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**Improving affective valuations of
physical activity with mobile technology:
A protocol for a hybrid
factorial/micro-randomized trial**

By

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A Master's Thesis

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Abstract

Background: Mobile health (mHealth) intervention can help sedentary adults increase physical activity. Specifically, having positive affective valuation (i.e., enjoyment towards walking) towards physical activity can have the potential for building an active lifestyle.

Objective: This study aims to evaluate and optimize each of the three affective valuation intervention components, deployed as a part of an mHealth intervention, for their ability to positively influence people's affective attitudes towards and affective associations with walking.

Design: The study is a 6-week full factorial experiment with 3 factors (i.e., for a total of 8 conditions) with an embedded micro-randomized trial.

Participants: Forty sedentary adults over 18 years old who have neutral to negative affect towards physical activity.

Intervention: The study will assess three intervention components: 1) Sending messages for conditioning positive affect to the thought of walking, 2) sending messages to increase salience of positive aspects of walking, and 3) planning for enjoyable experience on future walks.

Conclusion: The study will provide insights on decisions regarding the optimization of each of the intervention components to help sedentary adults positively revise their expectation that walking will be an enjoyable and a fulfilling experience.

Introduction

Background

Physical activity positively impacts long-term health and wellness, with a range of physiological (e.g., managing weight, blood glucose, and blood pressure), cognitive (e.g., feeling energetic, alert, confident), emotional (e.g., improved mood, reduction in anxiety and stress), and preventive health benefits (e.g., reduced risk of heart disease or diabetes) (Janssen & LeBlanc, 2010; Ploughman, 2008; Saxena et al., 2005; Warburton et al., 2006). However, research shows that 25% of American adults live a sedentary lifestyle with no regular physical activity, and more than 60% do not meet the recommended levels of activity (i.e., 150 minutes of moderate-intensity physical activity and 2 days of muscle strengthening activity) (Pate et al., 1995; Piercy et al., 2018). Despite the many documented benefits of physical activity for health and wellness, increasing physical activity on population level remains a challenge.

With a high penetration of smartphones and wearables across a broad range of population, there have been many interventions that have attempted to provide support for physical activity through mobile health (mHealth) applications (Orji & Moffatt, 2018). Compared to more traditional modes of intervention such as in-person behavior coaching, the key benefits of mHealth applications are high accessibility, low cost, and support for user autonomy (Stephens & Allen, 2013; Rollo et al., 2016; Bice et al., 2016). While mHealth research to-date has demonstrated meaningful short-term effects on physical activity (Spring et al., 2012; Afshin et al., 2016; Bardus et al., 2015; Direito et al., 2017), these effects usually decline by 6 to 12 months (Duncan et al., 2020; Murawski et al., 2019), and many interventions have faced high levels of abandonment (Attig & Franke, 2020; Fadhil, 2019; Lee & Lee, 2017). Among the reasons for the abandonment of interventions, the most frequently cited are the dynamic changes in people's intrinsic motivation and intention for the behavior (Attig & Franke, 2020). Having a sustainable, positive affective state such as emotionally enjoying and having positive associations towards physical activity are important factors for increasing intrinsic motivation and

intention for physical activity (Mohiyeddini et al., 2009; Mullen et al., 2011; Simonton, 2020). Studies show that affective states, a pleasant or unpleasant mood or emotion as well as the general feeling of pleasure and displeasure (Brand & Ekkekakis, 2018), impact the flow of information processing in the brain in a way that either enhances or inhibits behaviors (Pessoa, 2009; Fishbach & Labroo, 2007), and facilitating positive emotions have positive implications in physical activity among sedentary individuals (Simonton, 2020). Moreover, attitudes towards and associations with physical activity, an automatic cognitive and affective processes, have been found to dictate one's exercise behavior, performance, and exercise decision preference (Brand & Schweizer, 2015; Cheval et al., 2018; Deforche et al., 2006; Schinkoeth & Antoniewicz, 2017; Schinköth & Brand, 2020). Despite the close relationship of the affective associations on people's motivation and behavior, many mHealth interventions do not consider this important determinant of physical activity. Although more recent interventions have attempted to target people's affective states by mood tracking, these interventions do not directly influence the affective state of a user (Caldeira et al., 2017; Lathia et al., 2017).

An Affective–Reflective Theory of physical inactivity and exercise (ART) provides a theoretical framework for the role of affective valuation processes in exercise motivation and behavior change (Ekkekakis & Brand, 2019; Brand & Ekkekakis, 2018). The theory explains the relationship between automatic affective processing, which occurs quickly and automatically with minimal cognitive resources or effort, and reflective processing, which occurs slowly and requires cognitive reasoning through working memory (Brand & Ulrich, 2019; Schinköth & Brand, 2020; Ekkekakis & Brand, 2019; Brand & Ekkekakis, 2018). The interaction of the two processes together dictates an individual's behavior, with the automatic affective valuations acting as the basis for the reflective processes. Based on this theoretical framework, we developed a WalktoJoy mobile intervention aimed at improving sedentary individuals' affective attitudes towards and affective associations with walking (i.e., moderate physical activity) using three intervention strategies that target the affective valuation processes.

Aims

The aim of the current study is to optimize the WalktoJoy intervention by investigating the impact of the micro-randomized components on their respective proximal outcomes – outcomes through which these intervention components would improve individuals' affective attitude and affective association with physical activity. WalktoJoy intervention targets sedentary individuals who have negative to neutral affective attitudes, a person's overall feelings and emotions about the walking experience (Crites et al., 1994), and affective associations, feeling states connected with the walking behavior (Kiviniemi et al., 2007). Our intervention aims to help these individuals improve their affective attitude and affective associations of walking in three ways: (1) by eliciting positive emotions via smile-inducing stimuli, (2) increasing salience to the positive aspects of walking, and (3) planning modifications to walking behavior to make future walks more enjoyable.

Theoretically, there are two distinct intervention strategies used. The first intervention strategy is based on classical conditioning where we hypothesize that pairing suggestions to go for a walk with an unconditioned stimulus that induces smiling such as a GIF will, over time, create associations between smiling and feeling happy with the thought of walking. The second intervention strategy uses belief updating, and is designed to update people's existing expectations or prior beliefs about the negative experience of walking, which are shaped and solidified over time through repeated exposure to the experience, by repeatedly nudging participants to pay attention to the enjoyable aspects of walking (Ludwig et al., 2020). By positively changing the emotional value and reward of the walking behavior, we aim to make choosing to go for a walk more effortless since the choice will be driven by a revised expectation that walking will be a pleasant and fulfilling experience. (Petty et al., 2001; Zanna et al., 1970). We hypothesize that the WalktoJoy intervention will help make the walking experience more enjoyable, help users become more acutely aware of that enjoyable experience, and ultimately update their affective expectation about and reward value for walking to build sustainable intrinsic motivation towards walking behavior.

Methods

Overview

The primary objective of this study is to evaluate three affective valuation intervention components, deployed as a part of an mHealth intervention, for their ability to positively influence people’s affective attitudes towards and affective associations with walking.

The study is a 6-week full factorial experiment with 3 factors (i.e., for a total of 8 conditions) with an embedded micro-randomized trial.

Factorial experiments enable researchers to assess contributions of each tested intervention component to a common outcome. In our study, the factorial experiment will be used to test whether each of the three components contributes to an improvement in weekly measures of affective valuation and affective attitudes.

Micro-randomized trials (MRTs), an experimental study design that can be used to optimize and improve mobile health interventions (Klasnja et al., 2015; Smith et al., 2017; Qian et al., 2022), will be used to investigate the impact of the study’s intervention components on their respective proximal outcomes for positively influencing individuals’ affective attitude and affective association with physical activity. The MRTs help assess the relative effectiveness for each of the intervention options (i.e., GIF messages for conditioning positive affect related to walking) within the entire intervention package, and provide insights on building rules (e.g., timing and context) for the delivery of each component.

Eligibility screener	Onboarding	Baseline Week (+7 days)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Post-intervention	Post-study Optional Interview
Receive Participant ID & 8-letter token upon eligible	Baseline survey, Personalization , Fitbit authorization, Allocation to groups etc.	Baseline measure for daily step counts and activity level (i.e., number of walks)	For all participants: <ul style="list-style-type: none"> • Daily End-of-day measures • Weekly Check-in measures • Weekly Data Summary 						Post-study measure & analysis	Semi-structured interview

Table 1. Study Flow

We hypothesize that having access to each of the three components of our intervention will result in an improvement in affective attitudes toward walking as well as in affective associations with walking. This change will lay a foundation among sedentary individuals for building a sustainable motivation for moderately-intense physical activity.

Study Procedures

Participant Recruitment & Eligibility Criteria

The study population will be adults over 40 who currently live in the U.S. with access to a smartphone device and a Fitbit, an activity wearable tracker. We will recruit a total of 40 participants from various Fitbit community platforms as well as UM mailing lists. We will first send out a recruitment email or post containing a short description of the study and a link to the study recruitment website. The website will contain a full description of the study, contact information, and a link to the Qualtrics-based eligibility screener. In the screening survey, participants will be asked to self-report their satisfaction with their current activity level with a conditional 2-item measure that uses a 5-point scale: Potential participants will first be asked “I want to be more physically active,” with responses ranging from “strongly disagree” (1) to “strongly agree” (5). If a potential participant answers 3 or above, the second item will be asked: “To be more active, I want to increase how much I walk,” with responses ranging from “strongly disagree” (1) to “strongly agree” (5). Those who score 3 points or above for both measures will be invited to participate in the study. Eligible participants will then be asked to evaluate their intent to participate and complete the Informed Consent form. Upon completion, participants will be asked to provide their email address and phone number to receive further instructions on how to enroll into the study.

The inclusion criteria are as follows:

- Adults 40 years or older living in the U.S..
- Have no medical condition that would prevent them from safely engaging in a

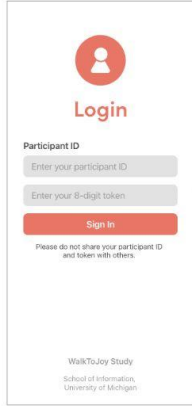
moderate physical activity (i.e., walking).

- Have access to a smartphone that can run the Fitbit app.
- Have and can use Fitbit device daily for the duration of the study.
- Have a safe and easily accessible place to walk.
- People who have neutral to negative affect towards physical activity (i.e., people who score 3 or more on the 2-item measure for satisfaction to activity level during screening survey).

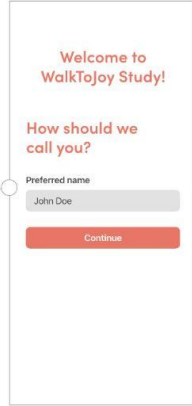
Application & Interaction

ONBOARDING

Login page



Preferred name



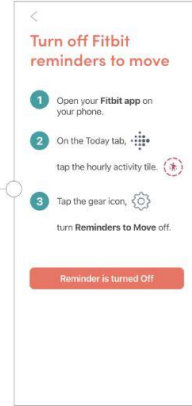
Personalize your experience



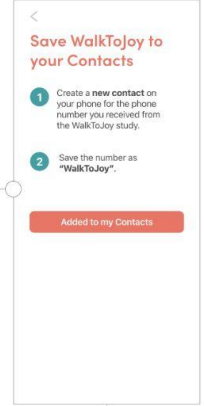
Authorize Fitbit



Turn off Fitbit reminder

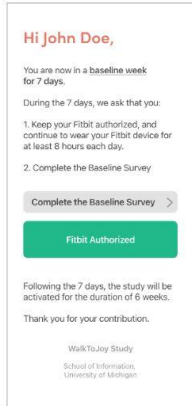


Save WalkToJoy to Contacts

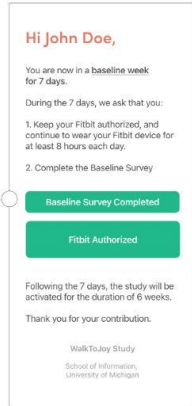


BASELINE WEEK

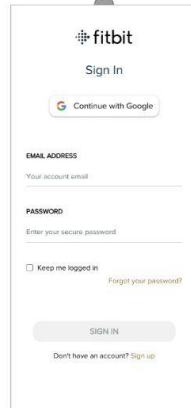
Baseline Week



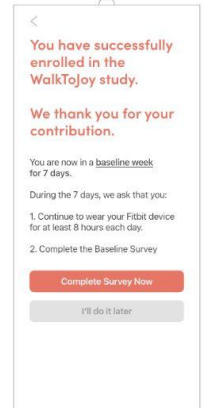
Baseline Week - 2



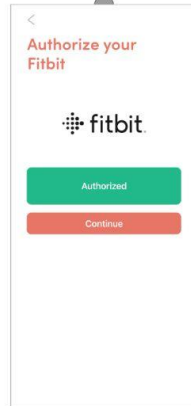
External Link



Enrolled in Study

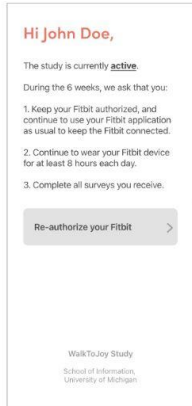


Authorize Fitbit - authorized



INTERVENTION WEEK

Intervention Week



Intervention Week - 2

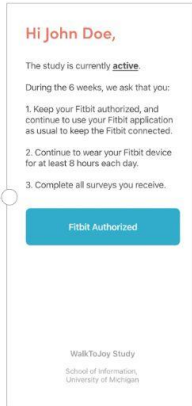


Figure 1. Application Interaction Map

Due to the COVID-19 limitation, the entire study is designed to be contact-free.

Eligible participants will be directed to the consent form to sign and start the onboarding process. Following the consent form, participants will be asked to provide their email address for receiving onboarding instructions and phone number to receive intervention via text messages. Participants will then receive their participant ID and 8-letter token along with the onboarding instructions via email. The participant ID and 8-letter token will be used to sign into the WalktoJoy application on their smartphones to complete the onboarding tasks. Participants will also be randomly assigned to one of 8 conditions at this time.

Upon signing into the WalktoJoy web application (see Figure 1), participants will be walked through the onboarding process of personalizing intervention experience (i.e., setting normal waking hour), authorizing Fitbit account, and configuring phone and Fitbit application settings.

The application architecture of the WalktoJoy intervention is shown in Figure 2.

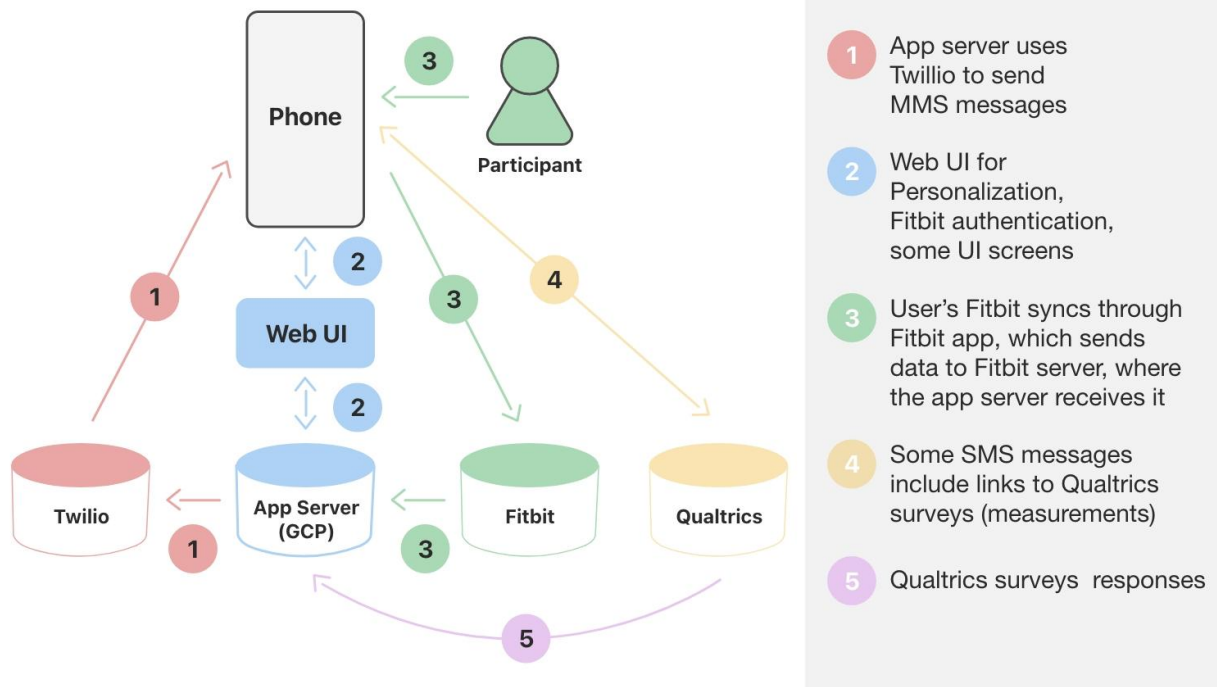


Figure 2. WalktoJoy App Architecture

Baseline Assessments

In the baseline survey, participants will be asked to indicate their gender, motivation for physical activity, best hours to receive prompts to walk (i.e., waking hours), baseline measure of affective attitude and affective association to walking, and a body awareness questionnaire. Once participants complete the baseline survey and other onboarding tasks, participants will be fully enrolled into the study and will immediately begin their baseline week. The study will measure daily step counts and activity level (i.e., number of walks) for at least 7 days as a baseline measurement period. Participants will be put into the intervention week the following Monday after the 7 day period.

Interventions

The intervention consists of text messaging targeting affective attitudes and

associations and a real-time activity tracking wearable device to encourage positive affect and affective reflection about walking. Specifically, the study will assess 3 intervention components.

Positive conditioning with GIF prompts to walk

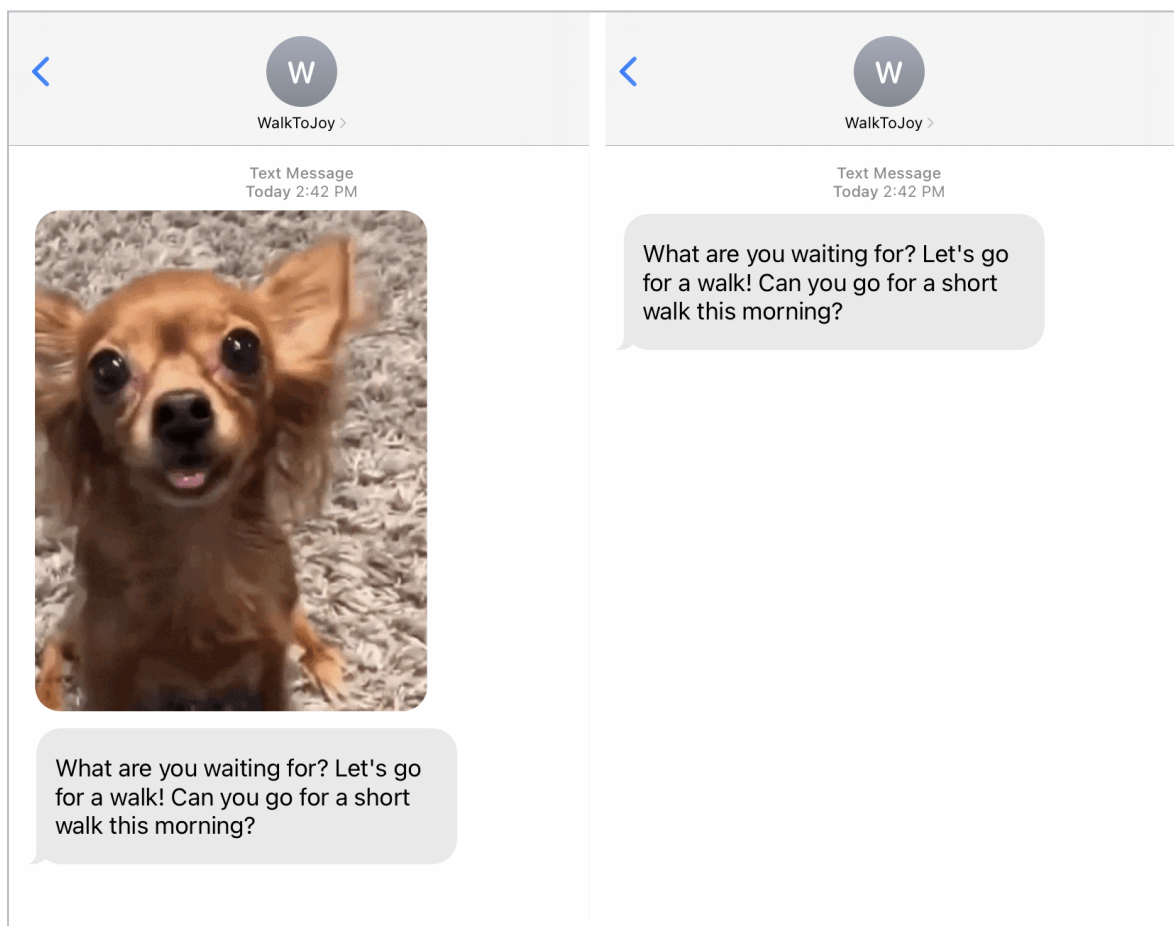


Figure 3. Example Prompt to walk for the GIF group (left) and Non-GIF group (right), respectively

The first intervention component involves sending participants a message that prompts them to find a time to go for a walk in the next few hours (see Figure 3). The short message is either sent with an animated image in a Graphics Interchange Format (GIF) that aims to elicit automatic positive affect upon receiving the message (GIF group), or it is sent without a GIF (Non-GIF group). The main goal for this intervention component is to test whether repeated pairing of acute smile-inducing stimuli in the form of a GIF

with the prompt to go for a walk will help participants to associate feeling good and smiling with the thought of walking. This pairing strategy is based on classical conditioning (Zanna et al., 1970), where an unconditioned stimulus, the GIF, is paired with a neutral stimulus, the message prompt to go for a walk, to create a conditioned emotional response where the thought of walking itself elicits positive emotions. Thus, we hypothesize that the association of positive emotion with the idea of walking will make participants more likely to go for a walk when prompted and enjoy the walking experience.

Salience of positive aspects of walking

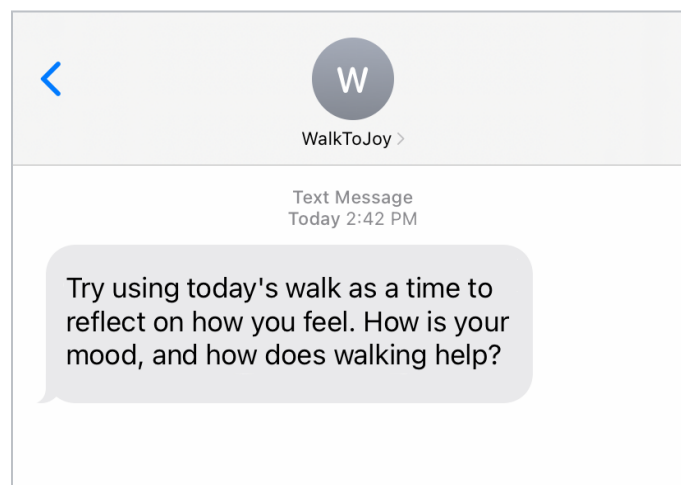


Figure 4. Example Salience message

The second intervention component involves sending a salience message (see Figure 4) that directs participant's attention towards the positive aspects of the walking experience. The salience message content will be randomly chosen among the topics of paying attention to the environment, body, affective state, or a particular behavior. The main goal for this intervention component is to test whether being cognisant of the positive aspects of the walking experience, an affective reflective process, will allow participants to associate the feeling of enjoyment to the experience of walking. This strategy uses salience to update the reward value of the walking experience, where the existing belief around the experience is replaced with the new positive experience to create a bias towards positive feelings towards walking (Ludwig et al., 2020). We

hypothesize that this method of belief updating via salience will positively increase the affective attitude towards walking over time.

Planning enjoyable walks

The third intervention component involves sending a reflection prompt once a week (i.e., Monday mornings) that asks participants to reflect on their previous week’s walking experience to make a plan for how they can modify their future walks to make them more enjoyable. The prompt will provide examples of potential planning strategies such as listening to one’s favorite album or a podcast, walking with a friend or family, and so on. Participants will randomly receive either a planning prompt that asks to try a new planning strategy or continue the same planning strategy from the previous week. Moreover, when participants complete the prompt, they will receive a reminder twice during the week (i.e. Tuesdays and Thursdays) on how they planned their walks. This intervention component aims to make the planned walk more enjoyable for the participants each time, which will in turn update the reward value for walking. Similarly to the second intervention component, we hypothesize that staging a more enjoyable experience from the beginning of each walk will help participants build expectations that walking will be more enjoyable over time. Also, the repeated reflection and planning for future walks will allow for more awareness, reflection and curiosity on ways to make the walking experience more enjoyable before, during and after the walk.

Randomization

Conditions /Factors	GIF	SALIENCE	PLANNING
1	*ON	*ON	*ON
2	*ON	OFF	*ON
3	*ON	*ON	OFF
4	*ON	OFF	OFF

5	*OFF	*ON	*ON
6	*OFF	*ON	OFF
7	*OFF	OFF	*ON
8	*OFF	OFF	OFF

*Embedded micro-randomized trials

Table 2. Intervention Conditions

When participants enter the study, they will be randomized on each of the three intervention components as shown in Table 2, meaning that participants can be randomized to one of eight conditions corresponding to unique combinations of the levels of the three factors.

Micro-randomization

Intervention Component 1: Positive conditioning with GIF prompts to walk

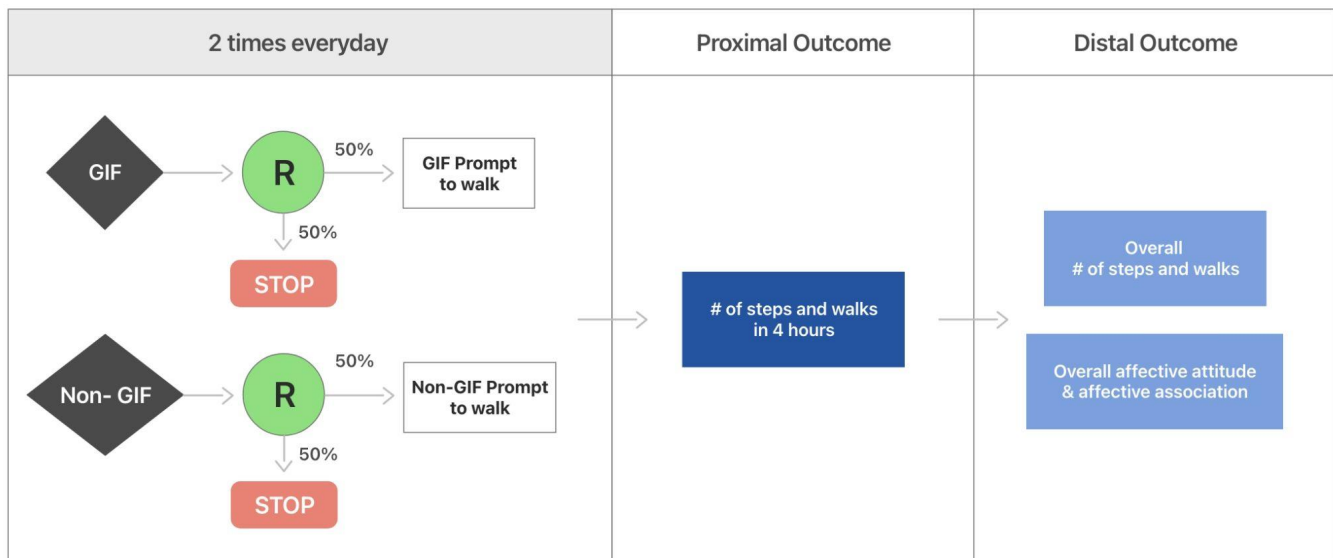


Figure 5. Implementation Map for Component 1

With embedded micro-randomized trials, message prompts for both GIF and Non-gif

groups have a 50% chance of activation twice a day (i.e., morning and afternoon), meaning participants may or may not receive up to two prompts to walk per day (See Figure 5).

Intervention Component 2: Salience of positive aspects of walking

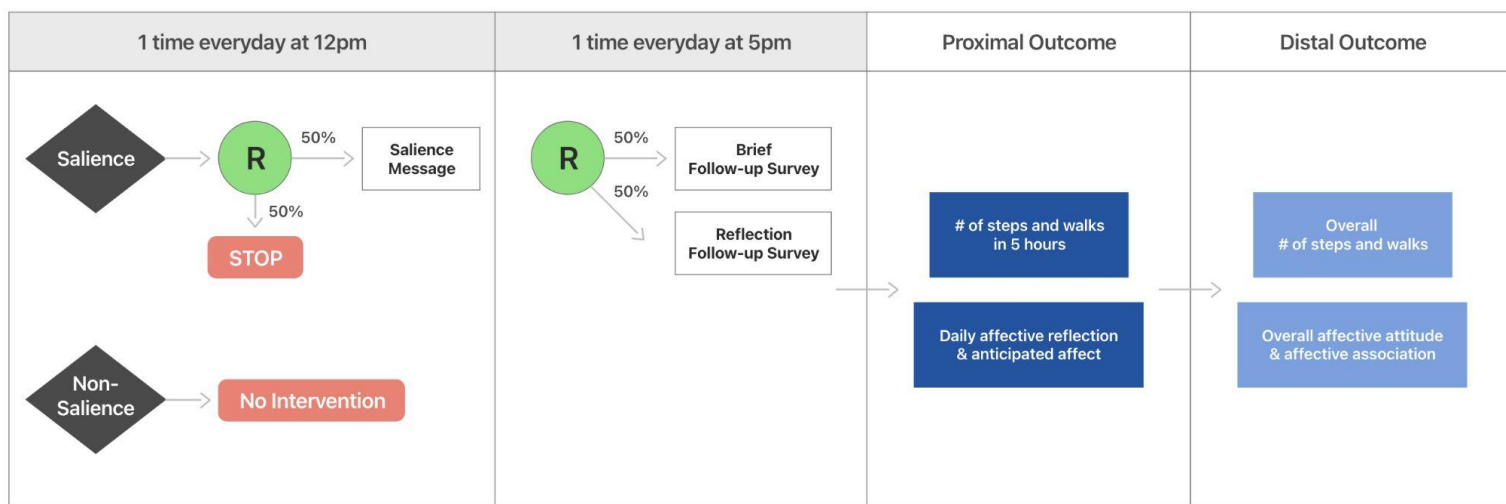


Figure 6. Implementation Map for Component 2

For the Salience group, the messages have an embedded micro-randomized trial where there is 50% chance of activation for the afternoon salience message (i.e., 12:00 pm) once a day, meaning participants may or may not receive the salience message at any given day. Whether participants have received the salience message or not and have gone for a walk or not, they will also randomly receive one of the two follow-up surveys with an equal chance 5 hours following the salience message (i.e., 5:00 pm), meaning participants will either receive the brief follow-up survey or the reflective follow-up survey each day with a 100% chance of activation (See Figure 6). Participants in the Non-salience group (i.e., messages are not activated) will not receive any salience message nor any of the salience-related follow-up surveys.

Intervention Component 3: Planning enjoyable walks



Figure 7. Implementation Map for Component 3

For the Planning group, participants will receive a planning prompt each Monday morning (see Figure 7). Participants in the Planning group have an activation chance of 100%, but will randomly receive one of the two prompts with an equal chance: a prompt to try a new planning strategy or a prompt to keep the same strategy as the previous week. Moreover, when participants complete the planning prompt, they will receive a reminder twice during the week (i.e. Tuesdays and Thursdays) on how they planned to modify their walks. Participants in the Non-planning group will not receive any planning prompts nor the reminder messages.

Outcome Measures

Outcome measure	Onboarding	Baseline Week	Intervention						Post-study
			Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	
Affective attitude	X		X	X	X	X	X	X	
Affective Association	X		X	X	X	X	X	X	
Affective Reflection			collected daily and weekly						
Anticipate			collected daily and weekly						

d Affect				
Steps		X	collected daily	
Number of Walks		X	collected daily	

Table 3. Summary of the outcome measures and assessment times

Primary outcome measure: Affective attitude

The primary outcome measure will consist of a 7-point scale, semantic differential 3-item measure of affective attitude towards walking experience (modified from Crites et al., 1994; Richard et al., 1996; Conner et al., 2013; Kiviniemi et al., 2007) on a weekly check-in survey. The specific items are listed below:

- *“For me, walking is...” very unpleasant (1) to very pleasant (7)*
- *“For me, walking is...” unenjoyable (1) to enjoyable (7)*
- *“For me, walking is...” boring (1) to interesting (7)*

By measuring the primary outcome on a weekly basis, the items capture the changes in affective attitude that would indicate changes in participants’ overall valuation towards walking experience. The items were thus selected as the primary outcome that (a) would be affected if the intervention is effective, and (b) is connected to the intervention theory of affective-reflective theory.

Our expectation is that each component of the intervention will lead to the participants:

1. Increasing the likelihood to go for a walk by conditioning the idea of walking with smile-inducing stimuli.
2. Updating the association to enjoyment of walking over time by repeatedly placing awareness to the positive aspects of the walking experience.
3. Setting up for a more enjoyable walking experience by modifying and planning for future walks.

Secondary outcome measure: Affective association

The secondary outcome measure will consist of a 7-point scale, semantic differential 1-item measure of affective association (modified from Crites et al., 1994; Kiviniemi et al., 2007) when thinking about walking on a weekly check-in survey. The item consists of “When I think about walking...” I cringe (1) to I smile (7).

By measuring the secondary outcome measures on a weekly basis, the item captures the changes in affective association that would indicate changes in participants’ automatic affective valuation towards walking experience. The items were thus selected as the primary outcome that (a) would be affected if the intervention is effective, and (b) is connected to the intervention theory of affective valuation.

Exploratory outcome measures

In addition to the primary and secondary outcome measures, the study will include Affective Reflection and Anticipated Affect measures on a weekly basis. Affective reflection item for the weekly measure consists of a 7-point scale, semantic differential 1-item measure of “How did you feel overall when walking this last week?” “I couldn’t wait for it to end” (1) to “Loved every second of it!” (7). Affective reflection item for the daily measure consists of a 7-point scale, semantic differential 1-item measure of “How did you feel overall when walking today?” “I couldn’t wait for it to end” (1) to “Loved every second of it!” (7).

Anticipated affect item (modified from Richard et al., 1996; Conner et al., 2013) for the weekly measure consists of a 7-point scale, semantic differential 1-item measure of “This coming week, I expect walking will feel...” Awful! (1) to Great! (7). Anticipated affect item for the daily measure consists of a 7-point scale, semantic differential 1-item measure of “Next time you take a walk for 5 minutes or longer, what will that be like for you?” Awful! (1) to Great! (7).

Proximal outcome measures for Micro-randomized factors

Micro-randomized Component 1: Positive conditioning with GIF prompts to walk

The proximal outcome measures for the first intervention component (i.e., GIF and Non-GIF groups) will measure the activity level and number of steps taken within 4 hours following the activation points of GIF and Non-GIF prompts twice a day.

Our expectation is that participants will go for more walks within 4 hours after receiving the message prompt compared to those who did not receive the message.

Micro-randomized Component 2: Salience of positive aspects of walking

Following the salience message, a follow-up survey that tries to assess expectation of the next walk will be sent. The proximal outcome measures for the second intervention component (i.e., Salience group) include the steps counts, whether participants went for a walk or not within 5 hours following the activation point of the salience message each day, and the daily affective reflection and anticipated affect measures (i.e., "Next time you take a walk for 5 minutes or longer, what would that be like for you?" "Awful!"(1) to "Great!"(7)). taken from the daily follow-up survey.

Our expectation is that participants will go for more walks within 5 hours after receiving the salience message, and have a positive impact on the daily affective measures. Our expectation is that participants will anticipate a future walk to be more enjoyable when they receive the salience message compared to when they do not.

Additional measures for potential effect modifiers

The Revised Body Awareness Rating Questionnaire (BARQ-R) will be measured before and after the intervention to evaluate participants' awareness of their own bodies as potential effect modifiers to the study outcome measures. The BARQ-R includes 12 self-reported items with 4-point response scale from Completely disagree (0) to

Completely agree (3) (Tihanyi et al., 2017; Dragesund et al., 2018). The BARQ-R will be measured at the baseline survey before the start of the intervention.

Post-study measures

At the end of the intervention week, participants will be prompted to complete a post-study survey to evaluate their experience with the intervention and barriers to participation. The measures consists of questionnaires covering the following topics: 1) general attitude toward the intervention, 2) participant's subjective evaluation of the intervention (i.e., whether it was beneficial and improved affective attitude towards walking), 3) participant's subjective evaluation of the intervention's usability (i.e., whether it was easy to implement in their daily lives, were there too many messages, and were the guidelines clear), and 4) any barriers to participating in walks and surveys.

At the end of the study, one participant from each intervention group (listed on table 2) will be randomly selected for an invitation to participate in an optional semi-structured interview to collect qualitative data regarding participants' experience with the intervention and barriers to participation in a more detailed manner. Those interviews will be audio and video recorded through the video conference software (e.g., Zoom). The recording will be transcribed to text for further analysis, with participants' identification removed.

Adherence protocol

All participants will receive a minimum of \$10 to a maximum of \$52 for participating in the study based on their adherence. Participants will receive their compensation amount via Amazon gift card at the end of their study period.

The *baseline measure adherence protocol* will be as follows: After enrolling in the study and signing into the WalktoJoy application, if a participant has not filled out the baseline survey after 24 hours, a reminder message will be sent. Another reminder message will

be sent after 24 hours (48 hours in total), and the participant will be dropped from the study if no response is received after the 7 days of baseline week.

The *weekly measures adherence protocol* will be as follows: The weekly check-in survey will be sent as a task on Sunday 8:00 PM for each week. For those that do not complete the survey by the next day, a reminder message will be sent every 24 hours up to two times.

The *daily end-of-day measure adherence protocol* will be as follows: The daily end-of-day survey will be sent as a task daily on 8:00 PM excluding Sunday. For those that do not complete the survey consecutively for two days, a reminder message will be sent in the afternoon, up to two times, encouraging participants to complete the survey that evening. , If the evening surveys are still not completed, this protocol will be followed by a phone call from a study coordinator on the 5th day.

The *activity data adherence protocol* will be as follows: The participants' heart rate data will be monitored for the purpose of checking whether participants have worn their Fitbit wearable device for more than 8 hours per day during the intervention. On days that device was worn for less than 8 hours, the day will be indicated as a non-worn day. For participants who accumulate a non-worn day consecutively for 2 days (i.e., 48 hours), the participant will receive an adherence reminder message up to three times. If a non-worn day continues for 6 consecutive days, a study coordinator will give an adherence reminder phone call.

Data Analysis

Given the sample size of the current study, the primary statistical analyses will examine the impact of micro-randomized components on their proximal outcomes. In addition, in exploratory analyses, we will assess the main effects of each of the three baseline-randomized factors on the weekly measures of affective attitudes and affective associations.

Sample size and power

Due to research constraints, instead of powering for the full factorial experiment, we calculated the sample size requirements by powering for the micro-randomized trial of the GIF messages. The calculation was conducted using the online MRT sample size calculator

(https://statisticalreinforcementlearninglab.shinyapps.io/mrt_ss_continuous/). Using a type II error rate of .05, we will have 90% power to detect a small standardized effect size of .1 with a sample size of 40 participants.

Data Safety & Security

We will first send out a recruitment email and posting via Fitbit online community platforms and UMSI's mailing list to screen for potential participants. The eligibility survey will assess potential participants' satisfaction to their current activity level. Collected information is only used for screening purposes and will not be used in the actual study. Once we have recruited all 40 participants in this study, we will immediately erase the screening survey data by deleting the survey records. We will virtually distribute and collect consent forms via Qualtrics survey to secure participants' privacy, and participants will need to put their e-signature on the consent form. The consent form will inform them of the study details and provide them with the team's contact information for troubleshooting. Participants' consent forms will be stored as electronic versions in a secured online storage.

All participants will be assigned to a participant ID upon enrollment, which will be encoded in the URL of the surveys participants are asked to complete. Because participants must receive surveys multiple times throughout the intervention and receive text messages sent via SMS messaging service (i.e., Twilio) activated by our cloud server, we will need to maintain records of their email addresses, phone numbers and names. Thus, all surveys and participants' responses will be stored on the survey instrument host (i.e., Qualtrics) and will be linked to a participant ID rather than to their

name. A master list connecting participant IDs to emails and phones will be kept securely on the contact list of the survey instrument host (i.e., Qualtrics) and our secure cloud server.

During the 42 days of study, participants' step data collected by Fitbit and survey data collected by the intervention will be uploaded to a secure online database. Only the investigators will have access to these data.

At the end of the study, eight selected participants, one randomly selected from each intervention group and with replacements if invitation is declined, will be invited for an optional interview. The interview will be audio and video recorded via the video conference software (e.g., Zoom), and the recording will be transcribed to text for further analysis, with participants' identification removed. The audio recordings from the interview will be de-identified and transcribed. Once the transcription is done, we will delete and destroy the audio recordings right away by deleting the audio files permanently. Furthermore, before analyzing the interview scripts, we will remove information that could directly identify the participants in any way. All the data will be stored in a secured online storage.

Participants' participation in this study is fully voluntary and they can request to withdraw from the study at any time and the investigator will do so immediately. Likewise, the investigator will stop the study if the participant is uncomfortable with the intervention process. If a participant withdraws from the study, participants have the option to request a deletion of their data we have collected so far. When requested, all their data will be destroyed immediately and no further data will be collected.

Participants who withdraw from the study will be partially compensated based on the study activities they completed up to that point.

Ethical criteria and ethics committee

The study (#HUM00217566) has been approved by the IRB: Health Sciences and Behavioral Sciences of University of Michigan.

Results

This study is funded by the School of Information at the University of Michigan. Participant recruitment will start in September 2022, with the 6-week deployment expected in October - November 2022.

Discussion

General

This mHealth intervention aims to evaluate the impact of the three affective valuation intervention components on their respective proximal outcomes for positively influencing people's affective attitudes towards and affective associations with walking. The study consists of a 6-week full factorial experiment with 3 factors (i.e., for a total of 8 conditions) with an embedded micro-randomized trial (MRT) to assess the effectiveness of each of the intervention options within the entire intervention package. The study will provide insights on decisions regarding the optimization of each of the intervention components, a key consideration in designing a mHealth intervention, for positively impacting the affective attitude and affective associations of the sedentary people. Specifically, by embedding a factorial design and a micro-randomized trial, the experimental design is made to be an efficient and cost-effective strategy for increasing the value of early-stage investigation by examining different ways in which several individual intervention components can be delivered.

We hypothesize that the WalktoJoy intervention will be effective in three ways: our intervention will 1) make the walking experience more enjoyable over time, 2) help users

become more aware of the enjoyable aspects of the walking experience, and 3) ultimately update their affective expectation about and reward value for walking. The positively revised expectation that walking will be an enjoyable and a fulfilling experience, a positive affective valuation process towards walking (Ekkekakis & Brand, 2019; Brand & Ekkekakis, 2018), will have a longitudinal impact on helping individuals build a sustainable intrinsic motivation towards walking behavior.

In future research, the intervention components that are randomized in the current study, if found to be individually effective, should be evaluated as an intervention package for their ability to improve affective attitudes compared to a meaningful control. If successful, the study can inspire a more intrinsic-based approach to mHealth interventions for physical activity by positively impacting the source of motivation and intention (i.e., positive affective valuation) for staying active (Mohiyeddini et al., 2009; Mullen et al., 2011; Simonton, 2020). Furthermore, the study can inspire existing and future mHealth interventions and applications to consider incorporating an affective valuation-based intervention strategy for people who have negative affect towards physical activity.

Moreover, future research should investigate the long-term effects beyond the 6 to 12 months period of the affective valuation-based intervention on people's motivation and intention for staying active. Specifically, future research should study how the intervention impacts users' that have past experience of abandonment of wearable devices.

Limitations

The following limitations of the study need to be considered. First, due to the nature of factorial and micro-randomized trials, each participant will receive varying numbers of notifications, prompts and tasks on their phone throughout the intervention period. Thus, participants may have mixed experience with the intervention where some may experience a reduced effect of an intervention component or have poorer proximal outcomes at later decision points during the intervention period due to habituation or

burden of receiving high amounts of notifications or receiving a message at the same time each day. For these reasons, we aim to obtain qualitative and quantitative data on participants' experience on message timing and burden through post-intervention surveys and optional semi-structured interviews to inform future designs.

Second, a related limitation concerns the message delivery timing of each intervention component. The timing of message delivery depended on participant's input at the onboarding stage of an individual's wake up time on weekdays and weekends. Current study does not account for days when participants have changes in their waking schedule nor the participants' lifestyles. Thus, some participants may experience a reduced effect of an intervention component or proximal outcomes due to the burden of receiving messages at a time when participants cannot pay attention to or act upon the intervention. Future research should investigate ways to personalize interventions for each participant for an optimal outcome of intervention such as an Just-in-Time Adaptive Interventions (JITAIs), a time-varying adaptive interventions that aim to deliver the right intervention components at the right times and locations to optimally support individuals' health behaviors (Klasnja et al., 2015; Qian et al., 2022).

Conclusion

The proposed study is an exploratory full factorial experiment with an embedded micro-randomized trial, assessing the effectiveness of each of the intervention components for positively influencing people's affective attitudes towards and affective associations with walking. With further optimization of the intervention package as a whole, this intervention can provide a proof-of-concept example for a novel approach to mHealth interventions for physical activity, an approach that positively updates affective expectations towards walking, thus helping individuals build a sustainable intrinsic motivation towards walking behavior.

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