Zhang, K. & Dallal, S. (2018, April). *Mobile Health Technology for Customized Learning: A Comprehensive literature review and an Extensive Framework*, paper presented at the annual conference of the American Educational Research Association, New York City, NY, USA.

Mobile Health Technology for Customized Learning: A Comprehensive literature review and an Extensive Framework

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Abstract (95 words)

Emerging mobile technologies are rapidly changing healthcare professional practices, and more importantly, they make highly customized learning possible, and may help achieve healthy life styles. "mHealth" thus has been recognized as one of the fastest growing fields, and demands interdisciplinary approaches to support its research and development. This paper reports a comprehensive review of relevant literature from a pool of 1,212 research articles in multiple disciplines to examine the current status of mHealth research, and proposes an extensive framework to guide mHealth technology design and research, in particular for customized learning and just-in-time health support.

Word count: 1528, excluding references, appendix, tables and figures

Introduction

Emerging mobile technologies are rapidly changing healthcare professional practices, and more importantly, they make highly customized learning possible, and may help achieve healthy life styles. As the World Health Organization Global survey suggests, mHealth may well change the face of health service across the globe (Ginsburg, 2014). At the end of 2016, 77% of the Americans own a smartphone (Pew research, 2017) and about 3.2 billion smartphone users worldwide have downloaded healthcare applications in 2016 (Research2Guidance, 2016). In addition, an estimate of 50 percent of smartphone users worldwide will download a healthcare application by 2018 (FDA, 2015). "mHealth" thus has been recognized as one of the fastest growing fields, and demands interdisciplinary approaches to support its research and development.

mHealth makes access to health resources faster and easier, patients with internet access can pull up health information from their own device. Healthcare providers can access more up-

to-date and accurate information to guide their treatment. Wearable technology, for example, can help users monitor and manage their health data and help promote healthy life styles. Mobile health apps also help people manage their health and wellness, facilitate just-in-time learning, and promote healthy living (FDA, 2015). With the thrive of mHealth technologies, effective design is becoming increasingly important (Schnall et al., 2016) to promote customized learning opportunities for patients, family, friends and health-conscious mobile users.

Objectives

This study critically examines recent refereed mHealth technology research publications from different fields, and focuses on the following research questions:

1. What fields are contributing to refereed mHealth research publications?
2. What theoretical frameworks have guided the design of mHealth technology, if any, as reported in refereed publications?
3. What design methods were applied in mHealth design, as reported in refereed research articles?
4. What new framework may be created to guide mHealth technology design, based on the comprehensive literature review?

Perspectives

mHealth growth is radically reconfiguring health care, as it allows people to self-monitor and regulate their health-related behaviors, sometimes even without any involvement of healthcare professionals (Rich & Miah, 2017). Despite its growing popularity and affordability, there has been limited evidence-based research. Researchers find that more than 95% of mHealth apps have not been tested or studied scientifically (Brown, Yen, Rojas & Schnall, 2013, p.1080), and many trials and research demonstrate the lack of evidences regarding the benefits of their interventions (Free et al. 2013). Researchers have called for integration of research and expertise from many disciplines in order to maximize the potentials of mHealth, and to ultimately achieve higher engagement and better health outcomes (Wilhide III et al., 2016). As a potentially powerful means to customized learning and just-in-time support, mHealth requires a comprehensive, interdisciplinary framework to guide the design and research of mHealth technologies.

Research Methods, Process & Analyses

This study involves multiple phases, starting from multi-step search and screening efforts. The search was carried out in 3 phases (Appendix A). During Phase 1, the researchers conducted multiple comprehensive bibliographic searches on 8 major databases (i.e., Web of Science, IEEE, MEDLINE, PLoS Medicine, PubMed, PsycINFO, Education Resource Information Center (ERIC) and Google Scholar), using key terms (e.g., “mobile Health”, “mHealth”, “mobile app”, “smartphone”, etc.), plus qualifiers like “Framework”, “Design”. The search efforts yielded a total of 1,212 articles, from which 286 duplicates were excluded, and further screening was conducted based on selection criteria.

At Phase 2, the same search strategies were applied 5 highly-regarded journals in Educational Technology (i.e., *British Journal of Educational Technology, Australian Journal of Educational Technology, International Journal of Mobile and Blended Learning, Journal of Educational Technology and Society and IEEE transaction of Learning Technologies*) to identify additional eligible articles for further analyses.

At Phase 3, snowball sampling techniques (e.g., Gao, Luo, & Zhang, 2012; Hung & Zhang, 2012) were applied by examining reference lists from papers identified in previous phases, and additional research articles were then included for further analyses.

Only empirical, evidence-based studies and research on the effectiveness of mHealth design and interventions were selected for further analyses. The following were excluded: theoretical or conceptual articles, reports of personal user experiences, and those without enough data. The researchers each did individual screenings and made decisions on inclusion or exclusion, and then discussed on any disagreements and reached consensus on article inclusions.

Inductive content analysis is conducted and the analyses of over 1,000 eligible research articles are ongoing as of July 2017. The researchers reviewed each of the study for the following characteristic: settings, participants, sample size, study type, country of the study, objectives, intervention and intervention outcomes (See Tables 1&4 for examples). To answer the research questions, for each research article, the following are identified: (a) fields or subject areas, according to the Web of Science classification (see Table2 for a partial list), (b) learning theories or other theoretical frameworks (see Table 3 for a partial list), and (c) the design methods applied in mHealth technology design and interventions.

Preliminary Results & Findings

The research is ongoing. Based on the analyses of approximately 900 articles as of July 2017, the preliminary findings are reported here by research question.

RQ 1: the following **disciplines** are identified as the major contributors to mHealth research literature: Computer Science, Interdisciplinary Applications, Medical Informatics (Schnall et al., 2016), Health Care Sciences & Services (Wilhide III et al., 2016; Zhang, Guo, Lai, Guo, & Li, 2014), Medicine (Lin et al. (2015), Medical Informatics (Mohr et al., 2017; Cafazzo, J. A., Casselman, M., Hamming, N., Katzman, D. K., & Palmert, M. R., 2012).; Engineering, Biomedical (Banos et al., 2015, Jia et al., 2015), Public, Environmental & Occupational Health, General & Internal Medicine (Burke et al., 2012, Evans, W. D., Wallace, J. L., & Snider, J., 2012), Oncology (Ginsburg et al., 2014), and Psychology (Zeng et al. (2016).

However, interdisciplinary collaborations are not evident in most studies (e.g., Kumar, S., Nilsen, W., Pavel, M., & Srivastava, 2013). Scholars from different disciplines work together on mHealth design and research efforts, but their relationship is mutual and cumulative yet not interactive (Holley, 2009).

RQ2: A range of **theories** were reported as have guided or otherwise influenced the design or implementation of mHealth technology, including Behavior Change Theory (Evans, W. D., Wallace, J. L., & Snider, J., 2012; Zeng et al. 2016; Mohr et al., 2017; Cafazzo, J. A., Casselman, M., Hamming, N., Katzman, D. K., & Palmert, M. R., 2012), Social cognitive theory (Burke et al., 2012, Lin et al., 2015, Wilhide III et al., 2016; Zhang, Guo, Lai, Guo, & Li, 2014), theory of reasoned action and planned behavior, and the trans theoretical stages of change model. More specifically, mHealth research articles reported a variety of applications of these theories, such as, providing feedback on human performance (Banos et al., 2015, Jia et al., 2015; Zhang, Guo, Lai, Guo, & Li, 2014), goal setting (Burke et al., 2012), promoting self-monitoring, changing behavior through just-in-time tips or other techniques (Evans, W. D., Wallace, J. L., & Snider, J., 2012; Lin et al. 2015; Schnall et al., 2016), tailoring (Zeng et al., 2016), disease management and awareness (Cafazzo, J. A., Casselman, M., Hamming, N., Katzman, D. K., &

Palmert, M. R., 2012; Ginsburg et al., 2014; Mohr et al. 2017; Wilhide III et al., 2016) (details will be shared in full paper upon acceptance).

RQ3: A few different **design methods** were reported in various fields, such as Waterfall Rapid Prototyping (Wilhide III et al., 2016) in Health Care Sciences & Services (Banos et al., 2015, Jia et al., 2015), in Engineering (Schnall et al., 2016), in Computer Science (Lin et al., 2015), and Behavioral Intervention Technology Model in Medical Informatics (Mohr et al., 2017). And, some studies, such as (Burke et al., 2012, Evans, W. D., Wallace, J. L., & Snider, J., 2012) from Public, Environmental & Occupational Health, General & Internal Medicine, report using psychological models such self-regulation model HBM (Health Belief model), TTM (Transtheoritical Model) and Theory of reasoned action (TRA) model in (Zhang, Guo, Lai, Guo, & Li, 2014) in Health Care Sciences & Services.

As we complete critical content analyses of all 1000+ selected mHealth research articles, we would share findings and results in more details to answer all research questions at the conference.

Significance

Mobile Health Technology is growing exponentially (Brown, Yen, Rojas, & Schnall, 2013). Its availability and popularity make it a powerful means for delivering health information and engaging people in more meaningful, highly customized learning as related to health care. For mHealth technology to be sustainable and effective it requires a rigorous interdisciplinary scientific approach (Nilsen et al., 2012), which brings together professionals from academia, healthcare, data sciences, technology, engineering and social science to collaborate in establishing design principles that are theoretically sound. Kumar et al. (2013) emphasize the need for timely and increased efforts in mHealth research, they also encourage having a new trans-disciplinary scientific discipline that incorporates medicine, engineering, psychology, public health, social science, and computer science. Having a specific set of theoretical bases, models, methods and standards is essential for mHealth; thus this study, upon completion will generate a comprehensive, critical review of related literature from multiple disciplines, and more importantly, we will propose an extensive, interdisciplinary theoretical framework to guide the design of and research on mHealth technology.

Selected References

Banos, O., Villalonga, C., Garcia, R., Saez, A., Damas, M., Holgado-Terriza, J. A., & Rojas, I. (2015). Design, implementation and validation of a novel open framework for agile development of mobile health applications. *Biomedical engineering online*, *14*(2), S6.

Brown, W., Yen, P. Y., Rojas, M., & Schnall, R. (2013). Assessment of the Health IT Usability Evaluation Model (Health-ITUEM) for evaluating mobile health (mHealth) technology. *Journal of biomedical informatics*, *46*(6), 1080-1087.

Burke, L. E., Styn, M. A., Sereika, S. M., Conroy, M. B., Ye, L., Glanz, K., & Ewing, L. J. (2012). Using mHealth technology to enhance self-monitoring for weight loss: a randomized trial. *American journal of preventive medicine, 43*(1), 20-26.

Free C, Phillips G, Galli L, Watson L, Felix L, et al. (2013) The Effectiveness of Mobile-Health Technology-Based Health Behaviour Change or Disease Management Interventions for

Health Care Consumers: A Systematic Review. *PLoS Med 10*(1): e1001362. doi:10.1371/journal.pmed.1001362

FDA (2015). Mobile Medical Applications, Retrieved on April 7, 2017 from: https://www.fda.gov/MedicalDevices/DigitalHealth/MobileMedicalApplications/default.htm

Gao, F., Luo, T., & Zhang, K. (2012). Tweeting for learning: A critical analysis of research on microblogging in education published in 2008–2011. *British Journal of Educational Technology, 43*(5), 783-801.

Ginsburg, O. M., Chowdhury, M., Wu, W., Chowdhury, M. D. Touhidul Imran, & Pal, B. C. (2014). *The oncologist (dayton, ohio): An mHealth model to increase clinic attendance for breast symptoms in rural bangladesh: Can bridging the digital divide help close the cancer divide?* AlphaMed Press. doi:10.1634/theoncologist.2013-0314.

Holley, K. A. (2009). *ASHE higher education report: Table of contents* Jossey-Bass. doi:10.1002/aehe.3502

Hung, J. L., & Zhang, K. (2012). Examining mobile learning trends 2003–2008: A categorical meta-trend analysis using text mining techniques. *Journal of Computing in Higher education, 24*(1), 1-17.

Kumar, S., Nilsen, W. J., Abernethy, A., Atienza, A., Patrick, K., Pavel, M., ... & Hedeker, D. (2013). Mobile health technology evaluation: the mHealth evidence workshop. *American journal of preventive medicine*, *45*(2), 228-236.

Kumar, S., Nilsen, W., Pavel, M., & Srivastava, M. (2013). Mobile health: Revolutionizing healthcare through transdisciplinary research. Computer, 46(1), 28-35. doi: 10.1109/MC.2012.392

Nilsen, W., Kumar, S., Shar, A., Varoquiers, C., Wiley, T., Riley, W. T., ... & Atienza, A. A. (2012). Advancing the science of mHealth. Journal of health communication, 17(sup1), 5-10.

Research 2 Guidance (2016). HEALTH APP DEVELOPER ECONOMICS 2016. Retrieved on April 7, 2017 from: http://research2guidance.com/r2g/r2g-mHealth-App-Developer-Economics-2016.pdf

Rich, E., & Miah, A. (2017). Mobile, wearable and ingestible health technologies: towards a critical research agenda. *Health Sociology Review*, *26*(1), 84-97.

Schnall, R., Rojas, M., Bakken, S., Brown, W., Carballo-Dieguez, A., Carry, M., ... & Travers, J. (2016). A user-centered model for designing consumer mobile health (mHealth) applications (apps). Journal of biomedical informatics, 60, 243-251.

Pew research (2017). Record shares of Americans now own smartphones, have home broadband. Retrieved on April 7, 2017 from: http://www.pewresearch.org/fact-tank/2017/01/12/evolution-of-technology/

Whittaker, R., Merry, S., Dorey, E., & Maddison, R. (2012). A development and evaluation process for mHealth interventions: examples from New Zealand. *Journal of health communication*, *17*(sup1), 11-21.

Wilhide Iii, C. C., Peeples, M. M., & Kouyate, R. C. A. (2016). JMIR research protocols: Evidence-based mHealth chronic disease mobile app intervention design: Development of a framework.JMIR. doi:10.2196/resprot.4838

Cafazzo, J. A., Casselman, M., Hamming, N., Katzman, D. K., & Palmert, M. R. (2012). Design of an mHealth app for the self-management of adolescent type 1 diabetes: a pilot study. *Journal of medical Internet research*, *14*(3).

Evans, W. D., Wallace, J. L., & Snider, J. (2012). Pilot evaluation of the text4baby mobile health program. *BMC public health*, *12*(1), 1031.

Ginsburg, O. M., Chowdhury, M., Wu, W., Chowdhury, M. D. Touhidul Imran, & Pal, B. C. (2014). *The oncologist (dayton, ohio): An mHealth model to increase clinic attendance for breast symptoms in rural bangladesh: Can bridging the digital divide help close the cancer divide?* AlphaMed Press. doi:10.1634/theoncologist.2013-0314

Jia, G., Yang, P., Zhou, J., Zhang, H., Lin, C., Chen, J., ... & Ning, G. (2015). A framework design for the mHealth system for self-management promotion. *Bio-Medical Materials and Engineering*, *26*(s1), S1731-S1740.

Lin, P. H., Intille, S., Bennett, G., Bosworth, H. B., Corsino, L., Voils, C., ... & Svetkey, L. P. (2015). Adaptive intervention design in mobile health: Intervention design and development in the Cell Phone Intervention for You trial. *Clinical Trials*, 1740774515597222.

Mohr, D. C., Schueller, S. M., Montague, E., Burns, M. N., & Rashidi, P. (2014). The behavioral intervention technology model: an integrated conceptual and technological framework for eHealth and mHealth interventions. Journal of medical Internet research, 16(6), e146.

Schnall, R., Rojas, M., Bakken, S., Brown, W., Carballo-Dieguez, A., Carry, M., ... & Travers, J. (2016). A user-centered model for designing consumer mobile health (mHealth) applications (apps). Journal of biomedical informatics, 60, 243-251.

Wilhide Iii, C. C., Peeples, M. M., & Kouyate, R. C. A. (2016). JMIR research protocols: Evidence-based mHealth chronic disease mobile app intervention design: Development of a framework.JMIR. doi:10.2196/resprot.4838

Zeng, E. Y., Heffner, J. L., Copeland, W. K., Mull, K. E., & Bricker, J. B. (2016). Get with the program: Adherence to a smartphone app for smoking cessation. Addictive Behaviors, 63, 120-124. doi:10.1016/j.addbeh.2016.07.007

Zhang, K., & Gao, F. (2014). Social media for informal science learning in China: A case study. *Knowledge Management & E-Learning, 6(*3), 262.

Zhang, X., Guo, X., Lai, K. H., Guo, F., & Li, C. (2014). Understanding gender differences in m-health adoption: a modified theory of reasoned action model. Telemedicine and e-Health, 20(1), 39-46.

Table 1: A summary of analyses of mHealth Technology Research Articles (an example)

Author (Study)	*Research Type*	*Participants/ Context/ Type of pub/ Country*	*Aim*	*Interventions*	*Outcomes*
Banos et al. (2015)	Descriptive	n=15; Biomedical Engineering, Journal Article; Spain	To evaluate the effectiveness of mHealthDroid, an open source Android implementation of a mHealth Framework, that is used to investigate on the analysis of human behavior.	Activity recognition model Body motion and vital signs	mHealthDroid is proved to be simple and agile through the reduced time required for development. mHealthDroid API potentials in monitoring and measuring human behaviors are revealed.

Table 2: Disciplines in mHealth Research Publications (a partial list)

Discipline	*n*	*Studies*
Engineering, Biomedical	1	Banos et al. (2015) Jia et al. (2015)
Public, Environmental & Occupational Health; General & Internal Medicine	1	Burke et al. (2012) Evans, W. D., Wallace, J. L., & Snider, J. (2012)
Healthcare Science & Services	1	Wilhide III et al. (2016) Zhang, Guo, Lai, Guo, & Li, (2014)
Computer Science, Interdisciplinary Applications; Medical Informatics	1	Schnall et al. (2016)
Medicine, Research & Experimental	1	Lin et al. (2015)

Table 3: Theories in mHealth Technology Research Articles (an example)

Guiding Theory	*n (studies)*	*Application or Technique*
Social cognitive theory/Social learning theory, theory of reasoned action and planned behavior, and the transtheoretical stages of change model	Wilhide III et al. (2016)	- chronic disease management through tailored messages that provide reminders, longitudinal or real-time feedback on self-monitoring, motivation or engagement.
social cognitive theory	Burke et al. (2012)	-setting goals - Participants received standard behavioral treatment for weight loss that included dietary and physical activity goals, -to promote self-monitoring of behavioural outcome.

Table 4: Sample Sizes in the reviewed studies (an example)

Sample Size	*n*	*Studies*
15 Volunteers (10 offline and 5 online evaluation)	1	Banos et al. (2015)
12 volunteer university students	1	Jia et al. (2015)
210 participants (overweight/obese adults (84.8% female, 78.1% white)	1	Burke et al. (2012)
481-survey respondent consisting of 44.7% women and 55.3% men	1	Zhang, Guo, Lai, Guo, & Li, (2014)
365 participants	1	Lin et al. (2015)

Appendix A: Search Strategy

Databases Search

Web of Science: 743 **articles**
TOPIC: ("m-health" OR "mhealth" OR "mobile health" OR "mobile Health app" OR "Mobile Health Application" OR "Wellness Apps" OR "smartphone Wellness") AND **TOPIC:** ("design" OR "Framework" OR "model" OR "instructional design" OR "educational technology" OR "Instructional Technology") **R**efined by: DOCUMENT TYPES: (ARTICLE) AND LANGUAGES: (ENGLISH) Timespan: 2012-2017. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC.
IEEE Xplore: 115
("Document Title":"m-health" OR "Document Title":"mhealth" OR "Document Title":"mobile health" OR "Document Title":"mobile Health app" OR "Document Title":"Mobile Health Application" OR "Document Title":"Wellness Apps" OR "Document Title":"smartphone Wellness") AND ("Abstract":"design" OR "Abstract":"Framework" OR "Abstract":"model" OR "Abstract":"instructional design" OR "Abstract":"educational technology" OR "Abstract":"Instructional Technology") Limits: Year: 2012-2017 ; Content Type: Conference Publications Journals & Magazines Early Access Articles.
MEDLINE: 56 articles
AB ("m-health" OR "mhealth" OR "mobile health" OR "mobile Health app" OR "Mobile Health Application" OR "Wellness Apps" OR "smartphone Wellness") AND AB ("design" OR "Framework" OR "model" OR "instructional design" OR "educational technology" OR "Instructional Technology")

Limits: Linked Full Text; Date of Publication: April 2012 -2017; English Language; Human; Age related: All adults 19+ years
PSYINFO: 45 articles
AB ("m-health" OR "mhealth" OR "mobile health" OR "mobile Health app" OR "Mobile Health Application" OR "Wellness Apps" OR "smartphone Wellness") AND AB ("design" OR "Framework" OR "model" OR "instructional design" OR "educational technology" OR “Instructional Technology”) Limits: Linked Full Text; Published Date: 2012/ 04, -2017/ 04; English; Population Group: Human; Age related: All adults 18+ years, Exclude Dissertations
PUBMED: 139 articles
(("m-health"[Title/Abstract] OR "mhealth"[Title/Abstract] OR "mobile health"[Title/Abstract] OR "mobile Health app"[Title/Abstract] OR "Mobile Health Application"[Title/Abstract] OR "Wellness Apps"[Title/Abstract] OR "smartphone Wellness"[Title/Abstract])) AND ("design"[Title/Abstract] OR "Framework"[Title/Abstract] OR "model"[Title/Abstract] OR "instructional design"[Title/Abstract] OR "educational technology"[Title/Abstract] OR “Instructional Technology”[Title/Abstract]) Filters: Full text, Publication date from 2012/04/15 to 2017/04/15, Humans, English, Adult: 19+ years.
Google Scholar: 17,000 Articles (most relevant articles: first 10 pages)
("m-health" OR “mhealth” OR "mobile health" OR "mobile Health app" OR "Mobile Health Application" OR "Wellness Apps" OR "smartphone Wellness") AND ("design" OR "Framework" OR "model" OR "instructional design" OR "educational technology") Limits: 2012-2017; patents are excluded
PLOS medicine: 5 articles
(abstract:""m-health" OR mhealth OR "mobile health" OR "mobile Health app" OR "Mobile Health Application"") AND abstract:""Design" OR "model" OR" framework"" Limits: Publication Date: 2012-04-15--- 2017-04-15
ERIC: 9 Articles
("m-health" OR “mhealth” OR "mobile health" OR "mobile Health app" OR "Mobile Health Application" OR "Wellness Apps" OR "smartphone Wellness") AND ("design"

OR "Framework" OR "model" OR "instructional design" OR "educational technology")

Limits: Last 5 years, Type: Journal Articles