HHS Public Access

Author manuscript

Ann Allergy Asthma Immunol. Author manuscript; available in PMC 2016 April 01.

Published in final edited form as:

Ann Allergy Asthma Immunol. 2015 April ; 114(4): 341–342.e2. doi:10.1016/j.anai.2014.12.017.

Design of a Smartphone Application to Monitor Stress, Asthma Symptoms, and Asthma Inhaler Use

Eldin Dzubur, MS[1], **Marilyn Li, MD**[1], **Keito Kawabata, MPA**[1], **Yifei Sun, BS**[2], **Rob McConnell, MD**[1], **Stephen Intille, PhD**[2], and **Genevieve Fridlund Dunton, PhD**[1]

[1]Department of Preventive Medicine, University of Southern California, Los Angeles, CA, USA

[2]Colleges of Computer and Information Science and Health Sciences, Northeastern University, Boston, MA, USA

Advances in the treatment and prevention of asthma have curtailed deaths, hospitalizations, and increases in prevalence rates over the past thirty years.[1] Nevertheless, the effectiveness of long-term asthma management is mediated by behavioral factors such as adherence to medication and psychosocial stress. In a study using ecological momentary assessment to monitor asthma inhaler use, half of all non-adherence cases occurred while participants were with their peers.[2] However, the study relied on subjective reports of adherence. Associations between stress and asthma symptoms have been observed, but these have relied on retrospective self-report, potentially introducing recall bias. Laboratory studies have demonstrated causal relationships between stress and biological markers of immune responses related to asthma.[3, 4] However, these settings may not represent real-world situations. Furthermore, both laboratory and longitudinal studies to date have not captured the effect of daily variations in adherence, stress, and symptoms.

Advancements in technology have led to commercial availability of low-cost personal computing devices (smartphones) capable of executing advanced health-related applications ("apps") and communicating with external sensors via short-wave radio signals (Bluetooth).[5] Ecological momentary assessment (EMA) using smartphones is a method of capturing real-time data that maintains ecological validity, reduces recall bias, preserves within-day changes, and captures objective data from external devices to reduce social desirability bias.[6] This letter describes the design of a smartphone application that integrates

Corresponding Author: Eldin Dzubur, MS, Department of Preventive Medicine, University of Southern California, Soto Street Building (SSB), 2001 Soto N. Street, 3rd floor, Los Angeles, CA 90032, Phone: (323) 442-7302, Fax: (323) 442-8201, dzubur@usc.edu.

Author Contributions:

ED, ML, KK, YS, RM, SI, and GFD contributed to the conception and design of the study.

ED, KK, YS, SI, and GFD contributed to data generation.

ED, ML, KK, RM, SI, and GFD contributed to the analysis and interpretation of the data.

ED, ML, KK, YS, RM, SI, and GFD contributed to preparation or critical revision of the manuscript.

EMA and Bluetooth-enabled sensors for asthma inhalers. This technology can measure real-time asthma symptomology, social and physical context, behavior, stress, and inhaler use.

Development of the application was a collaborative effort from a multidisciplinary team of researchers and computer scientists. The application was installed on Samsung Galaxy Y (Model S5460) smartphones running the latest available version of Google's Android operating system and loaned to participants. Study personnel conducted iterative development (alpha) testing before initiating pilot (beta) testing using a small (N=20) English-speaking convenience sample of Hispanic middle and high school students (ages 12–17) enrolled in a mobile asthma management clinic for low-income families.[7] Written parental consent and child assent were obtained at enrollment; the study was approved by the Institutional Review Board at the University of Southern California. Physicians assisted at enrollment to inform participants that the application was not a replacement for treatment. The application uses signal-contingent (i.e, randomly-timed) and event-contingent (i.e., context-sensitive) EMA sampling triggered by asthma inhaler use. Inhaler use is detected when the phone receives a signal from a Bluetooth sensor on the participant's quick-relief and controller medications.

The signal-contingent EMA component of the software prompts the user with an electronic survey at a random time within each of seven designated time windows: 7–9 AM, 9–11 AM, 11 AM–1 PM, 1 – 3 PM, 3 – 5 PM, 5–7 PM, and 7–9 PM. No surveys are deployed prior to 3 PM on weekdays (during school time). After receiving a prompt (eFigure 1), the participants are presented with a set of questions querying current levels of positive and negative affect, stress, energy, and fatigue, as well as the type of activity currently being performed, and information about social and physical contexts (eTable 1). Additionally, participants are asked to recall stressful events, asthma symptoms, and asthma coping-related behaviors occurring since the last survey (or in the past four hours if the last survey was completed more than four hours prior) (eTable 1).[8,9,10]

The event-contingent (i.e., context-sensitive) EMA component of the application runs a background service that monitors all incoming Bluetooth connections. Participants are provided with two small, button-like devices that attach to the tops of quick relief (i.e., rescue) and controller metered dose inhalers (Propeller sensor, provided at no cost by Propeller Health; Madison, WI) designed to transmit a Bluetooth signal to the phone when the inhaler is actuated. Approximately 5 minutes after the background service captures a Bluetooth sensor signal, the app initiates a real-time self-report survey. The first question in this survey asks whether the participant used a rescue inhaler, control inhaler, or neither (i.e., inhaler actuated unintentionally). If a participant reports any inhaler usage, the survey subsequently queries the severity of asthma symptoms experienced, the type of activity performed, and social and physical contexts encountered just before the inhaler use. Questions also ask about stressful events experienced since the last survey (or in the past four hours if the last survey was completed more than four hours prior) (eTable 1).

To reduce burden on participants, EMA surveys contain logical question branching for question subsets. With the exception of questions related to performed activity type, a randomized selection algorithm was used for signal-contingent question subsets such that

each subset had a 60% chance of appearing on any given survey. Data from all surveys are uploaded to a secure file transfer protocol (SFTP) server at the end of the day. At the completion of testing, the phones are retrieved from participants and the phone features are restored to factory settings.

During pilot testing, participants received a daily average of 3.2 (SD = 0.9, range = 1 – 4.57) signal-contingent and 2.1 (SD= 2.6, range = 0.1 – 7.8) event-contingent prompts across all seven days. EMA prompt adherence rates ranged from 20% to 100% (M = 51.4%, SD = 21.8%). Users reported general satisfaction and ease of use, while some reported difficulty with answering surveys that interrupted them in the middle of the night (Table 1).

Once rigorously tested, the EMA portion of the application (source code) will be made publicly available (at no cost) to researchers. Open-source Android applications allow for localization to languages other than English and installation on participant-owned devices or loaned phones, thereby reducing cost. Furthermore, the application also allows for monitoring using other sensors (e.g. built in motion and location sensors, external personal ozone monitors). Future studies should seek to improve adherence rates, generalize to non-Hispanic sub-populations, and assess health adolescent health literacy. This application has the potential to assist researchers and clinicians to better understand real-time experiences of adolescent patients with asthma, increase adherence to asthma treatment regimens, tailor treatments to their specific needs, and enhance patient-provider communication.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding Sources:

National Institute of Environmental Health Sciences Grant 5 P30 ES07048-16

American Cancer Society Grant 118283-MRSGT-10-012-01-CPPB

National Heart, Lung, and Blood Institute Grant 1 R21 HL108018-01

References

1. Akinbami LJ, Moorman JE, Garbe PL, Sondik EJ. Status of childhood asthma in the United States, 1980–2007. Pediatrics. 2009; 123:S131–S45. [PubMed: 19221156]
2. Mulvaney SA, Ho Y-X, Cala CM, et al. Assessing adolescent asthma symptoms and adherence using mobile phones. Journal of medical Internet research. 2013:15.
3. Theoharides TC, Enakuaa S, Sismanopoulos N, et al. Contribution of stress to asthma worsening through mast cell activation. Annals of Allergy, Asthma & Immunology. 2012; 109:14–9.
4. Chida Y, Hamer M, Steptoe A. A bidirectional relationship between psychosocial factors and atopic disorders: a systematic review and meta-analysis. Psychosomatic Medicine. 2008; 70:102–16. [PubMed: 18158379]
5. Kuntsche E, Labhart F. Using personal cell phones for ecological momentary assessment: An overview of current developments. European Psychologist. 2013; 18:3.
6. Stone, AA.; Shiffman, S.; Atienza, AA.; Nebeling, L. The science of real-time data capture. New York: 2007.

7. Morphew T, Scott L, Li M, Galant SP, Wong W, Lloret MIG, et al. Mobile Health Care Operations and Return on Investment in Predominantly Underserved Children with Asthma: The Breathmobile Program. Population health management. 2013; 16(4):261–9. [PubMed: 23941048]

8. Parfenoff, SHJ.; Paul, E. Measuring Daily Stress in Children. Distributed by ERIC Clearinghouse; Washington, D.C: 1989.

9. Asmussen L, Olson LM, Grant EN, Fagan J, Weiss KB. Reliability and validity of the Children's Health Survey for Asthma. Pediatrics. 1999; 104(6):e71. [PubMed: 10586005]

10. Aalto AM, Harkapaa K, Aro AR, Rissanen P. Ways of coping with asthma in everyday life: validation of the Asthma Specific Coping Scale. Journal of psychosomatic research. 2002; 53(6): 1061–9. [PubMed: 12479987]

Table 1

Sample Demographics and Usage Satisfaction in Pilot Testing (N=20)

	Percent	n
Age (M, SD)	14.55	1.73
Gender		
Male	55%	11
Female	45%	9
Ethnicity		
Hispanic	100%	20
Overall, how satisfied are you with the mobile phone surveys?		
Very Satisfied	50%	10
Satisfied	50%	10
Dissatisfied	0%	0
Very Dissatisfied	0%	0
Overall, how easy/difficult was it to use the mobile phone surveys?		
Very easy	95%	19
Somewhat easy	5%	1
Somewhat difficult	0%	0
Very difficult	0%	0
Overall, how easy/difficult was it to answer the mobile phone surveys after an asthma attack?		
Very easy	30%	6
Somewhat easy	15%	3
Somewhat difficult	5%	1
Very difficult	5%	1
Did not answer any after an asthma attack	45%	9
Overall, the mobile phone surveys interrupted my daily activities:		
Strongly agree	5%	1
Agree	5%	1
Disagree	65%	13
Strongly disagree	25%	5

Ann Allergy Asthma Immunol. Author manuscript; available in PMC 2016 April 01.

	Percent	n
Overall, answering the mobile phone surveys required too much of my time.		
Strongly agree	0%	0
Agree	5%	1
Disagree	50%	10
Strongly disagree	45%	9
Overall, how easy/difficult was it to answer the mobile phone surveys in the middle of the night?		
Very easy	25%	5
Somewhat easy	30%	6
Somewhat difficult	10%	2
Very difficult	0%	0
Did not answer any in the middle of the night	35%	7