in which suicide ideation arises. The amount of information that can be collected through these systems increases as mobile technology advances and as passive EMA systems are complemented by wearable devices. Given the large amount of potentially sensitive information collected through this method, special care must be taken to protect personal data so as to ensure the privacy of participants. There are ethical concerns involved when developing digital tools for mental healthcare, and a proper balance must be reached between safeguarding patients' health and respecting their privacy [81, 82].

Another important line of related research is ecological momentary intervention (EMI), a modality of EMA with therapeutic intent that seeks to provide remote psychological support with 24/7 availability. EMI is already beginning to be explored in other areas of mental health, such as depression [16]. Although EMI is a promising area, more clinical trials are needed to test the long-term effectiveness of these interventions before they can be implemented in clinical practice [83].

Strengths and Limitations

To our knowledge, this is the first systematic review of the use of EMA for studying STB. Among the limitations of our review, it

is worth noting the great heterogeneity of the studies (with different study populations, aims, and modalities of EMA), which has prevented a quantitative synthesis of the results.

Conclusions

EMA can reveal unknown features of STB by analyzing this complex phenomenon at a high level of detail. This methodology may facilitate the search for short-term predictors of STB and ultimately contribute to suicide prevention.

EMA may become a very useful tool in clinical practice, and we should begin to test this approach in conditions as close as possible to real life. However, there are also ethical issues to be resolved, such as the strategy to follow when EMA detects that a patient has a high SI, adequate protection of patient privacy, or the regulation of mobile health within healthcare systems.

Future studies will have to address these challenges over the coming years and integrate advances in new technologies to optimize the use of the EMA.

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Compliance with Ethical Standards

Conflict of Interest Alba Sedano-Capdevila, Alejandro Porras-Segovia, Hugo J. Bello, and María Luisa Barrigón each declare no potential conflicts of interest.

Enrique Baca-García designed the MEmind application, an Ecological Momentary Assessment tool.

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Consent to Participate Not applicable.

Consent for Publication Not applicable.

References

Papers of particular interest, published recently, have been highlighted as:
- Of importance

1. World Health Organization 2020 (2020) WHO | Suicide. In: https://www.who.int/news-room/fact-sheets/detail/suicide. .
2. Borges G, Nock MK, Haro Abad JM, Hwang I, Sampson NA, Alonso J, et al. Twelve-month prevalence of and risk factors for suicide attempts in the World Health Organization World Mental Health Surveys. J Clin Psychiatr. 2010;71:1617–28.
3. Liu RT, Bettis AH, Burke TA. Characterizing the phenomenology of passive suicidal ideation: a systematic review and meta-analysis of its prevalence, psychiatric comorbidity, correlates, and comparisons with active suicidal ideation. Psychol Med. 2020;50:367–83.
4. Bostwick JM, Pabbati C, Geske JR, McKean AJ. Suicide attempt as a risk factor for completed suicide: even more lethal than we knew. Am J Psychiatry. 2016;173:1094–100.
5. Hubers AAM, Moaddine S, SHM P, Stijnen T, van Duijn E, van der Mast RC, et al. Suicidal ideation and subsequent completed suicide in both psychiatric and non-psychiatric populations: a meta-analysis. Epidemiol Psychiatr Sci. 2018;27:186–98.
6. Van Spijker BAJ, van Straten A, Kerkhof AJFM, Hoeymans N, Smit F. Disability weights for suicidal thoughts and non-fatal suicide attempts. J Affect Disord. 2011;134:341–7.
7. Shepard DS, Gurewich D, Lwin AK, Reed GA, Silverman MM. Suicide and suicidal attempts in the United States: costs and policy implications. Suicide Life Threat Behav. 2016;46:352–62.
8. Kinchin I, Doran CM. The economic cost of suicide and non-fatal suicide behavior in the Australian workforce and the potential impact of a workplace suicide prevention strategy. Int J Environ Res Public Health. 2017;14. https://doi.org/10.3390/ijerph14040347.
9. WHO | Comprehensive mental health action plan 2013–2020-2030. In: WHO. http://www.who.int/mental_health/action_plan_2013/en/. .
10. Franklin JC, Ribeiro JD, Fox KR, Bentley KH, Kleiman EM, Huang X, et al. Risk factors for suicidal thoughts and behaviors: a meta-analysis of 50 years of research. Psychol Bull. 2017;143:187–232.
11. O'Connor RC, Portzky G. Looking to the future: a synthesis of new developments and challenges in suicide research and prevention. Front Psychol. 2018;9:2139.
12. Schmier JK, Halpern MT. Patient recall and recall bias of health state and health status. Expert Rev Pharmacoecon Outcomes Res. 2004;4:159–63.
13. Shiffman S, Stone AA, Hufford MR. Ecological momentary assessment. Annu Rev Clin Psychol. 2008;4:1–32.
14. Burke LE, Shiffman S, Music E, Styn MA, Kriska A, Smailagic A, et al. Ecological momentary assessment in behavioral research: addressing technological and human participant challenges. J Med Internet Res. 2017;19:e77.
15. Eaton LG, Funder DC. Emotional experience in daily life: valence, variability, and rate of change. Emotion. 2001;1:413–21.
16. Colombo D, Fernández-Álvarez J, Patané A, Semonella M, Kwiatkowska M, García-Palacios A, et al. Current state and future directions of technology-based ecological momentary assessment and intervention for major depressive disorder: a systematic review. J Clin Med. 2019;8. https://doi.org/10.3390/jcm8040465.

17. Yim SJ, Lui LMW, Lee Y, Rosenblat JD, Ragguett RM, Park C, et al. The utility of smartphone-based, ecological momentary assessment for depressive symptoms. J Affect Disord. 2020;274:602–9.
18. Walz LC, Nauta MH, Aan Het Rot M. Experience sampling and ecological momentary assessment for studying the daily lives of patients with anxiety disorders: a systematic review. J Anxiety Disord. 2014;28:925–37.
19. Bell IH, Lim MH, Rossell SL, Thomas N. Ecological momentary assessment and intervention in the treatment of psychotic disorders: a systematic review. Psychiatr Serv Wash DC. 2017;68:1172–81.
20. Mote J, Fulford D. Ecological momentary assessment of everyday social experiences of people with schizophrenia: a systematic review. Schizophr Res. 2020;216:56–68.
21. Russell MA, Gajos JM. Annual research review: ecological momentary assessment studies in child psychology and psychiatry. J Child Psychol Psychiatry. 2020;61:376–94.
22. Serre F, Fatseas M, Swendsen J, Auriacombe M. Ecological momentary assessment in the investigation of craving and substance use in daily life: a systematic review. Drug Alcohol Depend. 2015;148:1–20.
23. Bertz JW, Epstein DH, Preston KL. Combining ecological momentary assessment with objective, ambulatory measures of behavior and physiology in substance-use research. Addict Behav. 2018;83:5–17.
24. Davidson CL, Anestis MD, Gutierrez PM. Ecological momentary assessment is a neglected methodology in suicidology. Arch Suicide Res. 2017;21:1–11.
25. Glenn CR, Kleiman EM, Kearns JC, Santee AC, Esposito EC, Conwell Y, et al. Feasibility and acceptability of ecological momentary assessment with high-risk suicidal adolescents following acute psychiatric care. J Clin Child Adolesc Psychol Off J Soc Clin Child Adolesc Psychol Am Psychol Assoc Div. 2020;53:1–17.
26.• Oquendo MA, Galfalvy HC, Choo T-H, Kandlur R, Burke AK, Sublette ME, et al. Highly variable suicidal ideation: a phenotypic marker for stress induced suicide risk. Mol Psychiatry. 2020. https://doi.org/10.1038/s41380-020-0819-0 **This is an EMA study in suicide research with the longest follow-up period (2 years), although EMA assessment was not continuous (it consisted on 6 non-consecutive weeks over the course of 2 years).**
27. Peters EM, Dong LY, Thomas T, Khalaj S, Balbuena L, Baetz M, et al. Instability of suicidal ideation in patients hospitalized for depression: an exploratory study using smartphone ecological momentary assessment. Arch suicide res off J Int Acad suicide res. 2020:1–14.
28.• Porras-Segovia A, Molina-Madueño RM, Berrouiguet S, et al. Smartphone-based ecological momentary assessment (EMA) in psychiatric patients and student controls: a real-world feasibility study. J Affect Disord. 2020;274:733–41 **Among EMA studies in suicide research, this study has the largest sample size (457 participants for active EMA), and the longest continuous EMA assessment period (60 days).**
29. Vine V, Victor SE, Mohr H, Byrd AL, Stepp SD. Adolescent suicide risk and experiences of dissociation in daily life. Psychiatry Res. 2020;287:112870.
30.• Gratch I, Choo T-H, Galfalvy H, Keilp JG, Itzhaky L, Mann JJ, et al. Detecting suicidal thoughts: the power of ecological momentary assessment. Depress Anxiety. 2020. https://doi.org/10.1002/da.23043 **One of the most recent studies on EMA and suicide, this paper shows that EMA can reveal suicidal ideation in real time that patients do not report retrospectively.**
31. Rodríguez-Blanco L, Carballo JJ, Baca-García E. Use of ecological momentary assessment (EMA) in non-suicidal self-injury (NSSI): a systematic review. Psychiatry Res. 2018;263:212–9.
32. Spangenberg L, Glaesmer H, Hallensleben N, Rath D, Forkmann T. (In)stability of capability for suicide in psychiatric inpatients: longitudinal assessment using ecological momentary assessments. Suicide Life Threat Behav. 2019;49:1560–72.
33. Kleiman EM, Nock MK. Real-time assessment of suicidal thoughts and behaviors. Curr Opin Psychol. 2018;22:33–7.
34. Torous J, Larsen ME, Depp C, Cosco TD, Barnett I, Nock MK, et al. Smartphones, sensors, and machine learning to advance real-time prediction and interventions for suicide prevention: a review of current progress and next steps. Curr Psychiatr Rep. 2018;20:51.
35. Chaïb LS, Segovia AP, Baca-Garcia E, Lopez-Castroman J. Ecological studies of sleep disturbances during suicidal crises. Curr Psychiatr Rep. 2020;22:34.
36. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6:e1000097.
37. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. Syst Rev. 2016;5:210.
38. Nock MK, Prinstein MJ, Sterba SK. Revealing the form and function of self-injurious thoughts and behaviors: a real-time ecological assessment study among adolescents and young adults. J Abnorm Psychol. 2009;118:816–27.
39. Czyz EK, King CA, Nahum-Shani I. Ecological assessment of daily suicidal thoughts and attempts among suicidal teens after psychiatric hospitalization: lessons about feasibility and acceptability. Psychiatry Res. 2018a;267:566–74.
40. Czyz EK, Horwitz AG, Arango A, King CA. Short-term change and prediction of suicidal ideation among adolescents: a daily diary study following psychiatric hospitalization. J Child Psychol Psychiatry. 2018b;60:732–41.
41. Czyz EK, Glenn CR, Busby D, King CA. Daily patterns in nonsuicidal self-injury and coping among recently hospitalized youth at risk for suicide. Psychiatry Res. 2019;281:112588.
42. Rizk MM, Choo T-H, Galfalvy H, Biggs E, Brodsky BS, Oquendo MA, et al. Variability in suicidal ideation is associated with affective instability in suicide attempters with borderline personality disorder. Psychiatry. 2019;82:173–8.
43. Victor SE, Scott LN, Stepp SD, Goldstein TR. I want you to want me: interpersonal stress and affective experiences as within-person predictors of nonsuicidal self-injury and suicide urges in daily life. Suicide Life Threat Behav. 2019;49:1157–77.
44. Humber N, Emsley R, Pratt D, Tarrier N. Anger as a predictor of psychological distress and self-harm ideation in inmates: a structured self-assessment diary study. Psychiatry Res. 2013;210:166–73.
45. Ben-Zeev D, Young MA. Accuracy of hospitalized depressed patients and healthy controls retrospective symptom reports: an experience sampling study. J Nerv Ment Dis. 2010;198:280–5.
46. Ben-Zeev D, Young MA, Depp CA. Real-time predictors of suicidal ideation: mobile assessment of hospitalized depressed patients. Psychiatry Res. 2012;197:55–9.
47.• Links PS, Eynan R, Heisel MJ, Barr A, Korzekwa M, McMain S, et al. Affective instability and suicidal ideation and behavior in patients with borderline personality disorder. J Personal Disord. 2007;21:72–86 **Published in 2007, this is a study exploring the use EMA to assess suicidal ideation.**
48. Links PS, Eynan R, Heisel MJ, Nisenbaum R. Elements of affective instability associated with suicidal behaviour in patients with borderline personality disorder. Can J Psychiatr. 2008;53:112–6.
49. Littlewood DL, Kyle SD, Carter L-A, Peters S, Pratt D, Gooding P. Short sleep duration and poor sleep quality predict next-day suicidal ideation: an ecological momentary assessment study. Psychol Med. 2019;49:403–11.
50. Crowe E, Daly M, Delaney L, Carroll S, Malone KM. The intra-day dynamics of affect, self-esteem, tiredness, and suicidality in major depression. Psychiatry Res. 2019;279:98–108.

51. Husky M, Olié E, Guillaume S, Genty C, Swendsen J, Courtet P. Feasibility and validity of ecological momentary assessment in the investigation of suicide risk. Psychiatry Res. 2014;220:564–70.
52. Husky M, Swendsen J, Ionita A, Jaussent I, Genty C, Courtet P. Predictors of daily life suicidal ideation in adults recently discharged after a serious suicide attempt: a pilot study. Psychiatry Res. 2017;256:79–84.
53. Law MK, Furr RM, Arnold EM, Mneimne M, Jaquett C, Fleeson W. Does assessing suicidality frequently and repeatedly cause harm? A randomized control study. Psychol Assess. 2015;27:1171–81.
54. Kleiman EM, Coppersmith DDL, Millner AJ, Franz PJ, Fox KR, Nock MK. Are suicidal thoughts reinforcing? A preliminary real-time monitoring study on the potential affect regulation function of suicidal thinking. J Affect Disord. 2018;232:122–6.
55.• Torous J, Staples P, Shanahan M, Lin C, Peck P, Keshavan M, et al. Utilizing a personal smartphone custom app to assess the Patient Health Questionnaire-9 (PHQ-9) depressive symptoms in patients with major depressive disorder. JMIR Ment Health. 2015. https://doi.org/10.2196/mental.3889 **Similar to the findings of Gratch et al. (2020), in this study, it was found that patients tend to score higher in questionnaires assessed through EMA than in traditional retrospective questionnaires.**
56. Ben-Zeev D, Scherer EA, Brian RM, Mistler LA, Campbell AT, Wang R. Use of multimodal technology to identify digital correlates of violence among inpatients with serious mental illness: a pilot study. Psychiatr Serv. 2017;68:1088–92.
57. Kleiman EM, Turner BJ, Fedor S, Beale EE, Huffman JC, Nock MK. Examination of real-time fluctuations in suicidal ideation and its risk factors: results from two ecological momentary assessment studies. J Abnorm Psychol. 2017;126:726–38.
58. Kleiman EM, Turner BJ, Fedor S, Beale EE, Picard RW, Huffman JC, et al. Digital phenotyping of suicidal thoughts. Depress Anxiety. 2018;35:601–8.
59. Coppersmith DDL, Kleiman EM, Glenn CR, Millner AJ, Nock MK. The dynamics of social support among suicide attempters: a smartphone-based daily diary study. Behav Res Ther. 2019;120:103348.
60. Mou D, Kleiman EM, Fedor S, Beck S, Huffman JC, Nock MK. Negative affect is more strongly associated with suicidal thinking among suicidal patients with borderline personality disorder than those without. J Psychiatr Res. 2018;104:198–201.
61. Hallensleben N, Spangenberg L, Forkmann T, Rath D, Hegerl U, Kersting A, et al. Investigating the dynamics of suicidal ideation: preliminary findings from a study using ecological momentary assessments in psychiatric inpatients. Crisis. 2018;39:65–9.
62. Forkmann T, Spangenberg L, Rath D, Hallensleben N, Hegerl U, Kersting A, et al. Assessing suicidality in real time: a psychometric evaluation of self-report items for the assessment of suicidal ideation and its proximal risk factors using ecological momentary assessments. J Abnorm Psychol. 2018;127:758–69.
63. Hadzic A, Spangenberg L, Hallensleben N, Forkmann T, Rath D, Strauß M, et al. The association of trait impulsivity and suicidal ideation and its fluctuation in the context of the interpersonal theory of suicide. Compr Psychiatry. 2020;98:152158.
64. Hallensleben N, Glaesmer H, Forkmann T, Rath D, Strauss M, Kersting A, et al. Predicting suicidal ideation by interpersonal variables, hopelessness and depression in real-time. An ecological momentary assessment study in psychiatric inpatients with depression. Eur Psychiatr. 2019;56:43–50.
65. Rath D, de Beurs D, Hallensleben N, Spangenberg L, Glaesmer H, Forkmann T. Modelling suicide ideation from beep to beep: application of network analysis to ecological momentary assessment data. Internet Interv. 2019;18:100292.
66. Bishop TM, Maisto SA, Britton PC, Pigeon WR. Considerations in the use of interactive voice recording for the temporal assessment of suicidal ideation and alcohol use: a case series. Crisis. 2016;37:370–6.
67. Aan het Rot M, Hogenelst K, Schoevers RA. Mood disorders in everyday life: a systematic review of experience sampling and ecological momentary assessment studies. Clin Psychol Rev. 2012;32:510–23.
68. Laura Silver. Smartphone ownership is growing rapidly around the world, but not always equally. Pew Res. Cent. Glob. Attitudes Proj. 2019. https://www.pewresearch.org/global/2019/02/05/smartphone-ownership-is-growing-rapidly-around-the-world-but-not-always-equally/.
69. Wiklander M, Samuelsson M, Asberg M. Shame reactions after suicide attempt. Scand J Caring Sci. 2003;17:293–300.
70. Wilson TD. Know thyself. Perspect Psychol Sci J Assoc Psychol Sci. 2009;4:384–9.
71. Dunkley C, Borthwick A, Bartlett R, Dunkley L, Palmer S, Gleeson S, et al. Hearing the suicidal patient's emotional pain. Crisis. 2018;39:267–74.
72. Nock MK, Park JM, Finn CT, Deliberto TL, Dour HJ, Banaji MR. Measuring the suicidal mind: implicit cognition predicts suicidal behavior. Psychol Sci. 2010;21:511–7.
73. Tello N, Harika-Germaneau G, Serra W, Jaafari N, Chatard A. Forecasting a fatal decision: direct replication of the predictive validity of the suicide-implicit association test. Psychol Sci. 2020;31:65–74.
74. Vachon H, Viechtbauer W, Rintala A, Myin-Germeys I. Compliance and retention with the experience sampling method over the continuum of severe mental disorders: meta-analysis and recommendations. J Med Internet Res. 2019;21:e14475. https://doi.org/10.2196/14475.
75. Singer E, Couper MP. Do incentives exert undue influence on survey participation? Experimental evidence. J Empir Res Hum Res Ethics JERHRE. 2008;3:49–56.
76. Groth SW. Honorarium or coercion: use of incentives for participants in clinical research. J N Y State Nurses Assoc. 2010;41:11–3 quiz 22.
77. Ashcroft RE. Personal financial incentives in health promotion: where do they fit in an ethic of autonomy? Health Expect Int J Public Particip Health Care Health Policy. 2011;14:191–200.
78. Asselbergs J, Ruwaard J, Ejdys M, Schrader N, Sijbrandij M, Riper H. Mobile phone-based unobtrusive ecological momentary assessment of day-to-day mood: an explorative study. J Med Internet Res. 2016;18:e72.
79. Saeb S, Zhang M, Karr CJ, Schueller SM, Corden ME, Kording KP, et al. Mobile phone sensor correlates of depressive symptom severity in daily-life behavior: an exploratory study. J Med Internet Res. 2015;17:e175. https://doi.org/10.2196/jmir.4273.
80. Raugh IM, James SH, Gonzalez CM, Chapman HC, Cohen AS, Kirkpatrick B, et al. Geolocation as a digital phenotyping measure of negative symptoms and functional outcome. Schizophr Bull. 2020. https://doi.org/10.1093/schbul/sbaa121.
81. Torous J, Roberts LW. The ethical use of mobile health technology in clinical psychiatry. J Nerv Ment Dis. 2017;205:4–8.
82. McKernan LC, Clayton EW, Walsh CG. Protecting life while preserving liberty: ethical recommendations for suicide prevention with artificial intelligence. Front Psychiatr. 2018;9. https://doi.org/10.3389/fpsyt.2018.00650.
83. Gründahl M, Deckert J, Hein G. Three questions to consider before applying ecological momentary interventions (EMI) in psychiatry. Front Psychiatr. 2020;11:333.