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Real Time Tracking of Sleep Behaviors as a Predictor of Suicidal Ideation for Young Adults with Autism Spectrum Disorder and Social Anxiety

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with Autism Spectrum Disorder and Social Anxiety

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ABSTRACT

Real Time Tracking of Sleep Behaviors as a Predictor of Suicidal Ideation for Young Adults with Autism Spectrum Disorder and Social Anxiety

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Suicide continues to be a critical concern for society as one of the leading causes of death in the United States, increasing from 10.4 to 13.5 per 100,000 from 2000 to 2016. This risk is further increased up to 8 times for individuals with Autism Spectrum Disorder. Suicidal thoughts and behaviors have been difficult to predict on a moment-by-moment basis, in part due to technological challenges. Suicidal ideation has been identified as an important indicator of suicidal behavior and an important measurement for predicting suicide in both neurotypical individuals and individuals with autism spectrum disorder. In particular, sleep disturbances are one risk factor for suicidal behavior. Important aims of this study include identifying personalized predictors of leading up to suicidal ideation, including how sleep activity patterns affect suicidal ideation, and how these risk factors differ between those with autism spectrum, socially anxious groups. This will give further insight into predictors of suicidal ideation, providing a better understanding for predicting changes in suicidal ideation, with aims to bring more clarity in this at-risk population and improve treatment options.

To observe predictors of both long-term and short-term changes in suicidal ideation, I will analyze longitudinal data. The data includes daily phone questionnaires and actigraphy data tracking using GENEActiv wearable devices that includes sleep from individuals with autism spectrum and social anxiety with a history of suicidal ideation, and neurotypical individuals who are tracked over 24-36 weeks. Results of analysis indicate that sleep duration is not a significant predictor of suicidal ideation intensity, and that there is no difference between the autism spectrum and social anxiety groups in the predictive ability of sleep.

Limitations of this study include local convenience sampling which includes a large majority of white participants, part of the study and data collected occurring during the COVID-19 pandemic, and potential response bias for such a sensitive topic. This study shows overall that there is a working model for this type of analysis, however many more features of sleep including movement during sleep and waking during sleep need to be analyzed to see if there is any predictive power in information from actigraphy, which would be a low invasive method for detecting increases in suicidal ideation risk.

Keywords: Suicide, Autism Spectrum Disorder, Social Anxiety, Ecological Momentary Assessment, Actigraphy

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

Real Time Tracking of Sleep Behaviors as a Predictor of Suicidal Ideation for Young

Adults with Autism Spectrum Disorder and Social Anxiety

Background

Suicide is a critical concern as one of the leading causes of death in the United States (Nock et al., 2009) and suicide rates have been increasing in recent years from 10.4 to 13.5 per 100,000 from 2000 to 2016 (Hedegaard et al., 2018). Suicide continues to be a concern for all age ranges; however, it is the second leading causes of death for young adults ages 25-34 (Hedegaard & Warner, 2021). These rates are further increased for at risk populations such as for individuals with Autism Spectrum Disorder (ASD) where some research shows suicidal behaviors are increased up to 8 times higher (Cassidy & Rodgers, 2017), and those with social anxiety, where an estimated than 35% of individuals will experience suicidal feelings in their lifetime (Arditte et al., 2016). One of the major theories of why suicidal feelings occur is the Interpersonal Theory of Suicide, which in which the main components are thwarted belongingness, perceived burdensomeness, and acquired capability (Van Orden et al., 2010). The experience of thwarted belonging and perceived burdensomeness overlap with social challenges that are that are common for those with ASD (Pelton et al., 2020) and social anxiety (Duffy et al., 2020).

One method of trying to understand increasing rates of suicide is to better understand suicidal ideation, which has been identified as an important indicator of suicidal behavior and an important measurement for predicting suicide in the general population (Ben-Zeev, 2012), and in individuals with ASD (Mayes et al., 2013). A study reported that over 66% of adults with ASD have had experiences of suicidal ideation, and 35% have either planned or attempted suicide

(Cassidy & Rodgers, 2017). There is also some evidence that suggests that individuals with ASD and suicidal behaviors have histories of more frequent attempts (Richards et al., 2019). Suicidal ideation tends to occur with quick onset and short duration, making it difficult to track with intermittent questionnaires or interviews (Kleiman & Nock, 2018).

A potential risk factor for suicidal ideation is reduced duration of sleep (Khader et al., 2020). Poor sleep has been long established as a clear risk factor for suicidal behavior (Bernert & Joiner, 2007), and has been shown to lead to declines in mental and physical health (Hochard et al., 2020). 40-80% of individuals with ASD report some form of sleep concerns including difficulty falling asleep, frequent awakening, early morning awakening and other forms of insomnia (Devnani & Hegde, 2015), and these behaviors have continued to persist throughout adulthood (Morgan et al., 2020). These increased rates in insomnia for those with ASD stem from multiple areas, including genetic, neurological, environmental, and other factors such as melatonin rhythm and neurotransmitters (Devnani & Hegde, 2015).

A method that has shown promise is daily tracking through phone surveys and actigraphy devices. By engaging in real time tracking of behaviors, changes can be tracked throughout the day, and catch more of the nuanced fluctuations of suicidal ideation and sleep. Phone surveys of individuals feelings of suicidal ideation and related behaviors can be asked multiple times per day, and changes in the mood of an individual within a single day can be tracked. Additionally, sleep data can be collected in a cost-effective manner with actigraphy data that can track sleeping patterns over extended periods of time. These combined methods allow participants to be in their natural environments when reporting behaviors and provide greater consistency in timepoints in which they report.

In this study, we hypothesize that within subjects, reductions in quality of sleep will be associated with increases in suicidal ideation for participants with ASD and social anxiety with a history of suicidal ideation. We will also look to see if there are different effects of for suicidal ideation between the groups with a history of suicidal ideation and hypothesize that the relationship of actigraphy sleep and suicidal ideation behaviors for individuals with ASD will significantly increase suicidal ideation when sleep duration is reduced compared to socially anxious individuals. This study aims to fill gaps in the research by tracking suicidal ideation several times a day, as well as tracking risk factors over longer periods of time. There is a need for more research on suicidal risk factors for individuals with ASD with more consistent forms of tracking these behaviors. The impact of sleep on suicidal ideation also needs more in-depth research, especially using more valid forms of tracking sleeping behaviors. Even if there are small effect sizes, we hope that it will help to contribute to the literature of evidence for helping to understand and intervene in the occurrence of these events.

Methods

Participants

This study has taken place at Brigham Young University in Provo, Utah in the United States. Participants were recruited from the school, surrounding community, previous studies, and internet recruitment. Participants were included in the study if they were experiencing frequent suicidal thoughts at least once per week, currently have a diagnosis of either autism or social anxiety, were at least 18 years old, and have ownership and use of a smartphone. Participants were disqualified if they had other serious diagnoses such as schizophrenia, bipolar disorder, or a personality disorder, if they were an adult with a legal guardian, were not fluent in

English, and had any major medical concerns. This study initially recruited 102 participants, of which 72 reported their gender as female. They were recruited into 3 groups, ASD with a history of suicidal ideation, social anxiety with a history of suicidal ideation, and a control group. This data is used from a larger dataset looking on a wide array of potential risk factors across multiple domains for suicidal ideation behaviors. 5 participants did not meet criteria after clinical interview for any testing group. 18 participants withdrew from the original study before completing all visits (2 no group, 2 control group, 5 ASD group, 9 social anxiety group) and 8 participants withdrew from the study. Withdrawn participants stated reasons for leaving as moving away, the surveys were too taxing, or other reasons. No participant lodged a formal complaint during the withdrawal process. The participants who have completed at least one data collection period included 94 total participants, 33 in the ASD group (23 female), 29 in the social anxiety group (23 female), 27 in the control group (19 female), and 5 in no group (5 female). The participants who did not fit into a group were not used for analysis. All included participants completed an average of 5.39 visits. Participants had Full Scale Intelligence Quotient between 79-154 (M=119.89, SD=13.15). Three participants did not have IQ data due to dropping before assessment could be completed. The sample was 88.3% White, 8.5% Hispanic or Latinx, and 3.2% Asian, with ages between 18-40 (M=23.81, SD=3.80). All collected data has been deidentified and stored on Box data services.

Table 1

Demographic Summary

	Controls (N=27)	Autism (N=33)	Social Anxiety (N=29)	χ^2 or η^2	p
Age (Years)	22.67±2.32	25.85±4.82*	22.70±2.36	0.15	0.001*
Gender (M:F)	8:19	8:25	6:23	2.24	0.523
Race & Ethnicity	0:0:23:3:0	3:0:29:1:0	0:0:28:1:0	15.377	0.017*

(A : B : W : H : O)					
Estimated IQ (WASI)	119.8 ± 15.95	119.4 ± 15.95	119.8 ± 11.12	0.008	0.859

Design

Data was primarily collected in natural environments of the participants. After recruitment and passing the screening process, participants had an initial visit and complete an assessment process to determine eligibility and grouping, gather demographic information, baseline sleep, baseline suicidality, and create a safety plan. During this process, participants who were recruited for a specific group and through the assessment process no longer qualified, but did not meet any direct exclusion criteria, were moved to a "no group" designation, which was not used for analysis. The initial visit and assessment included using a clinical interview, which included The Mini-International Neuropsychiatric Interview (MINI) and the Autism Diagnostic Observation Schedule-Second Edition (ADOS-2) to assess for social anxiety, autism behaviors, and to rule other psychological disorders. Intelligence was initially assessed using the WISC-2 (Wechsler Abbreviated Scale of Intelligence-Second Edition). Initial suicidality was assessed using the C-SSRS (Columbia-Suicide Severity Rating Scale). Having an assessment at the initial visit allows us to have a secondary source on the presence of diagnosis in addition to self-reported diagnosis and confirm the intensity of these symptoms, and appropriate reassignment of groups. Participants may have varying levels of self-insight in self-reporting and different feelings and responsiveness towards questions, and we hope that having multiple modes of measurement improves quality.

Participants then had their sleep and suicidal ideation behavior tracked over the course of several visits. This was done using an GENEActiv actigraphy device to measure sleep duration, as well as setting up their mobile device to receive twice daily short 5–10-minute questionnaires that asked about daily, feelings of suicidal ideation and self-reported sleep. Additionally, each participant would be required to return and visit every 6 weeks for renewal of actigraphy devices, and each participant will have a minimum of 5 visits (24 weeks), after which each participant offered an option to extend for an additional 2 visits, up to 36 weeks.

Safety Protocol

Participants who did not meet recruitment requirements due to psychiatric concerns were given information on mental health resources in the community. At time of recruitment, all participants with suicidal ideation completed a safety plan with a clinician to outline strategies and resources to use for safety. Participants received a copy of this protocol, and researchers kept a copy in a secure digital format. Participants were also asked during daily surveys if they would like to be contacted by a clinician to seek help, and if so the participant and a licensed psychologist would be contacted and connected to discuss implementing an appropriate safety plan.

Compensation

Participants were compensated for their time and effort during the study. Participants were expected to have approximately five in-person visits for an estimated 10 total hours which participants were compensated $15/hour. Additionally, participants were compensated $1 per day they wore their GENEActiv actigraphy device and responded to daily surveys. Additional

payment was provided for participants depending on completion rate, with $25 for participants who completed between 50%-75% of the surveys and also wore the daily GENEActiv actigraphy device for 50%-75% of days; and $50 for each 12-week period for those who do achieve greater than 75% combined participation rates. Altogether, participants in the clinical groups who are perfectly compliant will receive about $418 ($150 for in-lab visits, ~$168 for phone surveys and actigraphy; and $100 in bonuses). Participants who withdrew early from the study were compensated at prorated rates for their time. Participants who had high participation rates were also asked if they would like to extend an additional 12 weeks, with similar compensation rates up to $175.

Measures

Actigraphy measurement: This measurement used GENEActive actigraphy devices to collect real time sleep data worn on their non-dominant wrist. Participants were instructed to wear the devices at all times during every day they participate within the study. Movement data will be collected every tenth of a second and processed using the DPSleep pipeline, separated by general thresholds, and the lowest 25% of activity are marked and analyzed for sleep patterns based on the surrounding activity (Rahimi-Eichi et al., 2021). Output from the pipeline was quality controlled with visual inspection from two intendent raters to ensure short periods of movement were not disrupting the tracking of sleep cycles. Studies have shown that validity of GENEActiv actigraphy is comparable to self-reported sleep quality, and some limitations of reliability include being based on motion, which can be affected in certain environments such as sleeping on a bus (Rahimi-Eichi et al., 2021). There have been some studies showing comparable

results of different actigraphy devices when compared to polysomnography, with generally low

percentage error ranges (Mantua et al., 2016). However, this method is reliant on the participant

consistently wearing the actigraphy device in their daily life, and not taking it off during times

where it might be uncomfortable, such as showering or sleeping. This is an additional concern

for individuals with ASD, who may have heightened sensory sensitivities that increase the

challenges involved in wearing the device for extended periods. The primary outcome measured

using the GENEActiv actigraphy device was sleep duration.

EMA measurement: Suicidality and sleep are also being measured using Metricwire,

which provided ecological momentary assessment (EMA), with participants using their personal

mobile phones to present them with a survey each morning. Participants had until the next survey

was sent to respond. Participants were asked to answer yes/no questions, report on feelings of

suicidal ideation with values from 0 to 100, with values depending on the question. For example,

in the question "How strong was your ability to resist the urge to kill yourself since the last

survey you completed (or over the past 12 hours, if you didn't complete the last survey)?" A

score of 100 indicates high ability to resist. The list of questions asked to each participant are

listed in the appendix and were adapted from similar studies and their questions (Kleiman et al.,

2017). Although these questions still rely on self-report, the methodology increases reliability

due to repeated assessment, immediate response based on recent feelings, and improved validity

by collecting in natural environments (Nock et al., 2009).

Power Calculation

Power for multi-level modeling was calculated using an online power analysis tool.

(https://ekleiman.shinyapps.io/powercurves/) (Kleiman & Nock, 2018). Based on the established

participant size of 94, with an expected 168 days with 1 response per day for participants who completed the standard 24-week portion of the study. Participants had an average response rate for EMA surveys of 75.18%, however days where both EMA and actigraphy data intersects may be lower. This model assumed an intraclass correlation (ICC) of 0.5. Similar studies have shown low effect sizes when looking at multi-level suicide related data for person level effects (Kleiman et al., 2017).
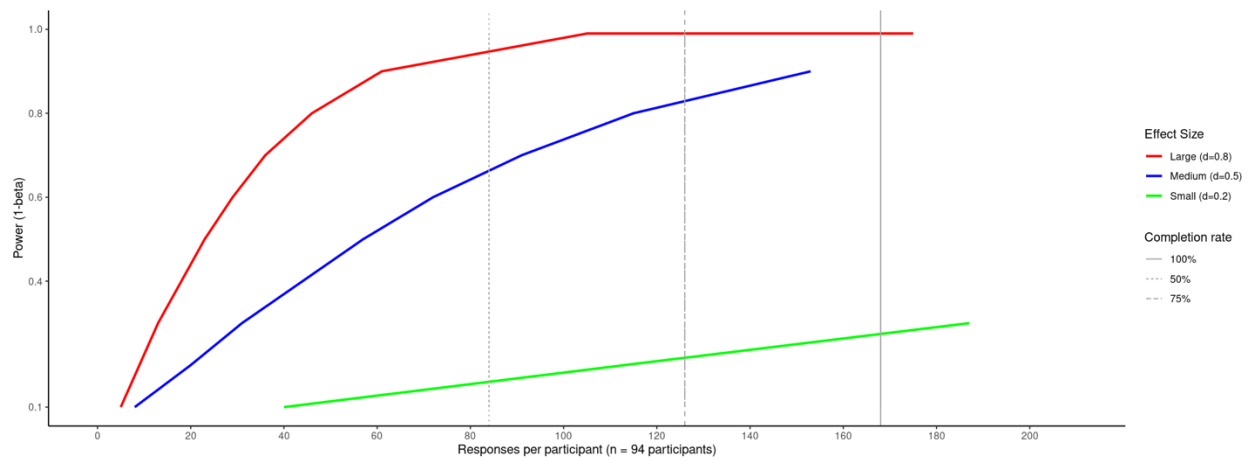
Figure 1

Power Analysis

Figure 1: Power analysis for 94 participants with 2 responses per day for an estimated 168 days. Gray lines indicate power for reductions in response rate for participants.

Analysis Plan

We plan to analyze the data using a multilevel two-part model to leverage daily responses from participants across a longitudinal model while accounting for non-independent observations within participants, using a logistic regression for zeroes to predict if they will have suicidal ideations, and a multilevel gamma regression to predict the intensity ideation using sleep measurements as a predictor (Ruf et al., 2021). This approach also allows us to account for the non-independent nature of each day and analyze our data two-fold, first with a binary response,

then with a continuous. The first part of this two-part model uses a logistic regression model will predict whether a person experienced a suicidal thought. This portion of the model allows us to estimate whether they will have suicidal thoughts (Nallamuthu, 2023). The second part of this two-part model uses a measure of intensity of suicidal ideation using a gamma distribution. Similar to the first portion of our model, where logistic regression is used to find person-specific estimates, random intercepts are group-specific that estimate the levels of suicidal composite value if they have suicidal ideations. This means that we are not assuming the effect to be a generalized average for each participant, but rather specific to each group. We will include several explanatory variables in the model. The categorical variables will include the stable traits of race, age, gender, IQ, and group (Autism and Social Anxiety). This model will be used on both a between group and within group level where random intercepts will be person-specific effects, representing the differences in probability unique to each person, and a person specific level with day specific effects.

Results

During the course of the study, the control group completed an average of 115 days 3702 days (SD=69.9), with a compliance rate of 63%. The social anxiety group completed an average 93.7 days (SD=71.5) with a compliance rate of 48%. The ASD group completed an average 92.8 days (SD=62.2) with a compliance rate of 43%. For the purposes of group analysis, those who were not able to be categorized into a group were removed due to the limited number of participants (n=5) and only 219 total days (M=64.5, SD=59.3) with sufficient information. Further information including the means, ranges, and variance on the group breakdown can be found on Table 2.

Table 2

Descriptive Statistics for Sleep and Suicidal Ideation

Variable	Descriptive Statistics				
	M	SD	Range	% non-zero	Skew
Control					
Suicidal Desire	0	0.1	0-4	0.03% (1)	60.8
Suicidal Intention	0	0.1	0-5	0.03% (1)	60.8
Suicidal Resistance	100	0.2	90-100	-	-60.8
Suicide Composite	0	0.1	0-6.3	0.03% (1)	60.8
Sleep Duration(hr)	7.8	1.5	0.63-20	-	0.45
Days	115	69.9	2-260	-	0.19
Social Anxiety					
Suicidal Desire	8.5	20.2	0-100	18.9% (474)	2.36
Suicidal Intention	3.8	11.2	0-79	16.4% (412)	3.51
Suicidal Resistance	94	17.8	9-100	-	-3.19
Suicide Composite	6.1	15.1	0-76	18.9% (474)	2.63
Sleep Duration(hr)	7.9	2.1	0.35-18.0	-	-0.23
Days	93.7	71.5	2-387	-	0.98
Autism Spectrum					
Suicidal Desire	2.4	10.1	0-100	8.5% (247)	5.27
Suicidal Intention	1	5.8	0-100	6.76% (197)	8.44
Suicidal Resistance	98.1	9.8	0-100	-	-6.56
Suicide Composite	2.8	7.9	0-100	8.44%(246)	5.83
Sleep Duration(hr)	7.8	2.5	0.69-19.9	-	0.28
Days	92.7	62.3	2-287	-	0.47

In order to demonstrate that multilevel modeling is an appropriate analysis for this data, an unconditional model is first run to test for appropriateness for using this model using the suicide composite, which shows that we have a unimodal distribution for our overall sample. This will show the probability of a participant having a day with suicidal ideation. This model estimates a mean probability of no suicidal thoughts at 92.13% (95% CI [39.6%, 99.5%]). This also shows overall that if they do have a day with suicidal ideation, the predicted level of suicidal ideation intensity. During those periods where suicidal ideation occurs, the composite score is an estimated 23.81 (95% CI [6.40, 88.52]). We then analyzed random intercept model with level 2 predictor analyzing if there were and differences of reporting of suicidal behavior between the ASD group and the social Anxiety group. Results indicate that there was not a significant

difference between the two groups (95% CI [-1.61, 0.01]). We then included actigraphy informed sleep duration into the model. We see that sleep duration has no meaningful effects (95% CI [-0.01, 0.10]) on suicidal probability or composite score with more details on Table 3.

Table 3

Multilevel Analysis Results Two Part Modeling

	Statistics		
	Estimate	l-95% CI	u-95% CI
Intercept only model			
Probability of No Ideation	92.13%	39.9%	99.5%
Suicide Ideation Intensity	23.81	6.40	88.52
Group Difference model		-1.61	0.01
Sleep Duration Model		-0.01	0.10

Discussion

This study sought to find a connection between sleep duration and suicidal ideation through the tracking of a less invasive means of actigraphy, and if there were any clear differences between different at-risk groups. The model of analysis we used was used to account for the high number of responses skewed to no suicidal ideation. In addition, this model was able to utilize the non-independent nature of each response within a participant. This would allow us to leverage the longitudinal nature of the data gathered and allow us to track these rare events. The first aim of this study was to look if sleep duration could be used as a predictor for if someone would have suicidal ideation in the overall group, and if so, how intense those feelings were. The results suggest that sleep duration is not an effective means of predicting suicidal ideation. Sleep did not appear to have any direct relationship with the increase or decrease of severity of suicidal ideations. The second aim was to see if there were differences in sleep duration as a predictor between the two groups experiencing suicidal ideation. There did not appear to be any major differences in the responses of participants in either group, with both

groups having similar suicidal ideation behavior. Overall, this model indicated no significant ability for sleep duration to identify increases suicidal ideations.

Limitations

This study should be viewed with the understanding of several limitations. Participants could potentially be less motivated to comply with self-reports when mood is reduced or during periods of suicidal ideation, and some participants dropped from the study due to negative emotional responses to asking about suicidal behavior. This may have affected responses of participants or created a biased response pattern. Additionally, the quality of the actigraphy data including battery issues, time with watch off, and other potential unknown factors that may affect overall recording. Several participants had technical issues with their actigraphy data, which caused loss of data. Another limitation is the local acquisition and restricted sample of participants for this study. Most participants were locally sourced around the area, which includes a predominantly white sample, and the reflection of these results on the generalizability of the greater population. This study also overlapped with the COVID-19 pandemic, where self-isolation and quarantine behaviors could have effects on individuals feeling of depression, isolation, and suicidal ideation, with restrictions on socializing and proximity with others might further influence suicidal ideation in unexpected ways. This pandemic may have also had influences on sleep patterns, with regular work, school, and social schedules impacted.

Conclusion

The difficult challenge of predicting suicidal thoughts through other indirect means is a continued challenge that continues to be important for the community. There are clear established interactions between sleep and suicidal thoughts, however this study shows that duration itself is not a clear indicator. The relationship between sleep and suicide is difficult to

track, and the results of our analysis indicate that we may need to investigate other factors involved in that relationship that were not explored during this study, including movement during sleep, and waking during sleep periods. These other factors when combined may improve our predictive ability, and allow us better insight into factors that contribute to suicidal feelings. Overall, we hope that establishing this model will allow for future analysis to expand on this and include other sleep characteristics that can be collected with actigraphy.

Although these findings were unable to detect a predictor, we feel there is still importance in understanding and collecting information on what factors do and do not contribute, especially if there are clear individual differences that can affect what predictors are stronger. Knowing what factors are not effective or significant allows us to continue to adjust our theories on what components of sleep in particular are good predictors. More research is needed exploring potential combinations of factors that could be adjusted for individuals, which hopefully will lead to the ability intervene with these individuals in the future. Being able to use a widespread and low invasive device will allow for a wide net to be cast, potentially catching and warning individuals who others in their social circles may not recognize being at risk. Many personal devices that people use include some form of measuring sleep, and the ability to use that already existing technology to help others would be cost effective and quicker to implement. Even if the effect sizes found using these devices are small, an increased chance of detecting and preventing these devastating events while using common devices that have little to no invasive qualities warrants future research.

Appendix

EMA Suicidal Ideation Questions

1.   How intense was your desire to kill yourself by suicide since the last survey you completed (or over the past 12 hours, if you didn't complete the last survey)?
2.   How strong was your intention to kill yourself by suicide since the last survey you completed (or over the past 12 hours, if you didn't complete the last survey)?
3.   Have you thought about killing yourself in the past 12 hours or since you last took a survey?
4.   How strong was your ability to resist the urge to kill yourself since the last survey you completed (or over the past 12 hours, if you didn't complete the last survey)?
5.   Have you thought about killing yourself in the past hour?
6.   Have you thought about killing yourself in the past 12 hours or since you last took a survey?
7.   Would you like a member of the research team to reach out to you because you are feeling unsafe?

EMA Sleep Questions

1.   What time did you actually try to go to sleep last night?
2.   How long (in minutes) did it take you to fall asleep last night once you started trying?
3.   Last night after you fell asleep, how many times did you wake up during the night?
4.   Altogether, the nighttime awakenings lasted _____ minutes.
5.   Did you have any bad dreams or nightmares last night?
6.   How distressing were these bad dreams or nightmares to you?
7.   What time did you get up in the morning to start your day?
8.   How much actual sleep did you get last night? (HH:MM)
          How would you rate your overall sleep quality for last night?

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