

Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

eAppendix 1. Additional Description of the Hypertension Coaching App

HPCP Background

In 2017, Lark Technologies developed a Beta version of its Hypertension program leveraging its conversational artificial intelligence (AI)-based design in support of a randomized controlled trial investigating the potential effect of the Lark hypertension personal control program (HPCP) on systolic blood pressure compared to the effects of a blood pressure tracking app. Lark had previously developed products leveraging conversational AI to promote behavioral health changes, such as weight loss, increased physical activity, improved stress management, and more adequate sleep. This study was an opportunity to investigate how conversationally-derived AI technology could potentially promote positive health behaviors and clinical outcomes for a hypertensive population compared to a blood pressure tracking application (“app”). This document describes specific features of the Coaching Platform, functionality created as a part of the HPCP, and information on usage recorded in the course of the study (eResults, eTable 1 and eTable 2).

HPCP Overview

This study used the HPCP, which was a Beta version of the Coaching Platform that added hypertension-specific coaching to Lark’s core features. As a Beta version, there were also known limitations in the functionality of the HPCP. These features and limitations are outlined below.

Hypertension Education

The HPCP provided educational content related to blood pressure in a variety of contexts, such as how blood pressure affects risk for conditions such as heart disease, stroke, and kidney disease, the importance of addressing out-of-range high or low blood pressure should it occur, and the impact on blood pressure of participant health habits, such as managing weight, being physically active, eating a nutritious diet, getting enough sleep, monitoring blood pressure, and adhering to prescription medication.

Medication Adherence Automated Reminders

During the onboarding process (see below), participants could enter into the HPCP prescribed blood pressure medications. Participants could then set up reminders for up to four medications via notifications on their smartphones.

Blood Pressure Monitoring and Provider Notification

Participants’ blood pressure measurements taken using the Omron 7 Series Wireless Upper Arm Blood Pressure Monitor Model BP761N HEM-7320T, which was provided to participants as part of the study, could sync with participants’ smartphones and be used by the HPCP. This was subject to certain technical limitations (discussed in more detail in the HPCP Limitations section of this document). Participants received a single weekly text notification to take their blood pressure. The HPCP reminded participants during in-app conversations to take their blood pressure if they have not for a few weeks.

The HPCP prompted participants who recorded a significantly different blood pressure (as compared to their personal typical measurements) to take that blood pressure measurement again. The HPCP offered recognition and encouragement when users took their blood pressure, and participants received weekly and monthly summaries on their blood pressure trends.

When participants logged extreme high or extreme low readings (over 180 mm Hg systolic or 110 mm Hg diastolic, or under 90 mm Hg systolic or 60 mm Hg diastolic), participants were asked to retake blood pressure, and if the second reading was also an extreme reading, Lark prompted participants to call their medical provider (if high, or if low with symptoms) or stay alert (if low without symptoms).

Hypertension-Specific Coaching on Lifestyle and Diet

The HPCP leveraged the Coaching Platform's weight loss, physical activity, nutrition, sleep, and stress management coaching, as described in more detail below.

Physical activity coaching included goal-setting and encouraging participants to increase physical activity levels and/or set goals of at least 150 minutes per week of moderate-intensity aerobic exercise. The HPCP provided education on the importance of physical activity in managing hypertension.

Nutrition coaching was consistent with the Dietary Approaches to Stop Hypertension (DASH) diet, which emphasizes consumption of whole grains, vegetables, fruit, reduced-fat dairy products, beans, vegetable oils, and nuts, while limiting fatty meat, tropical oils, and sugar-sweetened foods and beverages.

HPCP Limitations

As previously noted, the HPCP used in this study was a Beta version with several limitations that may have prevented maximum use and effects. Most critically, participants needed to take several manual steps to successfully sync blood pressure readings from the Omron blood pressure monitor with the HPCP. The monitor had limitations which required participants to manually open the HPCP within one hour of taking a blood pressure measurement and to be within range of the monitor in order for the HPCP to automatically record the measurement via Bluetooth. In the event blood pressure did not sync from the monitor to the HPCP within an hour of taking the reading, participants had to remember to manually press a sync button on the monitor, ensure the Bluetooth feature on their phone was turned on and functional, and have their phone within Bluetooth range of the monitor. The lack of the monitor automatically connecting to the HPCP on the backend meant blood pressure measurements did not sync in real time with the HPCP. Therefore, the HPCP could not provide real-time coaching on blood pressure measurements, which would have been the preferred approach rather than delayed messaging. Additionally, HPCP gave weekly reminders to take blood pressure readings, but subsequent review of data from the HPCP has shown that using more frequent reminders may be associated with improved blood pressure. More frequent reminders were not in place during the study.

Foundational Coaching Platform

The Beta HPCP was built on top of the existing Lark product's broad-based wellness platform ("Coaching Platform").

Platform Overview: Conversational Education and CBT

The Coaching Platform leverages conversational artificial intelligence (AI) to promote healthy behavior change. Conversations with the Coaching Platform look and feel as though participants are engaged in a text messaging conversation with a health educator around specific topics and issues related to their health program (eFigures 1-3). Weight loss coaching includes tracking features and content (conversations) regarding weight loss, such as relationships to food, physical activity, and other behaviors. The Coaching Platform detects physical activity via the phone's motion sensor and coaches participants to achieve either participant-set goals or the goal of at least 150 minutes per week of moderate-intensity activity. Participants can manually log their food and receive nutrition coaching emphasizing healthier food choices, such as whole grains, fish, nuts, and vegetables, and reducing less healthy foods such as fried foods, sugar-sweetened foods and beverages, and fatty red and processed meats.

Coaching within the Coaching Platform uses principles of cognitive behavioral therapy to help promote behavior change. In-the-moment coaching is possible via the Coaching Platform's ability to access and respond to real-time data, such as a newly logged meal or a reading of physical activity. Coaching strategies include reinforcing positive health choices, acknowledging setbacks and perceived failures as a normal part of working towards long-term health goals, and actively engaging members with an overall compassionate, sympathetic tone (eFigure 4).

Onboarding Process

The onboarding process increases the Coaching Platform's ability to deliver personalized coaching. Participants can set their weight loss goal (if desired) and can opt into receiving weight loss coaching. Participants can also set physical activity goals and select dietary preferences, such as gluten-free, vegan or plant-based, or lacto-ovo vegetarian, that affect coaching.

eAppendix 2. Engagement and Usage of the HPCP

The HPCP captured usage data for the participants randomized to this intervention arm. There were 166 participants randomized to the HPCP. Data from eight participants was not available for use in these analyses because participants who deleted their HPCP accounts following the end of the study before research data collection took place had their data deleted by an automated processes in place to support Lark's privacy policy. Results below are for the remaining 158 intervention arm participants. Data for engagement (conversations) and meals logged was aggregated at the individual participant level by Lark employees and provided to the Northwestern University study team for analysis. Data for home blood pressure measurements were provided to the Northwestern team at the individual observation level.

Usage data includes engagement as measured by the number of unique conversations with the HPCP conversational AI app, the number of blood pressure measurements successfully captured by the HPCP, and the number of meals logged during the 6-month study period. Additionally, 103 participants elected to turn on medication reminders.

During the 6-month study period, these 158 participants held 37,346 conversations with the HPCP. Participants logged a total of 27,807 meals and recorded 18,052 blood pressure readings. The medians, interquartile ranges, and overall ranges are shown in eTable 1.

Post Hoc Analysis of Engagement by Age

In the prespecified subgroup analyses, the difference between study arms was -4.0 mm Hg (95% CI, -8.1 to 0.1) among intervention group participants who were at or above the median age and 0.1 mm Hg (-3.8 to 4.2) for those below the median age; P for interaction 0.088. Therefore we conducted a post hoc analysis among the intervention group to determine if app usage differed by age. These results are provided in eTable 2 comparing intervention group participants below the median age with those at or above it. Older participants participated in more conversations with the app ($P < 0.001$) and performed more home blood pressure readings ($P < 0.001$). The median number of meals logged was higher for older participants (85 vs. 35) but the P value was not significant ($P = 0.08$).

eTable 1. Characteristics of Participants Who Did Not Complete Follow Up

Characteristic	Total (N = 36)	Hypertension coaching app and home monitor— Intervention (n = 22)	Tracking app and home monitor— Control (n = 14)
Age, mean (SD), y	53.4 (12.9)	51.4 (12.9)	56.7 (12.5)
Female, No. (%)	13	9 (40.9)	4 (28.6)
Ethnicity, No. (%)			
Hispanic or Latino	3	2 (9.1)	1 (7.1)
Race, No. (%)			
Asian	2	2 (9.1)	0 (0)
Black	14	12 (54.6)	2 (14.3)
White	16	6 (27.3)	10 (71.4)
Other/unknown	4	2 (9.1)	2 (14.3)
Education, No. (%)			
Less than high school graduate	0	0 (0)	0 (0)
Grade 12 or GED	2	1 (4.6)	1 (7.1)
College 1 -3 years	6	4 (18.2)	2 (14.3)
College 4 years or more	28	17 (77.3)	11 (78.6)
Unknown			
Primary Language, No. (%)			
English	35	21 (95.5)	14 (100)
Other	1	1 (4.6)	0 (0)
Refused			
Comorbidities, No. (%)			
Coronary heart disease	1	0 (0)	1 (7.1)
Stroke	2	1 (4.6)	1 (7.1)
Heart Failure	0		
Asthma or COPD	4	2 (9.1)	2 (14.3)
Diabetes	3	2 (9.1)	1 (7.1)
Body mass index, mean (SD), kg/m²	35.2 (7.8)	34.1 (7.6)	37.0 (7.9)
Current smoker, n (%)	1	0	1 (7.1)
Generalized self-efficacy, mean (SD)²¹	33.7 (4.4)	33.6 (4.7)	33.8 (4.1)

Abbreviations: GED, General Education Development exam; COPD, chronic obstructive pulmonary disease

eTable 2. Engagement, Blood Pressure Measurement, and Meal Logging, N = 158 Intervention Group Participants

Variable	Median	Interquartile Range	Range
Engagement (conversations), n	157.5	(74, 307)	(3, 1648)
Blood pressure measurements, n	99	(45, 178)	(1, 1191)
Meals logged, n	51	(4, 222)	(0, 1356)

eTable 3. Engagement, Blood Pressure Measurement, and Meal Logging by Age, N =158 Intervention Group Participants

Variable	At or above median age (≥ 60 years), n = 80	Below median age (<60 years), n = 78	p-value^a
Engagement (conversations), median, (IQR)	215.5 (109, 420.5)	124 (49, 236)	<0.001
Blood pressure measurement, median (IQR)	130 (73.5, 220.5)	71 (24, 117)	<0.001
Meals logged, median (IQR)	85 (3, 320)	35 (4, 140)	0.08

^a Performed using Wilcoxon Rank-Sum test