Title
Is it your phone or how you use it? The influence of smartphones on stress recovery

Author
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IRVINE

Is it your phone or how you use it? The influence of smartphones on stress recovery

DISSERTATION

Submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Psychological Science

by

John F. Hunter

Dissertation Committee:
Associate Professor Sarah D. Pressman, Chair
Assistant Professor Michelle A. Fortier
Assistant Professor Paul K. Piff

2019

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ACKNOWLEDGEMENTS

I would like to acknowledge all of the wonderful people who have helped me through my graduate school journey and made this dissertation possible. Sarah has been an outstanding mentor that has taught me so much about research, academia, and life. I am so lucky that she brought me under her wing and mentored me through the process of becoming a psychological researcher. She spurred a fascination with health psychology in me and has taught me so many things that will serve me well throughout my career. I would also like to thank Michelle for her guidance and mentorship over the last few years. She has taken so much of her time to help put me on a track to success. Her genuine care for me and expert academic guidance have been invaluable. Paul also deserves my profound thanks for being such an inspiration throughout my time in graduate school. He has served as a role model and mentor that truly inspires greatness. Each of these dissertation committee members have demonstrated patience, understanding, and invaluable insight and expertise that allowed this project to succeed. Thank you for all you have done!

I would not have made it to this point without the support of my unbelievably fantastic lab mates. Marie and Amanda (i.e., Miranda) exemplify the graduate experience for me and have been with me every step of the way. I cannot say enough good things about how supportive, helpful, encouraging, and fun they have been throughout the last five years. They have been amazing professional colleagues and even better personal friends! I will miss their infectious laughs, constant encouragement, and genius minds next to me every day. My other fellow lab mates over the years have also enriched my experience and supported me around every turn. Brooke and Emily have served as mentors that paved a successful path for me and taught me so many things about statistics and the academic world. Desi and Kennedy make me confident that the future of psychological research is in good hands, and I have been blessed to have them as part of my team. I also have so many research assistants to thank for all that they have done to make my projects possible, but I would particularly like to point out the hard work of those who contributed to this project (Ian, Grace, Kyle, Makenna, Anshu, Aadil, Kelly, Miranda, Ashe, Seth, Elsie, Vivian, Stephanie, and Eric) along with study managers Meryl, Chris and Robert. Thank you all for creating such a great environment that has allowed me to thrive!

Importantly, I would also like to thank my family. My beautiful wife April has been the most supportive, flexible and loving person imaginable throughout this process. It takes a lot of patience to support a fledgling graduate student, and April has done it with grace, vision and love. Thank you for being my person! I would also like to give a shoutout to my baby girl Magnolia, who has given me a renewed sense of inspiration and purpose. My parents, Mark and Jean, have financially, emotionally, and practically supported me throughout this journey. They have taught me everything I know about how to be a good person and live a great life. I am so lucky to have had this wonderful pair raise me. My siblings Jim, Julie and Jenna have also been a motivating and inspiring factor throughout my time in graduate school. They have pushed me to work harder and strive to succeed.

In addition, I would like to thank Acacia and Happify Inc. whose funding made this project possible. Finally, I need to acknowledge the decades of impactful scientific work done by the psychological researchers that laid the foundation for this project. I am truly standing on the shoulders of giants. I know that this list is not comprehensive, and there are dozens of other people who have contributed to my graduate journey and this dissertation. So I would like to throw out a final thank you to *everyone* in my life!

CURRICULUM VITAE

JOHN. F HUNTER

EDUCATION

2019 (expected) Ph.D., Psychological Science
University of California, Irvine

2017 M.A., Social Ecology
University of California, Irvine

2009 B.A., Psychology & History (Double Major)
University of California, Los Angeles

PUBLICATIONS

Jenkins, B.N., **Hunter, J.F.,** Richardson, M. J., Conner, T.S., Pressman, S.D. (2019). Affect variability and affect predictability: Using recurrence quantification analyses to better understand how predictability in affect relates to health. *Emotion*. *IF* = 4.3. Q1 in Psychology.

Hunter, J.F., Fortier, M.A., & Kain, Z.N. (2018). Pain relief in the palm of your hand: Harnessing mobile health to manage pediatric pain. *Pediatric Anesthesia*. *IF* = 2.2. Q1 in Medicine.

Hunter, J.F., Hooker, E. D., Rohleder, N., & Pressman, S. D. (2018). The use of smartphones as a digital security blanket: The influence of phone use and availability on psychological and physiological responses to social exclusion. *Psychosomatic Medicine, 80*, 345-352. *IF*=4.58. Q1 in Psychology.

Hunter, J.F., Cross, M. P**.,** & Pressman, S. D. (2018). The associations between positive affect & health: Findings and future directions. In C.R. Snyder, S. J. Lopez, L. M. Edwards, & S. C. Marques (Eds.), *The Oxford Handbook of Positive Psychology, 3rd Edition*.

Kushlev, K., **Hunter, J.F.**, Proulx, J., Dunn, E., & Pressman, S.D. (2018). Smartphones reduce smiling between strangers. *Computers in Human Behavior*. I*F*=3.45. Q1 in Arts & Humanities.

Jenkins, B. N., **Hunter, J. F.,** Cross, M. P., Acevedo, A. M., & Pressman, S. D. (2018). When is affect variability bad for health? The association between affect variability and immune response to the influenza vaccination. *Journal of Psychosomatic Research. 104*, 41-47. *IF*=3.4, Q1 in Psychology.

Diener, E. Pressman, S.D., **Hunter, J.F**. Delgadillo-Chase, D., (2017). If, why and when subjective well-being influences health, and future needed research. *Applied Psychology: Health and Well-Being*, *9*, 33-167. *IF*=1.16. Q1 in Applied Psychology.

Under Review

Gailey, S., **Hunter, J.F**., Davis-McKay, N., & Bruckner, T. *(under review).* Are nature lovers happier and healthier? Examining relations among nature connectedness, positive affect, and perceived general health. *Journal of Environmental Psychology*

In Preparation

Hunter, J.F., Olah, M.S., Parks, A.C., & Pressman S.D. Can your phone calm you down? A brief biofeedback exercise via a smartphone application aids in stress recovery

Schueller, S.M, **Hunter J.F.,** Figueroa, C., Aguilera, A. Use of Digital Mental Health for Marginalized and Underserved Populations

Hunter, J.F., Fortier, M.A., Acevedo, A.M., & Kain, Z.N. Pain Buddy: Reducing Chronic Pain for Children with Cancer.

Hunter, J.F., Cross, M. P., Smith, J.R., & Pressman, S. D. Facial Coding Methodology Review.

Guge, P.M., **Hunter, J.F.**, Howell, R.T., Pressman, S.D. Materialists report that experiences make them happier, but their faces say otherwise: How self-reported purchase happiness and behavioral measures of happiness diverge.

Celniker, J., Ringel, M.M., **Hunter, J.F.,** & Ditto, P.H. Too disgusted to eat clean meat: An investigation of preferences about eating clean meat.

Acevedo, A.M., Jenkins, B.N, **Hunter, J.F.,** Cross, M.P., & Pressman, S.D. Positive Affect, Arousal and Pain.

PRESENTATIONS

**denotes an undergraduate I directly supervised in research*

*Pappal, A., Pinks, M.E., Olah, M., **Hunter, J.F**., & Pressman, S.D. (2019, May) *Females with problematic phone use perceive increased interpersonal support.* Poster presented at the 31st Annual Convention of the Association for Psychological Science, Washington, D.C.

*Pinks, M.E., Tsai, G., Khan, A., **Hunter, J.F.**, & Pressman, S.D. (2019, May). *The association between salivary biomarkers of physiological stress and extraversion.* Poster presented at the 31st Annual Convention of the Association for Psychological Science, Washington, D.C.

*Olah, M., Hoangtran, B., Pappal, A., McReynolds, K.B., Halaka, M., Austin, V., Vasani, S., **Hunter, J. F.,** & Pressman, S. D. (2019, May). *A qualitative comparison of emotion regulation in individuals with high and low trait mindfulness*. Poster presented at the 26th Annual University of California, Irvine Undergraduate Research Symposium, Irvine, CA.

*Tsai, G., Le, K., & Waldrop, I., **Hunter, J.F.**, & Pressman, S.D. (2019, May). *Do Women and Men differ in Stress Recovery with the Aid of a Smartphone Application?* Poster presentation at the 26th Annual University of California, Irvine Undergraduate Research Symposium, Irvine, CA.

*Le, K. Jones, N.M., & **Hunter, J.F.** (2019, April). *Does Social Media Moderate the Link Between Social Support and Stress?* Poster presentation at the 26th Annual University of California, Irvine Undergraduate Research Symposium, Irvine, CA.

*Pinks, M.E., McReynolds, K.B., Olah, M., **Hunter, J.F.,** & Pressman, S.D. (2019, May). *Individuals high in mindfulness benefit more from the use of a biofeedback application.* Poster presented at the 26th Annual University of California Irvine Undergraduate Research Symposium, Irvine, CA.

*Khan, A., Armijo, M., Resendiz, E., **Hunter, J.F.** & Pressman, S.D. (2019, May). *Cultural Differences in the Effectiveness of Using a Mobile Health Biofeedback Exercise on Stress Recovery.* Oral presentation at the 26th Annual University of California, Irvine Undergraduate Research Symposium, Irvine, CA.

*McReynolds, K.B., Chiplunkar, A., Pappal, A., Thomas, M.E., **Hunter, J.F.,** & Pressman, S.D. (2019, April). *How mobile phone use influences loneliness, stress, and salivary alpha amylase as stress biomarker.* Poster presented at the 99th Annual Convention of the Western Psychological Association, Pasadena, CA.

*Tsai, G., Khan, A., **Hunter, J.F.,** & Pressman, S.D. (2019, April) *The Association Between Salivary Biomarkers of Physiological Stress and Extraversion.*Poster presentation at the 99th Annual Convention of the Western Psychological Association, Pasadena, CA.

*Le, K. Jones, N.M., & Hunter, J.F. (2019, April). *Does Social Media Moderate the Link Between Social Support and Stress?* Poster presentation at the 99th Annual Convention of the Western Psychological Association, Pasadena, CA.

Hunter, J.F. & Pressman, S.D. (2019, March) *Is it your phone or how your use it? An investigation of the benefits smartphones may provide when recovering from stress.* Talk presented at the 76th Annual Scientific Meeting of the American Psychosomatic Society, Vancouver, British Columbia, Canada

Jenkins, B. N., **Hunter, J. F.,** Richardson, M. J., Conner, T.S., & Pressman, S. D (2019, March). *Affect variability and predictability: Using recurrence quantification analysis to better* *understand how the dynamics of affect relate to health.* Talk presented at the 6th Annual Meeting of the Society for Affective Science Annual Conference, Boston, MA.

*Wilder, R. Jones, N.M., & **Hunter, J.F.,** (2018, May) *Social Media Application Use and Belongingness.* Poster presented at 24th Annual UCI Undergraduate Research Symposium, University of California-Irvine, CA.

*Wong, E.F., Falasiri, S.E., **Hunter, J.F.** & Pressman, S.D. (2018, May) *The Effect of Nature Connectedness on Symptoms of Fatigue***.** Poster presented at 24th Annual UCI Undergraduate Research Symposium, University of California-Irvine, CA.

Hunter, J.F., & Fortier, M.F. (2018, March) *Pain Buddy: Reducing Chronic Pain for Children with Cancer.* Talk presented at the 76th Annual Scientific Meeting of the American Psychosomatic Society, Louisville, Kentucky.

Jenkins, B. N., **Hunter, J. F.,** Cross, M. P., Acevedo, A. M., & Pressman, S. D. (2018, April). *Mean Positive Affect Moderates the Association between Positive Affect Variability and Immune Response to the Influenza Vaccination.* Talk presented at the 5th Annual Positive Emotions Pre-Conference of the Society for Affective Science Annual Conference, Los Angeles, CA.

Pressman, S. D., Acevedo, A. M., Cross, M. P., **Hunter, J. F**., & Jenkins, B. N. (2018, April). *Keep calm and fight pain: How arousal matters in the positive affect-pain connection.* Talk presented at the 5th Annual Meeting of the Society for Affective Science Annual Conference, Los Angeles, CA.

Proulx, J., Kushlev, K., **Hunter, J.F.**, Pressman, S., & Dunn, E. W. (2018, March). *Smartphones reduce smiling between strangers*. Poster presented at the Psychology of Media & Technology Preconference of the 19th Annual Convention for the Society for Personality and Social Psychology, Atlanta, GA.

Kushlev, K., Proulx, J., Dunn E. W., **Hunter, J.F.,** & Pressman, S. (2018, March). *The effects of smartphones on face-to-face social interactions*. Presented at the Annual Convention at the Society for Personality and Social Psychology, Atlanta, GA.

Ringel, M.M., Celniker, J., **Hunter, J.F.** (2017, November). *Disgust, Moral Opposition, and Food Technology Neophobia Negatively Predict Acceptance of Cultured Meat.* Poster presented at the 2nd Annual Psychology of Technology Conference, Berkeley, CA

Hunter, J.F., Hooker, E.D., Rohleder, N**,** & Pressman, S. D. (2017, November). *The Use of Smartphones as a Digital Security Blanket: The influence of phone use and availability on psychological and physiological responses to social exclusion.* Poster presented at the 2nd Annual Psychology of Technology Conference, Berkeley, CA

*Wong, E., **Hunter, J.F**. & Pressman, S. D. (2017, May). *Optimization of Modern Technology in Coping with Stress*. Talk presented at 23rd Annual UCI Undergraduate Research Symposium, University of California-Irvine, CA.

*Twidwell, R., Portillo, O., Falasiri, S., **Hunter, J.F.**, & Pressman, S.D. (2017, May). *Measuring Smiles: The Hunter Analysis of Smiles.* Poster presented at 23rd Annual UCI Undergraduate Research Symposium, University of California-Irvine, CA.

Hunter, J.F., Hooker, E.D., Rohleder, N**,** & Pressman, S. D. (2017, March). *Is your smartphone a digital security blanket? The influence of phone use and availability on psychological and physiological responses to social exclusion.* Talk presented at the University of California, Well-Being Conference in Riverside, California.

Hunter, J.F., Hooker, E.D., Rohleder, N**,** & Pressman, S. D. (2017, March). *Is your smartphone a digital security blanket? The influence of phone use and availability on psychological and physiological responses to social exclusion.* Poster was presented at the 75th Annual Scientific Meeting of the American Psychosomatic Society, Sevilla, Spain.

Cross, M. P., Acevedo, A. M., **Hunter, J. F.,** & Pressman, S. D. (2017, March). *Smile while your heart is breaking? The protective cardiovascular effects of smiling during social exclusion.* Poster presented at the 75th Annual Scientific Meeting of the American Psychosomatic Society, Sevilla, Spain.

Acevedo, A.M., Leger, K.A., Shader, J., **Hunter, J.F,** Cross, M. P., & Pressman, S.D. (2017, March). *Keep calm and carry on: Low arousal positive affect is associated with higher parasympathetic function but no sympathetic activation during experimentally induced pain.* Poster presented at the 75th Annual Scientific Meeting of the American Psychosomatic Society, Sevilla, Spain.

*Wong, E., Delgadillo, Q., **Hunter, J.F**., & Pressman, S.D. (2017, March) *Optimization of Modern Technology in Coping with Stress.* Poster and talk presented at Society for Behavioral Medicine Conference in San Diego, California.

*Degladillo, Q., **Hunter, J.F.,** & Pressman, S.D. (2017, March) *Are Smartphones Digital Security Blankets? How the Presence of a Smartphone Influences Salivary Alpha Amylase and Experiences of Exclusion Following a Stressor.* Poster presented at Western Psychological Association conference in Sacramento, California.

Hunter, J.F., Hooker, E.D., Rohleder, N**,** & Pressman, S. D. (2017, February) *Is your smartphone a digital security blanket? The influence of phone use and availability on psychological and physiological responses to social exclusion.* Talk presented at the Osher Lifelong Learning Institute in Irvine, California

*Reyes, K., Gomez, C., Wong, E., **Hunter, J.F.,** Pressman, S.D. (2016, May) *Gender Difference in the Stress Response to a Social Rejection Manipulation.* Poster presented at the 22nd Annual UCI Undergraduate Research Symposium, University of California-Irvine, CA.

*Wong, E., Gomez, C., Smith, S., Grigorian, S., **Hunter, J.F**., Pressman, S.D. (2016, May). *Effects of Social Exclusion and Cell Phone Use on People With Depressive Symptoms.* Poster presented at the 22nd Annual UCI Undergraduate Research Symposium, University of California-Irvine, CA.

*Gomez, C., **Hunter, J.F.,** Pressman, S.D. (2016, May). *Personality and Stress-Buffering: The Role of Neuroticism and Mobile Phone Use When Responding to Social Stressors.* Talk presented at the 22nd Annual UCI Undergraduate Research Symposium, University of California-Irvine, CA.

*Smith, S., **Hunter, J.F.,** & Pressman, S.D. (2016, May). *The role of trait anxiety in moderating the feelings of exclusion during social stress.* Poster presented at the 22nd Annual UCI Undergraduate Research Symposium, University of California-Irvine, CA.

Hunter, J.F., Gomez, C. & Pressman, S.D. (2016, May). *Cell Phone Use Patterns and Personality Factors*. Poster presented at Western Psychological Association Conference in Long Beach, California.

Hunter, J.F., Jenkins, B. & Pressman, S.D. (2016, January). *Association of Emotional Well-Being and Types of Internet Use.* Poster presented at Society for Personality and Social Psychology, Happiness & Well-Being Pre-Conference in San Diego, California.

HONORS & AWARDS

2018	Science in Action Fellow ($1500)
2018	Psychology of Technology Institute Dissertation Award (Runner-Up)
2018	Social Ecology Dean's Dissertation Data Collection Stipend ($1000)
2018	Certificate in Teaching Excellence
2017	UCI Pedagogical Fellowship ($2,000)
2017, 2018	Associated Graduate Students Symposium Judges Winner ($450)
2017, 2018	Associated Graduate Students Travel Award ($400)
2017	Citation Poster at 76th APS Conference
2017	Newsworthy Poster at 76th APS Conference
2015, 2016, 2017, 2018	Outstanding Mentoring Award ($200)
2009	UCLA Alumni Scholar

TEACHING EXPERIENCE

Instructor

2018	Psychology Fundamentals

Assistantships

2019	Human Stress
2019	Clinical Neuroscience
2018	Clinical Sports Psychology

2018	Positive Psychology
2018	Clinical Neuroscience
2017	Abnormal Psychology
2017	Social Relationships
2017	Naturalistic Field Research
2016	Positive Psychology
2016	Child Health Psychology
2016	Social Animal
2015	Health Psychology
2015	Psychology Fundamentals
2015	Environmental Psychology
2014	Social Epidemiology

Guest Lectures

2018	*Nature and Well-Being*, Positive Psychology
2018	*Health & the Environment*, Human Stress
2018	*Social Psychology & Health*, Social Animal
2016	*Natural Environments & Restoration*, Positive Psychology
2016	*Social Influences of Health*, Social Animal
2015	*Motivation & Emotion*, Psychology Fundamentals
2014	*Research Methodology in Epidemiology*, Social Epidemiology
2014	*Social Determinants of Health*, Social Epidemiology

Additional Teaching Experience

2017-2018 Pedagogical Fellow
Division of Teaching Excellence & Innovation, UCI

I have undergone a year of pedagogical training that covered evidence-based instructional techniques and methodology. I was trained to implement student-centered activities, develop course designs, conduct peer observations, and collaborate with pedagogical experts. Beyond implementing the practices into my own classroom, I have also developed, organized and facilitated a two-day workshop for incoming teaching assistants.

2017 Writing Consultant
Graduate Resource Center, UCI

I assisted graduate students from departments across campus with the writing process. My work included guidance and assistance for helping students with clarity, flow, coherence, grammar, and organization for a wide variety of writing projects. I revised and edited academic journal articles, grant applications, fellowship applications, job application materials, resumes, and class assignments among others.

2004-present Tutor

I have worked for a number of different tutoring organizations but have primarily worked as an independently contracted tutor. My clients have ranged in ages from pre-school to university level. I have worked with clients on a wide variety of subjects including: Psychology, SAT preparation, ACT preparation, GED preparation, AP test preparation, ESL education, Spanish, Reading & Writing, World History, US History, European History, and Human Geography.

2013-2014 Teacher
Irvine Unified School District

I served as a substitute teacher for various subjects in K-12 classrooms. The majority of my experience was spent teaching high school and I volunteered as an assistant football coach for a season. I accepted a long-term position and assumed the full responsibilities of a Kindergarten teacher for an entire trimester.

2010-2012 Peace Corps Volunteer
United States Peace Corps

In the remote islands of Micronesia, I taught elementary and middle school classes, trained local teachers, and reorganized the functioning and administration of the school. I built a water system to provide clean water to 10 households, initiated an agriculture project, fundraised for solar lamp technology, started a health education program, wrote a proposal for the establishment of a vocational high school, and built a basketball court.

MENTORSHIP

Anshuman Chiplunkar
Fall 2018 Undergraduate Research Opportunities Award ($775)

Grace Tsai
Fall 2018 Undergraduate Research Opportunities Award ($775)

Kyle Than Le
Fall 2018 Undergraduate Research Opportunities Award ($775)
Spring 2018 Undergraduate Research Opportunities Award ($600)

Aadil Khan
Fall 2018 Undergraduate Research Opportunities Award ($775)
Spring 2018 Undergraduate Research Opportunities Award ($700)

Ian Waldrop
Fall 2018 Undergraduate Research Opportunities Award ($775)
Spring 2018 Undergraduate Research Opportunities Award ($750)

Eric Falasiri
Fall 2017 Undergraduate Research Opportunities Award ($450)

Spring 2017 Undergraduate Research Opportunities Award ($750)

Benjamin Gibson
Current psychology PhD student at the University of New Mexico

Robert Twidwell
Summer 2016 Undergraduate Research Opportunities Award ($1700)
Fall 2016 Undergraduate Research Opportunities Award ($800)
Current psychology Master's student at University of Western Kentucky

Christopher Gomez
Spring 2015 Undergraduate Research Opportunities Award ($800)
Summer 2015 Undergraduate Research Opportunities Award ($1700)
Fall 2015 Undergraduate Research Opportunities Award ($800)

Kaitlin Tinker
Current psychology Master's student at University of Southern California

Emily Wong
Spring 2015 Undergraduate Research Opportunities Award ($900)
Fall 2015 Undergraduate Research Opportunities Award ($800)
Summer 2016 Undergraduate Research Opportunities Award ($1700)
Fall 2016 Undergraduate Research Opportunities Award ($800)
Fall 2017 Undergraduate Research Opportunities Award ($450)
Current psychology Ph.D. psychology student at UCLA

Kimberley Reyes
Summer 2015 Undergraduate Research Opportunities Award ($1700)
Fall 2015 Undergraduate Research Opportunities Award ($800)

Sabrina Smith
Fall 2015 Undergraduate Research Opportunities Award ($800)

Katherine Bailey
Spring 2015 Undergraduate Research Opportunities Award ($900)

SERVICE

2018 — Teaching Assistant Professional Development Program
Division of Teaching Excellence & Innovation

2017-2018 — Professional Development Coordinator
Psychology and Social Behavior Department

2017 — Dissertation Boot Camp Facilitator
UCI Graduate Division

2017 UCI Graduate Orientation Speaker
Presented a talk about "PhD Tips for Writing" to 600+ students

2017 Faculty Search Committee Member
Psychology and Social Behavior Department

2017 Graduate Awards Coordinator
Psychology and Social Behavior Department

2016-2018 Graduate Student Peer-Mentor
Psychology and Social Behavior Department

2015-2016 Departmental Colloquium Organizer
Psychology and Social Behavior Department

Ad Hoc Reviewer

2018 Child Development
2017 Biological Psychology
2015 Translational Issues in Psychological Science

PROFESSIONAL MEMBERSHIPS

American Psychological Association
Society for Personality & Social Psychology
American Psychosomatic Society
Western Psychology Association
Psychology of Technology Network

ADDITIONAL TRAINING

2018 Center for Integration of Research, Teaching & Learning (CIRTL) Associate
2017-2018 Pedagogical Training: University Studies 390 A, B, C, X
2017 Interdisciplinary Institute of Salivary Bioscience Research
2015, 2016, 2017 University of California Health Consortium Workshop
2017 SRCD-Jacobs Foundation Pre-Conference Workshop
2015 Teaching Assistant Professional Development Program

ADDITIONAL SKILLS

Statistical Packages: SPSS, STATA
Mindware BioLab (psychophysiological equipment)
Salivary Bioscience Laboratory Assays (cortisol and alpha-amylase)
Online Survey Creation: Qualtrics, SurveyMonkey, YourMorals, Amazon mTurk
Microsoft Office, Google Docs
Fluent in the Chuukese Language

MEDIA APPEARANCES

PsyPost.org "Strangers smile less to one another when they have their smartphones, study finds," by Eric Dolan, 22 October, 2018. https://www.psypost.org/2018/10/strangers-smile-less-to-one-another-when-they-have-their-smartphones-study-finds-52392

*Science News For Students. "*Smartphones may serve as digital security blankets: The trick seems to be having a phone on hand-but not using it-in awkward social situations," by Allison Pearce Stevens. 3 October, 2018. https://www.sciencenewsforstudents.org/article/smartphones-may-serve-digital-security-blankets

*KUCI. "*UCI research on phones, stress and well-being," Interview with Janeane Bernstein, 17 September, 2018.

Austrian Broadcasting Corporation. "Smartphones act as digital security blankets in stressful social situations," Interview with Ruth Hutsteiner. 13 September, 2018.

Radio New Zealand. "Phones as Digital Security Blankets," Interview with Wallace Chapman. 28 August, 2018. https://www.radionz.co.nz/national/programmes/sunday/audio/2018661753/smartphones-as-security-blankets-john-hunter

Early Edition on Newstalk ZB. "Why are we addicted to our phones?" Interview with Kate Hawkesby. 4 September, 2018.

*Los Angeles Times. "*Your smartphone is a teddy bear," by Ben Brazil. 20 August, 2018.

*Orange County Register. "*Cell Phones can act as digital security blankets," by Ben Brazil, 26 August, 2018.

The Nation. "Smartphones help escape from awkward situation," 21, August, 2018. http://www.nationmultimedia.com/detail/asean-plus/30352549

Daily Pilot. "Cellphones can act as 'digital security blankets,' UC Irvine researchers find," by Ben Brazil. 16 August, 2018 http://www.latimes.com/socal/daily-pilot/news/tn-wknd-et-uc-irvine-20180816-story.html

Salon. "Our smartphones have become social comfort blankets," by Allistair Charlton. 12 August, 2018. https://www.salon.com/2018/08/11/our-smartphones-have-become-social-comfort-blankets_partner/

Health News Digest. "Smartphones act as digital security blankets in stressful social situations," by Staff Editor. 8 August, 2018. *http://www.healthnewsdigest.com/news/Safety_310/Smartphones-act-as-digital-security-blankets-in-stressful-Social-Situations.shtml*

Inquirer. "Smartphones serve as 'security blankets' in awkward situations—study," by Alfred Bayle. 8 August, 2018. http://technology.inquirer.net/78285/smartphones-serve-security-blankets-awkward-situations-study#ixzz5PP9o40T2

Engadget. "Your smartphone is a 'security blanket' for your social life. Even when you're not looking at it, " by Jon Fingas. 7 August, 2018. https://www.engadget.com/2018/08/07/study-shows-smartphones-are-security-blanket/

ABSTRACT OF THE DISSERTATION

Is it your phone or how you use it? The influence of smartphones on stress recovery

John F. Hunter

Doctor of Philosophy in Psychological Science

University of California, Irvine, 2019

Associate Professor Sarah D. Pressman, Chair

Smartphones are often vilified for negatively influencing well-being and contributing to stress, but these devices may also be potentially used in positive ways to aid in stress recovery. Despite the vast potential afforded by smartphones, this topic has rarely been studied in experimental stress research and little is known about whether smartphones can alter recovery trajectories following a stressful experience. Thus, this dissertation investigates the psychological and physiological effects of utilizing smartphones in differing ways following the experience of an acute laboratory stressor. Specifically, this dissertation examines how having a phone present, using a phone freely, or using a guided application on a smartphone influences stress recovery. To examine this issue, an experiment was conducted in which participants underwent a social-evaluative laboratory stressor and then were left alone to recover in a specific way depending on condition. Those in the no phone condition did not have access to their phone. Those in the phone present condition had a phone in their possession but were restricted from using it. Those in the phone use condition could use their phone freely. Those in the guided phone use condition used an application that delivered heart rate variability biofeedback training. Psychological and physiological stress recovery was assessed via repeated measures of salivary alpha amylase and self-reported stress. Results indicated that those in the guided phone use condition had significantly steeper physiological recovery trajectories than those in the phone present and no phone conditions. The phone use and guided phone use conditions did not differ. No differences were found in regard to self-reported stress. In addition, mediation analyses were conducted to investigate mechanisms of interest based on a series of planned comparisons. Neither distraction, perceived social support, positive affect, negative affect, nor feelings of calm were found to be significant mediators. Therefore, no tested mechanisms explaining found effects were conclusively determined. From these results, it can be concluded that engaging in a brief biofeedback training session on a smartphone can effectively reduce physiological stress levels. Overall, this dissertation provides evidence to shed light on how, when, and why smartphones influence stress recovery.

Introduction

The majority of psychological research about the influence of smartphones on well-being has primarily concentrated on the negative social, attentional and health consequences of our increasing reliance on digital technology (e.g., Ralph, Thomson, Cheyne, & Smilek, 2014; Roberts, Yaya, & Manolis, 2014; Rosen et al., 2014; Twenge, Joiner, Rogers, & Martin, 2018). While it is important for us to recognize these emerging issues, there is little hope that we will return to a Luddite age of technological abstention. Rather, trends suggest that adoption of smartphones is increasing at a staggering rate, with over 75% of Americans owning smartphones (Smith, 2017) and ownership increasing amongst older populations (Anderson & Perrin, 2017; Joe & Demiris, 2013), lower socioeconomic groups (Anderson, 2017; Carroll et al., 2017), and those in emerging world economies (Poushter, 2017). With this inevitable reliance on mobile computing technology perpetuating rapidly, it is imperative that researchers shift their focus towards recognizing the *positive* aspects of engagement with smartphones and how best to use these ever present devices. Rather than simply documenting the problems associated with smartphones and advocating for abstention or reduction of use, a more solution-focused approach is to investigate ways in which these devices may be leveraged to maximize well-being.

One unique way in which smartphones may be utilized in regard to well-being is by helping to mitigate the negative consequences associated with stressful experiences. Stress is a constant companion in many people's lives and its accumulated effects can lead to a range of undesirable physical and mental health outcomes (McEwen & Gianaros, 2011). While most researchers focus on stress reactivity (i.e., the degree to which individuals respond during stress), one of the most important features that determine long-term health effects is stress recovery.

Stress recovery is the post-stressor period in which information is provided about the degree to which reactivity parameters (e.g., elevated heart rate) persist after the stressor has ended (Linden, Earle, Gerin, & Christenfeld, 1997). Research has shown that delayed recovery can have harmful health implications, such as increasing the risk for mortality (Cole, Blackstone, Pashkow, Snader, & Lauer, 1999). That said, recovery has been shown to be malleable based on different activities and interventions (e.g., cognitive behavioral therapy, social support, affective changes, distraction). By adopting specific strategies, individuals may be able to improve their psychological and/or physiological stress recovery trajectories. This dissertation will fill an important gap in the stress recovery literature by investigating how smartphones may facilitate the effectiveness of certain stress-buffering activities.

Why do smartphones present a promising opportunity for altering stress recovery trajectories? Smartphones can be used to deliver stress-reducing interventions or can provide a platform for distracting or socially supportive activities that can aid in stress recovery. Psychologists have developed a variety of evidence-based strategies that aid in stress reduction (Goldenberg et al., 1994) such as biofeedback training (Wheeler & Wheeler, 2017). In addition, contextual factors such as the perception of social support, distracting stimuli, and emotional alterations have been identified as elements that buffer stress (Cohen & Wills, 1985; Gerin, Davidson, Christenfeld, Goyal, & Schwartz, 2006; Pressman & Cohen, 2005). Unfortunately, for a variety of reasons, these factors are not taken advantage of and these techniques do not get utilized often enough in the appropriate contexts by those in need. However, smartphones provide an opportunity to put these stress-reducing strategies in the palm of one's hand to allow immediate and functional assistance.

Smartphones are ideally situated to be used as tools for combating the negative effects of stress because they are popular, mobile, and have an array of technological capabilities (Free et al., 2010). Specifically, since these devices are nearly omnipresent in daily life, interventions can be delivered and assistance can be garnered with precise timing wherever and whenever it is needed. Furthermore, visually attractive smartphone interfaces and the technological capabilities of these devices allow for cutting-edge design and innovative implementation of sophisticated strategies for reducing stress. While smartphones do indeed present an array of opportunities for technologically-enabled stress alleviation strategies, they are also used in less sophisticated but potentially beneficial ways. For example, smartphones are often used to garner traditional stress-buffering resources, such as social support (Hooker, Campos, & Pressman, 2018), because of the social connections facilitated by social media, texting and calling. The social networks accessed or symbolized via a smartphone can bolster the perceptions of resources available to help an individual recover from stress. Thus, using a smartphone in a social manner may reduce prolonged activation of physiological stress systems. Interestingly, even a smartphone's mere presence can aid in stress recovery (Hunter, Hooker, Rohleder, & Pressman, 2018). This "digital security blanket" effect may be due to the symbolic social support represented by a smartphone or the distraction induced by the device. Based on the stress recovery literature and the technological affordances of smartphones, it is apparent that there are many different ways in which smartphones may be relied upon to facilitate the effectiveness of stress-buffering factors. Therefore, it is important to investigate these different possibilities about how smartphones can best be used to aid in stress recovery and elucidate the pathways by which they may exert their beneficial effects.

The goals of this dissertation were to investigate specific ways that smartphones may be used to alter stress recovery and explore possible mechanisms underlying these effects. I examined the potentially additive benefits of having a phone, using a phone freely, and using a guided application on a phone. First, the potential stress-reducing benefits of merely having a smartphone present were examined, and the mediators of distraction and perceived social support were explored as explanatory pathways. Next, I investigated whether using a smartphone provided additional benefits beyond simply having a smartphone present, and the mediating roles of positive affect (PA) and negative affect (NA) induced by received social support and passive social media use were examined. Finally, I considered whether a guided skills training application provided additional benefits for stress reduction beyond other types of phone use and examined how feelings of calm may have played a role. Together, these comparisons of phone use and explanatory pathways can help determine how smartphones may best be utilized to aid in stress recovery.

Stress

Stress occurs when an individual perceives that they do not have the adaptive capacity to handle environmental demands. In these instances, stress results in psychological and physiological changes that may place an individual at risk for disease (Cohen, Kessler, & Gordon, 1995). For the remainder of this dissertation, I will often use the word "stress" to refer to both the psychological and physiological components of responses to a stressor (i.e., the event triggering the stress response). Stress can stem from a variety of factors and can be categorized as acute or chronic. Although chronic stress is primarily responsible for the negative health effects that are described in the literature, acute stress is a useful concept to study for a variety of reasons. Acute stress can be easily manipulated in laboratory settings, which is advantageous because it provides a controlled environment with few potentially confounding variables. Reactivity and recovery data can then be extrapolated to external circumstances that relate to chronic stress. For example, acute reactive changes in blood pressure during in-lab experiments (Matthews et al., 2004) and delayed blood pressure recovery (Stewart & France, 2001) have been shown to predict long-term hypertension. Thus, the temporary changes seen in laboratory experiments may have profound implications for predicting future health status. Additionally, it is more morally and logistically acceptable to manipulate acute stress with the implementation of laboratory-based stressors rather than attempting to induce chronic stress. For these reasons, the measurement of acute stress responses in experimental circumstances can provide valuable information about health.

There are many ways to induce acute stress in the laboratory, and each type of stressor is designed to simulate some type of real-world situation or elicit a specific type of response. If researchers hope to capture a general and externally valid stress response, it is best to use a well-tested and reliable stressor such as the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993). The TSST is one of the most commonly used experimental stressors across the psychology and health literature. This stressor involves participants preparing and delivering a novel speech followed by an oral cognitive math performance in front of a critically evaluative audience. One purpose of using a task such as the TSST in an experimental setting is to investigate whether certain manipulated factors may increase or decrease the magnitude of acute stress responses and recovery. For example, distracting oneself by observing virtual reality natural environments (Annerstedt et al., 2013) or connecting socially with close others (Meuwly, Bodenmann, Bradbury, & Angeles, 2012) have both been shown to facilitate physiological recovery after the TSST. In this way, the TSST is an effective tool that can be utilized to test whether specific factors (e.g., cognitive behavioral therapy, social support, distraction) alter stress recovery trajectories.

Stress recovery. Activation of our physiological stress systems in response to acute stress is often adaptive in the short-term because it gives us the ability to utilize resources and overcome threatening situations (Sapolsky, 1994), but the accumulated consequences of prolonged activation of physiological stress responses often lead to a high allostatic load (McEwen, 1998) as noted by numerous brain and bodily alterations (McEwen & Gianaros, 2011). High allostatic load (i.e., cumulative wear and tear on the body) is predictive of several detrimental health outcomes including diseases related to gastrointestinal, cardiorespiratory, metabolic, and immune systems (Chrousos, 2009; Cohen, Janicki-Deverts, & Miller, 2007). Allostatic load is generated by prolonged activation of physiological stress systems; therefore, the duration and trajectory of physiological stress *recovery* is particularly important in regard to health.

Research suggests that physiological recovery is critical for predicting long-term health outcomes (Linden et al., 1997). Studies have demonstrated that prolonged recovery from acute stressors can predict future morbidity and mortality (e.g., Chida & Steptoe, 2008). Specifically, delayed heart rate recovery in cardiac patients has been shown to predict overall mortality five (Nishime, Cole, Blackstone, Pashkow, & Lauer, 2000) and six years later (Cole et al., 1999). It is unclear about the exact mechanisms that are associated with prolonged recovery, but it may be influenced by factors such as perseverative condition that lead individuals to engage in continued rumination and worry (Brosschot, Pieper, & Thayer, 2005). That continued cognitive focus on the stressor keeps physiological systems activated for longer periods and adds to the wear and tear on our system (i.e., allostatic load). Much more research needs to be done in this area to pinpoint the exact health effects of prolonged recovery, but there is a strong logical and theoretical link between stress recovery and allostatic load that merits consideration. We know that persistent and long-lasting physiological stress activation leads to high allostatic load (McEwen, 1998), so it is imperative to find ways to reduce that activation and assist in stress recovery. Therefore, stress recovery and the ways in which it can be reduced are important concepts to consider in regard to augmenting overall health.

Assessing stress. Stress can be assessed in a variety of ways, and each method of assessment provides unique insight into the far-reaching complex dynamics of how stress impacts our bodies and brains. One of the most common ways to assess stress is simply to ask individuals to subjectively rate their stress levels. This can be done by measuring perceived stress (Cohen, Kamarck, & Mermelstein, 1983), the number of stressful events experienced (Holmes & Rahe, 1967), or just simple one-item questions such as, *"do you feel stressed?"* While self-report is advantageous for numerous reasons, there are many problems of bias that limit the accuracy or interpretation of these assessments (Paulhus & Vazire, 2005). Based on the complex nature of stress, the most appropriate and comprehensive manner in which to assess it is a multimodal approach that combines subjective and objective assessments. Each type of stress assessment provides unique information about the experience and its associated outcomes, so it is important to consider the differences and similarities in how they align. In order to provide convergent validity and/or disentangle the complexities of the stress experience, it is ideal to capture both self-report and physiological measurements.

One innovative and effective way to capture physiological measurements of stress is to analyze salivary biomarkers. Although it is rather understudied, salivary alpha amylase (sAA) is an emerging biomarker that holds great promise for assessing acute stress. This biomarker is highly correlated with cortisol, a stress hormone that is the most popularly used salivary biomarker, but offers separate and supplementary information about the stress response (Engert et al., 2011). sAA is an enzyme that is an indicator of autonomic nervous system activity, and is most strongly tied with sympathetic nervous system activity, the system responsible for the "fight-or-flight" response (Nater & Rohleder, 2009). When an individual is physiologically aroused, sAA is released via the salivary glands and indicates an immediate stress response; thus, higher levels of sAA imply a stronger stress response. Prolonged activation of the sympathetic nervous system and the subsequent release of sAA can lead to autonomic nervous system dysregulation that ultimately puts one at a greater health risk (Rohleder & Nater, 2009). For example, high levels of sAA have been linked to immune suppression (Nagy et al., 2015) and a greater prevalence of mental health disorders (Schumacher, Kirschbaum, Fydrich, & Strohle, 2013) for adults. Among children, higher levels of sAA are associated with greater illness susceptibility (Granger et al., 2006), chronic asthma-related stress (Wolf, Nicholls, & Chen, 2008), and more respiratory problems, frequency of illness, and fatigue (Granger, Kivlighan, El-Sheikh, Gordis, & Stroud, 2007) Very few studies (e.g., Hunter et al., 2018) have examined how interventions may influence sAA recovery, but given the importance of sAA for health, it is important to investigate how various interventions may attenuate sAA recovery. This dissertation will be one of the first studies to examine how various smartphone activities influence sAA recovery. These salivary assessments of autonomic nervous system activity combined with self-report provide a rather comprehensive understanding of stress recovery.

Improving stress recovery. The most obvious answer to reducing the harmful effects of stress would be to avoid stressful stimuli altogether, but unfortunately this is not always possible.

Instead, the best approach for trying to mitigate the ramifications of stress is to adopt strategies that better prepare us for stressful encounters, reduce the intensity of stress reactivity, or aid in recovery after experiencing a stressor. Researchers have identified numerous factors that may buffer the psychological and physiological consequences of stress (Varvogli & Darviri, 2011). For the purposes of this dissertation, I am specifically interested in examining factors that may influence stress recovery. While there are a range of potential stress-buffers to consider, a few of the most feasible approaches that can be leveraged by smartphones to influence stress recovery are distraction, reliance on social support, affective changes, and the use of cognitive behavioral therapies.

Distraction. Distracting oneself from the stressful stimulus is a simple and effective action for buffering stress (Inal & Kelleci, 2012). Diverting attention away from the stressor and towards a more innocuous stimulus can help alleviate some of the negativity stemming from the stressor. Specifically, when recovering from a stressful experience, thinking about something else besides the stressor shifts cognitive focus and hastens the physiological recovery process. Distraction is particularly beneficial during stress recovery because it can help an individual avoid rumination about the stressor (Gerin et al., 2006). As discussed previously, perseverative cognition (i.e., rumination) is one of the pathways by which activation of physiological stress systems is prolonged (Brosschot et al., 2005). Indeed, rumination has been shown to hamper blood pressure recovery (Radstaak, Geurts, Brosschot, Cillessen, & Kompier, 2011). However, if a stimulus in one's post-stressor environment is sufficiently distracting, it may occupy their cognitive attention and help them move beyond ruminating thoughts about the stressor. In support of this approach, distraction has been shown to reduce rumination and speed up blood pressure recovery processes in experimental settings (Gerin et al., 2006). In another example, individuals who were presented with a distracting stimulus after undergoing a stressful task recovered to baseline levels of blood pressure quicker than those who were not distracted (Glynn, Christenfeld, & Gerin, 2002). Distraction has also been associated with faster cardiac recovery in healthy women (Neumann, Waldstein, Sollers III, Thayer, & Sorkin, 2004). These distraction interventions are likely successful because they prevent cognitive fixation on the stressor and allow an individual to more quickly move beyond the stressful stimulus that has caused their physiological activation.

It is important to note that while distraction does seem to be beneficial in the short term, it may not be an adaptive long-term strategy. In fact, one longitudinal study demonstrated that if someone is not allowed to ruminate immediately after a stressor (due to distraction), then they show significant increases in blood pressure when thinking about the stressor a week later. Those who were allowed to immediately ruminate were able to mentally process the experience quickly and did not show significant blood pressure increases a week later (Glynn, Christenfeld, & Gerin, 2007). Therefore, distracting oneself immediately after a stressor may confer short-term benefits, but does not appear to be an efficacious long-term intervention. Nevertheless, due to the simplicity of distraction interventions and the wide range of possibilities for inducing distraction (e.g., via a smartphone), this is an interesting and potentially effective stress-buffering approach to examine.

Social support. One of the most well-researched areas in the stress-buffering literature is about the influence of social support. Having the perception that your social network could provide support helps combat stress by equipping you with more resources to handle the situation at hand. These feelings of support reduce psychological and physiological responses to stress and can protect individuals from the health impacts associated with stressors (Cohen &

Wills, 1985; Uchino, 2006). Most experimental studies focus on stress reactivity and manipulate support provisions prior to or during an acute stressor to demonstrate how social support can reduce stress paramaters such as cardiovascular responses (Lepore & Allen, 1993; Thorsteinsson & James, 1999). Additionally, several studies have shown that social support provided during recovery from a health event (e.g., myocardial infarction) predicts more desirable short and long-term recovery outcomes (Yates, 1995). However, very little work has examined how experimentally-manipulated social support influences recovery from an acute stressor. Therefore, more research is necessary to examine the optimal timing for provision of social support to determine how it may alter stress recovery processes.

While social support is often a suitable and beneficial stress-buffer, the type of support and manner in which it is delivered are important predictors that determine the effectiveness of social support for buffering stress. In some instances, social support can have detrimental effects (Rook, 1998). For example, when social support is overtly enacted in acute settings, it can sometimes lead to catastrophizing and actually increase reports of stress (McClelland & McCubbin, 2008). This may be due to the different perceptions and effects of invisible and visible social support on adjustments to stress (Bolger, Zuckerman, & Kessler, 2000). Visible support is characterized by tangible actions such as providing material or emotional resources, where invisible support is a “behind-the-scenes” process of providing support without the recipient being aware. Although visible support is intended to be helpful, it can sometimes induce feelings of dependence, incompetence or indebtedness (Thoits, 2011). In one experiment, receipt of visible social support was associated with greater distress than invisible support (Bolger & Amarel, 2007). Invisible support is often considered the most effective method because it bypasses many of the negative consequences associated with visible support. Overall, invisible support is much more subtle and indirect and is associated with more positive outcomes (Girme, Overall, & Simpson, 2013). By subtly receiving this indirect and non-evaluative type of support, individuals recoverying from stress may reap the benefits of social support resources without incurring the costs.

Another theoretically similar way to differentiate between types of support is to consider the distinction between perceived and received social support. Received social support is when an individual is presented with verbal or tangible support, which may or may not confer benefits (Nurullah, 2012). On the other hand, perceived social support lets an individual know that they have social resources to draw upon, but they do not actually directly receive any supportive comments or behavior. Interestingly, much research suggests that perceived support is more associated with positive outcomes than overt received support (Reinhardt, 2006). For example, one experimental study determined that passive support (i.e., just being present, but not interacting) was a more potent stress buffer than active support (i.e., talking supportively to the participant) for those undergoing a stressor (Brown, Sheffield, Leary, & Robinson, 2003). The evidence is mixed in regard to the effect of social support on stress, but research suggests that the most beneficial influences are noted when support is provided passively, invisibly or symbolically.

In light of this evidence supporting the effectiveness of perceived support, it may be interesting to explore if the symbolic representation of social support can effectively aid in stress recovery. Simply sensing that you are connected to others may help you overcome a stressful experience by providing the perception of supportive resources at your disposal. Subtle reminders of socially-laden stimuli have been shown to activate knowledge and memories of an individual's social network (Ferguson & Bargh, 2004). Thinking about the potential social resources one has may confer psychological and physiological benefits. For example, simply thinking about supportive ties has been associated with lower cardiovascular reactivity in response to a stressor (Smith, Ruiz, & Uchino, 2004; van Well & Kolk, 2008). A few studies have also explored this issue in regard to the stressful experience of pain. In one experimental pain paradigm, individuals who simply viewed a photograph of a romantic partner during a painful experience had reduced pain reports in comparison to those who viewed a photograph of a stranger or a distracting image. Surprisingly, viewing the photograph of a loved one had an even more potent buffering effect that holding the hand of an actual loved one (Master et al., 2012). Neuroscientists have proposed two different mechanisms for why this symbolic social support of a photograph may reduce stress and pain. One study showed that a photograph stimulates brain activity in areas associated with safety and security, the ventromedial pre-frontal cortex (Eisenberger et al., 2011). The close other presumably provides a sense of comfort in real-life interactions, and the simple depiction in the photograph is a powerful enough reminder to stimulate those feelings of comfort and ultimately reduce the intensity of the stressful experience. Another study suggests that viewing the photograph activates the reward system within the brain, and subsequent descending inhibition prompted by those processes is responsible for the analgesic effects (Younger, Aron, Parke, Chatterjee, & Mackey, 2010). Regardless of the neuroscientific mechanism that is responsible for the effect, it appears that the symbolic presence of a close other induces positive feelings and is sufficient to initiate a process of top-down stress reduction. There is a gap in the literature examining whether symbolically perceived social support influences acute stress recovery, but it seems plausible that this type of social support may provide helpful resources that allow an individual to recover more effectively following a stressful experience.

Affect. Levels of PA and NA are associated with responses to stress. Stress is usually a subjectively negative experience, and, indeed, higher levels of NA are generally associated with higher levels of stress (Dua, 1993). On the other hand, PA is usually inversely associated with stress. In fact, PA has been theorized to benefit health by specifically buffering the negative effects of stress (Hunter, Cross, & Pressman, 2018; Pressman & Cohen, 2005). According to the broaden-and-build theory, positive emotions can broaden an individual's awareness and allow them to build personal resources (Fredrickson, 2001). These resources can then be leveraged to overcome stress. For example, PA can help people secure and build resources like endurance and resilience that can then assist them in coping with stressors (Tugade & Fredrickson, 2004).

When specifically focusing on stress recovery in acute situations, higher levels of NA are associated with slower physiological recovery from stress (Radstaak et al., 2011). In scenarios of high NA and stress, PA may play a particularly beneficial role. It has been hypothesized that PA primarily exerts its benefits by "undoing" the negative psychological and physiological effects of NA (Fredrickson & Levenson, 1998). Indeed, there is substantial evidence supporting the role of PA in helping the process of stress recovery. In support of the undoing hypothesis, PA has been shown to help individuals bounce back quickly from stress and display faster cardiovascular recovery trajectories after undergoing an experimental stressor (Fredrickson, Mancuso, Branigan, & Tugade, 2000). Multiple studies have tested the role of PA as a stress-buffer in experimental paradigms and confirmed that PA inductions improve cardiovascular recovery from stress (e.g., Kraft & Pressman, 2012; Fredrickson & Levenson, 1998). Thus, there is considerable evidence that higher levels of PA are beneficial for stress recovery.

One understudied aspect of PA that may be particularly beneficial is calm. Calm is a low arousal component of PA that is sometimes operationalized by the combination of adjectives such as relaxed, calm, and at ease (Cohen, Doyle, Turner, Alper, & Skoner, 2003). Inductions of calm have been shown to boost parasympathetic activity and hasten cardiovascular recovery from painful stressors (Acevedo et al., 2017). Adaptive coping strategies such as mindfulness meditation interventions can also help reduce stress by cultivating feelings of calm (Brown & Ryan, 2003). Although the literature is still sparse in regard to the specific function of calm for stress recovery, there is potential for calm to play an important role in buffering stress. Based on prior evidence, it would be expected that higher levels of NA and lower levels of PA would be associated with slower physiological and psychological recovery from a stressful experience. Additionally, calm may be a particularly beneficial component of PA that can influence stress recovery.

Cognitive Behavioral Interventions. If one wants to take a more active approach to overcoming their stress, then it might be desirable to engage in specifically designed interventions. A number of cognitive and behavioral coping strategies have been used as interventions to help buffer acute stress (e.g., Goldenberg et al., 1994), and these strategies likely hold the most promise for actively overcoming the negative effects of stress. One effective cognitive and behavioral method is to monitor and increase one's heart rate variability (HRV) through biofeedback training (Moss, 2004).. HRV is an index of beat-to-beat changes in heart rate (HR) and indicates the autonomic activity of heart function, which regulates the balance between the parasympathetic and sympathetic nervous systems (Lacey & Lacey, 1978). HRV is a well-established proxy for physiological stress, and is inversely related to HR (Liew, Seera, Loo, Lim, & Kubota, 2016). When undergoing a stressor, HR often spikes and HRV drops. However, a healthier and more adaptive response to stress would be for an individual to exhibit higher HRV. This is because greater fluctuations in heart rhythm (higher HRV) indicate greater adaptability to physiological needs than fewer fluctuations (lower HRV; Lehrer & Gevirtz, 2014). High resting HRV is considered a protective factor and is associated with good health and well-being (Karemaker & Lie, 2000). Low resting HRV has numerous negative implications for long-term health outcomes, such as increased risk for mortality and morbidity (Del Pozo, Gevirtz, Scher, & Guarneri, 2004; Kleiger, Miller, Bigger, & Moss, 1987).

Interventions that teach HRV biofeedback (HRVB) instruct individuals to recognize the patterns of their HR by monitoring visual feedback displays of cardiovascular change and subsequently trying to alter their physiology with the goal of increasing HRV (Moss, 2004). Paying attention to the patterns of their HR rhythms and consciously attempting to alter their physiological activity through exercises such as deep breathing gives an individual a certain degree of control over their HRV. It would be ideal for an HRVB user to increase their HRV to induce a state of calm and relaxation while attempting to recover from stress. HRVB produces its beneficial effects throughout multiple pathways, but is most effective when deep breathing is involved (Hassett et al., 2007; Nolan et al., 2005). There are many ways that one can attempt to increase their HRV (e.g., progressive muscle relaxation, meditation), but research demonstrates that breathing alterations may be the most critical component of using HRVB to reduce stress responses (e.g., Lehrer & Gevirtz, 2014; Wells, Outhred, Heathers, Quintana, & Kemp, 2012). HRVB training usually involves purposefully slowing down one's breathing rate to specific frequencies that increase the amplitude of HRV. Taking about 5-6 breaths per minute can synchronize breathing rate and HR, which means that HR rises and falls at the same time that we inhale and exhale (Lehrer, 2013). Aligning the wave peaks of respiration rate with the peaks of HR creates a resonant frequency. When we breathe at this resonant frequency, the amplitude of HRV is maximized, which indicates higher HRV (Vaschillo, Lehrer, Rishe, & Konstantinov, 2002). Thus, deep breathing at a specific frequency is a promising strategy for influencing HR and recovering effectively from a stressor.

The beneficial effects that stem from HRVB are likely a combination of two factors related to breathing: magnification of the gas exchange effects of respiratory sinus arrhythmia (RSA) and stimulation of the baroreflex. RSA is an index of the corresponding oscillations of HR and breathing frequency. It is often simply summarized as the effect of breathing on HR and is sometimes equated with high frequency HRV (Lehrer & Gevitz, 2014). Because it is controlled by the vagus nerve, and subsequently linked with the parasympathetic nervous system, RSA is high during relaxed states and low during stressful states (Bernston, Quigley, & Lozano, 2007). RSA plays an important regulatory role in the flow of oxygen from the lungs to the heart (i.e., gas exchange), as noted by increased HR when oxygen is rich in the lungs (Lehrer & Gevitz, 2014). Breathing patterns marked by longer exhalations and overall slower respiration increase RSA (Strauss-Blasche et al., 2000). This increase in RSA is due to deep breathing, and the corresponding synchronization of breathing and HR is one reason why RSA prompts increases in HRV. In addition, deep breathing also stimulates the baroreflex (a mechanism that regulates blood pressure). When respiration is slow, the baroreflex triggers a reduction in blood pressure and HR. In this way, baroreflex stimulation further increases HRV (Vaschillo et al., 2002). To summarize, when one breathes at this resonant frequency, RSA increases, gas exchange functions more efficiently, the baroreflex is stimulated, and HRV is ultimately amplified (Lehrer & Gevitz, 2014).

Training in HRVB has been shown to be effective across a wide range of domains (see review by Gevirtz, 2013). Long-term training in HRVB can reduce symptoms related to specific diseases, such as fibromyalgia (Hasset et al, 2007), asthma (Lehrer et al., 2004), and PTSD

(Zucker, Samuelson, Muench, Greenberg, & Gevirtz, 2009). In regard to stress, short-term interventions of HRVB can also provide physiological benefits (Wheat & Larkin, 2010). Undergoing a 10-minute HRVB training session has been shown to increase HRV and improve cognitive outcomes on a stressful performance task (Prinsloo et al., 2011). When anticipating psychosocial stress, HRVB training can help control physiological arousal and reduce anxiety (Wells et al., 2012). In many cases, cardiovascular reactivity but not recovery is influenced by HRVB (Whited, Larkin, & Whited, 2014). In fact, there are only two studies to my knowledge that have investigated the effects of biofeedback training on acute stress recovery. In one instance, participants who used a skin conductance biofeedback device had lower HR and perceived stress during recovery than those in the control condition (Dillon, Kelly, Robertson, & Robertson, 2016). In another study, participants who underwent HRVB training displayed significant increases in HRV after being exposed to a physical stressor compared to those in the control group (Nolan et al., 2005). So although HRVB holds potential for buffering stress, there is a gap in the literature about whether it can alter stress recovery. This is an important area to consider because using HRVB after experiencing a stressor may be the most realistic way in which someone may utilize this type of intervention.

How smartphones may influence stress recovery

Phone presence. When phones are merely present, they may be able to aid in stress recovery by providing distraction or perceived social support. Previous research has shown that mere presence of a phone is distracting (e.g., Panova & Lleras, 2016; Ward, Duke, Gneezy, & Bos, 2017). The smartphone's symbolic pull occupies our limited cognitive resources and leads to a sort of "brain drain" that causes us to be distracted from other salient stimuli (Ward et al., 2017). Distraction induced by smartphones has usually been viewed as detrimental because of its negative effects on the dynamics of romantic relationships (Roberts & David, 2016), the quality of social interactions (Misra et al., 2014; Przybylski & Weinstein, 2012), and important tasks such as driving (Horrey & Wickens, 2006). However, what if the contextual circumstances are undesirable and an individual actually wants to be distracted from the situation at hand? For example, distraction can be beneficial when we are faced with a stressful situation (McCaul & Malott, 1984). As mentioned earlier, being distracted after undergoing a stressful experience can help an individual avoid rumination and recover more effectively. It is therefore plausible to assume that if an individual is recovering from an acute stressor, the presence of a smartphone may induce distraction, help avoid rumination, and alleviate stress. This assumption about how the distracting presence of a phone may influence stress has been tested in at least two contexts to demonstrate that the mere presence of a phone can indeed buffer stress. When faced with an anxiety-inducing situation, smartphones can be relied upon as "security blankets" that aid in emotional coping and reduce feelings of anxiety by providing distraction (Panova & Lleras, 2016). In addition, simply having a smartphone at your side has been shown to lessen the negative psychological and physiological impacts of being socially excluded. In that scenario, the presence of a phone exerted its beneficial effects during the recovery period (Hunter et al., 2018). Thus, the distraction caused by a smartphone's presence may provide assistance to deal with a stressor.

Furthermore, the mere presence of a smartphone has been shown to activate representations of social connections because it is a tool by which we can connect with our social networks (e.g., Misra, Cheng, Genevie, & Yuan, 2014; Przybylski & Weinstein, 2012). Even when we are not using the phone to engage in communication with family or friends, the phone itself represents a symbolic medium by which we can do those things to contact our social networks. If the presence of a phone makes us perceive that our social connections are easily accessible, then those perceptions of support may be leveraged to aid in stress-buffering. This type of symbolic support gleaning may be particularly beneficial because passively perceived social support has been shown to be the most effective form of support for stress-alleviation (Brown, Nesse, Vinokur, & Smith, 2003). The mere presence of a smartphone may provide comfort and security stemming from the perception of social support, but not lead to the negative consequences often associated with visible and received social support. If the simple presence of a smartphone can effectively elicit feelings of perceived support, it may be a more appropriate and effective approach than actually engaging with social support systems on social media or text. Just as receiving in-person social support can sometimes lead to undesirable outcomes, actually undertaking social activities on a smartphone can also be associated with poorer well-being (Przybylski, Murayama, Dehaan, & Gladwell, 2013; Verduyn et al., 2015). Therefore, just perceiving support from a smartphone but not actually engaging with social activities on the device may benefit stress recovery. By providing distraction and/or perceived social support, the mere presence of a smartphone may aid in stress recovery by serving as a digital security blanket (Hunter et al., 2018). Thus, it is important to investigate how merely having a smartphone in one’s presence may alleviate stress.

Phone use. When phones are used naturally in the context of stress, they not only potentially activate those same perceptions of social support and distraction, but also provide additional opportunities for activities. Smartphone users may play games, watch videos, browse websites, or engage in a wide variety of other activities that may influence stress recovery. However, according to my own research (Hunter et al., 2018) and large scale surveys (Perrin &

Anderson, 2019), the most common ways to use phones are to interact on social media applications or text with friends and family. So for the purposes of this study, I will focus on social actions that are likely to be undertaken by smartphone users while recovering from stress. There are many different potentially positive and negative ways in which someone can socially interact via text or social media. When texting or using social media, it is quite common for individuals to receive social support or passively use social media, and these behaviors in turn impact affective well-being and, ultimately, stress. However, it is unclear if these additional social activities are beneficial or detrimental for stress.

The communication functionality of a phone provides myriad opportunities for garnering social support. Smartphone users are able to foster social relationships through engagement with a variety of communication mediums and connect with an array of others outside of their immediate place-based environments. Research has shown that we are better able to integrate into new social environments (DeAndrea, Ellison, LaRose, Steinfield, & Fiore, 2012), make new friends (Burke, Marlow, & Lento, 2010; Ellison, Steinfield, & Lampe, 2007), and strengthen our current bonds (Jin, Borae, Park, 2010; Wei & Lo, 2006) because of social media and other technological communication channels. Social support from online chatrooms and forums has been shown to provide benefits for various groups, such as those with breast cancer (Fogel, Albert, Schnabel, Ditkoff, & Neugut, 2002) and diabetes (Barrera, Glasgow, McKay, Boles & Feil, 2002). Users can draw on the sheer number of possibilities for social communication to provide a fertile ground for receiving social support. This social support may in turn help provide resources that allow someone to quickly recover from stress. But is the receipt of this type of social support always beneficial, and how might it influence stress recovery?

Text messaging in particular has mixed effects on psychological and physiological well-being. In some instances, social support gleaned via text message has been shown to buffer cardiovascular responses to stress in females (Hooker et al., 2018). However, research about text messaging in general paints a more dire picture about its effects on well-being. The act of sending and receiving text messages can increase physiological indicators of stress such as HR, respiration, and skin conductance (Lin & Peper, 2009). The number of text messages sent and/or received per day is positively associated with percieved stress in females (Thomee, Gustafsson, & Nilsson, 2007). Several studies have also established a link between text-messaging and higher levels of anxiety (Lepp, Barkley, & Karpinski, 2014; Reid & Reid, 2007) and other adverse psychosocial outcomes (Rosen, Whaling, Rab, Carrier, & Cheever, 2013). Thus, while interacting with others via text message may be helpful through the provision of social resources, there are likely many negative consequences associated with this social smartphone action. It is unclear exactly why texting is associated with these negative outcomes, but it may have to do with convoluted effects of received social support. As discussed earlier, certain types of received social support can contribute to undesirable affective and health outcomes (Brooks & Schetter, 2011). Thus, texting with others and receiving social support may or may not benefit stress recovery.

The support gained from social media may also be good or bad depending on the nature of the interaction. Overall, excessive use of social media is associated with high levels of psychological stress (Fox & Moreland, 2015), but this association is quite complex and depends on various factors. Conflicting evidence has shown that using social media sites such as Facebook can provide social resources that sometimes help buffer acute stress (Rus & Tiemensma, 2018), but at other times fail to do so (Rus & Tiemensma, 2017). This discrepancy may be due to the way in which someone uses social media. Passive social media use (i.e., scrolling through your feed) is the most common way to engage on a social media platform and is associated with negative affective well-being (Verduyn et al., 2015). The detriments to affective well-being may be caused by the user engaging in upward social comparisons or having feelings of Fear of Missing Out (FOMO) that harm perceptions of self-image (Przybylski et al., 2013). So, using social media passively may provide no benefits (and potential detriments) in regard to stress reduction.

These inconsistencies in how phone use influences stress underscore the fact that the ways in which we commonly interact with our devices are not neccesarily benefical for stress. In fact, when looked at more broadly, greater use of smartphones is associated with higher levels of physiological stress (assessed via cortisol awakening response) in daily life (Afifi, Zamanzadeh, Harrison, & Acevedo, 2018). Therefore, we can infer that doing certain social acts on your smartphone such as receiving social support or passively using social media may actually be a hindrance to overcoming stress. But why might these types of social smartphone acts lead to undesirable outcomes?

When considering how smartphone use may influence stress recovery, prior research would suggest that receiving social support and passively using social media on one's phone may prompt negative emotional states that ultimately impact stress recovery. Passive social media use (Verduyn et al., 2015) and received social support (Brooks & Schetter, 2011) have both been associated with higher NA and lower PA. This may be due to the feelings of social evaluation, incompetence, or other negative emotions that are prompted from those social experiences that can, in turn, influence stress recovery. Specifically, it would be expected that a greater degree of passive social media use and received social support would lead to higher NA and lower PA.

That state of emotional well-being (i.e., high NA and low PA) should be associated with slower physiological and psychological recovery from a stressful experience. Thus, it may be interesting to experimentally explore whether those aforementioned social activities on one's phone (i.e., passively using social media and receiving social support) are associated with changes in affect that ultimately impact stress recovery. Establishing the role of those social phone activities and affective mechanisms can help determine whether using a phone produces benefits or drawbacks beyond simply having a phone present.

Using mobile health applications on a phone. As discussed above, research has demonstrated that using one's smartphone can exert varying influences on stress depending on how and when the device is used. Therefore, if we hope to highlight the most effective way to use a phone to reduce stress, it may be prudent to go beyond natural phone use habits and instead focus on guided applications that are specifically designed to reduce stress. Fortunately, many mobile health (mHealth) applications have emerged that provide guided activities aimed specifically at reducing stress (Fiordelli, Diviani, & Schulz, 2013). mHealth applications can exploit the technological affordances (e.g., phone sensors, interactive displays) and draw on the ubiquity of smartphones in everyday life to deliver engaging interventions that can be used whenever and wherever most desired. By combining evidence-based stress-reduction techniques with an engaging and ever-present medium, mHealth applications on smartphones hold great promise for mitigating the negative effects of stress.

As discussed in the section above, HRVB is one type of intervention that could effectively aid in stress recovery. Drawing on the technological affordances of smartphones, HRVB can be translated into the digital medium and delivered to individuals faced with acute stress. The delivery of this HRVB training through a smartphone application provides many advantages over traditional training. Other HRVB training session protocols need many weeks to undertake (e.g., Gervitz, 2013) and require bulky and expensive equipment that must be used within a laboratory setting (e.g., Wells, Outhred, Heathers, Quintana, & Kemp, 2012). One study used smartphones to administer biofeedback training and partially avoided these potential issues, but they still required participants to wear external cardiovascular monitoring equipment (Dillon et al., 2016). Most HRVB interventions have either been conducted over a long period of time leading up to the onset of an acute stressor task (e.g., Wheeler & Wheeler, 2017) or require a lengthy session of use in order to reap the benefits (Laurie & Blandford, 2016). Smartphone applications may be able to overcome these barriers because they can be quick to administer, portable (therefore can be used almost anywhere at any time), and have all the hardware and software integrated into a single device. Furthermore, the pleasing interfaces that could be designed on a smartphone are likely more engaging than simply watching direct psychophysiological output data on a screen. App developers can take advantage of mobile technology affordances to package an HRVB product in a way that should allow it to be used across a variety of contexts whenever an individual is faced with a stressor.

How might an HRVB training application provide benefits when recovering from stress? HRVB targets HRV, an indicator of parasympathetic nervous system activity (Lehrer & Gevirtz, 2014). Consequently, undergoing HRVB training should increase parasympathetic activity during recovery. Increased parasympathetic activity is usually accompanied by decreased sympathetic activity. Therefore, it would be expected that those who undergo HRVB training would have steep recovery trajectories for measures of sympathetic activity (i.e., sAA). Beyond the physiological alterations induced by HRV, what psychological factors may play an indirect role? When our parasympathetic nervous system is activated, we tend to relax psychologically and physiologically. Indeed, parasympathetic activity (e.g., HRV) has been associated with increases in positively valenced/low arousal emotions such as calm (Lehrer & Gevirtz, 2014; Porges, 2001). These psychophysiological connections between HRV and calm make this an interesting pathway to explore in relation to stress reduction. If individuals feel calmer after HRVB training, then it is likely that their psychological and physiological stress will also concurrently be reduced. As discussed earlier, greater feelings of calm should lead to quicker psychological and physiological recovery. When considering how smartphone usage would influence calm, it would be expected that HRVB training should induce more feelings of calm than aimlessly using a phone or merely having a phone present. Therefore, it would be prudent to determine if an HRVB application provides additional benefits beyond having or using your phone by inducing feelings of calm.

One example of a HRVB application. Happify is one exemplar mHealth application that provides guided activities aimed at reducing stress. Happify is representative of various aspects of other mHealth applications because it draws on multiple aspects of the rich possibilities of smartphone technological capabilities (e.g., photoplethysmography, visual and audio components, engaging interface) and incorporates empirically validated strategies to deliver training in a self-contained package. Within the Happify suite of activities, the Breather function delivers HRVB training. By undergoing a five-minute guided session on Breather, users may be able to calm their autonomic nervous system activity and recover effectively from a stressful experience.

Users of Breather simply place their index finger over the camera of their iPhone to generate HRV observations (see Figure 1). The light from the camera uses photoplethysmography techniques to measure blood volume changes within the finger. This process relies on measuring changes in light absorption on the skin of the finger. Algorithms programmed by Happify software engineers then transform that data into a simple signal that is visible to the user. After calibrating to the heart rate of the individual, a circular meter appears and directs the individual to follow the breathing patterns on screen (see Figure 2). The meter directs the individual to breath in for four seconds, and then out for six seconds. This 10-second breathing cycle is ideal for creating a resonant frequency that should maximize HRV amplitude (Vaschillo et al., 2002).

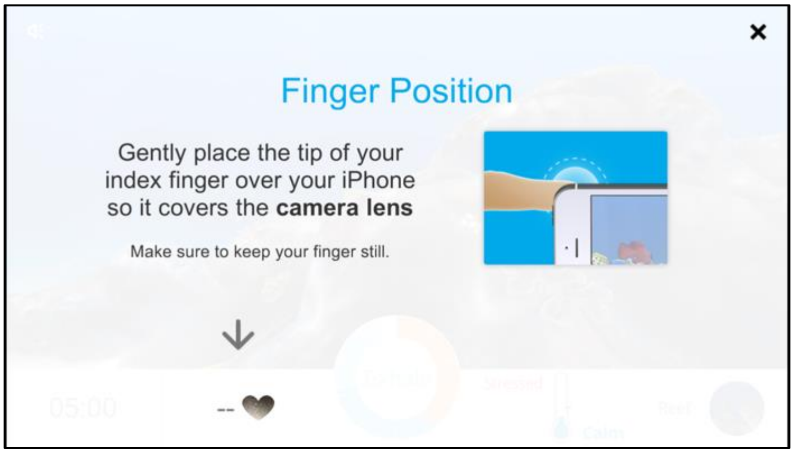

Figure 1. On-screen instructions for finger placement to obtain HRV measurement.

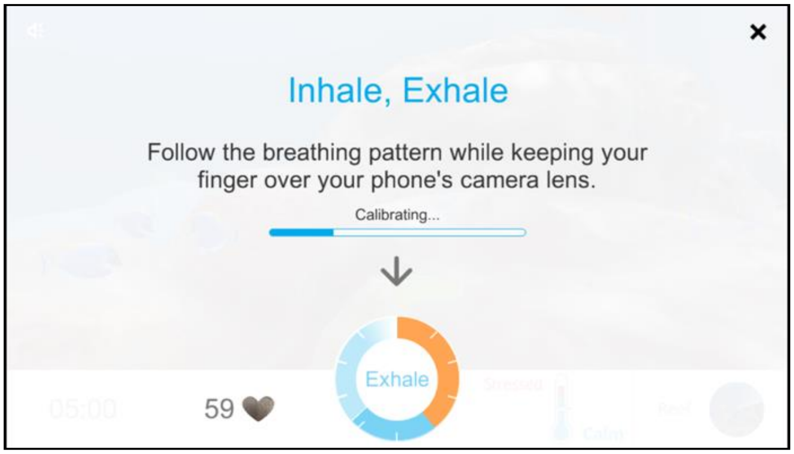

Figure 2. On-screen instructions for calibrating breathing guidance.

After calibration is complete, the interface will change and become a calming natural scene (e.g., underwater coral bed, tropical beach, pristine mountaintops). The user will then follow along an immersive journey through the natural environment while they continue to breathe along with the meter (see Figure 3). As they breathe deeply, their HRV should begin to increase. When this happens, the natural environment scene starts to change correspondingly. As they become physiologically calmer, the scene becomes more complex and beautiful (e.g., coral polyps bloom, flowers grow). The amount of change in the scene is based on how well the individual is altering their HRV. By visually monitoring the changes in the scene, individuals are undergoing HRVB. Monitoring the changes in the scene is analogous to how individuals monitor electrocardiogram signals in more traditional "non-gamified" HRVB trainings. If the individuals adhere to the directions properly, five minutes of using Breather should increase HRV and reduce stress.

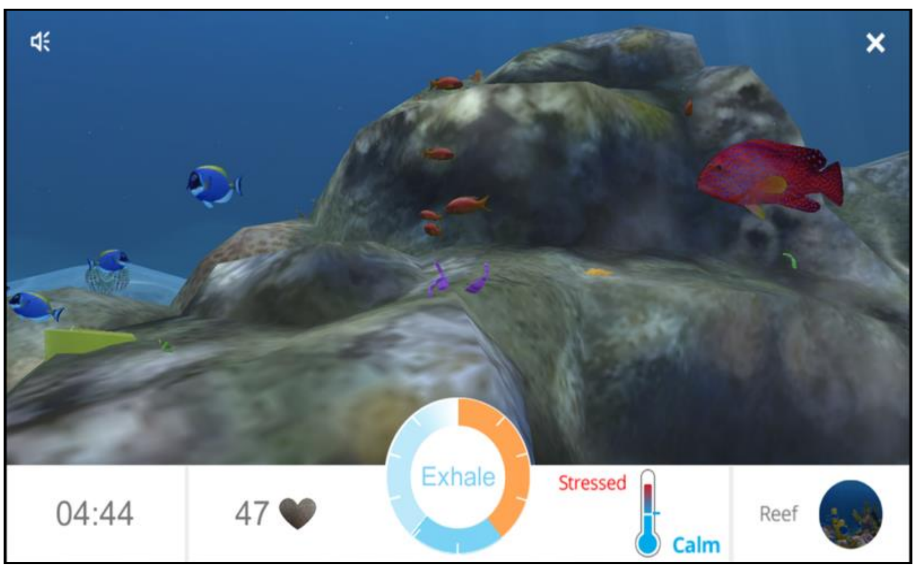

*Figure 3***.** Example of display when an individual is using Breather.

Current study

The overall aim of this dissertation is to fill important gaps in the literature about how smartphones influence stress recovery. This study is the first empirical investigation to compare several ecologically valid ways in which smartphones can be used following a stressful experience. This is important because there are a myriad of ways that smartphones can be used in the context of stress, and it may be that something as simple as having your phone in your presence is sufficient to provide the same benefits that a complex app might provide. This dissertation will also add a novel contribution to the literature by exploring potential mechanisms for how various ways of using a smartphone may influence stress recovery. This information will help us understand the complexities about how smartphones influence psychological and, ultimately, physiological outcomes. The inclusion of sAA as a physiological stress outcome provides a more comprehensive assessment of stress recovery than simply measuring self-reported stress, and sAA is a particularly apt biomarker to assess in this context because previous research (i.e., Hunter et al., 2018) has demonstrated links between smartphones and sAA recovery. Furthermore, this study will also be one of the first to investigate how social support gleaned via a smartphone influences stress recovery by examining the differing effects of perceived and received social support. Very few studies have focused on the role of social support during the stress recovery period, so the focus of this dissertation on stress recovery is also rather unique. Additionally, considering the mechanisms for how a smartphone may symbolically provide perceived social support in the context of stress recovery may shed light on previous findings about the stress-buffering effects of mere smartphone presence. Finally, this dissertation will also provide new evidence about the effects of HRVB. No previous studies have examined the effects of HRVB delivered via a smartphone application, and no previous studies have examined the effects of HRVB on salivary biomarkers of stress such as sAA. Furthermore, very few studies have investigated how HRVB training during a recovery period may influence stress recovery trajectories. The contributions of this dissertation will add to the literature in the fields of health psychology, social psychology, and the relatively new field of the psychology of technology.

This dissertation explores to what extent specific strategies may influence stress recovery through a series of planned comparisons. The additive approach of examining a priori comparisons between conditions allows me to focus on specific theoretical mechanisms that may be responsible for advantages that each type of phone interaction can provide. The benefits of phone presence compared to not having a phone at all are examined, and the role of perceived social support and distraction are considered as mediators. The differential effects of having a phone present and actually using a phone are also compared. The degree to which individuals passively use social media and receive social support while using their phones may drive changes in affect; thus, NA and PA levels are considered as mediators to explain how phone use influences stress recovery. Finally, using a phone in a guided manner that directs individuals to engage with a HRVB stress-reducing application is compared to other ways of using a phone, and calm is considered as a mediating factor. Knowing how these conditions perform is a critical step in a deeper understanding of why smartphones might be good for us in times of stress, which may inform future interventions.

Aims and hypotheses

Aim 1: To determine whether smartphone presence provides stress-reducing benefits compared to not having a smartphone.

Hypothesis 1: Individuals in the phone present condition will have a steeper sAA recovery trajectory and less self-reported stress than those in the no phone condition.

Aim 1a: To explore the mechanisms for why these groups may differ.

Hypothesis 2: Those in the phone present condition will report higher levels of perceived social support and distraction than those in the no phone condition.

Hypothesis 3: Perceived social support and distraction will mediate the association between phone condition and stress for the no phone and phone present conditions.

Aim 2: To determine whether using a smartphone provides additional stress-reducing benefits beyond merely having a smartphone present.

Hypothesis 4: Individuals in the phone present condition will have a steeper sAA recovery trajectory and less self-reported stress than those in the phone use condition.

Aim 2a: To determine if those in the phone use condition vary in their recovery depending on which social activities are utilized on a phone.

Hypothesis 5: Individuals in the phone use condition who have a lower degree of received social support will have a steeper sAA recovery trajectory and less self-reported stress than those who have a higher degree of received social support.

Hypothesis 5a: Received social support will be correlated with affect, whereby a higher degree of received social support will be associated with higher NA and lower PA.

Hypothesis 6: Individuals in the phone use condition who have a lower degree of passive social media use will have a steeper sAA recovery trajectory and less self-reported stress than those who have a higher degree of passive social media use.

Hypothesis 6a: Passive social media use will be correlated with affect, whereby the degree of passive social media use will be associated with higher NA and lower PA.

Aim 2b: To explore the mechanisms for why these groups may differ.

Hypothesis 7: Those in the phone present condition will report higher levels of PA and lower levels of NA than those in the phone use condition.

Hypothesis 8: Affect will mediate the relationship between phone condition and stress for the phone use and phone present conditions.

Aim 3: To determine whether using a guided skills training application on a smartphone provides additional benefits beyond using a smartphone naturally or merely having a smartphone present.

Hypothesis 9: Individuals in the guided phone use condition will have a steeper sAA recovery trajectory and less self-reported stress than those in the other conditions.

Aim 3a: To determine the mechanism for why these groups may differ.

Hypothesis 10: Those in the guided phone use condition will self-report greater feelings of calm than those in the other conditions.

Hypothesis 11: Feelings of calm will mediate the association between phone condition and stress.

Method

Participants. The study was approved by the University of California, Irvine (UCI) Institutional Review Board, and participants were recruited via the UCI undergraduate psychology subject pool. An a prior power analyses indicated that I needed to have 179 participants to have 80% power for detecting a medium sized effect at the .05 criterion for statistical significance. A total of 184 participants completed the study (M_{age} = 20.37, *SD* = 3.02; 77.7% female; 45.7% Asian; 28.3% Hispanic/Latino; 16.8% Caucasian). Participants were screened for eligibility and excluded from participation if they were diagnosed with a cardiovascular disease, were regularly taking mood altering or cardiovascular altering medication, regularly smoked cigarettes, were not fluent in English, or did not have an iPhone. All participants were UCI students and consented to participate. Data collection took place from July 2018 through February 2019.

Procedures. Participants underwent an approximately 90-minute laboratory session. Phones of all participants were confiscated at the beginning of the study under the pretext of measuring the external physical properties of the phone, which allowed the experimenter to later manipulate the phone conditions without arousing suspicion and ensure that all participants experienced similar circumstances of having their phone taken away. Participants were randomized to condition beforehand using a random number generator. For participants randomly assigned to the **guided phone use** condition, the Happify application was installed on their phone and the experimenter guided them through the calibration settings of the Breather function. This process only took a few minutes, and all efforts were made to conceal any information that would have given the participants a hint that the app was supposed to reduce stress. Participants in the other conditions filled out extra surveys during this time. After participants completed a series of questionnaires and acclimated to the laboratory environment (approximately 25 minutes), the experimenter returned to the laboratory room and collected a baseline saliva sample. Participants were instructed in the passive drool technique of collecting their own saliva sample.

The participants then underwent a modified version of the TSST (Kirschbaum et al., 1993) to induce moderate psychological and physiological stress. The TSST consisted of three stages. In the anticipatory stage, two interviewers entered the room and instructed the participant to prepare for a performance task. Specifically, participants were instructed that they would need to deliver a speech about why they are a strong candidate for a leadership position. Participants were told that the interviewers (and evaluators who would watch the video at a later time) were trained in rhetoric and public speaking and would evaluate the style, eloquence, and overall quality of presentation in addition to the content of the speech. One interviewer then gave the participant a piece of paper and a pen and told them that they had two minutes to prepare. After the two-minute preparation time had elapsed, one of the interviewers took away the paper with the participant's notes on it and the second phase began. For the second stage, the participant stood in front of a camera and the panel of interviewers and delivered a three-minute speech explaining why he or she was the ideal candidate for the position. Throughout the speech, the interviewers maintained neutral facial expressions and offered critically evaluative suggestions (e.g., *"use more eye contact," "speak louder," "continue speaking for the duration of the session"*). Immediately after the speech was concluded, the third stage began. In this arithmetic phase, participants were asked to count backwards by 13s starting at 1,022. Again, the interviewers maintained neutral facial expressions and offered critically evaluative suggestions.

If the participant made a mistake, they were asked to start again at the beginning. The TSST has been shown to be a valid and reliable instrument for inducing moderately strong physiological and psychological stress responses (Hellhammer & Schubert, 2012).

Immediately after the conclusion of the TSST, participants collected another saliva sample and self-reported their feelings of stress. For the next five minutes, participants were left alone in the room and used or did not use their phone in a particular way depending on condition. Those in the **no phone** condition did not have their phone returned and were told to sit quietly for the next five minutes while the next portion of the study was prepared. Those in the **phone present** condition were given their phone but told, "Please do not use your phone for the remainder of the study." Those in the **phone use** condition were given their phone and told, "Please feel free to use your phone as you normally would." Those in the **guided phone use** condition were told to open the Happify application, navigate to Breather, and, "Follow the instructions on the application." After the five-minute phone manipulation period, the researcher returned back to the room and instructed the participant to continue answering a series of questionnaires. Self-reported PA, NA, distraction, calm, and perceived social support were collected at this time. In addition, participants in the phone use condition answered follow-up questions about the ways in which they use their smartphone during the manipulation period. Twenty minutes after the completion of the TSST, a third saliva sample was collected. At the conclusion the study, the researcher and both interviewers debriefed the participant.

Measures.

Demographics and Covariates. Demographic information and potential covariates, including age, sex, ethnicity, subjective socioeconomic status via the MacArthur Scale of Subjective Social Status (Adler & Stewart, 2007), perceived psychological stress via the

Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983), measures of daily phone use via the Mobile Phone Involvement Questionnaire (Walsh, White, & Young, 2010), the Modified-Media & Technology Use and Attitudes Scale (Rosen, Whaling, Carrier, Cheever, & Rokkum, 2013), time since waking, caffeine intake, and pre-manipulation values of calm, NA, PA, distraction, and perceived social support were collected via self-report.

Self-Reported Stress. To assess psychological stress, participants were asked to indicate, "How stressed do you feel right now?" on a visual analog scale from 0 (not at all)-100 (extremely). This simple one-item scale has been shown to be valid and reliable for assessing perceptions of acute stress (Lesage, Berjot, & Deschamps, 2012). Self-reported stress was assessed at three time points (baseline, post-TSST, +20 minutes recovery). The dependent variable of interest, stress recovery, was assessed by considering the change from post-TSST to +20 minute recovery. In addition, baseline self-reported stress was controlled for in all analyses examining self-reported stress recovery.

Physiological Stress Responses. Salivary alpha amylase (sAA) was collected using the passive drool technique with polypropylene cryovial salivettes at three time points over the course of the study to assess physiological responses. Three samples were assayed for sAA to capture measures of baseline, post-TSST, and +20 minute recovery time points. Experimental sessions were conducted in the afternoon (between 1:00-6:00pm) to account for the diurnal rhythm of sAA.

Salivettes were stored at -80°C until batch analysis at the end of data collection at the laboratory of the Institute for Interdisciplinary Salivary Bioscience Research (University of California Irvine, Irvine, CA). Before assaying, the samples were thawed for an hour to return to room temperature. Samples of sAA were tested in duplicate using a commercially available kinetic enzyme reaction assay kit (Salimetrics, LLC; State College, PA). The assay range of sensitivity was 0.4 to 400 U/mL and the average intra-assay coefficient of variation was 3.3.%.

Self-reported affect. Self-reported PA and NA was assessed at two time points during the study (baseline, recovery). The recovery assessment was immediately after the completion of the phone manipulation period. In order to capture differences in valence and arousal of affect, participants completed the State Adjective Questionnaire (SAQ; Cohen, Doyle, Turner, Alper, & Skoner, 2003) and self-reported the extent to which each item reflects how they feel "at the moment" from 0 (not at all accurate) to 4 (extremely accurate). PA is a composite of the items pleased, active, calm, cheerful, energetic, full of pep, enthusiastic, happy, at ease, lively, quiet, and relaxed. NA is a composite of the items anxious, bored, drowsy, intense, jittery, nervous, overwhelmed, passive, sad, stressed, tired, and unhappy. This scale reliably captures arousal and valence components of affective states (Usala & Hertzog, 1989).

Distraction. A single-item question was used to assess perceived distraction. This question was added to the pre and post version of the SAQ. Participants self-reported the extent to which the item reflected how they feel "at the moment" from 0 (not at all accurate) to 4 (extremely accurate). Distraction assessed during recovery was the primary variable of interest and baseline feelings of distraction was controlled for in analyses.

Calm. The variable calm was derived from the validated low arousal/positive valence subscale of the SAQ that is a composite of the items relaxed, calm, and at ease. Participants self-reported the extent to which the item reflected how they feel "at the moment" from 0 (not at all accurate) to 4 (extremely accurate). In this study, these items were reliably associated (α=.92). Although this was drawn from the PA subscale of the SAQ, it was considered as a separate variable from PA for theoretical purposes. Feelings of calm were assessed at the same baseline and recovery time points as the other SAQ metrics.

Perceived social support. This variable was also measured via modifications to the SAQ. Participants were assessed at two time points during the study (baseline, recovery). Participants self-reported the extent to which the items reflected how they feel "at the moment" from 0 (not at all accurate) to 4 (extremely accurate). Perceived social support was a composite of the items supported, consoled, cared for, comforted, included, and connected (α =.90). These items have been adapted from adjectives that are common in other social support scales such as the Interpersonal Social Evaluation List (Cohen, Mermelstein, Karmark, & Hoberman, 1985), Berlin Social Support Scale (Schwarzer & Schulz, 2000), and Sarason Social Support Questionnaire (Sarason & Sarason, 1991).

Received social support. Received social support was assessed by asking the participants to rate, "How much support (e.g., advice, help, information, expression of care or concern) did you receive from social media, texts or other sources on your phone over the last 5 minutes?" Answer choices included (1 = none, 2 = a little, 3 = some, 4 = a lot). This question was only asked for those in the phone use condition. More in-depth follow-up questions were also asked to determine the content and manner in which the support was received.

Passive social media use. Previous studies have operationalized passive social media use as how often individuals scroll through personal feeds, look at friends' feeds, or look at public account feeds (e.g., Verduyn, 2015). For the purposes of our study, we have adapted these items to focus on the time period of the brief phone manipulation period following the stressor. Participants were asked to rate if they used social media. If they answered yes, then they were asked "to rate what percentage of their time during the last 5 minutes (on a sliding scale from

0%-100%) they scrolled through their personal feed, looked at their friends' feeds, or looked at public account feeds." This question was only asked for those in the phone use condition.

Analytic Strategy. All dependent variables (self-reported stress and sAA) were checked for skewness and kurtosis and transformed accordingly. No transformation was performed for values of self-reported stress. Values of sAA were moderately skewed and a square root transformation was used to transform the values to approximate a normal distribution. Outlying values above or below three standard deviations from the mean were assessed and removed if deemed appropriate. No outliers were removed for self-reported stress and 11 outliers (1.9%) were removed for sAA. A sensitivity analysis revealed the pattern of results remained the same with or without the outliers included.

Main effects. Independent sample *t*-tests were used to conduct the manipulation check and ensure that exposure to the TSST reliably increased self-reported stress and sAA from baseline (time 1) to post-TSST stress (time 2). A repeated-measures analysis of covariance (ANCOVA) was used to analyze the effect of condition on each dependent variable. Since the phone manipulation occurred after the TSST, analyses focused on differences in recovery and therefore used post-TSST stress (time 2) and +20 minutes recovery (time 3) as the within-subject factors. The slope of recovery (difference between time 3 and time 2) will be referred to as "recovery" for the remainder of this dissertation. Randomized condition was inserted as the between-subject factor and appropriate covariates were controlled for depending on the outcome of interest (see section below). If a main effect of condition was found, post-hoc comparisons were conducted to examine specific differences between each condition.

Covariates. Various covariates were considered (see Measures section) and controlled for if associated with the dependent variables or mediators. Bivariate correlations were conducted between the potential continuous covariates and outcome variables of interest, and independent samples t-tests were used for categorical covariates and the dependent variables. If the associations were significant, then the covariate was included in the model. Baseline sAA was associated with recovery and was therefore controlled for in all sAA analyses. Baseline self-reported stress was associated with recovery and was therefore controlled for in self-reported stress analyses. For the mediation analyses, baseline values of each potential mediator (calm, NA, PA, distraction, and perceived social support) along with the appropriate baseline measure of stress were controlled for.

Type of phone use. Within the phone use group, analyses were conducted to determine how the manner in which a phone was used (i.e., passively using social media, receiving social support) was associated with sAA and self-reported stress recovery through the influence of affect. Linear regression was used to assess whether the degree of received social support was associated with sAA and self-reported stress recovery (controlling for baseline values) for those in the phone use group. In addition, linear regression was also used to assess whether the degree of passive social media use was associated with sAA and self-reported stress recovery (controlling for baseline values) in the phone use group. The individuals in the phone use group were the only participants who had the ability to receive social support or passively use social media, so this was not considered across conditions. However, those social actions were hypothesized to exert effects on PA and NA for phone users, which would drive affective differences between conditions. Thus, correlations were conducted between degree of received social support/passive social media use and affect (PA and NA were analyzed separately) to establish the association between social phone actions and affect. The affective differences potentially predicted by type of phone use were then compared between the phone use and phone present conditions using ANCOVA analyses. A description of how individuals in this condition chose to use their phone during the manipulation period is presented in Appendix A.

Mediation. Regression analyses were used to test for mediation based on the process suggested by Preacher & Hayes (2004). Distraction and perceived social support were considered as mediators to explain differences between the phone present and no phone conditions. NA and PA were considered as mediators to explain differences between the phone use and phone present conditions. Finally, feelings of calm were considered as a mediator to explain differences between the guided phone use and other conditions. The PROCESS macro Version 3 (Hayes, 2017) was used to conduct the mediation analyses in SPSS. The effects of each mediator on the association between smartphone condition and the dependent variables were separately examined. First, the association between phone condition and the mediator was examined (path a) and then the association between the mediator and the dependent variable was assessed (path b). The association between phone condition and the dependent variable (path c') was then examined while controlling for the mediator. Finally, the indirect coefficient (path ab) was examined to determine the effect of the mediator. Unstandardized beta coefficients are presented in the mediation figures to note the association between each of the variables.

Results

Adherence to assigned condition. All of the participants adhered to their assigned condition during the manipulation period. Those in the no phone condition did not have access to their phone, so no one used a phone during this time. Based on self-reported responses and researcher observations, nobody in the phone present condition used their phone during this time. According to self-reported responses, all of the participants in the phone use condition used their phone during the manipulation phase, however, some participants did not use it for the full five minute duration. The median minutes of use was five, but the mean number of minutes spent on the device was 4.22. User data provided through the Happify application indicated that participants in the guided phone use condition were correctly using the HRVB app (i.e., had their finger placed properly on the light sensor) for 96.17% of the time.

Mediating variables. See Table 1 for descriptives about the mediating variables of interest across condition.

Table 1. Unadjusted mean levels of potential mediating variables by condition

	No Phone (N=47)		Phone Present (N=43)		Phone Use (N=45)		Guided Phone Use (N=49)	
	Mean	*SE*	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*
Distraction[a]								
Baseline	1.69	.14	1.65	.14	1.63	.14	1.89	.14
Recovery	2.23	.16	2.23	.17	1.95	.17	1.98	.16
Perceived Social Support[a]								
Baseline	2.65	.14	2.47	.14	2.23	.14	2.62	.14
Recovery	1.80	.13	1.85	.13	1.71	.13	1.95	.13
PA[b]								
Baseline	2.61	.12	2.63	.12	2.37	.12	2.62	.11
Recovery	1.82	.11	1.99	.11	1.84	.11	2.00	.11
NA[b]								
Baseline	1.64	.07	1.58	.08	1.75	.08	1.68	.07
Recovery	2.09	.10	1.90	.10	2.01	.10	1.92	.10
Calm[c]								
Baseline	3.26	.14	3.26	.14	3.05	.14	3.07	.14
Recovery	1.98	.15	2.36	.15	2.15	.15	2.32	.14

Note. None of these variables significantly differ between conditions. In the mediation models, recovery values were considered as the mediating variables while adjusting for baseline values.
[a] Examined as a mediator for stress recovery differences between the no phone and phone present conditions
[b] Examined as a mediator for stress recovery differences between the phone present and phone use conditions
[c] Examined as a mediator for stress recovery differences between the guided phone use and other conditions

Manipulation check. Analysis of sAA from before the TSST (M = 86.00, SD = 60.13) to after the TSST (M = 128.85, SD = 87.85) revealed that participants displayed significant increases in sAA following the TSST, $t(362) = -5.43$, $p < .001$. In addition, analysis of self-reported stress from before the TSST (M = 24.02, SD = 22.11) to after the TSST (M = 47.68, SD = 29.44) revealed that participants displayed significant increases in self-reported stress following the TSST, $t(364) = -8.70$, $p < .001$.

Differences in sAA recovery between phone present condition and no phone condition (Hypothesis 1). Repeated measures ANCOVA analyses revealed that there were no significant differences in sAA recovery between the phone present and no phone conditions, $F(1,86) = .033$, $p = .86$, adjusting for baseline sAA (see Figure 4 and Table 2).

Table 2. Unadjusted mean levels of sAA for the no phone and phone present conditions

	No Phone			Phone Present		
	Mean	*SE*	*CI*	*Mean*	*SE*	*CI*
Baseline	91.62	8.27	[75.30, 107.94]	90.19	8.55	[73.31, 107.07]
Post-TSST	140.02	11.92	[116.50, 163.54]	140.03	12.33	[115.70, 164.36]
Recovery	99.65	7.79	[84.28, 115.02]	98.95	8.06	[83.05, 114.85]

SE=Standard Error
CI= 95% Confidence Interval

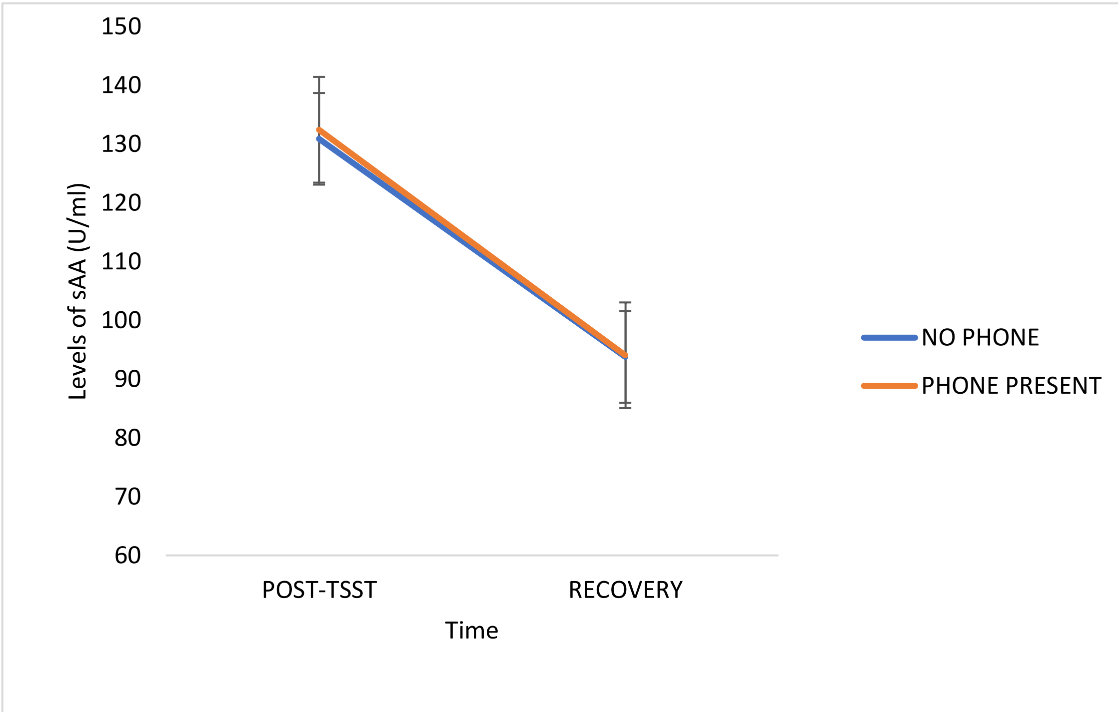

Figure 4. sAA recovery does not differ between the no phone and phone present conditions

Differences in self-reported stress recovery between phone present and no phone conditions (Hypothesis 1). Repeated measures ANCOVA analyses revealed that there were no significant differences in self-reported stress recovery between the phone present and no phone conditions, $F(1,85) = 2.68$, $p = .11$, adjusting for baseline self-reported stress (see Figure 5 and Table 3). Consistent with hypotheses, those in the phone present group reported lower stress during recovery, however, these differences were only approaching statistical significance.

Table 3. Unadjusted mean levels of self-reported stress for the no phone and phone present conditions

	No Phone			Phone Present		
	Mean	*SE*	*CI*	*Mean*	*SE*	*CI*
Baseline	24.73	3.25	[18.32, 31.14]	21.74	3.32	[15.19, 28.30]
Post-TSST	53.56	4.38	[44.91, 62.20]	42.28	4.48	[33.44, 51.12]
Recovery	39.44	3.79	[31.97, 46.92]	31.70	3.88	[24.05, 39.35]

SE=Standard Error
CI= 95% Confidence Interval

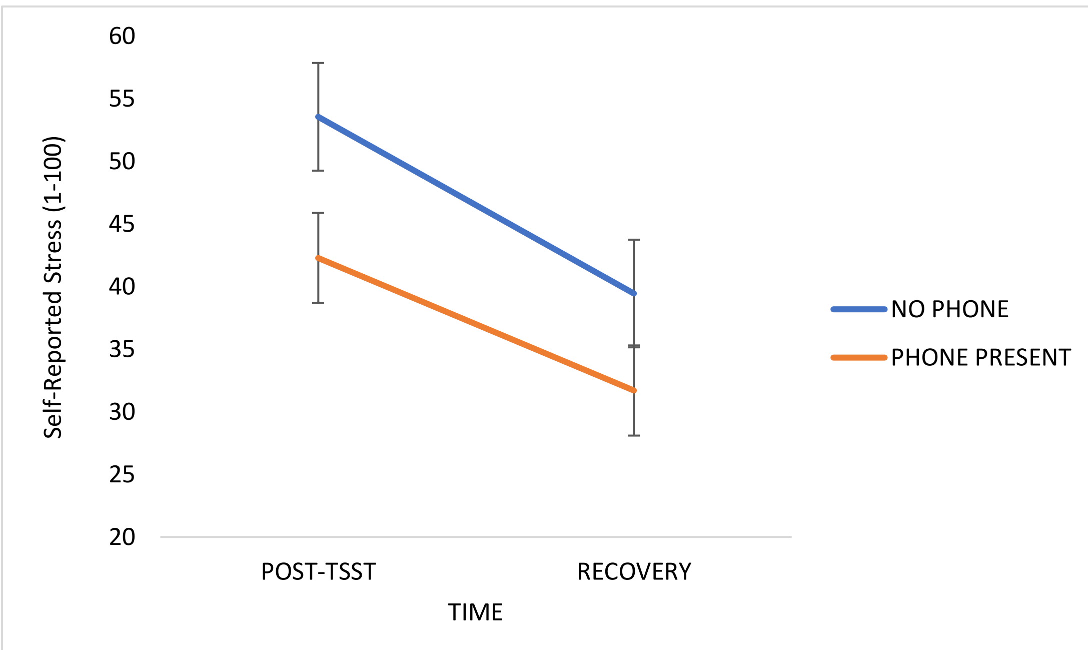

Figure 5. Self-reported stress recovery does not differ between the no phone and phone present conditions.

Differences in perceived social support and distraction between the phone present and no phone condition (Hypothesis 2). One-way ANCOVA analyses revealed no significant differences in feelings of distraction between the no phone (M = 2.23, SD = 1.61) and phone present (M = 2.23, SD = 1.65) groups, F(1,79) = .000, p = .99, while controlling for baseline feelings of distraction.

One-way ANCOVA analyses revealed that there were no significant differences in perceived social support between the no phone (*M* = 1.74, *SD* = .90) and phone present (*M* = 1.92, *SD* = .92) groups, *F*(1,79) = 1 .562, *p* = .22, while controlling for baseline feelings of distraction.

Distraction as a mediator between phone condition and sAA recovery (Hypothesis 3). Regression analysis was used to investigate the hypothesis that distraction mediates the effect of phone condition on sAA recovery. Baseline levels of distraction and sAA were controlled for in all analyses. Results indicated that phone condition did not predict sAA recovery, *B* = -.24, *SE* = .41, *p* = .56. Nonetheless, I continued with the mediation analyses to fully address the proposed hypothesis.

Results indicated that phone condition was not a significant predictor of distraction, *B* = .065, *SE* = .23, *p* = .52. However, distraction was a significant predictor of sAA recovery, *B* = -.507, *SE* = .20 *p* = .01, as higher reports of distraction were associated with greater reductions in sAA during recovery. Phone condition was still not a significant predictor of sAA recovery after controlling for the mediator, distraction, *B* = -.207, *SE* = .40, *p* = .60. The indirect effect was tested using a percentile bootstrap estimation approach with 10000 samples implemented with the PROCESS macro Version 3 (Hayes, 2017). These results indicated the indirect coefficient was not significant, *B* = -.033, *SE* = .13, 95% *CI* [-.38, .18]. These results do not support the mediational hypothesis (see Figure 6).

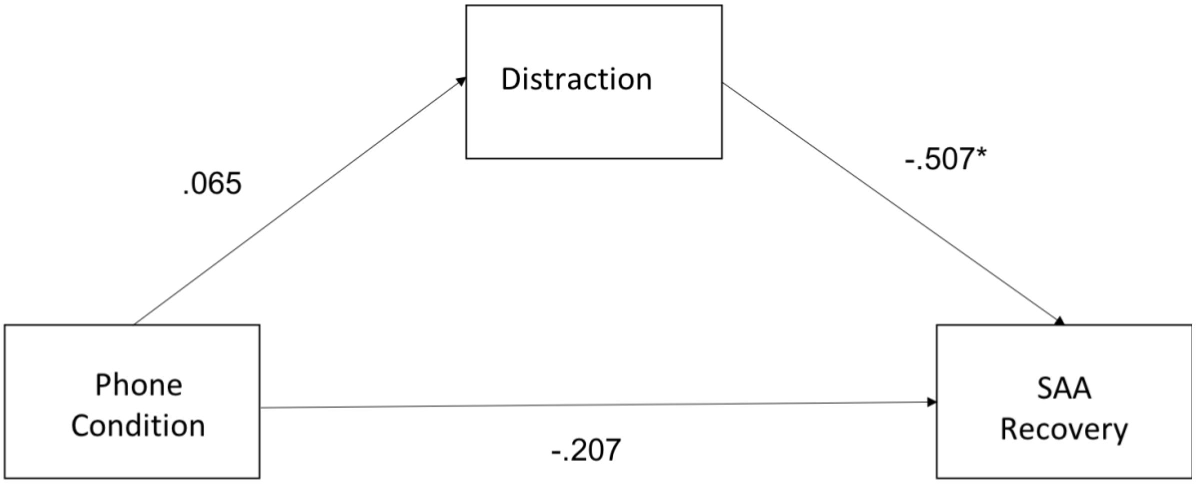

Figure 6. Unstandardized regression coefficients demonstrate that distraction does not mediate the association between phone condition and sAA recovery.

Distraction as a mediator between phone condition and self-reported stress recovery (Hypothesis 3). Regression analysis was used to investigate the hypothesis that distraction mediates the effect of phone condition on self-reported stress recovery. Results indicated that phone condition was not a significant predictor of distraction, B = .037, SE = .24, p = .88, and that distraction was not a significant predictor of self-reported stress recovery, B = -3.723, SE = 2.06, p = .07, adjusting for covariates of baseline distraction and self-reported stress. Consistent with hypotheses, higher reports of distraction were marginally associated with greater reductions in self-reported stress, but these differences were not statistically significant at the p<.05 level. Phone condition was not a significant predictor of self-reported stress recovery after controlling for the mediator, distraction, B = 5.386, SE =4 .25, p = .21. The indirect effect was tested using a percentile bootstrap estimation approach with 10000 samples implemented with the PROCESS macro Version 3 (Hayes, 2017). These results indicated the indirect coefficient was not significant, *B* = -.139, *SE* = 1.08, 95% *CI* [-2.18, 2.48]. These results do not support the mediational hypothesis (see Figure 7).

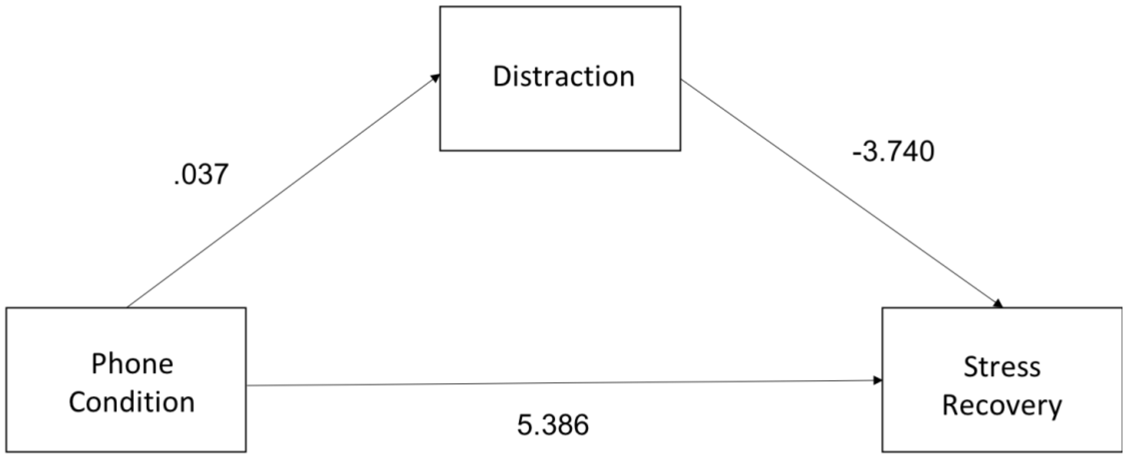

Figure 7. Unstandardized regression coefficients demonstrate that distraction does not mediate the association between phone condition and self-reported stress recovery.

Perceived social support as a mediator between phone condition and sAA recovery (Hypothesis 3). Regression analysis was used to investigate the hypothesis that perceived social support mediated the effect of phone condition on sAA recovery. Results indicated that phone condition was not a significant predictor of perceived social support, *B* = .163, *SE* =.14, *p* = .25, and that perceived social support was not a significant predictor of sAA recovery, *B* = .21, SE = .326, *p* =. 52, adjusting for covariates of baseline perceived social support and sAA. Phone condition was not a significant predictor of sAA recovery after controlling for the mediator, perceived social support, *B* = -.194, *SE* = .41, *p* = .64. The indirect effect was tested using a percentile bootstrap estimation approach with 10000 samples implemented with the PROCESS macro Version 3 (Hayes, 2017). These results indicated the indirect coefficient was not significant, *B* = -.035, *SE* = .08, 95% CI [-.07, .24]. These results do not support the mediational hypothesis (see Figure 8).

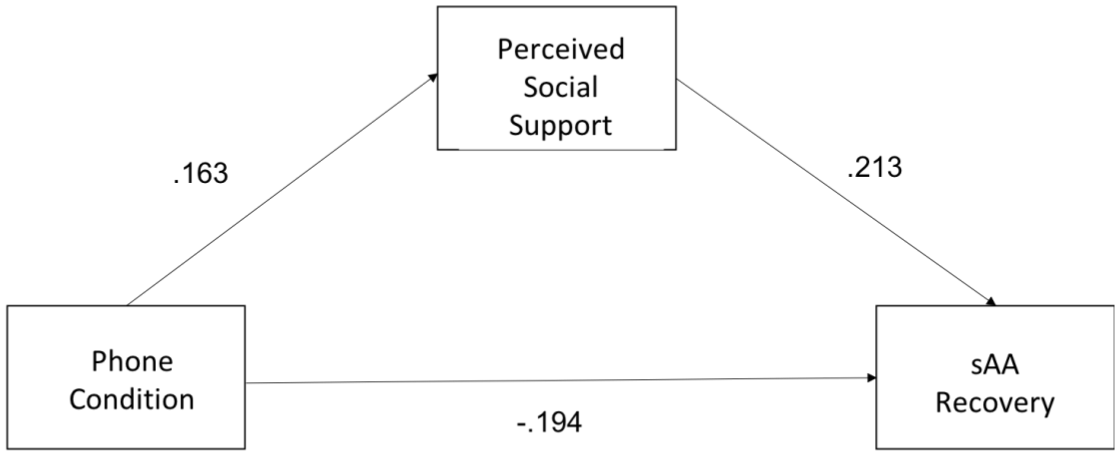

Figure 8. Unstandardized regression coefficients demonstrate that perceived social support does not mediate the association between phone condition and sAA recovery.

Perceived social support as a mediator between phone condition and self-reported stress recovery (Hypothesis 3). Regression analysis was used to investigate the hypothesis that perceived social support mediates the effect of phone condition on self-reported stress recovery. Results indicated that phone condition was not a significant predictor of perceived social support, *B* = .137, *SE* = .14, *p* = .34, and that perceived social support was not a significant predictor of self-reported stress recovery, *B* = -1.416, *SE* = 3.56, *p* = .69, adjusting for covariates of baseline perceived social support and self-reported stress. Phone condition was not a significant predictor of self-reported stress recovery after controlling for the mediator, perceived social support, *B* = 5.562, *SE* = 4.43, *p* = .23. The indirect effect was tested using a percentile bootstrap estimation approach with 10000 samples implemented with the PROCESS macro Version 3 (Hayes, 2017). These results indicated the indirect coefficient was not significant, *B* = -.193, *SE* = 1.02, 95% CI [-2.39, 1.99]. These results do not support the mediational hypothesis (see Figure 9).

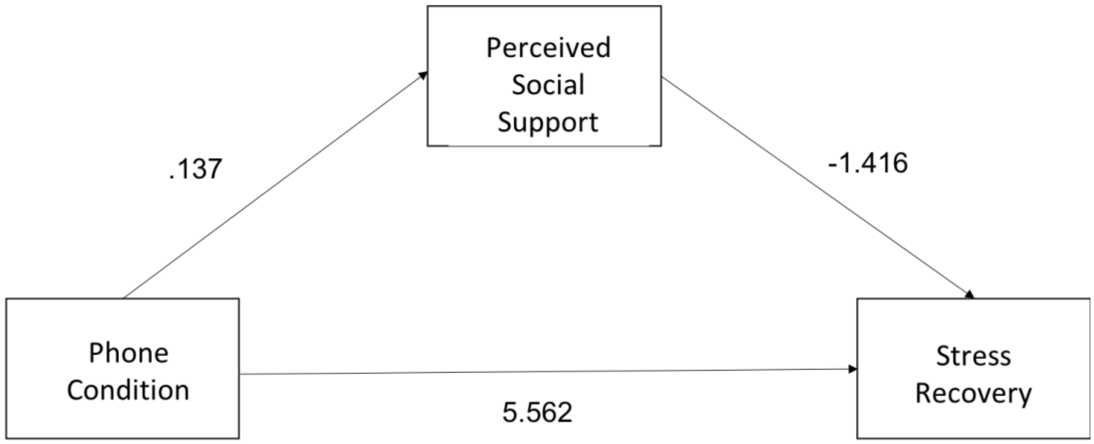

Figure 9. Unstandardized regression coefficients demonstrate that perceived social support does not mediate the association between phone condition and self-reported stress recovery.

Differences in sAA recovery between phone present and phone use conditions (Hypothesis 4). Repeated measures ANCOVA analyses revealed that there were no significant differences in sAA recovery between the phone present and phone use conditions, $F(1,81) = 1.17$, $p = .28$, adjusting for baseline sAA (Figure 10 and Table 4).

Table 4. Unadjusted mean levels of sAA for the phone use and phone present conditions

	Phone Use			Phone Present		
	Mean	*SE*	*CI*	*Mean*	*SE*	*CI*
Baseline	78.79	8.76	[61.51, 96.08]	90.19	8.55	[73.31, 107.07]
Post-TSST	117.23	12.63	[92.32, 142.15]	140.03	12.33	[115.70, 164.36]
Recovery	77.25	8.25	[60.97, 93.53]	98.95	8.06	[83.05, 114.85]

SE=Standard Error
CI= 95% Confidence Interval

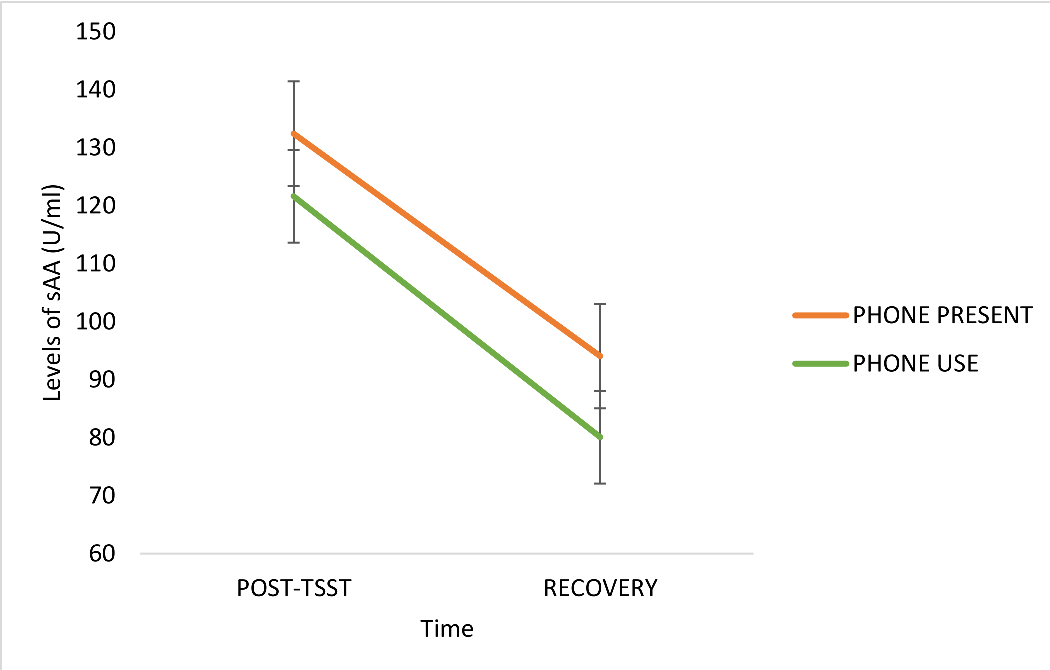

Figure 10. sAA recovery does not differ between the phone use and phone present conditions

Differences in self-reported stress recovery between phone present and phone use conditions (Hypothesis 4). Repeated measures ANCOVA analyses revealed that there were no significant differences in self-reported stress recovery between the phone present and phone use conditions, $F(1,84) = 1.00$, $p = .75$, adjusting for baseline self-reported stress (see Figure 11 and Table 5).

Table 5. Unadjusted mean levels of self-reported stress for the phone use and phone present conditions

	Phone Use			Phone Present		
	Mean	*SE*	*CI*	*Mean*	*SE*	*CI*
Baseline	28.41	3.29	[21.93, 34.89]	21.74	3.32	[15.19, 28.30]
Post-TSST	48.82	4.43	[40.08, 57.56]	42.28	4.48	[33.44, 51.12]
Recovery	35.27	3.83	[27.71, 42.83]	31.70	3.88	[24.05, 39.35]

SE=Standard Error
CI= 95% Confidence Interval

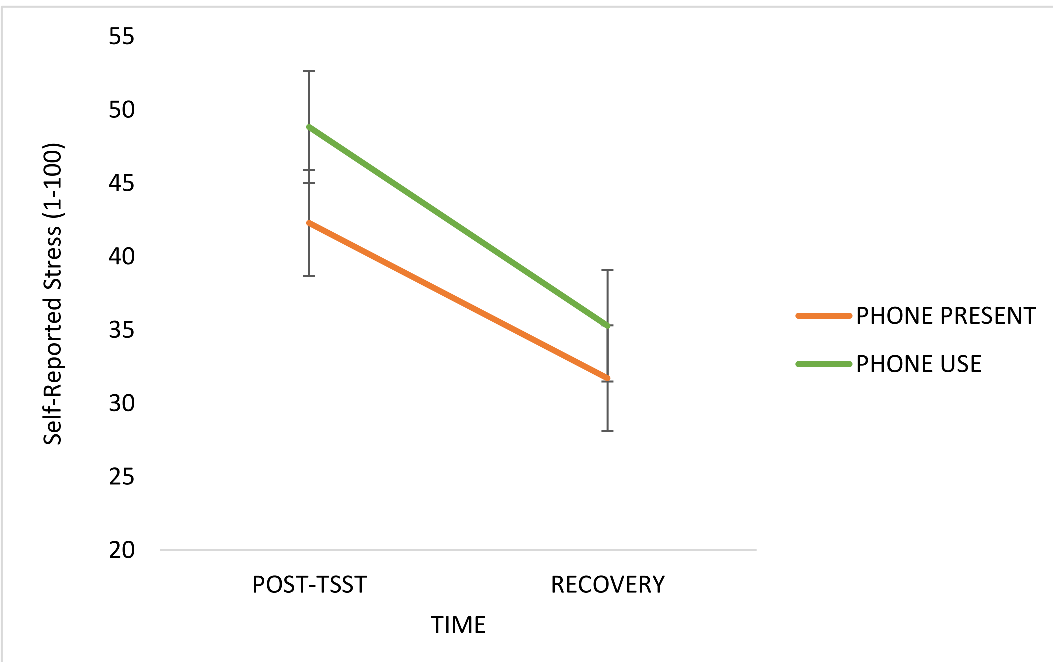

Figure 11. Self-reported stress recovery does not differ between the phone use and phone present conditions.

Received social support as a predictor of sAA recovery within the phone use condition (Hypothesis 5). Linear regression analyses revealed that received social support did not significantly predict sAA recovery, *b*= -.543, *t*(29) = -1.26, *p* = .22. Received social support also did not explain a significant proportion of variance in sAA recovery, R^2 = .054, F(1, 28) = 1.60, p = .22, as only 5.4% of the variation in sAA recovery can be uniquely explained by received social support (see Appendix A for a description of how phone users utilized their device during the intervention period).

Received social support as a predictor of self-reported stress recovery within the phone use condition (Hypothesis 5). Linear regression analyses revealed that received social support did not significantly predict stress recovery, b= -2.07, t(29) = -.51, p = .60. Received social support also did not explain a significant proportion of variance in stress recovery, R^2 = .008, F(1, 28) = 0.28, p = .60, as only 0.8% of the variation in stress recovery can be uniquely explained by received social support.

Association between received social support and affect within the phone use condition (Hypothesis 5a). Received social support was significantly positively associated with PA, r = .39, p = .02. Contrary to hypotheses, this indicates that higher levels of received social support were associated with higher levels of PA. However, received social support was not significantly associated with NA, r = -.09, p =. 58.

Passive social media use as a predictor of sAA recovery within the Phone Use condition (Hypothesis 6). Linear regression analyses revealed that passive social media use did not significantly predict sAA recovery, b = -.006, t(21) = -.452, p = .66. Passive social media use also did not explain a significant proportion of variance in sAA recovery, R^2 = .009, F(1, 20) = 0.21, p = .66, as only 0.9% of the variation in sAA recovery can be uniquely explained by passive social media use.

Passive social media use as a predictor of self-reported stress recovery within the phone use condition (Hypothesis 6). Linear regression analyses revealed that passive social media use did not significantly predict stress recovery, *b*= -.055, *t*(23) = -.373, *p* = .71. Passive social media use also did not explain a significant proportion of variance in stress recovery, R^2 = .006, *F*(1, 22) = 0.139, *p* = .71, as only 0.6% of the variation in stress recovery can be uniquely explained by passive social media use.

Association of passive social media use and affect (Hypothesis 6a). Passive social media use was not significantly associated with PA, *r* = .08, *p* = .69, or NA, *r* = .20, *p* = .34.

Differences in PA between the phone present and phone use conditions (Hypothesis 7). One-way ANCOVA revealed that, after controlling for baseline PA, there were no significant differences in NA between the phone use (*M* = 1.93, *SD* = 0.73) and phone present (*M* = 1.97, *SD* = 0.74) groups, *F*(1,85) = .100, p = .75.

Differences in NA between the phone present and phone use conditions (Hypothesis 7). One-way ANCOVA revealed that, after controlling for baseline NA, there were no significant differences in PA between the phone use (*M* = 1.94, *SD* = 0.72) and phone present (*M* = 1.90, *SD* = 0.72) groups, *F*(1,85) = .145, p = .71.

PA as a mediator between the association of phone condition and sAA (Hypothesis 8). Regression analysis was used to investigate the hypothesis that PA mediates the effect of phone condition on sAA recovery. Results indicated that phone condition was not a significant predictor of PA, *B* = .028, *SE* = .12, *p* = .81, and that PA was not a significant predictor of sAA recovery, *B* = .349, *SE* = .46, *p* = .44, adjusting for covariates of baseline PA and baseline sAA. Phone condition was not a significant predictor of sAA recovery after controlling for the mediator, PA, *B* = -.195, *SE* =.47, *p* = .68. The indirect effect was tested using a percentile bootstrap estimation approach with 10000 samples implemented with the PROCESS macro Version 3 (Hayes, 2017). These results indicated the indirect coefficient was not significant, *B*

=.010, *SE* = .09, 95% *CI* [-.23, .14]. These results do not support the mediational hypothesis (see Figure 12).

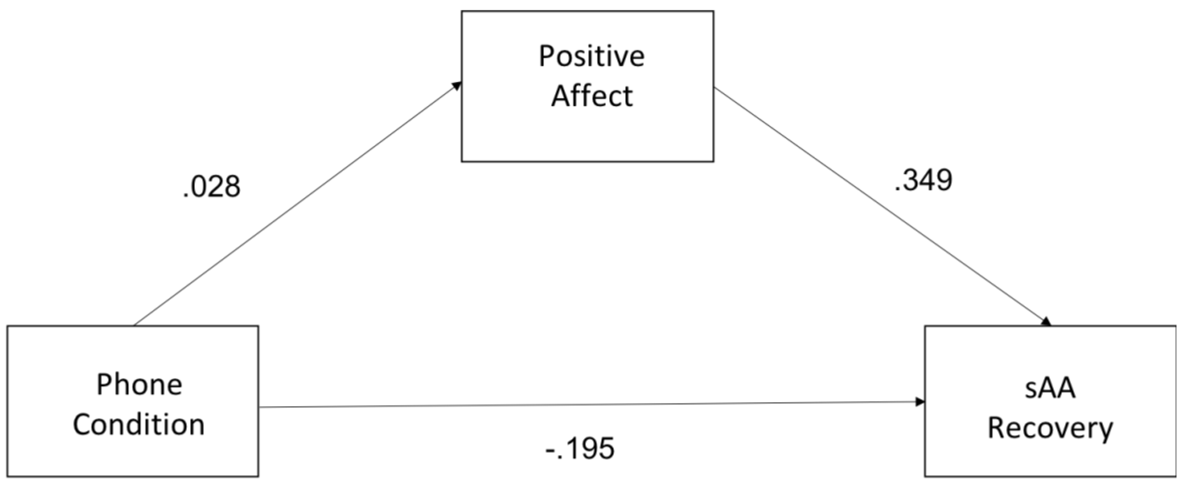

Figure 12. Unstandardized regression coefficients demonstrate that PA does not mediate the association between phone condition and sAA recovery.

PA as a mediator between the association of phone condition and self-reported stress (Hypothesis 8). Regression analysis was used to investigate the hypothesis that PA mediates the effect of phone condition on self-reported stress recovery. Results indicated that phone condition was not a significant predictor of PA, *B* = .047, *SE* = .12, *p* = .67, and that PA was not a significant predictor of self-reported stress recovery, *B* = 5.457, *SE* = 3.09, *p* = .16, adjusting for covariates of baseline PA and baseline self-reported stress. Phone condition was not a significant predictor of self-reported stress recovery after controlling for the mediator, PA, *B* = -2.577, *SE* = 3.84, *p* = .51. The indirect effect was tested using a percentile bootstrap estimation approach with 10000 samples implemented with the PROCESS macro Version 3 (Hayes, 2017). These results indicated the indirect coefficient was not significant, *B* =.257, *SE* = .74, 95% *CI* [-1.20, 1.94]. These results do not support the mediational hypothesis (see Figure 13).

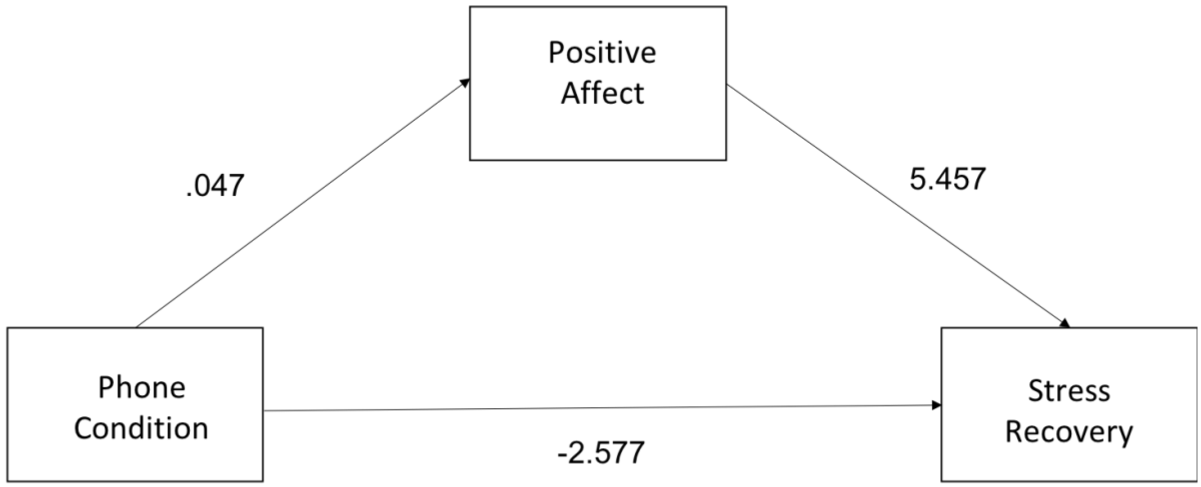

Figure 13. Unstandardized regression coefficients demonstrate that PA does not mediate the association between phone condition and self-reported stress recovery.

NA as a mediator between the association of phone condition and sAA (Hypothesis 8). Regression analysis was used to investigate the hypothesis that NA mediates the effect of phone condition on sAA recovery. Results indicated that phone condition was not a significant predictor of NA, *B* = -.041, *SE* = .12, *p*= .74, and that NA was not a significant predictor of sAA recovery, *B* = -.579, *SE* = .44, *p* = .19, adjusting for covariates of baseline NA and baseline sAA. Phone condition was not a significant predictor of sAA recovery after controlling for the mediator, NA, *B* = -.194, *SE* = .47, *p* = .68. The indirect effect was tested using a percentile bootstrap estimation approach with 10000 samples implemented with the PROCESS macro Version 3 (Hayes, 2017). These results indicated the indirect coefficient was not significant, *B* = .024, *SE* = .095, 95% *CI* [-.21, .20]. These results do not support the mediational hypothesis (see Figure 12).

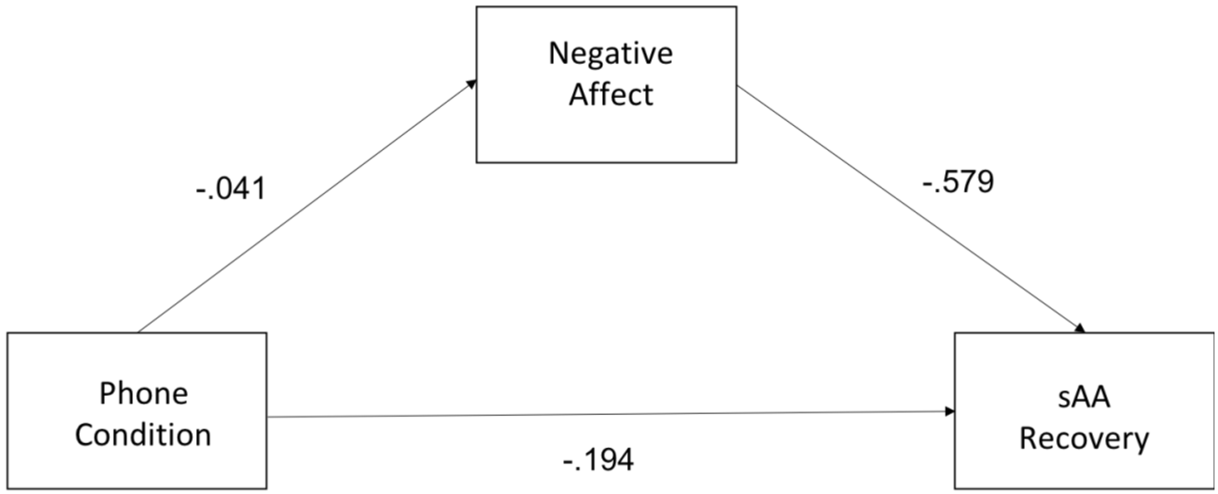

Figure 14. Unstandardized regression coefficients demonstrate that NA does not mediate the association between phone condition and sAA recovery.

NA as a mediator between the association of phone condition and self-reported stress (Hypothesis 8). Regression analysis was used to investigate the hypothesis that NA mediates the effect of phone condition on self-reported stress recovery. Results indicated that phone condition was not a significant predictor of NA, $B = -.039$, $SE = .12$, $p = .74$, and that NA was not a significant predictor of self-reported stress recovery, $B = -.721$, $SE = 3.63$, $p = .84$, adjusting for covariates of baseline NA and baseline self-reported stress. Phone condition was not a significant predictor of self-reported stress recovery after controlling for the mediator, NA, $B = -2.945$, $SE = 3.896$, $p = .45$. The indirect effect was tested using a percentile bootstrap estimation approach with 10000 samples implemented with the PROCESS macro Version 3 (Hayes, 2017). These results indicated the indirect coefficient was not significant, $B = .028$, $SE = .44$, 95% *CI* [-.92, .99]. These results do not support the mediational hypothesis (see Figure 13).

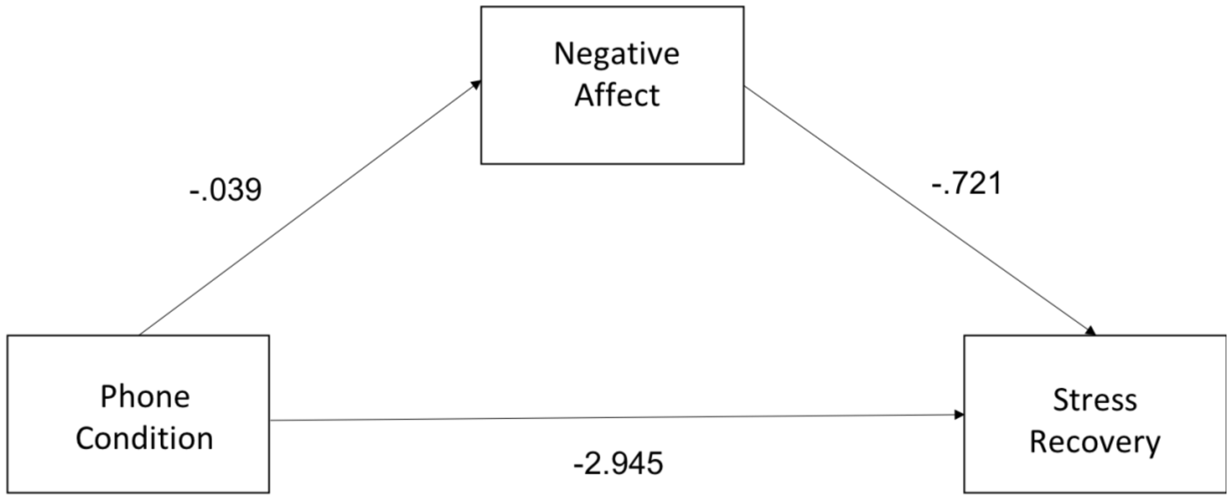

Figure 15. Unstandardized regression coefficients demonstrate that NA does not mediate the association between phone condition and self-reported stress recover

Differences in sAA recovery between guided phone use and all other conditions (Hypothesis 9). When considering all the conditions in the same model, there was a significant effect of condition on the slope of sAA recovery, $F(3, 173) = 2.875$, $p = .04$. Post-hoc comparisons revealed that those in the guided phone use condition displayed significantly steeper recovery trajectories than those in the no phone condition, $t(93) = 2.61$, $p = .01$. In addition, those in the guided phone use condition displayed significantly steeper recovery trajectories than those in the phone present condition, $t(90) = 2.36$, $p = .02$. This implies that those in the guided phone use condition recovered more effectively than those in the phone present and no phone conditions. However, there were differences in recovery trajectories between the guided phone use and phone use conditions, $t(88) = 1.17$, $p = 0.24$ (see Figure 16 and Table 6).

Table 6. Unadjusted mean levels of sAA by condition.

	No Phone			Phone Present			Phone Use			Guided Phone Use		
	Mean	*SE*	*CI*	*Mean*	*SE*	*CI*	*Mean*	*SE*	*CI*	*Mean*	*SE*	*CI*
Baseline	91.62	8.27	[75.30, 107.94]	90.19	8.55	[73.31, 107.07]	78.79	8.76	[61.51, 96.08]	71.78	8.09	[55.80. 87.75]
Post-TSST	140.02	11.92	[116.50, 163.54]	140.03	12.33	[115.70, 164.36]	117.23	12.63	[92.32, 142.15]	99.78	11.67	[76.75, 122.81]
Recovery	99.65	7.79	[84.28, 115.02]	98.95	8.06	[83.05, 114.85]	77.25	8.25	[60.97, 93.53]	70.02	7.63	[54.97, 85.06]

SE=Standard Error
CI= 95% Confidence Interval

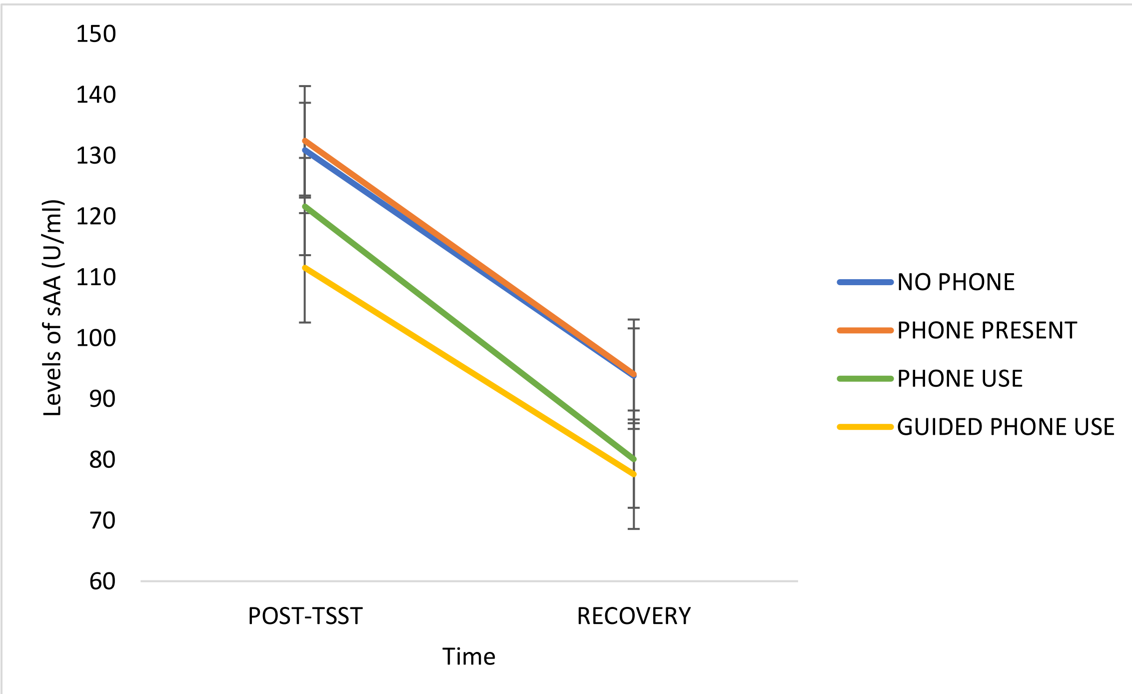

Figure 16. sAA recovery differs between conditions. Specifically, those in the guided phone use condition exhibited greater declines in sAA than those in the no phone and phone present conditions.

Differences in self-reported stress recovery between guided phone use and all other conditions (Hypothesis 9). Although self-reported stress did decline during recovery for all conditions, there was no effect of condition on the slope of self-reported stress recovery, $F(3,176) = 1.09$, $p = .354$, while controlling for baseline self-reported stress (see Figure 17 and Table 7).

Table 7. Unadjusted mean levels of self-reported stress by condition.

	No Phone			Phone Present			Phone Use			Guided Phone Use		
	Mean	*SE*	*CI*	*Mean*	*SE*	*CI*	*Mean*	*SE*	*CI*	*Mean*	*SE*	*CI*
Baseline	24.73	3.25	[18.32, 31.14]	21.74	3.32	[15.19, 28.30]	28.41	3.29	[21.93, 34.89]	21.04	3.11	[14.90, 27.18]
Post-TSST	53.56	4.38	[44.91, 62.20]	42.28	4.48	[33.44, 51.12]	48.82	4.43	[40.08, 57.56]	46.69	4.20	[38.41, 54.98]
Recovery	39.44	3.79	[31.97, 46.92]	31.70	3.88	[24.05, 39.35]	35.27	3.83	[27.71, 42.83]	32.22	3.63	[25.06, 39.39]

SE=Standard Error
CI= 95% Confidence Interval

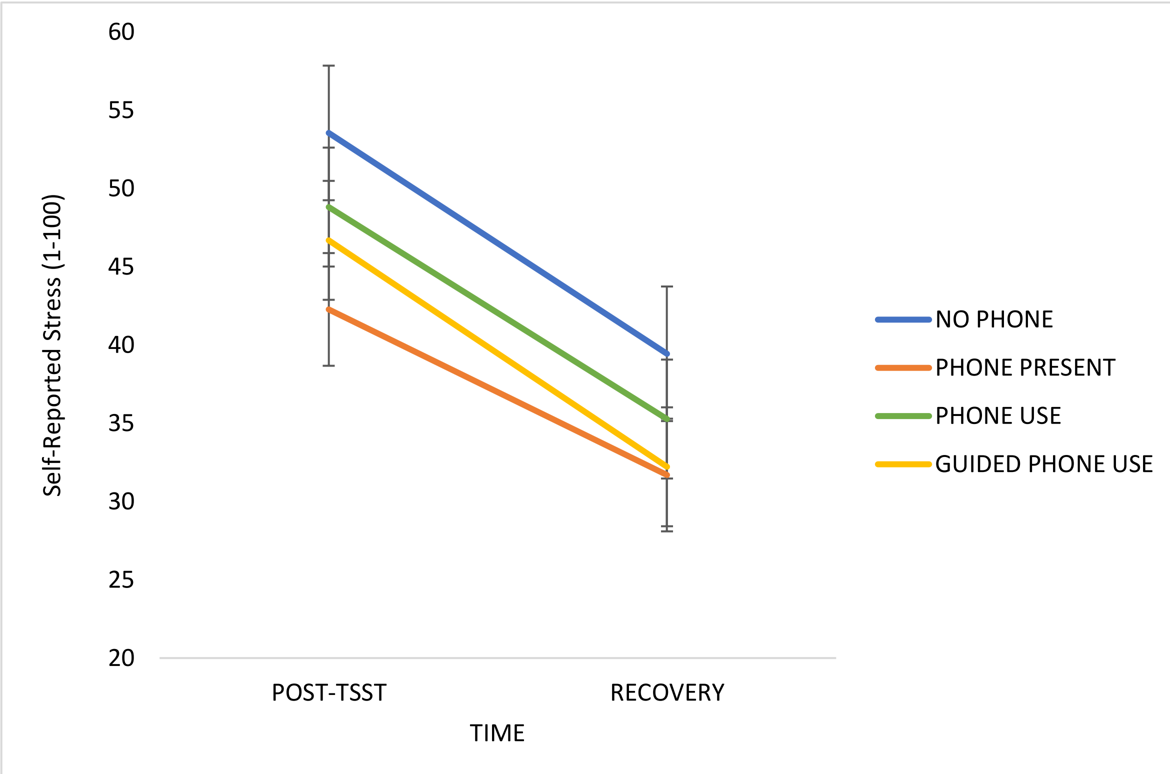

Figure 17. Self-reported stress recovery does not differ between conditions

Differences in feelings of calm between all conditions (Hypothesis 10). One-way ANCOVA revealed that there were no significant differences in feelings of calm between the no phone (M = 2.01, SD = 0.80), phone use (M = 2.19, SD = 0.84), phone present (M = 2.25, SD = 0.82), and guided phone use (M = 2.31, SD = 0.82) groups, $F(3,180) = 1.20$, $p = .31$, while controlling for feelings of baseline calm. Although the guided phone use group did report the highest feelings of calm, they were not significantly different than any of the other conditions.

Calm as a mediator between phone condition and sAA recovery (Hypothesis 11). Regression analysis was used to investigate the hypothesis that calm mediates the effect of phone condition on sAA stress recovery. Results indicated that phone condition was not a significant predictor of calm, $B = .089$, $SE = .05$, $p = .10$, and that calm was not a significant predictor of sAA recovery, *B* = .035, *SE* = .21, *p* = .87, adjusting for covariates of baseline calm and sAA stress. Phone condition was not a significant predictor of sAA recovery after controlling for the mediator, calm, *B* = -.006, *SE* = .15, *p* = .97. The indirect effect was tested using a percentile bootstrap estimation approach with 10000 samples implemented with the PROCESS macro Version 3 (Hayes, 2017). These results indicated the indirect coefficient was not significant, *B* = .003, *SE* = .022, 95% *CI* [-.05, .05], suggesting that calm only accounts for 0.3% of the total effect. These results do not support the mediational hypothesis (see Figure 18).

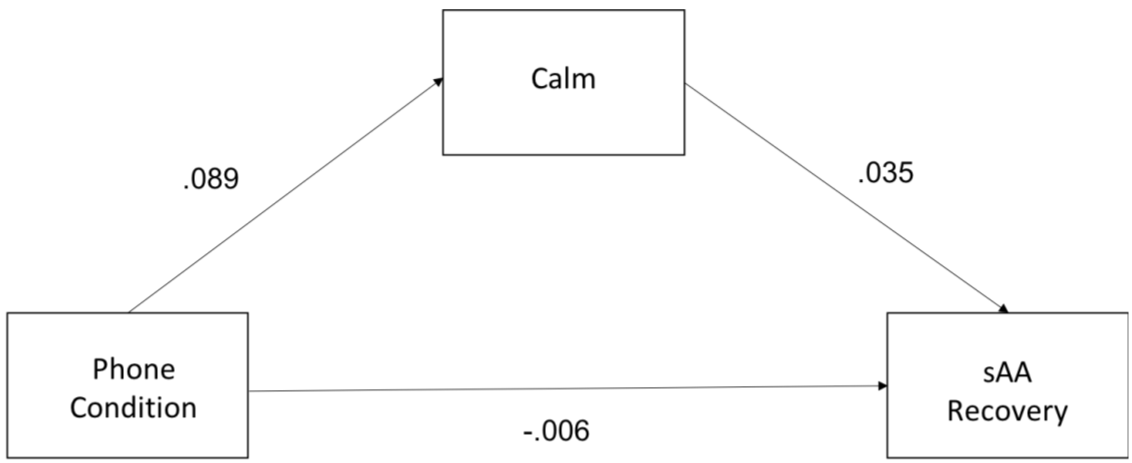

Figure 18. Unstandardized regression coefficients demonstrate that calm does not mediate the association between phone condition and sAA recovery.

Calm as a mediator between phone condition and self-reported stress recovery (Hypothesis 11). Regression analysis was used to investigate the hypothesis that calm mediates the effect of phone condition on self-reported stress recovery. Results indicated that phone condition was not a significant predictor of calm, *B* = .088, *SE* = .05, *p* = .10, and that calm was not a significant predictor of self-reported stress recovery, *B* = -.067, *SE* = 1.92, *p* = .97, adjusting for covariates of baseline calm and self-reported stress. Phone condition was not a significant predictor of self-reported stress recovery after controlling for the mediator, calm, *B* = -.164, *SE* = 1.37, *p* = .91. The indirect effect was tested using a percentile bootstrap estimation approach with 10000 samples implemented with the PROCESS macro Version 3 (Hayes, 2017). These results indicated the indirect coefficient was not significant, *B* = -.006, *SE* = .24, 95% *CI* [-.55, .50]. These results do not support the mediational hypothesis (see Figure 19).

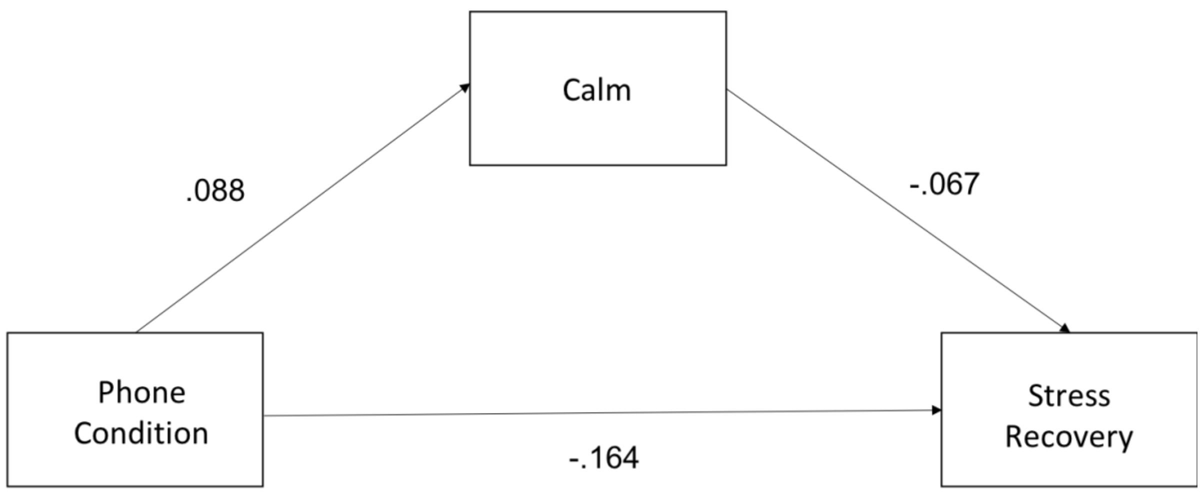

Figure 19. Unstandardized regression coefficients demonstrate that calm does not mediate the association between phone condition and self-reported stress recovery.

DISCUSSION

This dissertation examined the effects of using or having a smartphone on psychological and physiological responses to stress. This was the first empirical investigation to compare several ecologically valid ways in which smartphones can be used following an acutely stressful experience. Results revealed that individuals who used a biofeedback training application on their smartphone exhibited the most desirable trajectories of sAA recovery. Specifically, those in the guided phone use condition had significantly steeper physiological recovery trajectories than those who had their phones in their presence or had no phone at all. Importantly, this provides the first experimental evidence demonstrating that using a biofeedback training application on a smartphone may be beneficial for physiological stress recovery. While many of the other results were contrary to hypotheses, this dissertation nonetheless provides valuable information about how smartphones influence stress recovery.

A main goal of this dissertation was to go beyond just determining *if* different ways of using a phone may aid in stress recovery and additionally explore *how* and *why* a smartphone may exert its influence on stress. By examining the pathways responsible for stress recovery differences between phone conditions, I hoped to elucidate the mechanisms that explain how different ways of using a phone may buffer stress. While some interesting factors emerged that inform our understanding of how phones do indeed influence stress, the results paint a complicated picture that is contrary to many of the hypotheses. The group differences were not as pronounced as expected and, thus, I was unable to determine the mechanisms responsible for how different types of phone interaction impacted stress recovery. In the following sections, potential reasons for why the hypotheses were null are examined and broader implications and future directions for research are discussed.

Aim 1: Comparing stress recovery between the phone present and no phone conditions. One major aim of the dissertation was to determine whether smartphone presence provides stress-reducing benefits compared to not having a smartphone. Based on prior research (e.g., Panova & Lleras, 2016; Hunter et al., 2018), it was expected that the mere presence of a smartphone would buffer psychological and physiological stress. Since the mere presence of a phone has previously been shown to increase distraction (e.g., Ward et al., 2017) and perceptions of social connections (e.g., Misra et al., 2014), and high levels of distraction (e.g., McCaul & Malott, 1984) and perceived social support (e.g., Master et al., 2012) usually buffers stress, it was hypothesized that feelings of distraction and perceived social support activated by the phone itself would aid in stress recovery. However, the results of our study did not align with any of these previous findings.

Specifically, there were no significant differences in physiological or psychological stress recovery between the no phone and phone present conditions. However, self-reported stress differences were trending in the hypothesized direction. Those in the phone present condition did have lower levels of self-reported stress during recovery than those in the no phone condition, but these differences were not statistically significant. The lack of significance for these main effects of stress is likely because there were no group differences for the mechanisms of interest. One of the potential mechanisms, distraction, did in fact predict sAA and self-reported stress recovery. However, there were no differences in distraction between the conditions and, thus, distraction did not mediate the association of phone condition and stress recovery. Surprisingly, feelings of distraction were exactly the same between the phone present and no phone conditions (M=2.23), implying that simply having a phone present is not a sufficiently distracting stimulus to induce any meaningful differences. This was quite surprising because of the multitude of other studies demonstrating that phones do indeed cause distraction (e.g., Horrey & Wickens, 2006; Misra et al., 2014; Przybylski & Weinstein, 2012; Roberts & David, 2016). The lack of differences in the current study may be due to the way in which distraction was operationalized. Most of the previous studies examining phones and distraction have used observational (i.e., eye-tracking) or performance based (i.e., test score) variables to examine distraction rather than relying on self-report. This is because the distraction induced by smartphones is primarily happening at the subconscious level, and, thus, individuals are not actively aware that their cognitive attention is being drained by efforts to inhibit smartphone usage (Ward et al., 2017). So in the current study, when individuals were asked to rate how accurately the adjective "distracted" described how they felt at the moment, they may have been consciously unaware that their phones were potentially causing any distraction. Since there were no behavioral assessments, it was difficult to capture any potential distraction that was taking place at this subconscious level. Future studies examining the distracting effects of phone presence should utilize behavioral assessments rather than self-report to capture these differences.

While there were slight differences in perceptions of social support between the no phone (M=1.74) and phone present (M=1.92) groups, these differences were not significant. Although much research has demonstrated that phone presence primes relationship related concepts (e.g., Kardos et al., 2018), our study did not replicate these findings. This may have been due to the fact that there were no other social cues in the environment and participants were explicitly asked to not use their phones. And once again, issues of imprecise operationalization may have played a role. This variable of perceived social support was created from a composite of items drawn from various scales assessing this construct (e.g., Cohen et al., 1983), and although they were reliably related (α =.90), they may not have properly assessed in-the-moment perceptions of perceived social support. All other previous social support scales capture long-lasting trait perceptions of support, and the adaptation of those items in an attempt to capture state feelings may have been unsuccessful. On the other hand, it is also possible that phone presence simply did not activate perceptions of social support. Since there were no group differences for either of the dependent variables of stress or these two mechanism variables, it is understandable that no mediation effects were found.

This lack of differences demonstrate that the "digital security blanket" protective effect that was found in previous studies does not operate in this context. In the Hunter et al. (2018) experiment, participants had their phones with them *while undergoing* the stressor and in the current study, participants only had their phones immediately *after* the stressor. This difference in timing suggests that it may be helpful to have a phone present while undergoing stress, but it provides little to no benefit when present during recovery. In addition, a phone may serve as a digital security blanket in mildly stressful situations like social exclusion but may not exert similarly beneficial effects under more potent stressors such as the TSST. Future studies should continue to investigate the effect of phone presence in other stressful settings to explore if the digital security blanket effect is indeed context-dependent.

Aim 2: Comparing stress recovery between the phone present and phone use conditions. The second aim of this dissertation was to determine whether using a smartphone provides additional stress-reducing benefits beyond merely having a smartphone present. It was hypothesized that those in the phone present condition would recover more effectively than those in the phone use condition because of the mixed effects (e.g., Rus & Tiemensa, 2017; Verduyn; 2-15) that phone use often has on affect and stress. Results did not support these hypotheses, as those in the phone use group actually had slightly steeper (albeit non-significant) sAA and self-reported stress recovery trajectories compared to those in the phone present group. The null findings for these main effects may be explained by a lack of differences for the mechanistic pathways proposed.

Affective differences were hypothesized to mediate the association between phone condition and stress recovery, whereby higher NA and lower PA for the phone users would temper any potential benefits gleaned from their phones. Based on previous research demonstrating how certain types of phone use are associated with undesirable affective states (Lin & Peper, 2009; Verduyn et al., 2015), two routes were proposed (passive social media use and the receipt of social support) by which phone use would lead to higher NA and lower PA. In our study sample, all participants in the phone use condition either used social media or texted at some point. Thus, the hypothesized social actions that would supposedly lead to the affective changes were indeed undertaken in the study.

Receiving social support via text message or social media was expected to increase NA and decrease PA, but this was not the case, as our results indicated that there were minimal associations between these affective variables and the receipt of social support. The one significant association was in the opposite direction of my hypotheses, as higher levels of received social support were actually positively correlated with PA. As discussed earlier, received social support can be beneficial or detrimental depending on the nature of given support. In this case, receiving social support via a smartphone boosted PA. It is an interesting area of future research to examine if social support received via a smartphone differs from support received in-person. It may be that using a smartphone is a preferred medium for the transmission of social support that avoids many of the traditional pitfalls that can result from in-person social support.

In addition, there were no associations between passive social media use and PA or NA. It is unclear exactly why no affective differences were discovered, but it may have to do with the fact that the time period of phone use (~5 minutes) was too short to induce any meaningful changes. Since neither of these phone use actions led to changes in affect within the phone use group, there were subsequently no differences in affect between the phone use and phone present conditions. Therefore, affect did not operate as mediator of the association between phone condition and stress recovery. Surprisingly, levels of PA and NA did not predict stress recovery, which is contrary to previous research (e.g., Fredrickson, Mancuso, Branigan, & Tugade, 2000). This may have partially been due to the limited changes in affect induced by the manipulation, or the short time frame in which the intervention and stress measurements took place. Since these mediating factors never came to fruition, there was no main effect of phone condition on psychological or physiological stress recovery.

However, it is worth noting that these null findings were some of the least surprising for this dissertation. Both of the pathways that were supposed to induce undesirable affective changes have shown mixed results in different contexts, and it was unclear how they would operate in this experiment. In some situations, received social support is a positive stress-buffer (Uchino, 2006) and other times it is not (Rook, 1998). Similarly, passive social media use can be beneficial for stress recovery (Rus & Tiemensa, 2018) or can lead to undesirable outcomes related to stress (Verydun, 2015). Thus, the combination of positive and negative effects of engaging in these activities may have washed out any significant effects. Based on these results, I am unable to determine whether using a phone freely produces benefits or drawbacks beyond simply having a phone present in the context of a serious acute stressor recovery period.

Aim 3: Comparing stress recovery between guided phone use and all other conditions. The third aim of this dissertation was to determine whether using a guided skills training application on a smartphone provides additional benefits beyond using a smartphone naturally or merely having a smartphone present. The hypothesis that those in the guided phone use condition would recover most effectively was partially supported. Individuals who used the HRVB training application did display steeper sAA recovery trajectories than those in the no phone and phone present conditions, but there were no significant differences compared to the phone use condition. Furthermore, there were no self-reported stress differences between any of the conditions. However, the significant sAA finding does provide valuable information about how guided phone use utilizing an mHealth application may aid in stress recovery.

The results indicate that engaging in a brief five-minute HRVB training session on a smartphone can effectively reduce levels of sAA. Although the magnitude of the effect for the change in sAA was not particularly large, it was similar to previous studies (e.g., Hunter, Hooker, Rohleder, & Pressman, 2018; Stroud et al., 2009) and can therefore provide valuable information about how guided phone use may impact health. These sAA findings are particularly important because high levels of sAA are associated with a range of deleterious health outcomes (e.g., Granger et al., 2006; Granger, Kivlighan, El-Sheikh, Gordis, & Stroud, 2007; Wolf, Nicholls, & Chen, 2008), so a quick return to baseline levels of sAA is desirable from a health perspective. Since delayed physiological recovery can be predictive of risk for long-term health issues (Stewart and France, 2001), we can infer that using an application such as Breather when recovering from a stressful experience may provide long-term benefits. Future studies should explore the efficacy of other stress-reducing mHealth applications to examine whether they are effective tools for reducing stress.

Feelings of calm were explored as a mediating factor to explain the beneficial effect of using Breather, however, there were no significant differences in calm between groups and therefore calm did not mediate the association of phone condition and stress recovery. Those in the guided phone use group did report greater feelings of calm (M=2.31) than those in the no phone (M=2.01), phone use (M=2.19), and phone present (M=2.25) groups, but these differences were not significant. The role of calm in influencing stress recovery is understudied, and unfortunately this dissertation did not provide any solid empirical evidence to support its importance as a stress-buffer. Calm may have played a slight but minimal role, and did not mediate the association between phone condition and stress recovery.

Since I did find a benefit for the use of HRVB, it would be interesting in future studies to explore other potential mechanisms such as perceived control. It is likely that the ability to monitor stress responses via the visual interface of Breather increased perceptions of control, which subsequently alleviated feelings of stress. Stress is often induced by a perceived lack of control (Eysenck, 2013), and when that perceived control is increased, it can inhibit autonomic arousal (Leotti, 2010). In this way, the use of Breather may have given participants a greater sense of control over their situation, which prompted a decrease in autonomic arousal as noted by the steep decline in sAA. Due to ways in which HRVB training operates, it may also be interesting in future studies to examine physiological mediators such as respiration rate or blood pressure which could provide further insight into the reasons why HRVB via a smartphone application can provide benefits.

When considering a more comprehensive assessment of stress, conclusions from this study must be tempered by the lack of significant group differences in regard to self-reported stress. These inconsistencies in stress outcomes may be due a to variety of reasons. The HRVB training may have had a more robust impact on sAA secretion because autonomic nervous system activity is intricately linked to cardiovascular activity (Nater & Rohleder, 2009). HRVB specifically targets fluctuations in HRV (which is an indicator of parasympathetic nervous system activity), and because levels of sAA provide information about parasympathetic nervous system and sympathetic nervous system activity, it seems plausible that HRVB acutely influences sAA. In addition, the discrepancy between self-reported and physiological stress is quite common in studies that assess both constructs (e.g., Inagaki & Eisenberger, 2013; Rus & Tiemensma, 2017, 2018). Furthermore, studies examining the convergence of self-report and physiological measures of stress have found that the assessments are highly correlated during the TSST, but not before or after (Hellhammer & Schubert, 2012). Thus, it is not surprisingly that sAA was the only metric that yielded significant results. Future studies should consider how guided phone use may influence a wider range of health-relevant outcomes. For example, since HRVB specifically targets the parasympathetic nervous system, it may be prudent to include indicators of parasympathetic nervous system activity (i.e., RSA) in future studies to more accurately assess the effectiveness of the training exercise.

Additionally, the broader implications about the most effective way to use a phone for stress recovery are limited because those in the guided phone use group did not recover better than those in the phone use group. Post-hoc analyses were conducted to analyze the ways in which phone users interacted during the study. However, the type of phone use (i.e., going on social media, texting, emailing, playing games) had no effect on the outcomes of interest. Thus, there do not seem to be stark distinctions about the benefits yielded from different types of phone use (i.e., using it freely or in a guided manner). Why were there no differences based on how one used a phone? This lack of differences may once again be explained by the mixed positive and negative influences of phone use wiping out any directional effects. Research has demonstrated that actually using one's smartphone can exert varying influences on stress depending on how and when the device is used. Texting can be beneficial (e.g., Hooker, Campos, & Pressman, 2018) or detrimental (e.g., Thomee, Gustafsson, & Nilsson, 2007) for stress. Similarly, using social media can buffer stress (Rus & Tiemensma, 2018) or excacerbate its effects (Rus & Tiemensma, 2017). Thus, it is unclear if social phone use exerts a net positive or negative effect, especially when consdering the complexity of a robust experimental stress task. Taken together, our results do indicate that an HRVB app on a smartphone is a successful aid for stress recovery, but there may also be other effective ways to utilize a phone when recovering from stress.

Additional post-hoc analyses. Since there were very few significant findings, it was deemed prudent to explore other levels of nuance that were not initially proposed to be examined. Pairwise comparisions were conducted using repeated measures ANCOVA analyses for both self-reported and sAA trajectories across all the conditions, not just the a priori comparisons initially discussed. However, none of these comparisions (e.g., phone use vs. no phone) yielded any significant results. Furthermore, each condition was compared to all other conditions combined. For example, the no phone group was compared to the combination of the other three groups to test for an overrall effect of phone presence. However, none of these combined group comparisons were significant for sAA or self-reported stress recovery.

In addition, the mechanistic pathways were explored across all condtions. Pairwise comparisons between the conditions were conducted for all the mediators (i.e., PA, NA, distraction, percevied social support, and calm) to examine if these variables were different between groups. This was done to explore whether a variable that was not initially proposed to mediate an association may have in fact played a role. Preliminary analyses showed that there were no pairwise group differences on any of those mediating variables (see Table 1). However, to ensure there were no mediating effects, all variables were analyzed as mediators between each of the condition combinations. For example, PA was examined as a mediator between phone conditon and stress recovery for the phone present and no phone conditions. Once again, none of these analyses yielded significant mediation.

Furthermore, it was possible that stress reactivity to the TSST may have influenced the effects of condition on stress recovery. Would phone condition exert a different influence for those who were highly stressed or minimally stressed? To test this question, a median split was conducted for stress reactivity change scores. Individuals who had high and low stress reactivity were then tested independently to see if condition made a difference for stress recovery. Again, there were no significant results. In addition, the type of phone use for those within the phone use group was considered and compared to other groups. For example, individuals who used social media were separated from those who texted, and these distinct groups were compared to others. However, no significant findings emerged.

Although many of these comparisons were atheoretical, it was still worth exploring to see if any interesting trends emerged because the results may have informed future study designs. Unfortunately, nothing was significant and therefore did not provide any additional insight into how these processes operate.

Explanation of reasons for null findings. The results of this dissertation imply that smartphones do not necessarily have a potent effect on stress recovery. Although we can see that using an HRVB application is beneficial in this context, the findings were not as robust as hoped for (i.e., no self-report differences, no advantages over the phone use group). Why were so many of the hypotheses unsupported? Some of the specific reasons were already discussed above in their respective sections, but when synthesized across analyses, a few themes emerge that provide clues about the reasons for the lack of findings.

The primary reason seems to be that the phone condition manipulation was too subtle and did not induce differences between the groups. Not only did the manipulation fail to influence the primary variables of interest (i.e., sAA and self-reported stress), but it also did not exert an influence on the other self-reported variables that were expected to be mediators. So why was the manipulation ineffective? It is quite possible that phones simply do not aid in this type of stress recovery. However, it is more likely that methodological issues within this dissertation were responsible for the lack of effects.

The intervention period was quite short (only about five minutes). It is plausible to assume that this was too short of a time to induce any significant differences between the groups. A longer intervention period may have yielded larger differences. This 5-minute period was selected to align with the amount of time that it took to complete the HRVB activity. However, the results indicated that this may not have been enough time to impart meaningful changes. The majority of other studies examining the effectiveness of HRVB instruct participants to engage in training for a period of multiple weeks or days (e.g., Lehrer et al., 2004), and even the interventions that claim to be the most short-term are still around 10 minutes in duration (Prinsloo, 2016). Thus, our five-minute session was not a sufficient period of time to reap the benefits from HRVB. The effects may have been different if participants engaged in the training multiple times beforehand or had a longer session of HRVB training during recovery. Future studies and future app developers should incorporate these time considerations if they hope to impart significant benefits for stress recovery.

Another issue of study design was the specific intervals of the sampling timeline. For the salivary samples, there was only one recovery timepoint 20 minutes after the stressor. This was based on a pilot study that showed that the trajectories did not appear to be much different at the +5, +10, and +20 time points. Based on that pilot information, it was decided to only use the +20 timepoint. This may have been a mistake because the actual data from the complete study looked quite different from the pilot data (i.e., the pilot data mainly aligned with hypotheses about main effects). Important nuances of physiological recovery may have been overlooked by under-sampling during the recovery period. Similarly, the lack of differences in all the self-report variables may also have been due to under-sampling. If affect and stress were assessed minute-by-minute during the intervention and recovery periods, I may have discovered more nuance between the conditions that would have informed the reasons why each group recovered the way that they did.

Furthermore, the contextual circumstances of this study were different than previous studies which showed how smartphones can buffer stress (Hunter et al., 2018). In this study, the phone manipulation took place right after the stressor due to logistical and ecological validity concerns. In the previous study, the phone manipulation took place *during* the stressor. This timing difference may be quite impactful, as recent studies have demonstrated that using social media before a stressor can buffer stress (Rus & Timensa, 2018) but using it afterwards can exacerbate stress (Rus & Timensa, 2017). If the phone manipulation took place before or during the TSST, then our results may have been different. Future studies should examine the optimal timing for phone use to determine how they can best be used to reduce stress.

Additionally, the lack of mediation may have partially been due to measurement issues. All of the mediator variables were assessed on a 0-4 self-report scale. The limited range of answer choices did not allow for much variation across conditions. Self-report data also often has a positivity bias that may lead to inaccurate findings. More creative or comprehensive assessments of the mediators may have led to different outcomes.

Finally, the effectiveness of Breather may have been limited by user error issues that happened within the app. The primary functionality of Breather is using photoplethysmography to measure HRV. In order to do this, the program requires that the user's finger is placed very precisely on the light sensor. It is sometimes difficult to maintain this position and warnings pop up on the screen each time that a finger is placed incorrectly. In the pilot study, it was discovered that frustration can occur when this happens because the user feels like they are failing at a task/game. The instructions from the researcher were slightly altered in an attempt to avoid this issue, but it still may have played a role. To investigate whether user error played a role, adherence to finger placement was assessed using metrics provided from the app's database. Data showed that users had their fingers placed correctly for around 96% of the time; however, that still means that for 4% of the session, they were getting warnings telling them to "please place your finger on the sensor." This may have been bothersome and unduly reduced the effectiveness of Breather.

Another logistical inconsistency in the methods may have contributed to the lack of robustness in regard to the guided phone use findings. The individuals in the guided phone use condition had a slightly different experience during the baseline period before undergoing the TSST. In order to prepare them for immediate use of Breather in the post-TSST intervention period, the application needed to be installed and understood beforehand so that they could use it with ease. So, individuals in this condition spent approximately two to four minutes downloading the application, going through the sign-up process, and getting trained by the researcher about how to properly use Breather. Although this period was quite short and all efforts were made to conceal the fact that Breather was supposed reduce stress, the participants still may have been influenced by this experience. In addition, the researchers were not blind to condition, so although they were trained to treat all conditions equally, it is possible that researcher bias may have played a role. Possibly due to the influence of this brief training period, individuals in the guided phone use group had lower baseline levels of sAA and displayed less sAA reactivity to the TSST (although neither of these values were significantly different than the other conditions). This low ceiling of peak sAA levels then restricted the potential magnitude of sAA change during recovery. If those in the guided phone use condition hypothetically had higher levels of peak sAA, then it is quite possible that they may have seen steeper declines during recovery. The brief training period may have contributed to this issue. However, it is worth noting that if indeed the brief training did reduce reactivity to the stressor then maybe using Breather could be an effective method for buffering stress reactivity. Future studies should explore the optimal timing for HRVB implementation and determine whether it is most effective before or after a stressor.

Limitations. There are several limitations of this dissertation that constrain the generalizability of the results. Firstly, the population of our participants is not representative of the population at large. The majority of our participants were healthy young Asian women, all of whom were iPhone users and college educated. Although there were no between group differences in demographic variables of interest (SES, age, sex, ethnicity, phone dependence), the sample was not representative of the larger population as a whole. Since we drew our sample from a university population, our participants were likely wealthier, younger, more phone dependent, and more educated than the average person. Thus, these conclusions cannot be extrapolated to all populations.

Additionally, there was insufficient information provided about all the actions that were or could have been undertaken for those in the phone use group. I focused specifically on social actions that were related to passive social media use or received social support, but this may have limited the scope of investigation. The use of follow-up questions after the intervention phase did provide some variable information, but using phone tracking software or video cameras to monitor the specific types of smartphone use could provide more comprehensive information.

Finally, there were only significant findings in regard to physiological stress. Therefore, we cannot make sweeping claims about how guided phone use comprehensively buffers stress. Instead, we can only conclude that guided phone use had a targeted effect on autonomic nervous system recovery. Regardless of these limitations, this dissertation provides valuable information about how, when, and where phones may or not influence stress recovery.

Conclusions and Implications. Based on these results, one can conclude that using HRVB training on an application such as Happify may be a practical and effective strategy for reducing physiological stress. The other potential ways to rely on a phone as a stress-buffer (i.e., use it freely or merely have it with you) may not provide as potent of benefits. This demonstrates that using a guided stress-reducing application is a practical and ecologically valid way that one may rely on a smartphone to help recover immediately after undergoing a stressful experience. Our smartphones are conveniently with us at most times and, thus, we have this effective stress-reducing tool at our disposal anytime and anywhere we need it. To further examine how smartphones can aid in stress recovery, future research should further unpack the mechanisms for why a guided stress-reducing application may buffer stress and how it compares to other ways of using a phone. This will inform future interventions and provide recommendations for the development of other stress-buffering tools that can be delivered through smartphone applications.

The complexity of these results demonstrates that the benefits phones may provide are context dependent. In the context of this current study, phones only had a slightly beneficial effect. Phones can exert varying influence depending on the goals, environment, and timing of use. In certain situations, phones may be detrimental, neutral, or positive. Thus, it will be important for future researchers to continue to delineate the different contexts and use-scenarios in order to recognize how phones operate in different environments. Studying the impact of phones on stress in a variety of contexts is a major goal of my future program of research. I hope to explore how phones may reduce stress in the context of workplace environments, relationship struggles, traumatic events, and many other common real-world stressors. The accumulation of this knowledge about when and where phones influence stress will hopefully inform users about the most appropriate ways to utilize their device when faced with a stressor.

Although the findings are not overly convincing or conclusive, results such as these are beginning to change the narrative about the effects smartphones exert on our well-being. While it is important to recognize the deleterious effects of these devices on our lives, it may be even more critical to recognize the positive potential of smartphones and begin to develop and use technology in ways that augment well-being. Instead of simply hoping that individuals use technology in a beneficial manner, it is imperative that the hardware and software are designed in a way that facilitates positive behavior, thoughts, and interactions. Designing tools that take advantage of the technological affordances and ubiquity of smartphones to put stress-reducing tools in the palm of one's hand is a promising strategy for finding ways that smartphones may maximize well-being.

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APPENDIX A

In Appendix A, descriptive statistics about how individuals in the phone use condition used their devices are presented. A total of 45 participants were randomized to this condition, but only 35 had useable data. The information is arranged by the question categories that were asked immediately following the intervention period.

- How long did participants use their phones during the 5-minute intervention period?
    - All individuals reported that they used their phones at some point during the intervention period.
    - Individuals used their phones for an average of 4.22 minutes and the median number of minutes for use was 5.
- What smartphone features were used?
    - 40% of the total time was spent texting
    - 38% of the total time was spent on social media
    - 7% of the total time was spent playing games
    - 4% of the total time was spent using email
    - 11% of the time was spent doing other activities
- How many participants used social media?
    - 71% of participants used social media
- Which types of social media were used?
    - Out of the 23 individuals who did use social media…
        - 6 used Facebook
        - 16 used Instagram
        - 13 used Snapchat
- How did participants use social media?
    - Only two participants posted anything on social media
    - Participants passively used social media for 72% of the total time spent on social media
- How many participants texted during the intervention period?
    - 63% of participants texted