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HeartPhone: Mobile Evaluative Conditioning to Enhance Affective Processes and Promote Physical Activity

David E. Conroy
The Pennsylvania State University and Northwestern University

Ian Kim
University of Southern California

Objective: Most American adults fail to achieve recommended levels of physical activity and, as a result, are at elevated risk for many chronic diseases. Affective processes have been validated as targets for increasing physical activity but are rarely targeted directly by behavioral interventions. This article describes 2 early phase studies used to develop HeartPhone, a smartphone application for conditioning associations between physical activity and pleasure. HeartPhone exposes users to brief doses of evaluative conditioning stimuli via background images on a smartphone lock screen. ***Method:*** Study 1 evaluated the feasibility of delivering mobile evaluative conditioning and estimated doses received over 7–21 days in a small sample of users ($n = 6$). Study 2 used a single-group prepost design to evaluate user experience and determine whether any change in reflective motivation or physical activity was possible over 8 weeks of HeartPhone use ($n = 19$). ***Results:*** In Study 1, users accumulated almost 2 min/day of exposure to conditioning stimuli, indicating the feasibility of delivering microdoses of evaluative conditioning via smartphone lock screens. In Study 2, adults reported accepting the application and conditioning stimuli, improved affective judgments of physical activity (enjoyment, intrinsic motivation, integrated regulations), and increased physical activity. ***Conclusions:*** These results provide proof-of-concept for a low-friction approach for enhancing affective processing and increasing physical activity. Based on early phase success as a tool for engaging smartphone users in behavior change, the HeartPhone intervention is ready for a Phase IIb pilot and III efficacy trials.

Keywords: health, intervention, mobile, user experience

Physical activity is an important health behavior across the life span. People who engage in regular physical activity live longer and have better physical and mental health than those who do not engage in regular physical activity (Physical Activity Guidelines Advisory Committee, 2018). Unfortunately, few American adults engage in regular physical activity (Whitfield et al., 2019). Many interventions have been developed to promote physical activity and individual-level determinants have been targeted most often (King et al., 2019). Until recently, it has been relatively uncommon for interventions to directly target the affective processes that regulate physical activity (Williams, Rhodes, & Conner, 2019). Even fewer have targeted automatic motivational processes that can occur rapidly and can lie outside of conscious awareness. This article reviews research that identified a novel affective target for physical activity interventions—automatic affective evaluations—and presents early phase work developing a digital tool to promote physical activity by altering automatic and reflective affective processing of physical activity.

Automatic Affective Evaluations Are a Target for Promoting Physical Activity

Social–cognitive and control theories have either explicitly or implicitly guided most individual-level physical activity promotion efforts (Rhodes & Nigg, 2011). These theories posit that goals are proximal determinants of behavior (Bandura, 1997; Carver & Scheier, 1998). One limitation of these approaches is that goals do not always translate into action and people who intend to engage in physical activity often fail to convert their intention into action (Rhodes & Dickau, 2012). In those cases, people seem to default to predictable, counterintentional behaviors without any effort or awareness. Automatic processes have been proposed to account for some of these failures to engage in intended physical activity, as well as for some occasions when people accumulate unintended physical activity.

Dual-process models that differentiate reflective and automatic motivational processes regulating behavior—and health behavior specifically—have gained considerable traction in recent years (Deutsch & Strack, 2014; Evans, 2008; Hofmann, Friese, & Wiers, 2008; Sheeran, Gollwitzer, & Bargh, 2013; Smith & DeCoster, 2000). Reflective processes involve relatively more awareness, intention, and effort. They draw on propositional reasoning which slows their effects. Physical activity interventions that enhance

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David E. Conroy, Department of Kinesiology and Department Human Development and Family Studies, The Pennsylvania State University, and Department of Preventive Medicine, Northwestern University; Ian Kim, Department of Preventive Medicine, University of Southern California.

Correspondence concerning this article should be addressed to David E. Conroy, Department of Kinesiology and Department Human Development and Family Studies, The Pennsylvania State University, 266 Rec Hall, University Park, PA 16802. E-mail: conroy@psu.edu

efficacy beliefs, set goals, or promote self-monitoring are targeting reflective processes. In contrast, automatic processes involve relatively less awareness, intention, and effort. They draw on learned associations to inspire rapid action. A variety of automatic affective and cognitive processes exist and several have been linked with physical activity (Rebar et al., 2016). This article builds on research that identified automatic affective evaluations (i.e., implicit attitudes) as a novel target for physical activity interventions (Conroy, Hyde, Doerksen, & Ribeiro, 2010).

Automatic affective evaluations represent "the affective experiences that arise rapidly and involuntarily when the concept of physical activity is activated" (Conroy & Berry, 2017, p. 230). They are evaluative dispositions arising from the repetition of affective experiences during physical activity. As affectively charged experiences accumulate, physical activity becomes associated with characteristic pleasant or unpleasant affective states. Subsequently, when the concept of physical activity is activated, activation spreads—rapidly and involuntarily—to associated memories of affective experiences (Anderson, 1983). The valence of affective states associated with physical activity may evoke subtle but almost immediate attentional biases and approach-avoidance motivational tendencies that could increase or decrease the likelihood of action (Cheval, Sarrazin, Isoard-Gautheur, Radel, & Friese, 2015). Even if affective memories do not rise above the threshold of awareness that would immediately manifest in reflective affective judgments, they can provide a seed that is elaborated into a reflective affective judgment with a bit of effort (Gawronski & Bodenhausen, 2006). For example, a person who experiences a pleasant automatic affective evaluation of physical activity could reflect on that gut feeling and decide that it is because he or she enjoys physical activity. Affective judgments are not affective experiences but instead represent "judgments about the overall pleasure/displeasure, enjoyment, and feeling states expected from enacting physical activity" (Rhodes, Fiala, & Conner, 2009, p. 181). On average, automatic affective evaluations of physical activity appear to be largely independent of reflective affective judgments about physical activity but automatic affective evaluations can be elaborated into reflective affective judgments as well (Conroy & Berry, 2017; Hyde, Doerksen, Ribeiro, & Conroy, 2010). Thus, automatic affective evaluations could have both direct and indirect influences on physical activity.

A recent meta-analysis of 55 effect sizes from 26 observational studies conducted with adult (primarily student) samples in North American and European laboratories revealed a small positive association between automatic affective evaluations and physical activity (Chevance, Bernard, Chamberland, & Rebar, 2019). This evidence was drawn from observational designs and does not permit strong causal inferences about the effects of automatic affective evaluations on physical activity. Experimental manipulations of automatic affective evaluations are needed to add rigor to this literature. Meta-analyses of observational and experimental studies also revealed medium and small-to-medium effect sizes, respectively, linking reflective affective judgments with physical activity (Rhodes et al., 2009; Rhodes, Gray, & Husband, 2019). Interventions that modify affective processing can influence physical activity through both automatic and reflective mechanisms.

Modifying Affective Processing and Promoting Physical Activity

Evaluative conditioning is an established behavior change technique used to promote associative learning. This technique conditions new associations via the repeated pairing of a target (i.e., conditioned stimulus) with a desired attribute (i.e., valenced unconditioned stimulus; De Houwer, Thomas, & Baeyens, 2001). The conditioned and unconditioned stimuli can be presented sequentially or simultaneously. Effects do not differ as a function of forward, backward or simultaneous presentation (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010). This technique has consistently proven effective for increasing reflective affective judgments, such as liking, of the conditioned stimulus (De Houwer et al., 2001; Forscher et al., 2019; Hofmann et al., 2010; Lai et al., 2014). In fact, effects are significantly larger for explicit than implicit measures of affective processing (Hofmann et al., 2010).

Associative learning processes have been widely targeted in marketing and politics to manipulate consumer behavior and votes (Schachtman, Walker, & Fowler, 2011; Westen, 2007). For example, one of the most devastating health-related applications came from Big Tobacco. In 1924, Marlboro cigarettes—one of the first filtered cigarettes—were marketed as a "mild as May" ladies' cigarette. In the early 1950s, researchers in the U.S. and United Kingdom reported links between smoking, cancer, and mortality (Doll & Hill, 2004; Wynder & Graham, 1950). By 1954, Phillip Morris sensed an opportunity to market their filtered cigarettes to men by changing packaging and marketing strategy. They commissioned the famous Chicago advertiser, Leo Burnett, to rebrand their product. To make filtered cigarettes seem more masculine, he created the Marlboro man—a handsome cowboy smoking, sometimes on horseback, in what came to be known as Marlboro Country ("The Marlboro Man," n.d.). This ad campaign created a new association between Marlboro cigarettes and a masculine archetype that appealed to frontier values. The Marlboro Man was launched nationally in 1955 and, within a year, Marlboro went from 1% market share to being the fourth leading brand with $5 billion sales (3,241% revenue increase). Despite growing popular attention to the health risks associated with smoking, by 1957 Marlboro sales were up to $20 billion annually. By 1971, smoking commercials were banned but the Marlboro Man had become an iconic presence in print ads. Marlboro was the #1 brand worldwide within a year. When the tobacco industry diversified their holdings in the 1980s, they applied this same conditioning technique to market sugar-sweetened beverages to children (e.g., Kool Aid; Nguyen, Glantz, Palmer, & Schmidt, 2019).

Associative learning via evaluative conditioning is not the exclusive purview of profit-motivated industries and can be harnessed to promote health-enhancing behaviors as well. It has been applied in laboratory settings to improve healthy eating, reduce alcohol use, and even improve relationship satisfaction (Bui & Fazio, 2016; Hollands, Prestwich, & Marteau, 2011; Houben, Schoenmakers, & Wiers, 2010; McNulty, Olson, Jones, & Acosta, 2017; Walsh & Kiviniemi, 2014). Three attempts to condition more pleasant automatic affective evaluations of physical activity have yielded mixed results. A 3-min audio-recorded imagery script altered automatic affective evaluations of physical activity (Markland, Hall, Duncan, & Simatovic, 2015). In another study, a single computer-based evaluative conditioning activity with 120 trials

(60 involving physical activity as the conditioned stimulus) increased automatic affective evaluations of physical activity (Antoniewicz & Brand, 2016). Participants with negative automatic associations who were assigned to receive evaluative conditioning to create more positive associations selected more intense activity on a subsequent cycle ergometer task. A third trial installed posters in hospital rooms for 4 days as conditioning stimuli. The posters combined an image of physical activity with a printed affectively pleasant adjective. Although the posters were displayed for 4 days, participants' exposure to those images could not be quantified and there was no change in automatic affective evaluations or accelerometer-measured physical activity (Chevance, Berry, Boiché, & Heraud, 2019).

These evaluative conditioning interventions to promote physical activity have been limited to relatively controlled environments. Three different modalities have been used to deliver the conditioning interventions (imagery, computer task, posters) but none lend themselves to widespread dissemination and implementation in the field. These limitations can be addressed by developing an evaluative conditioning intervention that could be implemented on smartphones.

A Digital Tool for Evaluative Conditioning

The HeartPhone application is a new digital tool for mobile evaluative conditioning. The smartphone provides a flexible means for exposing users to conditioning stimuli in the natural context of their daily lives. Mobile health applications are vulnerable to fail if users do not open the application and engage with the behavior change technique(s) regularly (e.g., Laing et al., 2014). The HeartPhone application circumvents this barrier to engagement by presenting conditioning stimuli via background wallpaper graphics on the lock screen every time a smartphone is activated. Human-computer interaction studies indicate that people typically activate their smartphones an average of 40 times/day (Harbach, De Luca, & Egelman, 2016; Harbach, De Luca, Malkin, & Egelman, 2016). Thus, HeartPhone users are expected to be exposed (briefly) to an average of 40 conditioning stimuli per day.

Purpose

Guided by the obesity-related behavioral intervention trials (ORBIT) model (Czajkowski et al., 2015), two studies were conducted to establish proof-of-concept for the HeartPhone intervention. Modeled on the drug development pipeline, the ORBIT model outlines an iterative phased approach for translating basic discoveries (e.g., that affective processes predict physical activity) into behavioral interventions (e.g., HeartPhone). The work presented here represents Phase I (Design) and Phase II (Preliminary Testing) of the ORBIT model. Study 1 evaluated the technical feasibility of changing lock screen wallpaper with every screen activation and measuring the duration of each exposure to conditioning stimuli (i.e., duration the background wallpaper was presented on the screen). Study 2 evaluated the effects of HeartPhone exposure on reflective affective judgments and self-reported physical activity to establish whether there was a clinically meaningful signal of intervention effects.

Study 1

HeartPhone v1.0 was designed to present a collage of four stimuli involving two images of physical activity (conditioned stimuli) and two affectively pleasant images (unconditioned stimuli) every time participants activated their smartphone. Stimulus collages varied randomly across trials to reduce boredom.

Exposure to the evaluative conditioning stimuli requires that participants look at their screen when unlocking the phone. Screen activation by itself proved to be an insufficient measure of exposure because notifications from apps or incoming messages can activate screens automatically and may not elicit attention in the way voluntary unlocking actions do. Thus, exposure time was measured as the duration required to successfully unlock the smartphone. This metric may underestimate exposure time because participants could turn on their phones, look at the screen, and be exposed to evaluative conditioning stimuli without fully unlocking the smartphone. Indeed, it is known that people who do not wear watches activate their phone screens more frequently than people with watches (Harbach et al., 2016).

Method

Participants and procedure. Six adults with smartphones that used an Android operating system were recruited via fliers in community locations to install HeartPhone v1.0 for 7 ($n = 2$), 14 ($n = 2$), or 21 days ($n = 2$). Participants provided written informed consent and procedures were approved by the Institutional Review Board. With every screen activation, the app presented a randomly selected lock screen background wallpaper.

Measures. The HeartPhone v1.0 app recorded all screen activations and the duration of exposure to each image presented (i.e., time from a smartphone screen turning on until the lock screen pattern password was entered successfully) and transmitted results to a backend server.

Results and Discussion

This sample was women (67%), not Hispanic or Latino (83%), White (83%), capable of performing unassisted physical activity (100%), employed full-time (83%), not married (67%), and without children (67%). The average age was 34.3 years ($SD = 8.5$; range = 25 – 49). Few participants were members of a walking/exercise/physical activity club (17%) or used an activity tracker regularly (17%). None used smartphone apps to motivate themselves to exercise regularly (0%).

Participants screens were activated on 4,973 occasions over 84 person days. Of those activations, 2,466 involved the user unlocking the phone (either after a notification or spontaneously) and 2,327 involved the screen being activated without involvement of unlocking behavior (e.g., due to an incoming notification or message). Daily unlocking frequencies ranged from three to 76 times/day ($M = 28.0$, $SD = 17.6$, $Mdn = 25.5$, interquartile range = 13.0–40.8). The median daily exposure time during successful unlocking events was 116.75 s (interquartile range = 61.6–220.0 s). Screen activation frequencies without unlocking ranged from one to 94 times/day ($M = 26.4$, $SD = 24.8$, $Mdn = 16$). It was not clear that participants were exposed to stimuli during these automatic screen activations so daily exposure time was not calculated.

These results confirm that participants activated smartphones frequently throughout the day. The average number of activations was lower than previous estimates from field studies of unlocking behavior (Harbach et al., 2016; Harbach, von Zezschwitz, Fichtner, Luca, & Smith, 2014). This difference may be attributed to the requirement that participants use the pattern-to-unlock lock screen. This format creates more friction than other unlocking methods and could dissuade participants from opening their phone as frequently as they might without that friction. It may also be conservative because it does not include exposures that did not lead to unlocking (e.g., reading notifications, checking the time). Notwithstanding this difference, participants were exposed to evaluative conditioning stimuli for approximately 2 min/day. Based on this estimate, cumulative exposure time should rapidly exceed that of laboratory-based evaluative conditioning procedures. These findings led to the conclusion that delivering mobile evaluative conditioning via background wallpaper on a lock screen is technically feasible.

Study 2

The second step in the intervention development process involved evaluating the effects of HeartPhone exposure on reflective affective judgments and self-reported physical activity to establish whether there was a clinically meaningful signal of intervention effects. Based on Study 1, the app was refined to reduce friction by presenting evaluative conditioning stimuli on a slide-to-unlock lock screen (Van Bruggen et al., 2013). HeartPhone v1.1 simply involves swiping the image after activating their phone instead of entering a pattern as with HeartPhone v1.0. Each collage was also refined to include a single pair of images that activated the concept of physical activity (conditioned stimulus) and evoked pleasure (unconditioned stimulus). Figure 1 presents an illustrative image of a conditioning stimulus.

Figure 1. Illustrative evaluative conditioning image presented as a smartphone lock screen wallpaper. ©Africa Studio (top image) and Boggy (bottom image)—stock.adobe.com. See the online article for the color version of this figure.

Method

Participants and procedure. Adults (n = 19) using smartphones with an Android operating system were recruited via fliers placed in the community. Procedures were approved by the Institutional Review Board. Participants provided written informed consent and completed questionnaires about their demographic characteristics, motivation, and physical activity during a baseline lab visit. The researchers assisted participants in installing the HeartPhone v1.1 app on their Android device. At the end of each week, participants were prompted via e-mail to complete an online questionnaire about their past-week physical activity. After 8 weeks, participants returned to the lab to complete questionnaires and remove the app from their smartphone.

Measures. The HeartPhone v1.1 app recorded all screen activations and the duration of exposure to each image presentation and transmitted results to a backend server.

Participants reported on past-week physical activity every week using a web-based short-form of the International Physical Activity Questionnaire (Booth, 2000; Craig et al., 2003; Sjöström et al., 2005). For walking, moderate-intensity and vigorous-intensity activity, participants reported the number of days when they engaged in that activity over the past week and the average daily duration of activity at that intensity on those days. Established scoring criteria were used to generate scores for total physical activity volume and to classify participants as low (<600 metabolic equivalent [MET] • minutes/week), moderate (600–2,999 MET • minutes/week), or high (≥3,000 MET • minutes/week) active (Sjöström et al., 2002).

During the baseline and Week 8 lab visits, participants described their motivation and reflective affective judgments about physical activity using seven questionnaires with established psychometric properties. A four-item scale from the Self-Report Habit Index was used to measure behavioral automaticity (Gardner, Abraham, Lally, & de Bruijn, 2012; Verplanken & Melkevik, 2008; Verplanken & Orbell, 2003). Items were rated from 1 (*strongly disagree*) to 7 (*strongly agree*) and responses were averaged to create a scale score. The 18-item Physical Activity Enjoyment Scale was used to assess affective judgments of enjoyment for physical activities over the past 4 weeks (Kendzierski & DeCarlo, 1991). The original items on this scale were bipolar and were reformatted for clarity using the anchor on the left side of the original scale as the item stem (e.g., "I enjoy it" to "I hate it" simply became "I enjoy it"). Items were rated from 1 (*disagree a lot*) to 5 (*agree a lot*). Responses were reverse-scored as needed and averaged to create a scale score. Two scales from the Intrinsic Motivation Inventory were completed to assess interest/enjoyment (seven items) and value/usefulness (seven items; McAuley, Duncan, & Tammen, 1989). Items were rated from 1 (*not at all true for me*) to 7 (*very true for me*) and responses were averaged to create each scale score. The 23-item extended Behavioral Regulations for Exercise Questionnaire-2 was used to measure a range of intrinsic and extrinsic behavioral regulations (Markland & Tobin, 2004; Mullan, Markland, & Ingledew, 1997; Wilson, Rodgers, Loitz, & Scime, 2006). Items were rated from 0 (*not true for me*) to 4 (*very true for me*) and responses were averaged to create scale scores for intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, and amotivation. Attitudes toward physical activity were assessed using six bipolar items each (Rhodes, Blanchard, Matheson, & Coble, 2006). Affective attitude item anchors were enjoyable/unenjoyable, pleasant/unpleasant, and exciting/boring. Instrumental attitude item anchors were useful/useless, wise/unwise, and beneficial/harmful. Each item was rated by dragging a slider between the two poles. Responses were recorded on a 101-point scale ranging from 0 to 100 and averaged to create each scale score.

At the end of the study, participants also completed the 10-item System Usability Scale (Bangor, Miller, & Kortum, 2009; Lewis & Sauro, 2009) and custom items about their experience with the HeartPhone app. Items were rated from 1 (*strongly disagree*) to 5 (*strongly agree*) and responses were averaged to create scale scores. Custom items included: "I found the pictures in the HeartPhone app to be interesting [enjoyable]" (rated from −2 [*strongly disagree*] to +2 [*strongly agree*]), "I would be more interested in using the HeartPhone app if I could choose my own images" (rated as yes/maybe/no), "How useful did you find the HeartPhone app?" (rated from 0 [*not at all useful*] to 4 [*extremely useful*]), "Would you keep the HeartPhone app on your telephone if that was possible?" (rated as yes/maybe/no), "Did the HeartPhone app slow the processing speed of your phone?" (rated as yes/maybe/no), "Did you ever tell your friends or family about the HeartPhone app?" (rated as yes/maybe/no), "Would you recommend the HeartPhone app to your friends or family?" (rated as yes/maybe/no), "I would use the HeartPhone app if it was free" (rated as yes/maybe/no), "Using the HeartPhone app reminded me to exercise" (rated as yes/maybe/no), "Using the HeartPhone app made exercise seem more pleasant" (rated as yes/maybe/no), and "How useful did you find the HeartPhone app?" (rated from 0 [*not at all useful*] to 4 [*extremely useful*]).

Results and Discussion

Participants (53% male) were not Hispanic or Latino (100%), White (79%), capable of performing unassisted physical activity (100%), employed full-time (63%), not married (58%), and without children (79%). The average age was 30.1 years (SD = 9.3; range = 20–49). Few participants were members of a walking/exercise/physical activity club (11%), used an activity tracker regularly (16%), or used smartphone apps to motivate themselves to exercise regularly (11%). One participant withdrew after 2 weeks but the remaining sample (95%) completed the entire protocol (Mdn = 57 days).

A total of 50,243 unlock-triggered screen activations were recorded. On average, participants unlocked their smartphones 45.7 times/day (SD = 32.3; range = 7.3–107.0). Median presentation time for stimuli during each unlocking cycle was 1.25 s (after removing outliers in the top 5% of presentation times). Switching from a pattern unlock (v1.0) to a slide-to-unlock (v1.1) lock screen increased recorded screen activations but decreased average exposure time for each unlocking episode.

With respect to system usability, the app was rated in the good-to-excellent range (M = 4.2/5, SD = 0.6). Images were rated as moderately interesting (M = 3.8/5, SD = 1.4) and enjoyable (M = 3.7/5, SD = 1.3). The majority (77%) of participants agreed or strongly agreed that the images were interesting and enjoyable. Only 29% expressed that they would be more likely to use the app if it included their own images.

Most participants would consider using the app if it was free (88%), were interested in keeping the app on their phones (77%), had told friends or family about the app (82%), and would recommend the app to friends or family (77%). A minority (12%) believed that the app slowed the processor on their phone. Finally, participants reported that the app reminded them to exercise (77%) and made exercise seem more pleasant (65%). Overall, most participants (88%) rated the app as being moderately useful or better and only a minority (12%) rated it as not useful.

Table 1 summarizes descriptive statistics and internal consistency estimates for each motivation scale. Three scales representing less autonomous behavioral regulations for physical activity had unacceptable internal consistency estimates (i.e., $\alpha < .70$) on one occasion. As shown in the table, statistically significant increases were observed for ratings of enjoyment, affective attitudes, overall attitudes, value/usefulness, intrinsic motivation, and integrated regulations. Although not statistically significant, trends (i.e., $d \geq 0.30$) were observed for more favorable instrumental attitudes, greater interest/enjoyment, increased identified regulations, and stronger habit strength (behavioral automaticity).

Observed changes in affective judgments and autonomous motivation were consistent with downstream effects of evaluative conditioning predicted by the associative-propositional model (Gawronski & Bodenhausen, 2006) and emerging dual-process models of physical activity (e.g., Brand & Ekkekakis, 2018; Cheval et al., 2018; Conroy & Berry, 2017). Affective judgments, such as enjoyment, have consistently demonstrated medium-sized positive associations with physical activity (Rhodes et al., 2009, 2019). Likewise, more autonomous behavioral regulations, such as

Table 1
Motivation Measures From Baseline and 8-Week Assessments

Motivation scale	Baseline α	Baseline *M* (*SD*)	Week 8 α	Week 8 *M* (*SD*)	*t*	*p*	*d*
Physical activity enjoyment	.83	3.70 (0.65)	.90	4.14 (0.54)	2.22	.044	0.57
Attitude toward exercise							
Instrumental attitude	.97	86.02 (23.40)	.84	93.44 (8.58)	1.66	.119	0.43
Affective attitude	.92	57.43 (25.67)	.96	78.52 (18.78)	3.09	.009	0.83
Overall attitude	.90	72.08 (21.80)	.88	85.92 (12.28)	2.83	.004	0.76
Intrinsic Motivation Inventory							
Interest/enjoyment	.95	4.47 (1.92)	.89	5.20 (1.27)	1.14	.272	0.30
Value/usefulness	.90	6.05 (0.95)	.90	6.63 (0.53)	3.10	.009	0.83
Intrinsic motivation	.89	5.13 (0.96)	.88	5.99 (0.75)	3.22	.007	0.86
Behavioral Regulations in Exercise Questionnaire-2							
Intrinsic motivation	.96	2.28 (1.14)	.92	2.83 (0.92)	2.63	.020	0.68
Integrated regulation	.88	2.07 (0.93)	.88	2.47 (1.00)	3.81	.002	0.98
Identified regulation	.80	2.68 (0.96)	.75	3.01 (0.71)	1.98	.068	0.51
Introjected regulation	.64	1.89 (0.91)	.76	2.12 (0.85)	1.08	.298	0.28
External regulation	.82	0.77 (0.43)	.54	0.69 (0.39)	−0.54	.599	−0.14
Amotivation	.49	0.67 (0.59)	.77	0.52 (0.54)	−0.98	.349	−0.28
Habit strength (behavioral automaticity)	.98	2.82 (2.17)	.94	3.55 (1.64)	1.82	.090	0.47

intrinsic motivation and identified regulations, have been linked with greater physical activity (Teixeira, Carraça, Markland, Silva, & Ryan, 2012). These changes are consistent with the pattern of reflective elaboration that one would expect if the app enhanced automatic affective evaluations but do not demonstrate that HeartPhone modified automatic affective evaluations. Future research should investigate whether the HeartPhone intervention is effective for modifying this target of behavior change and compare the contributions of automatic and relative affective processing mechanisms to behavior change.

The dataset had 16 participants with complete weekly physical activity data (one participant failed to complete the baseline measure and another failed to complete the final measure). Most (82%) showed positive trends in their weekly self-reported physical activity volume. Prepost change was statistically significant, $t(15) = 2.27$, $p < .05$, $d = 0.75$. Figure 2 indicates a monotonic trend for increasing weekly physical activity across the eight assessments during the intervention. We conducted a sensitivity analysis using the first and last valid scores from each participant, and prepost change remained statistically significant, $t(17) = 2.61$, $p < .05$, $d = 0.64$. Participants classified as low active at baseline increased to moderately active (75%) or highly active (25%) at 8 weeks; none remained low active. Participants classified as moderately active at baseline increased to highly active (80%) or remained moderately active (20%) at 8 weeks. Participants classified as highly active at baseline remained highly active (88%) or decreased to moderately active (12%) at 8 weeks.

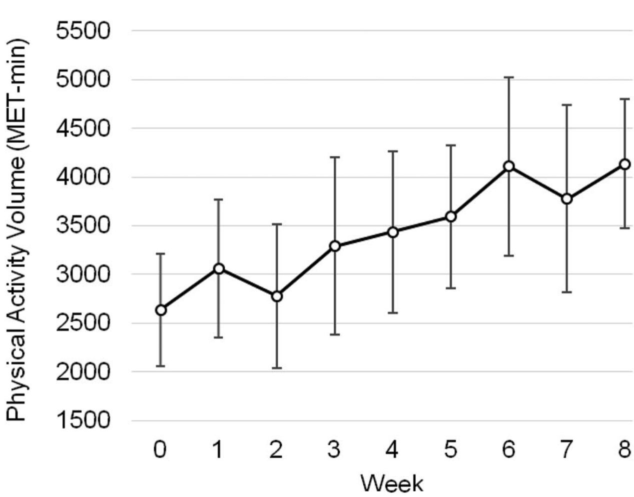

Figure 2. Weekly changes in total physical activity volume. MET = metabolic equivalent.

Overall, the observed changes in physical activity in this study were more than three times larger than the average effect of physical activity interventions with healthy adults (Conn, Hafdahl, & Mehr, 2011). As provocative as this finding appears to be, caution is warranted pending replication with a larger sample using a randomized controlled trial design and device-based measures of physical activity.

General Discussion

This early phase intervention development research translated basic findings that validated a new target for increasing physical activity into a digital tool for enhancing affective processing and promoting physical activity. Findings indicated that delivering evaluative conditioning on a temporally-distributed schedule via background graphics on lock screens is both feasible and acceptable to participants with Android smartphones. As expected, reflective affective processes and physical activity increased with cumulative exposure to these conditioning stimuli. Conclusions about intervention efficacy are premature because of the small sample size and absence of a rigorous experimental design with an appropriate comparator. Nevertheless, these findings provide proof-of-concept for temporally distributed evaluative conditioning via smartphone lock screens.

The first contribution of this work involved demonstrating that microdoses of evaluative conditioning can be delivered via smartphone lock screens. Lock screen use has typically been studied in the context of security and risk aversion (Egelman et al., 2014; Harbach et al., 2016; Harbach, De Luca, Malkin, et al., 2016; Harbach et al., 2014; Van Bruggen et al., 2013). Others have placed widgets on lock screens to engage users with a health behavior intervention that involves self-tracking (Choe et al., 2017). To the best of our knowledge, the HeartPhone app is the first to capitalize on this digital storefront to deliver a health behavior intervention without imposing burden or creating friction for users.

Approximately 65% of smartphone owners use a lock screen to secure their smartphone (Harbach, De Luca, Malkin, et al., 2016; Van Bruggen et al., 2013). These screens are activated frequently and, although each exposure is relatively brief, cumulative exposure time will rapidly exceed what can be achieved in laboratory evaluative conditioning protocols. Thus, HeartPhone may solve a long-standing problem for how to deliver evaluative conditioning interventions in the field. This strategy reduces friction by integrating exposures in users' existing workflows with their smartphones.

One limitation of this approach is that it can be difficult to persuade users to use lock screens if they do not already use them (Van Bruggen et al., 2013). Potential intervention reach was increased in HeartPhone v1.1 by refining the app so users could use a slide-to-unlock method instead of a pattern-to-unlock method. Additionally, the type of lock screen used can influence the duration of exposure to conditioning stimuli. Specifically, pattern and passcode methods take longer than the slide-to-unlock method (Harbach et al., 2016). Tradeoffs exist. Pattern users initiate their patterns quicker and enter them more quickly when successful. Pattern users also make more errors and repeat their patterns more frequently. Future research should investigate the impact of different lock screen methods on exposure time, affective processing, and behavior change.

A second contribution of this work was in providing proof-of-concept for smartphone-based delivery of evaluative conditioning in the natural context of daily life. Evaluative conditioning is well-established as a technique for modifying affective processing and behavior in the laboratory (De Houwer et al., 2001; Forscher et al., 2019; Hofmann et al., 2010; Lai et al., 2014). Physical activity researchers have examined environmental modifications to facilitate evaluative conditioning (Antoniewicz & Brand, 2016; Chevance, Berry, et al., 2019). The present study extended prior work by implementing a method to deliver evaluative conditioning via the digital environment of smartphone lock screens. This implementation requires the temporal distribution of exposures (unlike most laboratory studies). Some evidence suggests that distributed exposures enhances conditioning effects so this spaced implementation may be preferable to massed conditioning protocols in the lab (Richter & Gast, 2017). It is also possible that cumulative exposure time from this approach is overestimated if users do not visually orient to their screens immediately upon activation.

This application of evaluative conditioning sought to create or strengthen associations between physical activity and pleasure. If this approach increases physical activity—and light-intensity physical activity in particular—it is possible that it could also reduce sedentary behavior, either by displacing sedentary time or offsetting the reward value of energy conservation (cf. Cheval et al., 2018). Future work should consider sedentary time as a potential secondary outcome when evaluating HeartPhone. It may be possible to reduce sedentary behavior by creating or strengthening associations with displeasure directly; however, the images used to activate displeasure in conditioning stimuli are unlikely to be well-accepted by users. For example, the most unpleasant images in the International Affective Picture System involve themes such as contamination, mutilation, and threat (Bradley & Lang, 2007). It is difficult to conceive that users would tolerate seeing those images upon every screen activation, especially when others in their vicinity might also see the images. Thus, we expect that mobile evaluative conditioning may be best suited to appetitive rather than aversive conditioning of target behaviors.

Evaluative conditioning is a classical conditioning technique that aims to strengthen associations between a conditioned and unconditioned stimulus (as opposed to a stimulus and a behavioral response). Health psychologists have long been interested in automatic processes that support health behaviors but much of this work has focused on operant conditioning processes (Hunt, Matarazzo, Weiss, & Gentry, 1979). Observed changes in motivation and behavior during HeartPhone use were consistent with expectations from the associative-propositional evaluation model (Gawronski & Bodenhausen, 2014); however, other mechanisms of behavior change may also be engaged. For example, repeated exposure to images that activate the concept of physical activity may breed familiarity and increase liking (i.e., the mere exposure hypothesis; Zajonc, 2001). Alternately, conditioning stimuli that evoke pleasure could engage thought-action repertoires involving playful or exploratory behavior (e.g., broaden-and-build theory; Fredrickson, 2004). As research moves through the ORBIT pipeline from Phase II (preliminary testing) to Phase III (efficacy) trials, it will be important both to evaluate both the efficacy of the intervention and to determine the mechanism(s) of effects. In other contexts, evaluative conditioning effects have shown resistance to extinction (Baeyens, Crombez, Van den Bergh, & Eelen, 1988; Forscher et al., 2019; Gawronski, Gast, & De Houwer, 2015; Pine, Mendelsohn, & Dudai, 2014; Vansteenwegen, Francken, Vervliet, De Clercq, & Eelen, 2006). It will be important to investigate whether this technique can address the persistent challenge of behavioral maintenance (Rothman, Sheeran, & Wood, 2009). Questions about stimulus optimization, optimal dosing, and characteristics of responders and nonresponders will also require attention.

In the spirit of "failing fast," the studies reported here used small sample sizes and were not recruited to be representative of the more diverse general population. Motivational and behavioral outcomes were self-reported so changes may be due to demand characteristics or testing threats. The single-group design also makes it impossible to distinguish change from maturation so causal inferences about efficacy are not possible. Notwithstanding these limitations, the results clearly provide the proof-of-concept that warrants progression to the next phase of intervention development with more rigorous evaluations of effects on behavior, biomedical risk factors and clinical outcomes.

In sum, the HeartPhone intervention was developed to promote physical activity by engaging affective processing in a low-friction manner. It provides a potential solution to the challenge of delivering evaluative conditioning interventions outside of laboratory settings. The early phase studies reported here informed the design and preliminary testing of the intervention. Results justify additional investment in Phase IIb/III development with pilots and efficacy trials that incorporate more rigorous research designs, more diverse samples, device-based behavioral outcome measures, and biomedical risk factors as distal outcomes. If successful, the HeartPhone intervention could also be adapted to intervene on other affectively-regulated lifestyle behaviors that impact health and well-being. This intervention approach could provide a much-needed counterweight to commercial determinants of health that target affective processing to advance industry interests. Thus, this early phase intervention development work represents a beginning of research—and is far from the final word—on the HeartPhone intervention and its mobile evaluative conditioning method.

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