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Original Research

Confirming the theoretical structure of expert-developed text messages to improve adherence to anti-hypertensive medications

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Abstract

Background: Text messages can improve medication adherence and outcomes in several conditions. For this study, experts developed text messages addressing determinants of medication adherence: disease beliefs, medication necessity, medication concerns, and forgetfulness, as well as positive reinforcement messages for patients who were adherent.
Objectives: To validate expert-developed text messages to address medication non-adherence with a group of non-researchers.
Methods: A two-wave, card-sorting activity was conducted with students and staff at the University of Michigan. In the first wave, 40 participants grouped 32 messages addressing barriers for medication adherence (disease beliefs, medication necessity, medication concerns, and forgetfulness) according to their perceived relationship. Messages with poor grouping agreement were deleted or modified. In the second wave, positive reinforcement messages were developed and tested along with the previous categories (36 messages) by 37 participants. Similarity and cluster analyses were used to assess agreement between experts and participants.
Results: In the first card-sorting wave, participants grouped messages into between 2 and 13 separate categories. Similarity analysis showed four groupings of messages, however, some had an agreement below 50% and clusters appeared dispersed. In the second wave, and after messages being edited, participants grouped the messages into between 4 and 9 categories. Five groups (now including positive reinforcement

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messages) were identified with higher agreement in the similarity and cluster analyses.
Conclusions: The structure of expert-developed text messages to address medication adherence key barriers was confirmed. Messages will be used in future research to determine their impact on affecting medication adherence to anti-hypertensive medications using a reinforcement learning controlled text messaging service.

Keywords: Adherence; Card-sort technique; Mobile health; Text messaging

Introduction

Self-management of chronic conditions involves complex behaviors, and patients vary in their adherence to these behaviors.[1,2] Studies suggest that 33–50% of patients do not take their medications properly, contributing to nearly 100,000 premature deaths each year and $290 billion in health care costs.[3] Adherence to anti-hypertensive medications is of particular importance, as medication non-adherence is a major cause of uncontrolled hypertension and hypertension is a major cause of stroke, coronary heart disease, heart failure and mortality.[4,5] A one-year study of approximately 5000 hypertensive patients showed that most patients took their medications only intermittently with half of patients eventually discontinuing their medications against medical advice.[6] Improving medication adherence requires addressing multiple challenges because patients typically have a variety of reasons for not taking their medication as prescribed, including beliefs about their disease and its treatment, organizational challenges and cost barriers.[7–9]

Mobile health (mHealth) services such as patient text messaging have been used as a way of enhancing the communication between health care systems and patients.[10] Several studies have shown that mobile text message reminders can increase attendance at health care appointments[11,12] as well as patient adherence to follow-up appointments.[13,14] Text messages also have been used to improve medication adherence for patients with chronic medical conditions[15] such as cardiovascular disease,[16] coronary heart disease,[17] diabetes,[18,19] hypertension,[20] asthma,[21] allergic rhinitis,[12] HIV,[22,23] or schizophrenia.[24] Although some studies have not shown improvements in outcomes associated with text messaging,[25,26] others have found that text messages significantly improved allergic rhinitis symptoms,[12] asthma control,[27] diabetes control,[28,29] or hematologic parameters in children with sickle cell anemia receiving hydroxyurea.[30]

Messages used in text messaging services vary in their goals and targets, ranging from standard reminder messages (e.g., "remember to take your medication"[21]) to more personalized messages like "please decrease your long acting insulin by two units."[31] Some studies combined text messaging services with real time medication monitoring using electronic pill dispensers so that patients received text messages when they actually failed to take their medication.[19] Other tailored approaches to delivering text messages have included asking patients to send their lab value (self-monitored blood glucose levels) to an offsite researcher via the internet and the researchers sent recommendations for medication adjustment using text messages.[32] In a recent study, subjects were asked to complete a short assessment prior to the receipt of messages in order to determine their illness perception and tailoring the messages accordingly.[33] In other cases, messages were created based on theoretical models such as the Health Belief Model,[34] the Self-Determination Theory[34] or the Theory of Planned Behavior.[35] One study found that patients with diabetes preferred to receive text messages about general health compared to messages about necessary diet modification, physical activity and complications of diabetes.[36] Further, in considering the use of text messages, it is critical to recognize that patient informational fatigue may affect message effectiveness as the user becomes increasingly desensitized to the content.[37,38] Thus, devising a mechanism to keep messages variable and tailored is important,[34] and to do that, it is critical that service developers have a clear idea of what types of messages align with the key drivers of patients' adherence behavior.

In the present study, experts developed a library of text messages based on a theoretical framework for two key determinants of medication adherence: patient intention to take their medication as prescribed and patient remembering to take the medication given that they intend to.[39,40] Messages

addressing intention to take the medication aim to improve patients' beliefs about the disease, in this case hypertension, as well as beliefs about the medications themselves (e.g., perceived side effects and efficacy). Messages addressing forgetfulness present the recipient with specific strategies to help remember to take the medication and create environmental cues to reinforce medication taking. Researchers created a number of individual text messages meant to reflect each of these categories. The aim of this study was to validate expert-developed text messages to address medication non-adherence with a group of non-researchers. This study was conducted using an iterative card-sorting methodology[41] and the text messages derived through the process are being used in an ongoing study aimed to improve medication adherence to anti-hypertensive medications using a reinforcement learning (a form of artificial intelligence) controlled text messaging service.

Methods

Design and setting

A card-sorting study was conducted in two-waves between February and May 2013 at the University of Michigan, College of Pharmacy. The study was approved as exempt by the University of Michigan Institutional Review Board.

Expert text messages development

As part of a larger study that will use text messaging coupled with artificial intelligence and objective feedback about patients' medication use, 120 text messages were developed by experts based on the theoretical framework described above that recognized disease beliefs, medication necessity, medication concerns, and forgetfulness as key barriers to medication adherence (30 messages to address each barrier). For example, messages addressing disease beliefs focused on the consequences of hypertension (e.g. *Uncontrolled high blood pressure can lead to heart failure*) or the asymptomatic nature of this condition (e.g. *You can still have high blood pressure even if you don't feel sick*). Messages designed to address medication necessity beliefs reinforced the need to take the medication (e.g. *Taking BP medications keeps your blood pressure under control*) and the benefits that resulted from taking it (e.g. *Reduce your risk of serious health problems by taking your blood pressure medication every day*). Messages aimed at improving medication concerns encourage patients to seek medical advice to get more information on the medications they are on (e.g. *If you are concerned that your BP medication may do more harm than good, talk to your pharmacist*) or to talk about potential side effects that they might be experiencing (e.g. *If you have side effects, talk to your doctor about ways to make it better*). To address forgetfulness, messages with several suggestions were created (e.g. *Set an alarm on your watch or phone to remind you when it's time for your medication*). A fifth set of 10 messages with positive reinforcement for potentially adherent patients was also created at a later stage (e.g. *Glad to see the BP meds are being taken*). Messages were developed and iteratively reviewed by a group of experts in medication adherence (K.B.F), technology in health services research (J.D.P. and L.A) and health communications (J.D.P. and L.A.).

Participants and recruitment

The card-sorting activity included 40 subjects in the first wave and a group of 37 different subjects in the second. In the first wave, volunteer participants included pharmacy students as well as staff and graduate students at the University of Michigan, College of Pharmacy. In the second wave, participants included staff at the College of Pharmacy and the Center for Health Communications Research (University of Michigan). Emails, posted flyers and word of mouth were the strategies used to recruit volunteer participants. As an appreciation of participation in the study a complimentary meal was provided to subjects at the time of the card-sorting activity.

Procedures

Participants gathered in a room at the College of Pharmacy for the card-sorting activity during lunch break. One element of the research team explained the aim of the study and how the activity would take place. The activity was performed by each volunteer individually. During the first card-sorting wave, each participant was given a sample of 32 messages (Table 1), including eight different messages from each of the four categories (disease beliefs, medication necessity, medication concerns, and forgetfulness), purposively selected for variety of content within each category from the total pool of 130 messages. Participants were asked to group the messages according to their content similarity in as many

Table 1
Expert-developed messages used in the first card-sorting wave and participants' grouping into each of the four clusters identified

Card number	Expert-derived category	Message	Cluster
1	Disease beliefs	High blood pressure can lead to heart attack, stroke, vision problems and kidney failure.	Disease beliefs
2	Disease beliefs	Having high blood pressure means you are at risk for heart disease and stroke. These are among the leading causes of death in the U.S.	Disease beliefs
3	Disease beliefs	Uncontrolled high blood pressure can lead to heart failure, aneurysm (abnormal swelling in a weakened artery), and stroke.	Disease beliefs
4	Disease beliefs	You can have high blood pressure even if you don't feel sick.	Disease beliefs
5	Disease beliefs	You can have high blood pressure even if you don't have any symptoms.	Disease beliefs
6	Disease beliefs	High blood pressure is "the silent killer." People may not have symptoms even though it is damaging their body.	Disease beliefs
7	Disease beliefs	Make choices that are right for you. Choosing to put your health first benefits you and your loved ones.	Medication necessity
8	Disease beliefs	Having high blood pressure is very common. One in 3 adults in the United States has high blood pressure.	Disease beliefs
9	Medication necessity	Your doctor prescribed your blood pressure medication because he or she knows it's important to improve your health.	Medication necessity
10	Medication necessity	It's important to exercise and eat healthy, but that alone won't control your high blood pressure. You still need to take your medication each day.	Medication necessity
11	Medication necessity	Exercising and eating a low-salt diet are helpful, but you also need to take your blood pressure medicine every day.	Medication necessity
12	Medication necessity	Blood pressure medication is your best defense against serious health problems, so be sure to keep taking it!	Medication necessity
13	Medication necessity	Taking your blood pressure medication will help keep you healthy.	Medication necessity
14	Medication necessity	Your doctor prescribed your blood pressure medicine because it's important for your health.	Medication necessity
15	Medication necessity	High blood pressure will not go away on its own—take your medication to keep it under control.	Medication necessity
16	Medication necessity	Your blood pressure medication works with your kidneys to keep your blood pressure low.	Medication necessity
17	Medication concerns	Your doctor wants to know if you are having side effects from your blood pressure medication. Call or make an appointment to discuss them.	Medication concerns
18	Medication concerns	Talk to your doctor or pharmacist about things you can do to help reduce side effects.	Medication concerns
19	Medication concerns	Take control of your health. If your medication is making you feel sick, make an appointment with your doctor.	Medication concerns
20	Medication concerns	You are the expert on your own health, but if you're having trouble understanding how to take your medication, be sure to ask your doctor.	Medication concerns
21	Medication concerns	If you're worried that your medication could be	Medication necessity

(*continued on next page*)

Table 1 (*continued*)

Card number	Expert-derived category	Message	Cluster
		harmful to you, remember that without it, you put yourself at risk for a heart attack or stroke.	
22	Medication concerns	If you're not sure you really need your blood pressure medicine, ask your doctor to explain the reasons why it was prescribed.	Medication concerns
23	Medication concerns	If you're having trouble paying for your medicine, there may be a less expensive option you could try. Call your doctor's office to find out.	Medication concerns
24	Medication concerns	It's not safe to stop taking your medicine without first talking to your doctor.	Medication concerns
25	Remembering strategies	To help remember your blood pressure medication, try putting your pillbox or bottles near something you see every day, like your toothbrush.	Remembering strategies
26	Remembering strategies	If you've been missing pills, taking them even one more day a week can help. Try timing your pill-taking with a chore to help you remember.	Remembering strategies
27	Remembering strategies	It can be frustrating to have memory problems affect your medication use. Don't forget that small changes, like moving your pillbox, make a big difference!	Remembering strategies
28	Remembering strategies	Remembering to take your medicine is a very important step on the road to better health!	Remembering strategies
29	Remembering strategies	It's important to remember your medicine every day. Keeping your blood pressure under control helps protect you from serious health problems.	Medication necessity
30	Remembering strategies	If you're having trouble remembering your pills, write yourself a note. Post it somewhere you look often, like the bathroom mirror.	Remembering strategies
31	Remembering strategies	Having a plan for how to keep track of your medication may help you stay on schedule. Pick a place where you'll always find them, like a pillbox or kitchen shelf.	Remembering strategies
32	Remembering strategies	Is your system of organizing your medication working for you? Can you think of any ways to improve it? Do it today.	Remembering strategies

The shaded rows highlight messages where card-sort participants and experts' groupings differed.

or as few groups that they considered appropriate. To assist in message grouping, participants labeled each group of messages with a word or a sentence that captured the underlying common theme of the related messages. No information about the four categories developed by the experts *a priori* was revealed to participants. This process took between 15 and 20 min.

After analyzing the results of the first wave, it was clear that participants grouped messages somewhat differently than the categories created by the experts. To address this, messages were modified by the same group of experts to improve clarity and better reflect the type of adherence barrier they were meant to address. As the larger study developed, the team of experts realized that messages providing positive reinforcement to patients who were adherent should also be developed and tested. Therefore, a second card-sorting activity was conducted to evaluate participants' perspectives of the revised messages and the positive reinforcement messages. In this second wave, each participant received a set of 36 messages (Table 2), where 32 were the same, but revised, messages addressing the previous four categories of adherence barriers and an additional four messages consisted of positive reinforcement for patients who were doing well in managing their medications (e.g., "Good to see you're taking your BP meds"). The same protocol described for the first card-sorting wave was followed in the second wave.

Table 2
Expert-developed messages used in the second card-sorting wave and participants' grouping into each of the five clusters identified

Card number	Expert-derived category	Message	Cluster
1	Disease beliefs	The risk of having a stroke is 4–6 times higher in people whose blood pressure is not controlled.	Disease beliefs
2	Disease beliefs	High blood pressure can damage blood vessels in your eyes and lead to vision problems, including blindness.	Disease beliefs
3	Disease beliefs	Uncontrolled high blood pressure can lead to heart failure.	Disease beliefs
4	Disease beliefs	You may know that high BP can cause heart attacks and strokes. It can also cause vision problems and kidney failure.	Disease beliefs
5	Disease beliefs	Having high blood pressure is very common. One in 3 adults in the United States has high blood pressure.	Disease beliefs
6	Disease beliefs	If your blood pressure is too high (180 systolic or 120 diastolic), you are at risk for a hypertensive emergency.	Disease beliefs
7	Disease beliefs	You can still have high blood pressure even if you don't feel sick.	Disease beliefs
8	Disease beliefs	Having high blood pressure is dangerous to your health even if you don't notice it.	Disease beliefs
9	Medication necessity	Blood pressure medication is one of the most effective ways you can take control of your health.	Medication necessity
10	Medication necessity	High blood pressure will damage your body unless you keep it under control with your blood pressure medicine.	Disease beliefs
11	Medication necessity	High blood pressure will not go away on its own—take your medication to keep it under control.	Medication necessity
12	Medication necessity	Control your high blood pressure before it controls you by taking your medications every day.	Medication necessity
13	Medication necessity	Reduce your risk of serious health problems by taking your blood pressure medication every day.	Medication necessity
14	Medication necessity	An important step on the road to better health is remembering to take your medicine for your BP.	Medication necessity
15	Medication necessity	Taking BP medications keeps your blood pressure under control.	Medication necessity
16	Medication necessity	Taking BP meds = BP control = improved health and reduced health risks.	Medication necessity
17	Medication concerns	Some side effects are unpleasant at first but get better with time. Speak to your doctor if you are bothered by side effects.	Medication concerns
18	Medication concerns	If you have side effects, talk to your doctor about ways to make it better.	Medication concerns
19	Medication concerns	Talk to your pharmacist about things you can do to help reduce side effects if this is a problem.	Medication concerns
20	Medication concerns	Sometimes medication that's supposed to help you has unpleasant side effects. Ask your pharmacist about dealing with this.	Medication concerns

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Table 2 (*continued*)

Card number	Expert-derived category	Message	Cluster
21	Medication concerns	[Having to take medicine worries me] If concerns about your medication are keeping you from taking it, make an appointment to talk to your doctor.	Medication concerns
22	Medication concerns	If you're concerned about long-term effects of your BP medication, talk to your pharmacist about these concerns.	Medication concerns
23	Medication concerns	[more harm than good] If you're worried your medication could be harmful to you, talk to your doctor. You put yourself at risk without the medication.	Medication concerns
24	Medication concerns	If you are concerned that your BP medication may do more harm than good, talk to your pharmacist.	Medication concerns
25	Remembering strategies	To help remember your BP medication, try putting your bottles near something you see every day, like your toothbrush.	Remembering strategies
26	Remembering strategies	Some people find it helpful to use an alarm on their mobile phone to remember to take medications.	Remembering strategies
27	Remembering strategies	Once you have a routine, it's easy to remember to take pills. A few weeks of reminding yourself will pay off in the long run!	Remembering strategies
28	Remembering strategies	[personal reasons – traveling] You may not always be home when it's time for your pills. Keep a small supply in your purse, briefcase, or toiletry bag.	Remembering strategies
29	Remembering strategies	Make sure to pack enough pills when you're away from home. Your high blood pressure doesn't take a vacation!	Remembering strategies
30	Remembering strategies	Set an alarm on your watch or phone to remind you when it's time for your medication.	Remembering strategies
31	Remembering strategies	Going on a trip? Don't forget to pack your blood pressure medication!	Remembering strategies
32	Remembering strategies	Get into a routine with your medication. Taking them at the same time every day will help you stay on track.	Remembering strategies
33	Positive reinforcement	Your BP meds … you're taking them. ☺	Positive reinforcement
34	Positive reinforcement	Good to see you're taking your BP meds.	Positive reinforcement
35	Positive reinforcement	Taking your BP meds is terrific.	Positive reinforcement
36	Positive reinforcement	Glad to see the BP meds are being taken.	Positive reinforcement

The shaded rows highlight messages where card-sort participants and experts' groupings differed. The smiley face (☺) is part of the positive reinforcement message.

Analyses

Statistical analysis was conducted using SAS 9.3 (SAS Institute, Cary NC) and R version 3.0.1[42] using the gplots package[43] and the vegan package.[44] Similarity analysis was used to produce heat maps for the agreement results between participants and experts in the two-waves of the card-sorting activity. In this analysis, the percent of participants that grouped messages under the same category was determined. If few of the respondents agreed that two messages were grouped together, then that number was represented in blue in the heat map. High agreement among participants was depicted in a progression from white toward red, with full red representing 100% agreement (Figs. 1 and 2).

Participants' groupings of messages within categories were further analyzed with statistical cluster analysis. Since cluster analysis requires a pre-determined number of clusters, validated techniques including cubic clustering criterion, the pseudo-F method and the pseudo t-squared method were used to estimate the number of clusters in the raw data. Hierarchical and k-means clustering were used to find the optimal groupings of the messages. The principal co-ordinates analysis output displays cluster centroids linking the cluster members together, with ellipses showing a 95% confidence region (Figs. 3 and 4).

Results

In the first card-sorting activity, 40 participants grouped messages into between 2 and 13 separate categories. The results of the similarity analysis showed four groupings of messages with two of those groupings, 'disease beliefs' and 'remembering strategies' having the highest agreement across participants (Fig. 1). However, three messages (numbers 7, 21 and 29, Fig. 1 and Table 1) did not fit with their intended groups. For example, message 7 ("*Make choices that are right for you. Choosing to put your health first benefits you and your loved ones.*") was found to agree with its group less than 15% of the time and message 21 ("*If you're worried that your medication could be harmful to you, remember that without it, you put yourself at risk for a heart attack or stroke.*") agreed less than 25% of the time. Message 29 ("*It's important to remember your medicine every day. Keeping your blood pressure under control helps protect you from serious health problems.*") agreed below 50%. An additional three messages (numbers 9, 14 and 16) also had poor agreement (Fig. 1). The three methods of

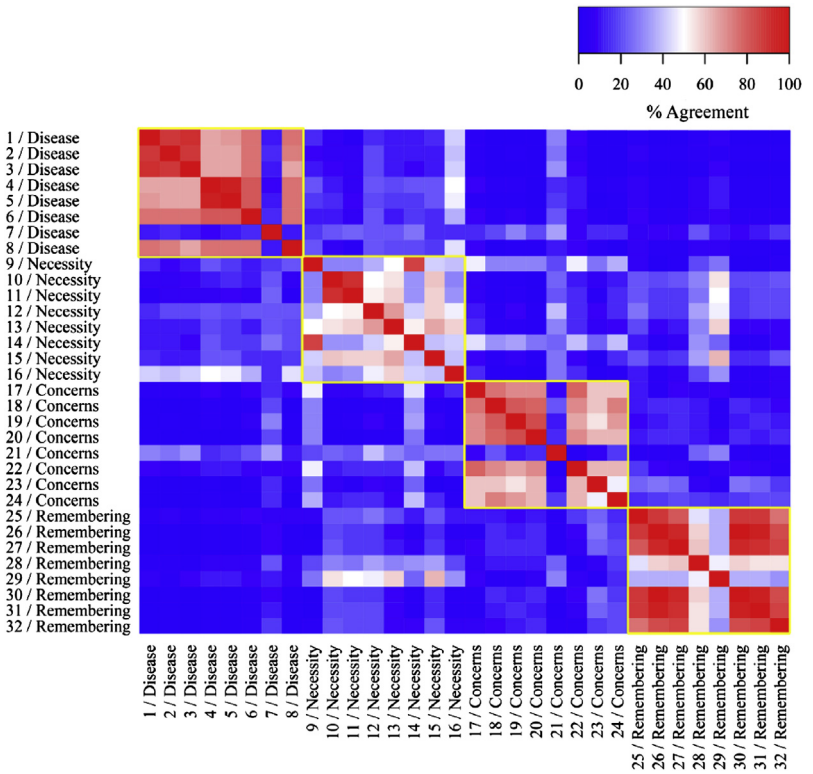

Fig. 1. Similarity matrix (heat map) of participants' grouping messages into each of the four clusters identified during the first card-sorting wave (the axes contain each of the messages tested; high agreement among participants is depicted in a progression from white toward red, with full red representing 100% agreement). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

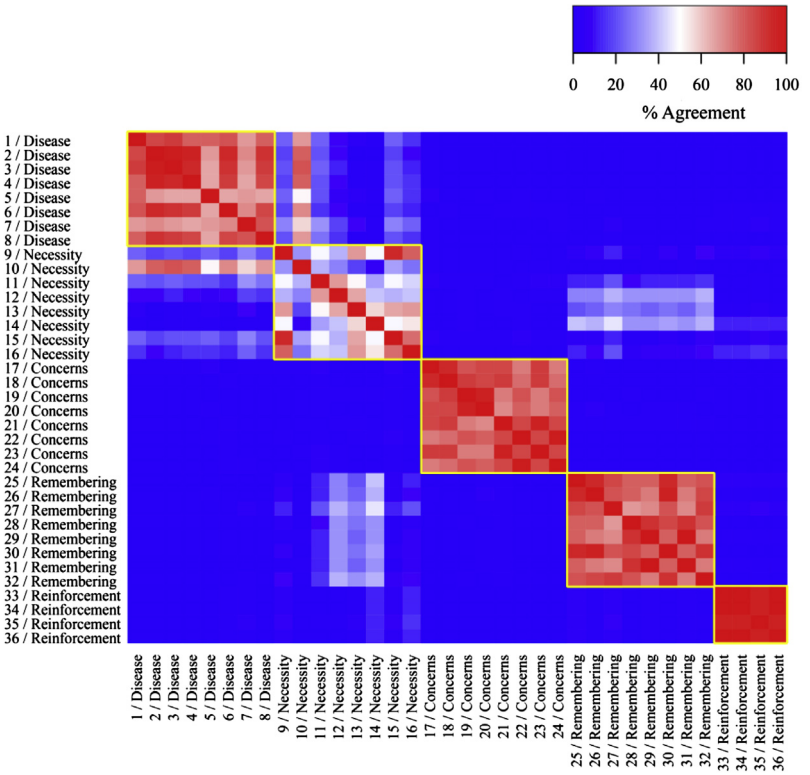

Fig. 2. Similarity matrix (heat map) of participants' grouping messages into each of the five clusters identified during the second card-sorting wave (the axes contain each of the messages tested; high agreement among participants is depicted in a progression from white toward red, with full red representing 100% agreement). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

determining numbers of clusters in the data showed that four was the optimal number. The first four principal components explained 94% of the variability in card-sorting agreement. The cluster analysis using data grouped in four clusters also showed that messages 7, 21 and 29 did not belong with the pre-determined group, both in the hierarchical and k-means clustering (Table 1, Fig. 3). The principal coordinates show the results of the clustering and several points appeared projected beyond the 95% confidence region displayed by the ellipses, particularly for the 'medication necessity' and 'medication concerns' clusters.

In the second wave of card-sorting, 37 participants grouped the messages into between 4 and 9 categories. The similarity analysis showed that five types of messages were identifiable, with four of them, 'disease beliefs,' 'medication concerns,' 'remembering strategies' and 'positive reinforcement' presenting the highest agreement across participants (Fig. 2). 'Medication necessity' was the most dispersed category. Message 10 ("*High blood pressure will damage your body unless you keep it under control with your blood pressure medicine.*") presented higher agreement in the 'disease beliefs' group, but according to the experts was intended to reflect the 'medication necessity' group (Fig. 2), for which the agreement was below 40%. The 36 messages tested in the second card-sorting wave were confirmed to be in five clusters and the first five principal components explained 98% of the variability. Both k-means and hierarchical clustering showed that message 10 fit better with 'disease beliefs' (Table 2, Fig. 4). In the principal coordinates graphic, the areas in the ellipses were generally smaller than clusters obtained in the first card-sorting wave (Fig. 4), which denotes more agreement.

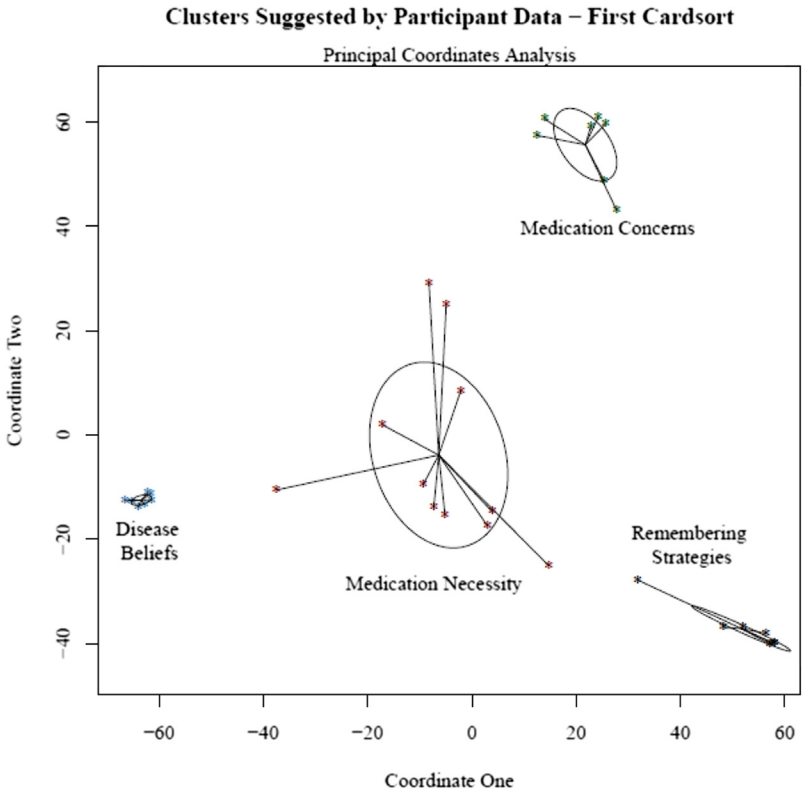

Fig. 3. Principal coordinates analysis depicting four different clusters in the first card-sorting wave.

Discussion

The findings of this study provide support for the five-category structure of expert-developed text messages to address medication adherence barriers such as disease beliefs, medication necessity, medication concerns and forgetfulness, and to provide positive reinforcement to patients who were adherent to their medication. Card-sorting methodology is a common technique for exploring patterns in the way people tend to group a collection of concepts.[41,45] In this study, it was found to be an effective way to validate and improve the thematic structure of text messages designed for addressing multiple major barriers to chronically-ill patients' medication adherence. The advantages of using card-sorting include its simplicity, low cost, short execution time, participant involvement, and identification of terminology that is likely to be misunderstood or items that are likely to be difficult to categorize.[41] An alternative to this methodology could be having other experts or patients participate in a Delphi panel to agree upon which category would each message fit, but the team opted for a more exploratory approach.

After modifying the messages based on feedback from the first wave of card-sorting, participants in the second wave grouped the messages into fewer categories, which suggests that the modification and deletion of the messages based on the findings of the first wave improved the conceptual consistency within categories. In the 'disease beliefs' cluster, message 7 ("*Make choices that are right for you. Choosing to put your health first benefits you and your loved ones.*") was found to have low agreement in the first card-sorting wave, and the heat map allowed us to identify this and pinpoint the problem, i.e., that the message did not mention anything about the disease (hypertension) when 'disease beliefs' was the intended category. More messages were created for this category and the ones tested in the second

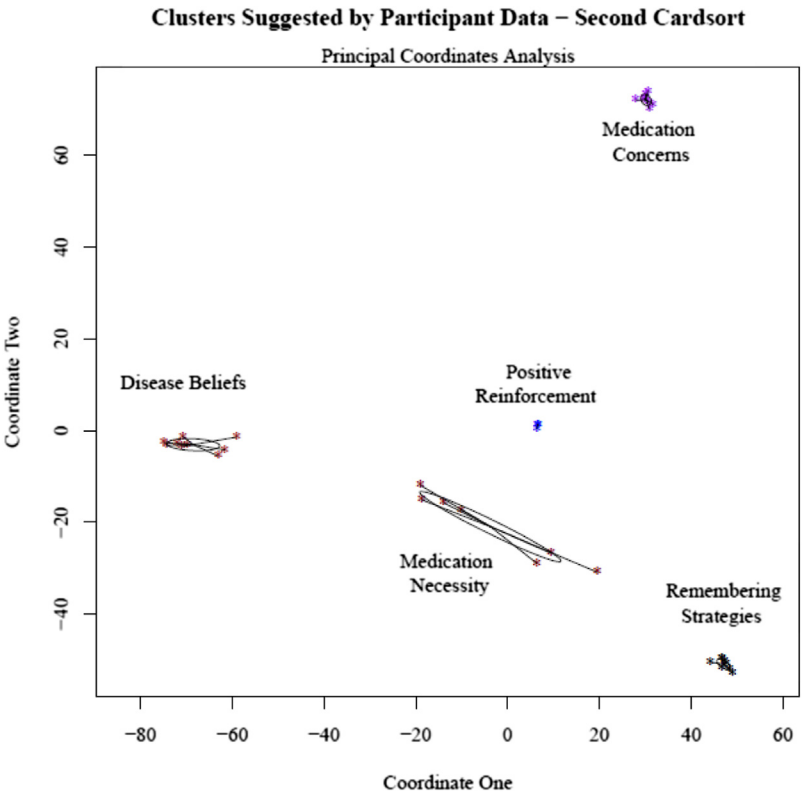

Fig. 4. Principal coordinates analysis depicting five different clusters in the second card-sorting wave.

card-sorting were shown to have better agreement. The 'medication necessity' cluster was found to be problematic in both waves. Therefore, necessity messages containing any reference to the physician were rewritten to remove this word, message 16 ("*Your blood pressure medication works with your kidneys to keep your blood pressure low*.") was deleted for referring to the mechanism of action of anti-hypertensive drugs, and other messages were created or edited to stress medication taking necessity. For the remaining clusters, agreement among participants was very high in the second card-sorting wave.

The text messages developed in this study will be used in another study designed to test an intervention using a reinforcement learning text messaging service to improve medication adherence to anti-hypertensive medications. The fact that the messages developed by the experts were subsequently validated by a group of non-researchers constitutes a strength of this study. For that study, a considerable number of messages had to be created for each category to ensure that participants remained interested in the messages by receiving a variety of messages reflecting each category during the follow-up period. The content of the messages was designed to address disease beliefs, as well as beliefs about the necessity of a medication versus concerns of its potential harms since these were shown to be powerful predictors of reported adherence.[46] Therefore, sending text messages to influence patients' beliefs relating to their illness and medication that are predictive of adherence may be a way of improving it. In fact, a study performed to enhance adherence to asthma preventer medication demonstrated that sending individually tailored text messages to patients that took the recipient's baseline perceptions of illness and medication beliefs into account increased the perceived necessity of preventer medication, as well as users' perceived control over the disease and ultimately their adherence.[33]

While traditional tailoring such as that conducted in this prior study[33] is important, our recent simulation modeling suggests that an

automatically-adaptive tailoring system could do better – particularly in 'real world' situations such as when patients do not accurately report their health beliefs or become desensitized to messages that are sent too frequently.[47] Message fatigue has been reported as a major issue in chronic disease management[37,38] and reinforcement learning can use feedback from patients to develop the content of messages and schedules that meet each individual's needs and preferences for information.

This study has several practice implications. As noted, the pool of messages created and tested will be used in a larger study consisting of a reinforcement learning controlled text messaging service. The perspectives of participants in the card-sorting activity were consistent with what experts who developed the text messages expected, and therefore these messages based on a theoretical model may be able to influence targeted patients' beliefs and, ultimately, adherence behavior to anti-hypertensive medications. Previous studies showed that interventions using text messages were successful in attaining behavior modification, such as improving heart failure self-management,[48] cervical cancer screening,[49] or weight management.[50] Second, the messages can be adapted to subsequent studies using text messaging services to address non-adherence to medications in other medical conditions.

As a limitation of the present study, patient input was not incorporated when initially developing the messages. However, both students and college staff participated in the card-sorting activity to include perspectives from different ages and backgrounds. We believe that having participants who might not be familiar with the medications and the disease, as opposed to having patients with hypertension in our study, would be a strong endorsement to the validity of the messages. Previous studies used health communication and traditional behavior theories such as health belief model or self-regulation as underlying theories for the development of the messages, but we developed our own theoretical model based on previous research and incorporating concepts from multiple theories to address the common adherence barriers described in the literature that could be impacted by text messaging.[39,40] However, other contributing factors to non-adherence like those cost-related cannot be resolved using text messages.[51] The text messages generally targeted patients' adherence to their anti-hypertensive medications, however chronically-ill patients typically have multiple diagnoses and medications in their regimens. Future work should include subjects reporting medication non-adherence to other medication types.

Conclusion

A pool of 120 text messages were developed by experts based on a theoretical framework. Participants in a card-sorting activity confirmed the structure of expert-developed text messages about reasons for medication non-adherence. This study illustrates the validity of the underlying message structure as well as the utility of the card-sorting approach for examining the practical content of text messages developed using theory.

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