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Feasibility and Preliminary Efficacy of a Public Mobile App to Reduce Symptoms of Post-disaster Distress in Adolescent Wildfire Survivors: Sonoma Rises

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Abstract

In October, 2017 Northern California experienced devastating and historic wildfires leaving the community in need of support to foster emotional resilience during the recovery process.

Adolescents represent a particularly vulnerable population in the wake of disaster, and digital mental health interventions may hold promise for reaching teens at scale. The current study examined the feasibility and efficacy of a mobile mental health app for disaster, Sonoma Rises. A multiple-baseline single case experimental design utilizing a research-enabled version of the app was employed with seven adolescents who experienced significant damage to their homes and schools in the wildfires. Participants completed daily mood ratings, weekly measures of post-traumatic stress symptoms, internalizing and externalizing symptoms, psychosocial functioning, and then pre-post measures of anxiety, depression, wellbeing, sleep, academic engagement, and perceived social support as well as quantitative and qualitative measures of intervention satisfaction and feasibility. Sonoma Rises was found to be feasible in terms of engagement, satisfaction, and likelihood of recommending to a friend. During the study, another wildfire occurred and all participants underwent a prolonged mandated evacuation and were subject to a series of extended power outages. Uptake of the publicly available version of the Sonoma Rises app among the general population was modest but engagement among users was sustained. Lessons learned are offered to contribute to the science and practice of building, disseminating, and implementing digital tools to conduct more equitable disaster mental health outreach and research.

Keywords: Adolescent, Mobile App, Digital Health, Disaster, Trauma

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Impact Statement

In October of 2017, Sonoma County, California experienced devastating and historic wildfires and subsequent community trauma. This manuscript details the development, dissemination, and evaluation of a public mobile mental health app for wildfire survivors. Lessons learned are offered to contribute to the science and practice of using digital tools to conduct disaster mental health outreach and research.

Background

In October of 2017, Northern California endured the second most deadly and destructive fire storm in California history. Twenty-two people were killed, over 5,600 structures were lost (5% of the area's housing stock), and tens of thousands of residents were evacuated and displaced. Children and families fled their homes in the middle of the night, often driving through flames and thick smoke, with little to no warning. Schools were closed or partially closed for nearly a month with nearly all aspects of life disrupted during this time. Psychologists and local health champions, many directly impacted themselves, were compelled to address the growing fire-related mental health needs in the community that were spurred by this historical trauma.

The Sonoma Wildfire Mental Health Collaborative was created to (1) democratize access to evidence-based mental health resources and services for personal recovery and long-term community resilience building, and (2) measure reach and efficacy of the strategies employed in order to create a knowledge base to inform more equitable and inclusive disaster response in other communities. A multi-pronged approach to community-based mental health was employed and included: (1) a trauma-informed mind-body program, (2) counselor training in the delivery of Skills for Psychological Recovery (SPR), and (3) development and dissemination of a public mobile mental health app for coping with disaster (Sonoma Rises). In this manuscript we detail the experience of creating and disseminating Sonoma Rises for individuals impacted by the wildfires and report findings from an evaluation of the app with adolescents who lost their homes in the wildfires. To learn more about the Wildfire Mental Health Collaborative and the yoga and SPR initiatives please see Heinz, Wiltsey-Stirman, Sharin, Loskot, Mason, Jaworski, & McGovern, 2021.

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The opportunity to advance the science and practice of employing digital mental health interventions post-disaster holds great promise in supporting the health, well-being, and resilience of communities devastated by natural disasters. During times of evacuation and displacement, mobile apps are available anywhere, any time. Further, survivors of disaster typically have limited time and bandwidth to access care and resources as they must juggle everyday responsibilities with the overwhelming task of rebuilding a home and life. Mobile health interventions also have the potential to reach and positively impact and more equitably serve historically underserved populations (Montague & Perchonok, 2012). Specifically, they can help overcome many of the barriers that limit access to treatment, which include stigma, immigration status, low perceived need for help, cost, geography, access, lack of convenience, and competing time priorities (Montena et al., 2021).

Adverse Childhood Experiences (ACEs) are difficult and highly stressful events that can happen to anyone before age 18 and are associated with worse mental and physical health outcomes over the lifespan (ACE Resource Network, 2021). Previous research estimates that approximately fourteen percent of American youth will experience a disaster during their childhood (Becker-Blease et al., 2010; Self-Brown et al., 2013). Adolescents have been identified as a vulnerable subgroup that stand to particularly benefit from mental health recovery services following natural disaster (SAMHSA, 2018; Disaster Preparedness Advisory Council, Committee on Pediatric Emergency Medicine, 2015). During disaster adolescents tend to endure school disruption, isolation from peers, loss of personal space (when displaced), relocation away from social support, and they bear witness to parental psychological distress during a formative stage of emotional development.

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Among Australian schoolchildren in the 1983 Ash Wednesday Bushfire, the negative fire-related mental health effects endured 1.5 years after the disaster (McFarlane, 1987). Although the majority of adolescents exposed to trauma will not go on to develop PTSD (Hamblen et al., 2014), initiatives that support resilience and bolster psychosocial functioning are critical for this demographic of disaster survivors in order to prevent development of mental health problems. Adolescents need safe, stable, supportive, predictable relationships and environments to thrive - disasters disrupt both relationships and environment. In the context of other Adverse Childhood Experiences (e.g., mental illness of a parent, neglect, divorce/separation), mobile mental health resources can be particularly helpful with increasing access for teens who must rely on their parents to obtain behavioral health support.

Digital mental health solutions may help sustainably address the problematic low supply-high demand gap that adolescents and their families face regarding access to mental health care services and resources. Indeed, according to the National Alliance on Mental Illness, only fifty percent of youth age eight to fifteen and forty percent of American adults with a mental health condition accessed care in the previous year (NAMI, accessed 2021). A growing evidence-base now demonstrates that technology-based health solutions are efficacious in the treatment of a variety of mental health conditions including anxiety (Firth et al., 2017), depression (Firth et al., 2017), and PTSD (Miner et al., 2016; Rodriguez-Paras et al., 2017). The World Psychiatry Association's Commission on the Future of Psychiatry has named digital psychiatry as a key priority area for improving global mental health in the next decade (Bhugra et al., 2017). Given that young people are more accepting of technology, technology-based approaches to addressing mental health may be particularly well-suited in the context of disaster (Bakker et. al., 2016). Further, burgeoning evidence now suggests that teens find mobile mental health applications

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acceptable and use them with moderate to good engagement (Grist et al., 2017). Despite the potential of these technologies to dramatically increase the reach of care and resource delivery, there is presently a dearth of research on mobile mental health applications for adolescents.

Sonoma Rises Origin Story

In the months immediately following the wildfires, the Healthcare Foundation Northern Sonoma County worked with psychologists from the VA National Center for PTSD and the University of Colorado, Colorado Springs Trauma, Health, and Hazards Center to develop a website for self-guided post-disaster mental health support. The website, www.mysonomastrong.com, was well-received by the community but had several limitations including requirement of an email address and password, no content specific for teens, very poor optimization for mobile phone use (i.e., requires a computer), and an outdated aesthetic not tailored for younger users. It was decided by the collaborative that a mobile app would address these barriers to creating scalable mental health support to all demographic cohorts of disaster survivors. The Healthcare Foundation Northern Sonoma County contracted with Overlap Health to develop and maintain the app and then contracted with four psychologists from the VA National Center for PTSD to develop the app content, facilitate the design process, optimize the user experience (UX), and conduct quality assurance testing across the iOS and Android operating systems.

Sonoma Rises is a mobile app that was designed for anyone who has been impacted by wildfires or other natural disasters. It is intended to help survivors of disaster find their new normal, build resilience, and increase well-being. The Sonoma Rises content calls upon components of Skills for Psychological Recovery (SPR; Berkowitz et al., 2010) and uses select audio tools from the National Center for PTSD mobile app, PTSD Coach.

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Sonoma Rises was free, available in English and Spanish, and could be downloaded on Apple iOS and Android platforms from October 2018 – June 2020. The Spanish version of the app was extensively reviewed for cultural competence by a clinical psychologist with expertise in Latinx mental health. Users could access evidence-informed, audio-guided, and interactive tools to help cope with stress, heal from loss, prioritize self-care, connect with others, manage anger, and track their mood using validated assessments and data visualizations. There were also tools designed specifically for teens to address relationships with family and peers and problems that may arise in school following a disaster. Specifically, the app includes six self-paced content sections, psychoeducation, and direct connections to free and local mental health care services in Sonoma County and nationally. Please see Appendix A for screenshots of the Sonoma Rises app from the Apple App Store.

The app did not require users to input any identifying information. Fully non-identifying, anonymous, and encrypted event sequences were securely stored on a HIPAA-compliant, cloud-based platform. Upon first launch of the app, a unique, randomly-generated code was assigned to that particular app installation. Completely anonymous usage data, such as screens selected, button presses, and other non-identifying patterns, were collected and associated with this install code. Install codes served as a proxy for app users since the unique identity of each app user could not be determined.

Although the app is called “Sonoma Rises,” it can be readily customized for other communities impacted by disaster. Development of the app was funded by the Healthcare Foundation Northern Sonoma County and the Spanish and English app content and related video, audio, and graphic assets are publicly available. The backend coding of the app is proprietary and the intellectual property belongs to Overlap Health.

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Examination of Sonoma Rises with Adolescent Wildfire Survivors

A research version of Sonoma Rises was created for the to track engagement among research participants. A unique invite code and link was generated and then sent to participants to download the research version of the app. The study evaluated the feasibility and efficacy of a trauma-informed mobile mental health app, *Sonoma Rises*, for adolescent disaster survivors. The primary objective of the study was to determine the feasibility (i.e., acceptability, retention, adherence, satisfaction) of a digital self-guided intervention based on Skills for Psychological Recovery for the treatment of post-disaster distress among adolescents. The secondary objective was to examine the efficacy of the intervention on clinical outcomes and psychosocial functioning.

Method

Public Use of Sonoma Rises. Sonoma Rises was promoted to the public through multiple channels including flyers, social media ads (contact corresponding authors for examples), teen app ambassadors, and radio and print ads. The English version of Sonoma Rises was launched on the one-year anniversary of the October 2017 Tubbs fire and download and use data were recorded through December 31st, 2019.

This Sonoma Rises research study with adolescents received approval from the Stanford School of Medicine IRB and the Palo Alto VA IRB. The study was prospectively registered as a clinical trial (<https://clinicaltrials.gov/ct2/show/NCT03868761>). A multiple-baseline single case experimental design (SCED) was employed with seven adolescents who experienced significant damage to their schools and also lost their homes or were displaced as a result of the wildfires. By using a series of cases, data can be combined with multilevel modelling to permit more

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general conclusions about a common participant group. The randomization of participants to baseline periods of varying lengths enables assessment of whether symptom changes occur when, and only when, the intervention is applied (Dallery et al., 2013). SCEDs lend well to digital data capture as they collect rich individual data, an approach which helps investigators detect fine-grained, person-level changes in behavior over time. Single-case research replicates patterns across and within participants and is a widely accepted design and methodology for testing preliminary efficacy and demonstrating clinically significant improvements over the course of treatment (Dallery et al., 2013; Kazdin, 2019; Shamseer et al., 2015; Tate et al., 2016).

Participants were randomized to baseline durations of either two, four, or six weeks and then received access to the intervention. Participants completed daily ratings of anxiety and fear (Loerinc, 2018), weekly measures of post-traumatic stress symptoms (Child PTSD Symptom Scale for DSM-5; CPSS-5; Foa et al, 2018), internalizing and externalizing symptoms (The Behavior and Feelings Survey; BFS; Weisz et al., 2019), psychosocial functioning (Ohio Scale for Youth– Functioning subscale; OSY; Ogles et al., 2001), and then measures of anxiety (GAD-7; Spitzer et al., 2006), depression (PHQ-9; Kroenke, Spitzer, & Williams, 2001), well-being (Warwick-Edinburgh Mental Well-being Scale; WEMWBS;. Tennant et al., 2007); sleep (Insomnia Severity Index; ISI; Bastien et al., 2001), academic engagement (Student Engagement Instrument; SEI; Appleton et al., 2006), and perceived social support (Wills’ Social Support Scale; WSSS; Wills et al., 2004) at baseline, pre-intervention, post-intervention, and follow-up. If participants indicated any suicidal ideation on the PHQ-9, they were contacted by the study coordinators and automatically emailed resources for a higher level of care. Please see Appendix B for a complete description of all study measures. Following the intervention, participants

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completed quantitative and qualitative measures of treatment satisfaction and feasibility.

Treatment engagement was tracked within the app.

Eligibility Criteria

In order to be included in the study participants had to (1) be aged thirteen to seventeen years old, (2) be directly impacted by the 2017 wildfires having lost their home or been temporarily displaced, (3) report at least four symptoms of PTSD (Child Trauma Screening Questionnaire; Kenardy et al., 2006) with the wildfire as Criterion A¹, (4) have regular access to a smartphone and a computer, (5) have a personal email address, (6) speak and read English fluently, and (7) have parental consent. Individuals were excluded for participation if they self-reported (1) a positive history of psychosis, bipolar illness, or schizophrenia, (2) serious physical health concerns necessitating surgery or with prognosis <6 months, (3) current suicidal ideation, (4) pregnancy, or (5) less than four weeks of stable prescription medication for anxiety, anti-depressant, and sleep-promoting medications prior to the screening assessment.

Procedure

See Figure 1 for visualization of the study procedures. First, the parents of teens affected by wildfires were contacted by Sonoma County school guidance counselors and administrators about an opportunity to participate in research. Those who were interested provided electronic consent in REDCap for their teens to be considered for participation in research. Following provision of parental consent, teens were asked to provide electronic assent and then completed a digital screening questionnaire to assess eligibility for the study against inclusion/exclusion criterion. Screening questions included demographic and medical history questions, wildfire

¹ The CTSQ can range from 0-10 with endorsement of 5 or more symptoms suggesting an increased risk for a diagnosis of PTSD (Kenardy et al., 2006). A lower cut score of 4 was used in the current study as a positive PTSD diagnostic status was not required to participate in the study.

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exposure and impact questionnaires, and a digital self-report version of the Child Trauma Screening Questionnaire. If suitable, teen participants were contacted by the study coordinator to explain the study and obtain verbal assent. Participants were then randomized to one of three baseline assessment periods (either 2, 4, or 6 weeks in duration). Participants completed an assessment each week of their participation in the study, totaling thirteen to seventeen assessments. In total, the maximum duration a participant was to be included in the study was fifteen weeks (6 weeks baseline, 6 weeks of treatment, and 3 weeks follow-up), and the minimum was eleven weeks (2 weeks baseline, 6 weeks of treatment, and 3 weeks follow-up).

Upon entering the study, participants were immediately asked to complete a baseline assessment battery. Each day during the study, participants were asked to complete one item regarding how anxious or fearful they felt in the past twenty-four hours. This item was administered by digital capture (mobile phone SMS) between approximately three and six pm, depending on the participant's preference.

After a two, four, or six-week baseline assessment phase, all participants were given access to the intervention, Sonoma Rises, for six weeks. The research version (and public version) of the app was developed by Overlap Health (www.overlaphealth.com). The key difference between the publicly available version of the app and the research version was that the research version only contained a measure of mood (Photo Affect Meter; Pollack et al., 2011), and all other assessments in the public version of the app were removed and were conducted outside the app using Qualtrics. In addition, participant engagement data, as measured by time spent engaging with the app content, were collected within the app.

In terms of dosing, participants were instructed to access the app seven days a week for five to ten minutes, each day, for six weeks. Participants could repeat tools if they completed the

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mobile app program early. Participants received regularly scheduled push notifications to remind them to use the app, every evening of every day of the six-week intervention period. In addition, they received specialized push notification reminders if they did not enter the app for three days. Receipt of other interventions to address post-disaster mental health struggles was not prohibited during the trial. Use of over-the-counter and prescription medication(s) as well as other forms of psychotherapy was tracked each week over the course of the study. The study coordinator conducted qualitative interviews over the phone with participants following the intervention phase to better understand participants' user experience and to obtain their general feedback.

Following the intervention phase, participants completed a three-week follow-up period with no active treatment. They were instructed that they were no longer being asked to use the app, but still had access to the app during this follow-up period. At four weeks from treatment end, participants were asked to complete a follow-up assessment consisting of the full assessment battery, and then concluded their participation in the study. Four participants enrolled in the study at a juncture that did not allow them to complete the follow-up period due to an end in grant funding and available research assistant support.

All participants received the active intervention. The entire study was conducted online. Participants were instructed to contact the study coordinator by phone or email with questions or concerns.

Participant Compensation

Participants were paid on a reloadable Mastercard gift card for study participation time and received compensation after each completed assessment. Depending on the baseline condition assigned and the length of their participation, participants earned from \$165 to a maximum of \$205 for completion of the entire study protocol, which ranged between eleven and

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fifteen weeks. Participants received \$15 for the initial baseline, pre-treatment, post-treatment, and one-month follow-up assessments (\$60 total). They received \$10 for each assessment completed within the baseline phase, throughout the course of treatment, and the three weeks following treatment. In addition to payment for study participation, a bonus of \$15 was awarded to participants who completed all scheduled assessments. These payments were not contingent upon use of the Sonoma Rises app, which was carefully explained to participants prior to study start. Participants who did not complete the study due to study closure were paid the full amount for their participation at their last visit (posttreatment assessment).

Efficacy Data Analyses

Data from daily (single-item anxiety and fearfulness) and weekly self-reports (posttraumatic stress symptoms, internalizing and externalizing symptoms, functioning) were analyzed as a series of single-case statistical analyses and then combined into multilevel analyses. Secondary efficacy outcomes assessed at baseline, pre-treatment, post-treatment, and follow-up (depression, anxiety, academic engagement, sleep, well-being, and social support) were analyzed similarly. Efficacy outcomes were combined for the baseline, intervention, and follow-up periods and then graphed. Data were examined both within-subjects and between-subjects in order to evaluate the magnitude (i.e., level) and rate of change (i.e., slope) across phases. These analyses utilized the visual analysis methods detailed by Au et al. (2017) and Barlow, Nock, & Hersen, (2009), and Auerbach and Zeitlin (2014), and were implemented with the R statistical package, SSDforR (<https://cran.r-project.org/web/packages/SSDforR/SSDforR.pdf>), specifically the lmer procedure in the R package, *lme4* (Rosseel, 2012).

Results

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Public Use of Sonoma Rises

The public version of the Sonoma Rises app was downloaded by 845 iOS users and 213 Android users. Among those who downloaded the app, 388 used the app one day only, 204 used the app for two days, and 286 used the app three or more days. In terms of time spent using the app, the average amount of time per day using the app was three minutes and twenty-two seconds with the average visit lasting one minute and thirty-four seconds. A subset of users provided demographic data for age ($n = 94$, age 13-19; $n = 129$, age 20-34; $n = 180$, age 35-49; $n = 241$, age 50+) and race ($n = 494$, Caucasian; $n = 91$, Hispanic/Latino; $n = 107$, all other ethnic/racial groups). Public users of Sonoma Rises ($N = 1,058$) utilized tools from the following content areas (1) Stress-reduction (949 views), (2) Teen-specific (697 views), (3) Self-care (532 views), (4) Grief/loss (342 views), (5) Anger/Irritability (297 views), (6) Fostering connection (246 views), indicating that stress management tools were most desired. Public users also viewed additional resources for local treatment and services (174 views), crisis support (100 views), other mobile mental health apps (84 views), psychoeducation of effects of disaster on health (71 views), and resources for Veterans and service members (35 views).

Participant Wildfire Experience

Participants were seven adolescents (3 Male, 4 Female, mean age = 16 ($SD = .98$); 5 Caucasian, 1 Hispanic, 1 Filipino/Caucasian) in 10th ($n = 1$), 11th ($n = 5$), and 12th ($n = 1$) grades. All participants attended schools that suffered significant damage and were either fully or partially burned down in the 2017 Tubbs fire. At one school, the administrative office buildings, counselor offices, gymnasium, and approximately twenty classrooms burned down. At another school, classes were cancelled for four months and then students were temporarily relocated to a church.

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Six participants lost their homes and one participant reported that their house was still standing but was significantly damaged from fire and smoke and thus was temporarily uninhabitable. Several related adverse fire experiences were endorsed by participants including (1) knowing someone who died in the fires ($n = 1$), (2) witnessing someone suffer fire-related physical injuries ($n = 1$), (3) witnessing other fire survivor's emotional distress ($n = 7$), (4) sheltering other fire survivors ($n = 2$), (5) working or volunteering with evacuees during the fires ($n = 2$), (6) significant loss or damage to property other than their home ($n = 2$), and (7) loss of one or more pets ($n = 2$).

Participants reported that they first learned about the wildfires from a variety of sources including from (1) the smell of smoke ($n = 5$), (2) sight of flames ($n = 2$), (3) local news sources ($n = 2$), (4) a household member ($n = 3$), (5) a neighbor ($n = 2$), or (6) a friend or family member not in the home ($n = 4$). No participants first learned of the fires from law enforcement or the fire department. Most participants were evacuated once, but one participant was evacuated three times over the course of the fires. During evacuation, two of the seven participants were separated from their household members. In terms of fire recovery approximately 18 months after the fires, only one participant had since returned to their repaired home. When asked about other fire impacts on themselves or their families, participants provided additional open-ended responses, listed in Table 1.

Participant Characteristics

See Table 2 for a summary of participants' clinical characteristics at baseline.

Socioeconomic and Academic Characteristics. The majority of participants reported that their parents were married ($n = 5$; divorced $n = 2$). Four of the seven participants reported that

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their combined family income was \$240,000 or higher. Four participants reported that they were currently employed.

Three students started the study during summer break and four students started at the beginning of the academic school year. The average number of unexcused absences in the past academic year was .14 ($SD = .38$). Participants reported their past year grade point average as follows: A (57%), B+ (14%), and B (29%). All participants reported they would like to finish a four-year college and four participants indicated that they also wanted to obtain a graduate or professional degree.

Psychiatric History and Concomitant Treatment. One participant reported an anxiety diagnosis, another reported an ADHD diagnosis, and another a depression diagnosis. Four participants reported history of having received mental health treatment. One participant reported that they were currently taking a psychiatric medication and another participant reported they were currently attending psychotherapy. At screening, one participant screened positive for possible problematic substance use. Participants drank alcohol an average of 1.43 ($SD = 1.81$) days in the past year and one participant reported cannabis use in the past year. Five participants screened positive on the Child Trauma Screening Questionnaire, with an average score of 6.14 ($SD = 2.85$; possible score 0-10). Finally, during the baseline assessment, one participant endorsed passive suicide ideation.

At baseline, two participants met the cutoff for probable PTSD, all participants exceeded the mean observed in clinical populations for functional impairment, one participant reported clinically significant depression, two participants reported clinically significant anxiety on the GAD-7, one participant reported clinically significant low mental well-being, and two participants endorsed clinically significant risk for insomnia. Participants endorsed a lower level

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of perceived social support from peers in general ($M = 12.86$, possible range 5-25) but reported higher levels of academic engagement and achievement ($M = 108.71$, possible range: 35-140).

Feasibility

Engagement. All participants completed the intervention portion of the study except for one, who elected to terminate their participation because of technical difficulties downloading the research version of the app. One participant had technical difficulties downloading the research version of the app and was not able to engage with it until the last two weeks of the intervention period. The participant was instructed to modify their dosing schedule of app usage to 15-30 minutes a day for 14 days. During the fall of 2019 there were two multiple-day power outages scheduled to prevent wildfires and thus phone charging ability and phone use was limited during these outages. All participants were evacuated from their homes during the 2019 Kincade Fire. One participant lost their phone during evacuation and could not replace it for several days.

App Engagement. The six participants who completed the intervention phase of the study used the app an average of 17.00 days ($SD = 8.92$; observed range: 3-26 days). Participants visited the app an average of 43.50 times ($SD = 30.56$; observed range: 6-87 visits) with an average session lasting 56.85 seconds ($SD = 27.87$). Participants spent a total average of 35.77 minutes ($SD = 30.03$; observed range: 7.15 – 93.53 minutes) in the app. They completed an average of 11.67 tools ($SD = 8.69$; observed range: 3-27) and visited these same tools an average of 18.16 times ($SD = 16.70$; observed range: 4-49). The stress management and self-care treatment components were the ten most frequently accessed tools. Participants completed an average of 15.83 ($SD = 9.95$) mood ratings using the Photo Affect Meter. Four participants

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accessed the resources within the app that provided psychoeducation on PTSD and what to expect after disaster, local services, and crisis resources.

Treatment Satisfaction. Four participants completed the post-intervention assessment. Participants rated their satisfaction with the mobile app as extremely high ($M = 8.50$, $SD = .58$; possible range: 0 = totally dissatisfied - 10 = totally satisfied). In terms of a net-promoter score, all four participants were likely to recommend this intervention to a friend (Agree, $n = 2$; Strongly Agree, $n = 2$). Using an agreement scale of 1 (strongly agree) to 5 (strongly disagree), participants felt that the intervention was helpful for them ($M = 2.00$, $SD = .82$), had the content, functions, and capabilities they needed ($M = 3.00$, $SD = 1.12$), and were satisfied with how easy it was to use the app ($M = 2.00$, $SD = .00$).

Qualitative Feedback. When asked what could be better or improved about the program, one participant indicated they would like “*more notifications*” to return to the app. Another expressed that the app would be most helpful had it been available immediately after the fires, “*I think that the treatment as a whole, especially for me, was less effective than had it been right after the fire. My responses and feelings now are very different than how I felt even a few months after the fire.*” When asked about what they liked and enjoyed about the program, participants reported liking the following features: “*the complexity of the different sessions,*” “*the audio guided tools,*” “*I enjoyed using the mood rating on the app. I also enjoyed becoming more aware of myself and my feelings while answering the questions.*” Another participant responded that it changed their overall outlook, “*I liked this program because it let me look over my life in a way I don't usually. I always expressed my feelings and checked my life over.*”

When asked about what ways the program was helpful, participants responded positively, saying, “*I could reevaluate my life,*” and “*It helped me become more aware.*” They found it

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“relaxing” and helpful “with handling stress and learning to deal with loss.” When asked about cessation of use, none of the participants indicated that they intentionally wanted to stop using the intervention during the six-week period, and one participant reported that they were definitely planning to use it after the study. During the Kincade wildfire evacuation that occurred during the study, one participant emailed, unsolicited, to share that “*I’ve gained some more stress and anxiety from the Kincade fire that occurred last week. I would like to keep using the app and following through with the meditation and coping activities. Since my anxiety has intensified the app is something I really want to spend time with.*” Finally, in response to asking if there was anything participants would want the study team to know about the app user experience, one participant offered that “*It was a pleasant experience.*”

Qualitative Interview. See Table 1 for transcript of an extensive qualitative interview with one participant which was transcribed and reviewed for emergent themes.

Efficacy

Unfortunately, the longitudinal aspect of the study was impacted by limited statistical power due to limited sample size (i.e., recruitment ended before reaching target) and historical confounds (i.e., the Kincade Fire evacuations, multiple “red flag” high-wind fire risk warnings, and power outages), such that participants missed opportunities for data submission due to disruptions in schedules and access to a computer. In addition, elevations in distress were noted in conjunction with these fire-related events. Accordingly, no significant effects on clinical or functional outcomes were detected. However, some noteworthy trends were observed. No deterioration in outcomes was observed (i.e., did not escalate to clinical crisis level), suggesting that the potential for negative side effects associated with using Sonoma Rises is minimal.

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First, visual inspection of individual data indicated downward stabilizing trends in daily levels of anxiety and fearfulness across the study phases following the intervention (Estimated marginal means: Baseline, $M = 1.22$ ($SE = .46$); Pre-Intervention, $M = 1.01$ ($SE = .37$); Intervention, $M = .89$ ($.30$); Post-Intervention, $M = .74$ ($SE = .27$)). The intraclass coefficient correlation for daily fear and anxiety was $.47$, indicating significant individual heterogeneity and that forty-seven percent of variance in daily anxiety and fearfulness responses was attributable to between-subjects characteristics (53% to longitudinal within-subject effects). See Figure 2 for illustration of daily fear and anxiety over time. Second, examination of individual posttraumatic stress symptom severity over the course of the study indicated downward trends upon beginning the intervention that were disrupted by historic events during the study protocol. See Figure 3 for two case examples.

Discussion

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The current study offers preliminary evidence to suggest that Sonoma Rises can offer a safe and potentially effective means for addressing mental health among teens following disaster. To replicate and expand these findings, further research is warranted with this geographically customizable app with populations from other disaster areas as well as Spanish-speaking communities. Sonoma Rises was found to be feasible in terms of engagement and satisfaction among a sample of teens who demonstrated high levels of disaster-related post-traumatic stress symptoms. Teens were willing to recommend Sonoma Rises to their friends and used the app when feeling triggered by new fire-related threats and during evacuations. The self-assessment and data visualization features of the app strongly appealed to all the participants.

Clinical outcome data on this app-based intervention were inconclusive due to uncontrollable historical cofounds. Several areawide multiple-day power outages throughout 6-8 weeks of the study, and active wildfires at the time of evaluation and follow-up, significantly impacted response rates. Collection of results for all evaluations were disrupted and lower than desired. Indeed, the Kincade Fire spurred the largest mandated evacuation in Sonoma county history (180,000 residents), closed schools for weeks, and caused enduring economic hardship for families and businesses. These events represent a profound limitation of this study.

Public uptake was somewhat lower than hoped though engagement and repeat visits among users was encouraging and robust for a public mental health app. The app became available one year after the wildfires occurred and one possibility is that it may have felt less relevant. It was also notable that the majority of the public app users were older adults indicating that they are open to using mobile apps for disaster despite generational differences. Unfortunately, no budgetary resources were available to collect analytics on the Spanish version of Sonoma Rises. Use of public mental health apps in the Spanish-speaking community is an important area for

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future research as they can help alleviate health disparities (Schueller et al., 2019). Moreover, in order to achieve Techquity in digital mental health, collection of demographic information can help allow for creation of equity engagement dashboards (Rhee et al., 2021).

Lessons Learned.

First, although users were generally enthusiastic about Sonoma Rises and found it helpful, wide dissemination of the app was a tremendous challenge. A multi-pronged “full-court sprint” dissemination and implementation strategy is mission critical for sharing about mobile health apps (e.g., social media, app-ambassadors, radio and print campaigns, school and employee outreach, organization-wide pipe-texting). A “thunderclap approach” amplifies key messages and generates enthusiasm for the narrative. Second, as evidenced in the Sonoma Rises public demographic data, older adults can and will use mobile apps. Accordingly, they should also be targeted in dissemination efforts though educational accommodations on how to use mental health apps are indicated (Gould et al., 2020). Third, mobile apps are especially helpful in the acute stages of disaster as evacuees and the long-term displaced rely heavily upon their phones. They have the benefit of scalability and ability to reach an entire community, thus democratizing access to resources and coping tools. Mobile health apps do, however, need to make use of reminders to optimize engagement so that users return frequently and derive sustained benefit. Higher levels of user engagement observed in the public app as well as in the current study are attributed to frequent push reminders with “catchy” and encouraging messages to return to the app. Fourth, mobile apps require maintenance and quality assurance testing after their launch. New operating system updates can break the app or cause bugs and regular support is needed through the duration of an app’s life. In addition, contingency plans for how to continue offering an app should be considered should the contracted app developer cease to operate. Finally, it is

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important that researchers have flexible contingency plans to accommodate the possibility of unforeseen, new disasters occurring while recovering from previous disasters.

Future Directions and Recommendations. First, the acute stages of disaster are brief whereas research shows that the mental health recovery process can take years. Accordingly, governments and organizations should identify strategies to sustain the implementation of public mental health programs in the years following disaster. Examples of such challenges from the current study include finding funding to continue hosting, maintenance, and refinement of the mobile app. Mobile apps are expensive to maintain and update. Funding for Sonoma Rises ended in June 2020 and the app “sun-setted” (i.e., no longer available for download on the App or Google Play Stores). Although funding sources end, public mobile mental health app concepts and content can be adapted for new disasters and new communities.

Second, in the wake of a disaster, there are conflicting priorities of providing support to children and families over advancing the knowledge base on disaster mental health by conducting research (Grolnick et al., 2018). Government agencies and local nonprofits prioritize cleaning, preparing, and reopening schools, rehousing and assisting families who suffered property losses, addressing environmental and other safety concerns, and navigation of insurance and other state and federal safety nets. Only recently has addressing long-term mental health among disaster survivors and traumatized communities emerged as a priority. Conducting research on best practices for bolstering mental health and resilience among children who endure disaster, although incredibly important, is daunting as it requires coordination and collaboration across multiple stakeholders and agencies. In addition, the time required to propose a study, obtain funding to conduct the study, and then receive ethical approvals means that programmatic mental health resource development and associated research activities commence well after the

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acute disaster period. More flexible funding mechanisms and ready access to research infrastructure support need to be instituted to overcome these challenges.

Finally, consideration should be given to how to address mental health needs following disaster in communities simultaneously impacted by intersecting forms of adversity (e.g., COVID-19) and chronically repeated disasters. The rates of psychiatric disorders among adolescents are expected to rise exponentially as a result of the COVID-19 pandemic (Guessoum et al., 2020) and student mental health and academic performance has suffered greatly in Sonoma County (Press Democrat, 2020). Sonoma County has now experienced historic wildfires in 2017, 2019, and 2020. In the 2020 evacuation, many families were managing previous wildfire-related trauma, distance learning, unemployment/financial stress, threat of contracting COVID-19 at an evacuation center or by sheltering with friends and family, and imminent threat of property loss. The associated overwhelm of such predicaments poses risk for a collective mental health crisis in the absence of necessary emotional support and resources. New digital health solutions have started to emerge to address the shadow mental health pandemic. For instance, Covid Coach was developed by the VA National Center for PTSD (including four psychologists who also developed Sonoma Rises). This free, secure, and evidence-informed mobile mental health app has demonstrated success in engaging the public with tools and resources for coping with stress during the Covid-19 pandemic (Jaworski, Taylor, Ramsey, Heinz, Steinmetz, Pagano, & Jason, 2021).

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In summary, mobile apps represent one way to address the surge capacity depletion that survivors experience under accumulated climate trauma burden (Rosenthal, Stover, & Haar, 2021). Findings from this study suggest that adolescent disaster survivors are willing and able to use digital health tools and find them beneficial.

Table 1

Quotes Gathered from Participants – Digital Health Study

Context	Sub-prompt	Participant Open-ended Responses
Open-ended responses from participants	Asked about other fire impacts on participants or their families	<p><i>“Caused a lot of tension and stress within the family. We lived in a 2-bedroom 2-bath apartment for 5 months with 3 people and 3 animals. We were very lucky to have survived, but we still weren't left with much.”</i></p> <p><i>“added tensions, stress, emotional distress”</i></p> <p><i>“[We] just lost everything.”</i></p> <p><i>“It caused me to lose sight of the importance of school for about a year after the fires. My grades dropped from a 4.0 to about a 3.6.”</i></p>
Qualitative interview with one participant	<p>Features found helpful</p> <p>App relevance to experiences of someone who lives through the fires</p> <p>How the app addressed the experience of teens</p> <p>Would teens want to use this?</p> <p>Barriers to using the app</p> <p>Changes to the app you'd like to see</p> <p>Usefulness of app for other types of disasters</p>	<p><i>“The daily mood rating where I could click the picture and answer a few questions. It would tell me how happy or sad I was. Maybe I was and I thought it was interesting to see. To make me more aware what my mood was and make me pay attention to it more.”</i></p> <p><i>“Yes, it did. I think the hardest part for me was that getting this app almost two years later was too late for me. I think the week after, this would have been a lot more relevant but the experience and the emotions described on here were pretty accurate.”</i></p> <p><i>“I think it does address the experience of teens pretty well. I think it's what we went through.”</i></p> <p><i>“I know for guys, it's harder for us to go get help so I think an app would help. I mean we don't want to talk to our moms. We don't want to talk to a counselor. I think an app is pretty useful.”</i></p> <p><i>“Some days I would just forget about it before it became a routine and sent a reminder. That was really helpful so I think what would get in the way was honestly to forget about it.”</i></p> <p><i>None - “I think it was pretty good. Pretty easy to use and it covered everything I thought.”</i></p> <p><i>“Yes, I definitely do and I think even a lot of the app could apply to people who didn't go through disasters who are just having a hard time and so I think this could be used for any type of disaster and even people that are just struggling in life.”</i></p>

Added comments/thoughts	<i>“Honestly, a week or two after the fires, even a few months after the fires, even six months to a year after the fires I was still experiencing all the emotions described on there but now it’s been you know 22, 23 months. So, I think introducing the app to a group of people that had just gone through a hard time would be a lot more useful. And yeah, I think that would help a lot.”</i>
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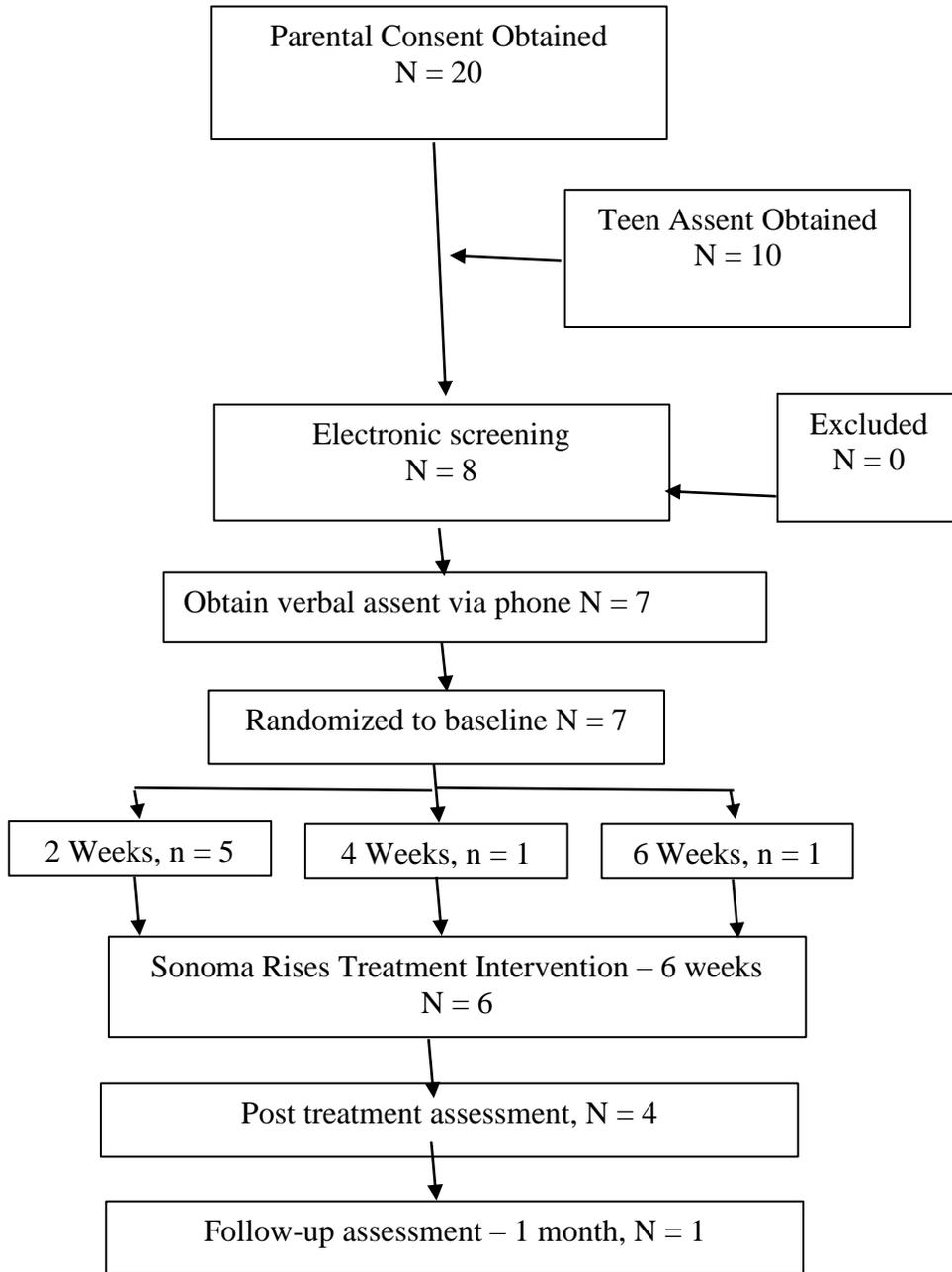
Table 2

Participant Clinical Characteristics at Baseline

	Possible Range of Scores	Internal Consistency	Baseline $n = 7$ $M(SD)$
PTSD symptoms - Child PTSD Symptom Scale DSM-5	0-80	.94	25.43 (16.81)
PTSD symptoms – Functional Impairment	0-7	-	2.00 (2.08)
Internalizing symptoms –Behavior and Feelings Survey	0-24	.70	6.43 (4.28)
Externalizing symptoms –Behavior and Feelings Survey	0-24	.78	1.86 (2.04)
Psychosocial functioning – Ohio Youth Survey	0-100	.83	62.00 (8.98)
Anxiety - Generalized Anxiety Disorder 7-item	0-21	.94	7.14 (6.84)
Depression - Patient Health Questionnaire 9-item	0-27	.94	6.86 (6.72)
Sleep - Insomnia Severity Index	0-28	.87	7.00 (4.65)
Academic achievement - Student Engagement Instrument	35-140	.89	108.71 (9.88)
Teacher-student relationships	9-36	-	27.43 (3.10)
Peer support at school	6-24	-	18.42 (1.90)
Family support for learning	4-16	-	14.57 (1.81)
Control and relevance of school work	9-36	-	26.86 (5.40)
Future aspirations and goals	5-20	-	17.71 (2.09)
Intrinsic motivation	2-8	-	3.71 (1.38)
Well-being - Warwick-Edinburgh Mental Well-being Scale	14-70	.90	47.54 (9.09)
Peer social support - Wills' Social Support Scale	5-25	.95	12.86 (4.06)

Figure 1

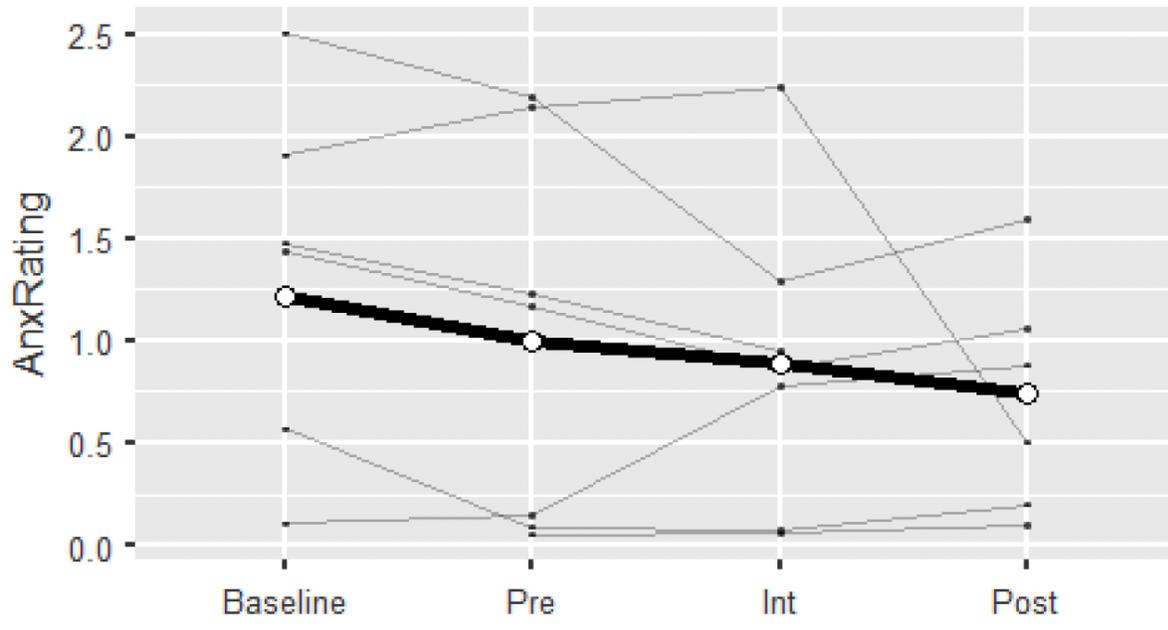
Sonoma Rises Study Procedures



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Figure 2

Daily Fear and Anxiety Over Time

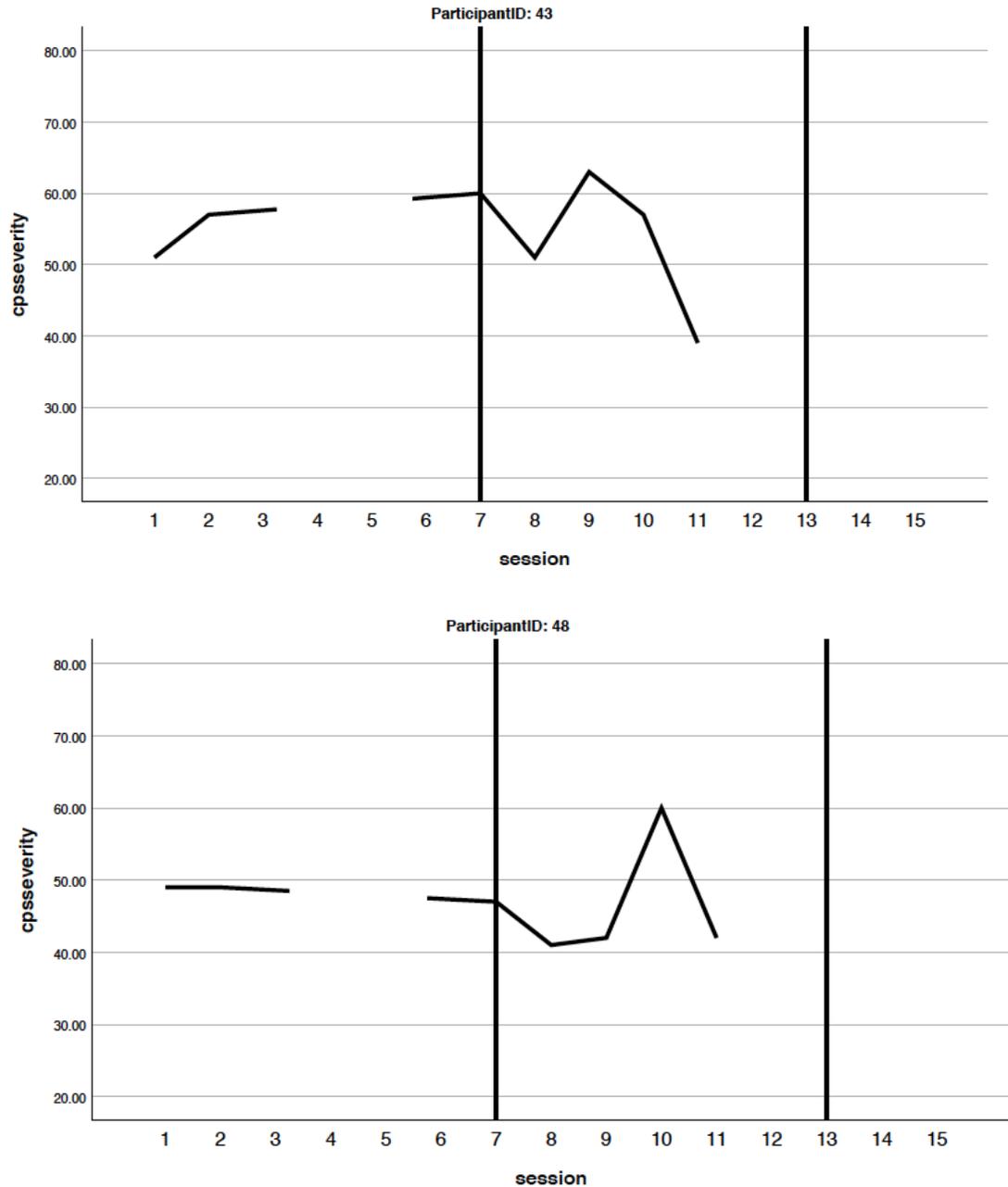


*Thick dark line denotes the average for the sample and the light gray lines are plots for individual participants.

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Figure 3

Two Case Examples of How Increases in Posttraumatic Stress Symptom Severity Corresponded with Historic Events



Note. The vertical lines indicate the beginning of the intervention period and the subsequent peaks correspond with the red flag warnings/power outages that occurred on the two-year anniversary of the Tubbs fire, and then Kincade Fire evacuation, respectively.

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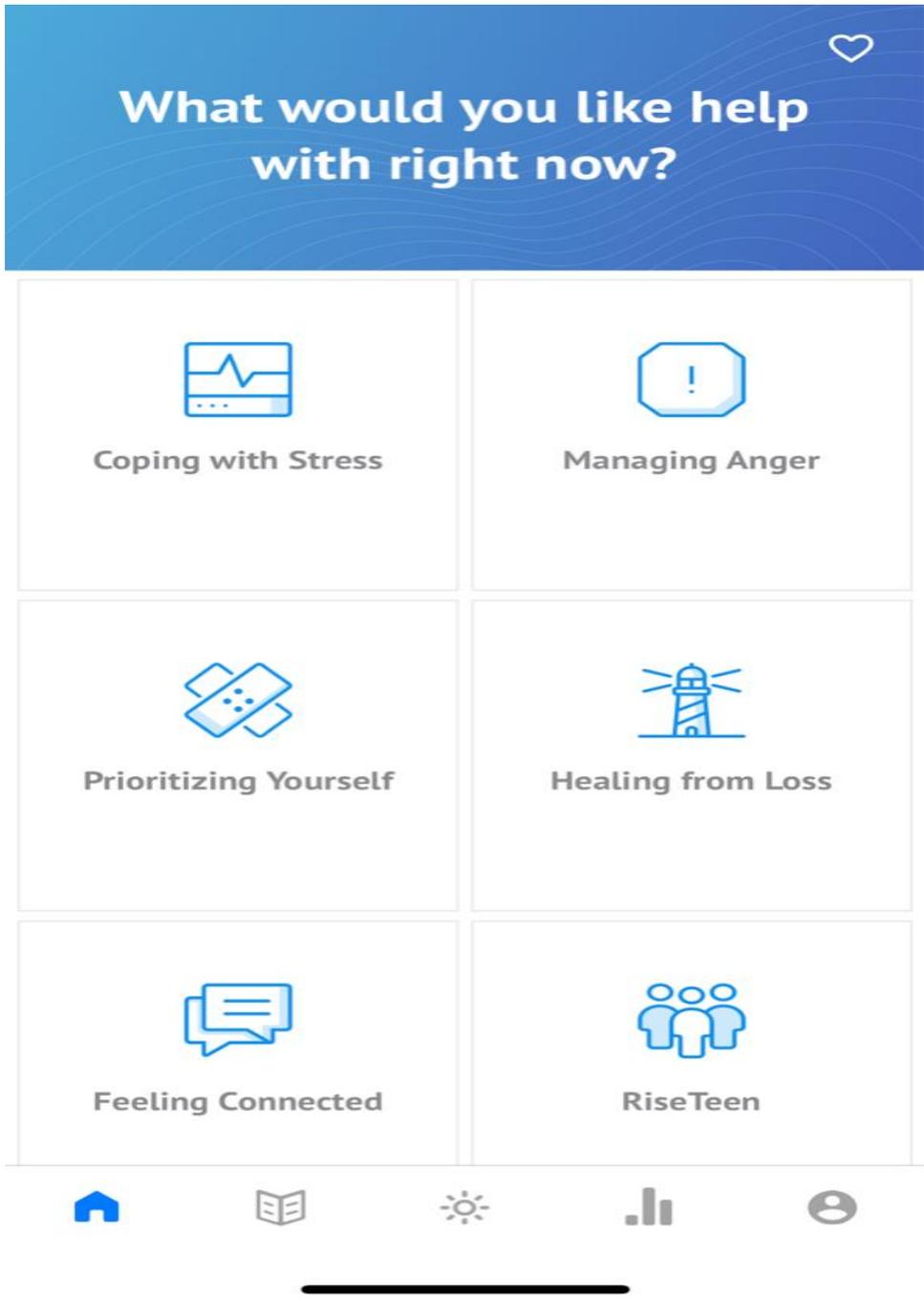
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Appendix A

Screen Shot of Sonoma Rises Home Screen



Appendix B

Sonoma Rises Study Measure Descriptions

Screening, Demographic, and Fire Experience and Impact Questionnaires

During the screening process, participants were asked about their experience of the 2017 wildfires and related impacts, and also completed a brief measure inquiring about their substance use in the past year (i.e., CRAFFT; Knight et al., 2002). Participants completed the Child Trauma Screening Questionnaire (Kenardy et al., 2006) as well, which can range from 0-10 with endorsement of 5 or more symptoms suggesting an increased risk for a diagnosis of PTSD. At baseline, demographic information was collected along with psychiatric history and concomitant treatment utilization.

Primary Outcomes

Feasibility. Feasibility was measured by: (1) retention (i.e., number of treatment completers; Bowen et al., 2009), (2) adherence and engagement rates ((a) number of days used the app, (b) the number of sessions in the app, (c) average duration of session, (d) total time in app, and (e) number of treatment components completed, and (f) number of mood self-assessments completed), (3) acceptability (i.e., participant satisfaction with treatment, Hoozeboom et al., 2012; Morton et al., 2017; Richards et al., 2016), and (4) qualitative feedback (see Table 1 for qualitative interview questions). The participant satisfaction questionnaire (i.e., acceptability) included the following items: (1) “How would you rate your overall satisfaction with the program - ranging from 0 (totally dissatisfied) to 10 (totally satisfied),” (2) net promoter score “I would recommend this program to a friend.” (1 = strongly agree; 5 = strongly disagree), (3) “I believe this program was helpful for me.”, (4) “This program has all the content, functions, and capabilities I needed”, and (5) “Overall, I am satisfied with how easy it is to use this program.”

Efficacy – Primary Outcomes

Daily anxiety and fearfulness. Daily levels of anxiety and fearfulness were captured in response to the following single-item question, based on Loerinc’s (2018) daily measure of anxiety: ‘*On average over the past 24 hours, how anxious or fearful have you felt?*’ Response options were modified to include 5 response categories including 1 = “not at all”; 2 = “a little”; 3 = “moderately”; 4 = “quite a bit”; 5 = “extremely.”

Posttraumatic Stress. The Child PTSD Symptom Scale for DSM-5 (CPSS-5; Foa et al, 2018) is a self-report measure that assesses PTSD diagnosis and past-month symptom severity in youth age 8-18 who have experienced a traumatic event. It includes 20 symptom items (0 = “not at all,” 4 = “6 or more times a week/almost always”) and 7 functional impairment items which are scored as 0 = “absent” or 1 = “present”. The CPSS-5 yields a total symptom severity scale score (ranging from 0 to 80) and a total severity-of-impairment score (ranging from 0 to 7) with higher scores indicated greater symptom severity and functional impairment, respectively. Scores can also be calculated for each of the 4 DSM-IV PTSD symptom clusters (i.e., B - intrusions, C - avoidance, D – changes in cognition and mood, E – increased arousal and reactivity). A total score of 31+ has been identified by ROC analysis as a cut-off point for probable PTSD. Previous

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research with trauma-exposed youth demonstrates that the CPSS-5 possesses excellent internal consistency and good test-retest reliability, convergent validity, and discriminant validity (Foa et al., 2018).

Internalizing and externalizing symptoms. The Behavior and Feelings Survey is a brief measure of internalizing and externalizing problems intended for frequent monitoring with treatment-seeking children and adolescents (BFS; Weisz et al., 2019). The BFS is comprised of 12 items asking about the past week using a scale of 0 = “not a problem,” to 4 = “a very big problem.” There are 6 items that assess internalizing problems (e.g., “I worry about bad things happening,” “I feel sad,” “I think sad or scary thoughts over and over again,” “I feel bad about myself, or don’t like myself”) and 6 items that assess externalizing problems (e.g., “I argue with people,” “I do things I am not supposed to,” “I am rude or disrespectful to people”). Scores for each subscale can range from 0 to 24 with higher scores indicating greater problem severity.

Psychosocial functioning. The Ohio Scales (Ogles et al., 2001), were developed to measure outcomes for youth (age 12-18) who receive mental health services. The short-form scales include a 20-item Problem Severity scale and a 20-item Functioning scale. The Ohio Scale for Youth– Functioning subscale was employed in the current study to assess psychosocial functioning. Functioning sub-scale items are scored on a 5-point scale (0 = “extreme troubles” - 4 = “doing very well”) that measures the youth’s level of functioning in a variety of daily activities (e.g., interpersonal relationships, recreation, motivation) for the last 30 days. The total score is calculated by summing each item and can range from 0-80 with higher scores indicating higher psychosocial functioning. Average scores observed in clinical and community populations are 36.31 and 18.18, respectively. The Ohio Scales have shown evidence of reliability and validity as a clinical outcome measure with adolescents (Turchik et al., 2007).

Efficacy - Secondary Outcomes

Anxiety. The GAD-7 (Spitzer et al., 2006) was employed to assess the severity of self-reported Generalized Anxiety Disorder (GAD) symptoms. The GAD-7 consists of seven items that assess the frequency of symptoms associated with GAD and are rated on a 4-point Likert scale ranging from 0 (not at all) to 3 (nearly every day). Total scores range from 0 to 21 and a score of 10 or higher suggests presence of a diagnosable anxiety disorder (Spitzer et al., 2006).

Depression. Depressive symptom severity was assessed by the 9-item PHQ-9 modified for adolescents (PHQ-9; Kroenke, Spitzer, & Williams, 2001). Items are rated on a 4-point Likert scale ranging from 0 (not at all) to 3 (nearly every day). Item 9 screens for self-harm and suicidal ideation. Total scores range from 0 to 27 with higher scores indicating more depression severity and scores of 10 and higher indicating clinically significant symptoms of depression.

Mental well-being. The Warwick-Edinburg Mental Well-being Scale (WEMWBS; Tennant et al., 2007) is a self-report measure of mental well-being. It comprises 14 items, each rated on a 5-point Likert scale from 1 (none of the time) to 5 (all of the time). Total scores range from 14 to 70, with higher scores indicating greater mental well-being. Scores below 40 indicate clinically significant low mental well-being. The WEMWBS has also been previously employed with adolescent samples and demonstrates strong psychometric properties (Clark et al., 2011).

Academic achievement and engagement. Self-reported Grade Point Average (GPA), attendance (i.e., the number of unexcused absences), and attitudes about school (Student Engagement Instrument (SEI); Appleton et al., 2006) were assessed to capture academic

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achievement and engagement. The SEI is a 35-item scale that assesses a student's level of engagement at school and with learning, including multiple dimensions of engagement that go beyond academics. The two scales (and six subscales) include: (1) Affective (Psychological) Engagement: (a) Teacher-Student Relationships (TSR), (b) Peer Support at School (PSS), (c) Family Support for Learning (FSL); and (2) Cognitive Engagement: (a) Control and Relevance of School Work (CRSW), (b) Future Aspirations and Goals (FG), (c) Intrinsic Motivation (IM). The measure has been validated for use in grades 3 to 12 and students respond to a 4-point response scale ranging from “strongly disagree” to “strongly agree.” Negatively worded items are reverse scored. The total score can range from 35 to 140, with higher scores reflecting greater educational engagement.

Sleep Problems. The Insomnia Severity Index (ISI) was developed by Morin and colleagues (2001) and is comprised of 7-items scale assessing the perceived severity of insomnia symptoms (initial, middle, terminal), the degree of satisfaction with sleep, interference with daytime functioning, noticeability of impairment, and concern caused by the sleep problems within the last 2 weeks. The scale is Likert-type with 5 anchor points ranging from 0 = “none” to 4 = “very severe” for insomnia problems and 0 = “very satisfied, not noticeable at all, not worried at all, not at all interfering” to 4 = “very dissatisfied, very much noticeable, very much worried, very much interfering” for sleep satisfaction, noticeable impairment, concern, and daily interference items, respectively. The ISI has been validated for use with adolescents and ROC analyses suggest that a score of 9 or higher is indicative of probable clinical insomnia among adolescents (Chung et al., 2011). Scores range from 0 to 28, with higher scores indicating more sleep problems.

Perceived Peer Social Support. The Wills’ Social Support Scale (WSSS; Wills et al., 2004) is a 4-item scale that assesses level of connection felt with peers, with responses on a Likert-type scale from 1 (never) to 5 (always). Items include how often youth discuss feelings with a friend, get emotional support from a friend, get sympathy and understanding from a friend, and talk with a friend about how they feel. Scores range from 4 to 20, with higher scores indicating greater perceived peer support and belonging.